



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CHEMICAL AND BIO-ENGINEERING

**Quality Characterization of Haricot Bean (*Phaseolus Vulgaris L.*)
and Pumpkin Flours for the Development of Functional Kemesha, A
Traditional Food in Ethiopia**

PhD Dissertation

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June 2023

Addis Ababa, Ethiopia



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A Dissertation

By

DERESE WODAJO BEKELE

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the Requirements for the degree of
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(FOOD ENGINEERING)**

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June 2023

Addis Ababa, Ethiopia

Declaration

I declare that this dissertation is an original report of my work and has not been submitted in any previous application for a degree. The experimental work is almost entirely my work; the collaborative contributions have been indicated clearly and acknowledged

DERESE WODAJO BEKELE

Signature and Date: _____

Dedication

This work is dedicated to my dear families, whose blessings, words of support, and calls for firmness echo in my ears.

Approval of Dissertation
Addis Ababa University
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As a *PhD* research advisor, I hereby attest that I have read and assessed this dissertation with the following title:

“Quality Characterization of Haricot Bean (*Phaseolus Vulgaris L.*) and Pumpkin Flours for the Development of Functional Kemesha, A

Traditional Food in Ethiopia” prepared under my guidance by **Derese Wodajo Bekele**.

Hence, I recommend that it can be submitted as fulfilling the requirements of the degree of Doctor of Philosophy (PhD).

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As a member of the *Board of Examiners* of the *Dissertation Open Defense Examination*, we Certify that we have read and evaluated the dissertation prepared by **Derese Wodajo Bekele** and examined the candidate. We recommend that the dissertation be accepted as fulfilling the requirements for the Degree of Doctor of Philosophy (PhD) in Chemical Engineering (Food Engineering Stream) with respect to originality and quality.

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Quality Characterization of Haricot Bean (*Phaseolus Vulgaris L.*) and Pumpkin Flours for the Development of Functional Kemesha, A Traditional Food in Ethiopia

Abstract

Traditional foods are significant in using local resources and are generally more available to rural communities. *Kemesha* is a traditional food of the Arsi Zones in Ethiopia, made by mixing common wheat flour (*Triticum aestivum*) and water, followed by sheeting, rolling, cutting, and sun-drying. However, the process is labor-intensive, extremely sluggish, and produces uneven quality and unhygienic products. The study aimed to standardize, optimize and characterize *Kemesha* while enhancing its nutritional and functional qualities to increase its appeal. Initially, documenting the existing *Kemesha*-making process, then standardizing *Kemesha* based on the sensory acceptability test and quality characterization. The compositional analysis showed that standardized *Kemesha* contains 9.22, 2.13, 8.90, 1.25, 2.41, and 76.08 g/100 g moisture, fat, protein, crude fibre, and ash content, respectively. Findings on textural properties also revealed that the firmness, springiness, cohesiveness, adhesiveness, and chewiness were 904.94 g, 0.28, 0.45 24.94 g*s, and 114.40 g, respectively. Standardized *Kemesha* has a low cooking loss (7.25%) and a high water absorption percentage (180.62%). Wheat-based food is high in carbohydrates but low in other vital nutrients, including protein, fibre, and bioactive ingredients, which frequently cause nutrient imbalances among consumers. However, there has been a noticeable rise recently in the desire for a balanced diet that contains all the essential components, has fewer calories, and offers health benefits as a functional food. So, the study's goal was also to use characterized haricot bean and pumpkin flour as raw materials to increase the nutritional value and functionality of standardized *Kemesha*, thereby increasing its acceptability. It is crucial to conduct a thorough analysis to preserve the bioactive components and other nutritional values of the crops while minimizing their anti-nutritional values to produce the value-added food product *Kemesha* from dry beans and pumpkin flour. Before processing first, we assessed the impact of bean variety on the geometric characteristics and mass-volume-area attributes of four improved haricot bean varieties. The moisture content, 1000 seed weight, and true density varied significantly ($p < 0.05$) in the range of 9 to 11.28%, 199.9 to 529.93 g, and 1127.52 to 1212.40 kg.m⁻³; also, the dimensional properties of the improved haricot bean were significant ($p < 0.05$) among the varieties indicating that these would require some variation in the processing equipment

design. Then, the impacts of soaking (for 24 hours), germination (for 96 hours), autoclaving (at 121°C for 30 minutes), and germination followed by autoclaving processing methods were assessed on the physicochemical properties of haricot bean flours. The beans flour composition varied significantly from 8.05 to 9.72%, 23.11 to 27.96 %, 1.33 to 2.87 %, 3.82 to 5.97 %, 3.45 to 5.52%, and 51.79 to 57.14%, respectively for moisture, crude protein, crude fat, crude fibre, ash, and carbohydrate contents. Germinated flour demonstrated a notable degree of DPPH scavenging activity (EC50) and a range of total flavonoids and phenols (2.79 to 3.69 mg QE/g and 0.72 to 1.04 mg GAE/g, respectively). The germination process decreases flour's thermal and pasting properties, which could enhance its better utilization in the food industry due to the loosening structure caused by increased amylase activity. Additionally, sprouted flour has the potential to be employed in a number of culinary products as a functional ingredient and nutritional supplement. During pumpkin processing, pre-drying methods are essential to prevent the effect of high temperatures involved in conventional air drying, which degrade the color, nutritional value, and bioactive component of pumpkin flour and boost drying effectiveness. In these experiments, the pre-drying methods comprised ultrasonication for 10, 20, or 30 minutes, microwave blanching for 6 minutes at 300 W, and combined ultrasound followed by microwave blanching. The proportions in terms of moisture, ash, crude fat, crude protein, crude fibre, and carbs in the pumpkin flours were 7.57 to 8.23 %, 5.73 to 6.57 %, 1.17 to 1.85 %, 8.72 to 11.32 %, 10.92 to 13.11 %, and 61.47 to 64.23 %, respectively. In comparison to other pre-drying treatments, 20UM was the optimum method in terms of reducing drying time (32.78 %), preserving a color change (9.06), total phenol (6.31-229.99 mgGAE/g), total flavonoid (1.97-135.22 mgQE/g), total carotenoid (131.50-9.84 g/g), and DPPH activities during processing. In order to expand the potential applications of pumpkin flour in functional food products, the fibre and bioactive components of the flour were enhanced through particle size reduction. After pre-drying treatment, the pumpkin flour ground to a particle size of < 75 µm exhibited the highest concentrations of total phenol, flavonoids, and carotenoids (6.52±0.59 mg GAE/g, 1.92±0.85 mg CE/g, and 139.79±0.96 µg/g). However, the moisture content and color brightness showed a decline after pretreatment and improved when the particle size was reduced. The maximum pasting viscosities were found in the pretreated fine-milled flour (20UM1), whereas the lowest viscosities were found in the untreated coarse-milled flour (CON3). Generally, 20UM1 flour has outstanding composition, thermal, functional, and structural features compared to other flours, making it a superb component to increase the important ingredients in various food formulations. The production of *Kemasha*, which included common wheat flour, haricot beans, pumpkin flour, and carboxymethyl

cellulose, was optimized in this study using a D-optimal approach to determine the most significant factors. The outcomes of numerical optimization and model validation showed that the combination of 63.00 g of common wheat flour, 19.01g of germinated haricot bean flour, 14.51 g of ultrasonically fine-milled pumpkin flour, and 3.48 g of carboxymethyl cellulose per 100 g of flour composition with 0.596 desirability's was viable for the preparation of *kemesha*. The total phenolic, flavonoid, and carotenoid content of the optimized functional *Kemesha* was 7.47, 3.67, and 149.20 times greater than that of the control *Kemesha*. The increase in these phytochemicals signifies that this *Kemesha* may offer the user the natural health benefits of pumpkin and germinated haricot beans. The study found that the addition of CMC, finely ground ultrasonicated pumpkin flour, and germinated haricot bean flour has improved the nutritional value, texture, cooking properties, and sensory characteristics of *Kemesha*. Furthermore, the optimized *Kemesha* exhibited improved cooking loss (4.95%) and water absorption (220.68%) compared to the standardized control *Kemesha*.

Keywords: Bioactive component, Functional food, Germination, Haricot bean, Pre-drying treatment, Pumpkin, Optimization, Traditional food

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Derese Wodajo Bekele & Shimelis Admassu (2023). Pasting, thermal and structural properties of haricot beans flour (*Phaseolus vulgaris*, L.) as affected by variety and germination, International Journal of Food Properties, 25:1, 963-973, <https://doi.org/10.1080/10942912.2023.2197174>

List of Abbreviations and Acronyms

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
AS	Ascorbic acid
CMC	Carboxy methyl cellulose
DSC	Differential Scanning Calorimeter
FAO	Food and Agricultural Organization
GHBF	Germinated haricot bean flour
GRAS	Generally Recognized as Safe
FD	Freeze-dried
FM	Microwaved pretreated
FT-IR	Fourier Transform Infrared
GAE	Gallic Acid Equivalent
OAC	Oil Absorption Capacity
SEM	Scanning Electron Microscopy
T _c	Conclusion Temperature
T _o	Onset Temperature
T _p	Peak Temperature
UFPF	Ultrasonicated fine milled pumpkin flour
WAC	Water Absorption Capacity
XRD	X-Ray Diffractometer

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CHAPTER 1: INTRODUCTION

1.1. Background

Traditional foods are typically made from traditional crops and are probably easier for rural areas to get than modern foods. Improving the production, processing, and use of locally accessible resources in the form of indigenous crops is a more sustainable strategy to address the population's food and nutrition problems[1]. *Kemesha* is a traditional food around Arsi Zones, Ethiopia. It is prepared from common wheat flour through traditional processing steps of mixing, sheeting, hand rolling and cutting, and sun-drying. All age groups of people consume it. But the nutritional worth of traditional *Kemesha* and how recipe and process parameter variations and adjustments affect the nutritional quality is not fully known. In addition, wheat-based products typically contain high levels of starch but low levels of fibre, minerals, carotenoids, and phenolic compounds [2]. In recent decades, there has been a notable shift in consumer demands for manufactured food products towards a desire for a balanced diet that is convenient, quick, and provides all necessary nutrients. Because of this, modern foods are made not just to sate hunger and offer essential nutrients but also to prevent diseases linked to poor nutrition and improve customers' physical and emotional well-being. [3],[4]. With an increasing concern by health-conscious people, more nutritious products rich in minerals, phenolic compounds, and dietary fibre with low glycemic index have become the subject of primary significance [5]. In this context, foods which contribute health benefits, such as functional properties, with the incorporation of nutrients and reduced caloric values, are notable [6]. A viable approach to rectifying nutrient imbalances in wheat-based products is through the consumption of composite flour mixtures [7].

In addition to their cultivating advantages, supplementing wheat flour with legumes, especially common bean (*Phaseolus vulgaris* L.), is vital for supplementing protein contents [8]. The ongoing rise in the price of animal protein has prompted research into novel protein sources in an effort to provide a significant section of the population with nutritious, balanced alternatives [9]. Food legumes, particularly grain legumes or pulses, are considered staple foods in many countries, while others are viewed as the second-best source of energy and plant proteins, behind cereals [10]. Ethiopia produces a variety of haricot bean cultivars, including mottled, red, white, and black forms. Due to rising market demand, pure red and white beans are the most widely farmed variety.

They are also the most commercially successful cultivars. Dry beans are low in fat and rich in proteins, minerals, vitamins, and complex carbohydrates [11]. Despite their high nutritional value, dry beans are a good source of antioxidants, vitamins, minerals, and bioactive compounds that are important for preventing and regulating chronic diseases such as obesity, diabetes, cancer, and coronary heart disease [10,11].

However, most legumes are poorly utilized due to the presence of anti-nutritional factors [13], which can cause stomach cramping, diarrhea, flatulence, and vomiting and prevent the absorption of nutrients into the body [14][15]. Studies have demonstrated that various processing techniques, including soaking, autoclaving, germination, and germination followed by autoclaving, can effectively decrease or remove antinutritive compounds from legumes [16] [17]. Furthermore, other processing methods such as sprouting, malting, and fermentation have been shown in studies to further improve the functional properties of legumes [18]. Germination, in particular, is beneficial for improving the nutritional makeup and bioactive substance content of seeds, and it has been shown to reduce some anti-nutritional factors, leading to greater bioavailability of nutritional compounds [19]. Also, studies in the field suggest that the germination process leads to the reduction in some anti-nutritional factors, which favors a greater bioavailability of the nutritional compounds from the seeds exposed to the germination process [19]. Using different types of legumes to make innovative foods like pasta [20], bakery products [21], drinks [22], etc., or in value-added bean-based products is a growing trend today that may satiate consumer demand for healthy diets as functional and nutraceutical food, so their use for consumption would be preferable. Several studies documented in the literature have underscored the potential utilization of diverse legumes, either in the form of germinated seeds or derived flours. These investigations have brought to light the substantial influence that the incorporation of germinated legumes can have on the nutritional composition and quality attributes of food products [20].

In addition to common bean and wheat flour, adding pumpkin (*Cucurbita* sp.) flour during the product's production can enhance its nutritional value and overall health [23]. The exploitation of pumpkin as a food crop has been limited to a large extent by a lack of sufficient information on the physicochemical, nutritional, and functional properties of its fruits and seeds. Similar to other conventional vegetables, pumpkin has been linked to modest rural lifestyles and inferior social status. Urbanization and cultural change have neglected this crop. In addition, the consumption of

pumpkins in Ethiopia was still taken as a sign of poverty [8] and utilized in its primary form by cooking with sauce before consumption. Pumpkin flesh is rich in fibre, vitamin C, vitamin E, Mg, K, and a variety of carotenoids being the important sources of these amazing phytonutrients [24]. Pumpkins can be processed to become stable foods with a long shelf life instead of perishable produce [25]. One of the processed forms of pumpkin fruit is pumpkin flour, which is easily stored for a long time and used to produce formulated foods [24][26]. In conventional air drying, high temperatures adversely affect the products' texture, color, and nutritional value [27]. Utilizing emerging technologies like ultrasound [28] and microwave [29] as pre-drying treatments is a method of producing high-quality dried products while also decreasing the occurrence of unfavorable changes in the final dried product properties. This is achieved by reducing the drying time [30]. In this study, ultrasonic and microwave pre-drying were employed prior to a fluidized bed drying to turn pumpkin flesh into powder. Also, an attempt was made to increase the levels of bioactive components and fibre by reducing the particle size of the pumpkin flour. According to Padalino et al. [31], research has been done to increase the nutritional value of pasta by adding pumpkin, a vegetable that is incredibly rich in phenolics and carotenoids, can offer health advantages by being able to scavenge reactive oxygen species, and can protect against degenerative diseases like cancer and cardiovascular diseases.

In this study, a D-optimal mixture design was utilized to develop an optimized *Kemesha* by combining common wheat flour, germinated haricot bean flour, ultrasonicated fine-milled pumpkin flour and carboxymethyl cellulose. The study focused on four response variables: protein (Y_1), fibre (Y_2), total carotenoid content (Y_3), and firmness (Y_4) of the *Kemesha*, in relation to the independent variables: common wheat flour (X_1), germinated haricot bean flour (X_2), ultrasonicated fine-milled pumpkin flour (X_3), and CMC (X_4). The research was divided into different stages, including the production and characterization of haricot bean and pumpkin flour, standardizing the *Kemesha* processing method and quality characterization, and optimizing and characterizing the developed functional *Kemesha*.

1.2. Statement of the Problem

Kemesha is a popular food in the Arsi Zone of Ethiopia, traditionally made at home by combining common wheat flour with water, rolling it out, cutting it to the desired size, and sun-drying it before cooking in hot water. However, the production of *Kemesha* has been declining due

to several factors, including its tedious preparation process, extended drying time, exclusive use of wheat flour, lack of standardization in production, poor nutritional and functional value, and unattractive appearance. Additionally, the modern way of life has made people busier and under time pressure to use foods with a lengthy preparation procedure, leading them to prefer processed foods. So, traditional food processing techniques need to be standardized and updated to take advantage of modern processing technology to save time and energy without compromising desirable qualities.

Consumption of wheat-based foods is known to frequently lead to nutrient imbalances among consumers [2], as they are typically high in carbohydrates and low in protein, fibre, and bioactive components. Therefore, it is necessary to enhance the nutritional value and functional properties of *Kemesha* by adding nutrients that are absent in wheat flour, through partial substitution with flour derived from indigenous agricultural products. One solution to this issue is to fortify *Kemesha* with beans, fruits, and vegetables. Pumpkin, a fruit rich in phytochemicals and fibre, and haricot beans, a grain legume with high protein content similar to soybean, could be used to enrich *Kemesha*, which could cater to the population's growing interest in health and diet issues. This could serve as an alternative to consuming minor plant components that may have health benefits [32]. [32]. Therefore, optimizing *Kemesha* by incorporating ingredients high in macro and micronutrients is necessary to ensure its nutritional and functional quality.

The majority of Ethiopia's traditional vegetarian dishes are made with highland pulses, including chickpeas, split peas, faba beans, and lentils, because of the country's deep cultural ties to pulse crops. However, haricot beans are still viewed as a lesser value and lower esteem pulse crop, despite the fact that they are becoming more and more popular among low-income groups for reasons of food security and income generating [33]. They are underutilized due to a lack of information on the potential of common beans as a healthy food source and the presence of anti-nutritional factors. Therefore, it is necessary to explore different processing techniques that can reduce the anti-nutritional components while improving the nutritional composition of haricot beans, in order to increase their consumption and provide superior nutritional value.

Pumpkin fruit is used in Ethiopia in its natural state by boiling it with sauce before consumption. Yet, understudied crops like pumpkin deserve to be the subject of study because they are a rich source of phytochemicals that are helpful to humans in the battle against deadly

diseases like cancer and cardiovascular issues [34]. These facts lead to the processing of pumpkin into various food products. However, high-temperature drying during processing can adversely affect pumpkin, causing the breakdown of carotenoids (resulting in color loss), loss of vitamins, and destruction of other pigments [35]. Therefore, it is essential to process pumpkin into flour with the least nutrient loss to improve its compositional, thermal, functional, and structural properties.

1.3. Research Questions

This study was required to answer the following questions:

- How does pumpkin and haricot beans use to formulate functional kemesha?
- How can the kemesha processing techniques be standardized?
- How do hydrocolloids impact the quality of functional kemesha, which is made from a wheat composite with haricot beans and pumpkin flour?

1.4. Objectives of the Study

General objective

- The general objectives of this dissertation were to characterize haricot beans and pumpkin flour quality and study the impact of ingredient level on the quality of functional *Kemesha*.

Specific objective

To accomplish the general goal, the following specific objectives were developed:

- To evaluate the effect of variety and processing methods on the haricot bean flour quality
- To investigate the effects of innovative pretreatments (ultrasonic and microwave) and particle size on the pumpkin flour quality
- To standardize *Kemesha* processing methods and quality characterization
- To optimize the haricot bean, pumpkin flour, and carboxymethyl cellulose blending ratio for functional *Kemesha* development
- To evaluate quality attributes of developed functional *Kemesha*

1.5. Research Hypotheses

The hypotheses formulated for the study were:

(1) Germination, autoclaving, and germination followed by autoclaving affect the physicochemical, functional, and structural properties of haricot bean flour (*phaseolus vulgaris* L.) differently. Therefore, the resulting flours have varying functionalities.

- 2) The physical, chemical, and functional characteristics of pumpkin flour treated with ultrasound, microwaves, or combined ultrasound followed by microwaves are not significantly different.
- 3) Haricot beans and pumpkin flour-based *Kemesha* provide good nutritional and functional properties than wheat-based *Kemesha*.

1.6. Organization of the Dissertation

The dissertation is organized into ten chapters as outlined below:

Chapter one of the dissertation provides a general introduction, highlighting the study's background, problem statement, research questions, objectives, and hypotheses.

Chapter two presents the literature review that briefly describes traditional food, its standardization, and functional food, followed by a presentation of haricot beans and pumpkin processing. The chapter also describes hydrocolloids to create some fundamental understanding. Finally, the literature review is summarized to conclude the remarks and show research gaps.

Chapter three describes general materials and methods commonly used for the different experiments. It briefly describes sample collection and preparation, analytical methods for determining various parameters, and statistical methods for data analysis.

Chapter four presents and discusses the findings from the investigation of geometric characteristics and mass-volume-area properties of haricot beans (*Phaseolus vulgaris* L.): effect of variety. The paper was published in the International Journal of Food Properties and presented the effect of variety on the Engineering properties of four improved haricot beans.

Chapter five presents and discusses the result of haricot beans (*Phaseolusvulgaris* L.) flour: the effect of varieties and processing methods to favor the utilization of under-consumed common beans. The paper was published in the International Journal of Food Properties in 2022.

Chapter six presents the results from the investigation of the pasting, thermal, and structural properties of haricot bean flour (*Phaseolus vulgaris*, L.) as affected by variety and germination. The result of the investigation of how 'variety and germination affect the pasting, thermal, and structural properties of haricot bean flour was presented and discussed with a brief introduction. The paper is published in the International Journal of Food Properties in 2023.

Chapter seven presents the results from the investigation of the Pumpkin flour qualities as affected by ultrasound and microwave pre-drying treatment. The results of the study were

presented and discussed with a brief introduction. The paper was published in the International Journal of Food Properties in 2022.

Chapter eight presents the results from the investigation of the effects of pre-drying treatment and particle sizes on pumpkin flour's physicochemical and structural properties. The results of the study were presented and discussed with a brief introduction. The paper is submitted to Heliyon.

Chapter nine presents the results from the investigation of standardization, optimization and characterization of functional *Kemesha*. The results of the study were presented and discussed with a brief introduction. The paper is submitted to the Heliyon.

Chapter ten gives a general conclusion and recommendation based on the study's findings.

CHAPTER 2: LITERATURE REVIEW

2.1. Overview of Traditional Food Products and Consumption Patterns

Traditional foods were commonly consumed in ancient times by native people worldwide. These foods have been accepted and highly consumed by the local people for a long time, and the methods of preparation of such meals have been transmitted from generation to generation [36]. Traditional foods are vital for a country's cultural heritage, history, lifestyle, and local economy, as they not only play an essential role in local identity and consumer behavior but also facilitate the transfer of cultural heritage to future generations and the interaction of this heritage with the rest of the world[37] [38].

Due to the high cost of developing new products in marketing, traditional foods offer potential for product diversification. Moreover, in numerous countries, there is a growing demand for traditional foods, and utilizing this trend can benefit small and medium-sized enterprises in particular. Although traditional foods have an essential function in rural development and especially in the development of small and middle-size enterprises [39] [40], this situation is not sufficiently exploited [41]. Today, traditional foods attract considerable attention as a country's potential resources to create a difference in the market [42]. It positively affects rural economies and is considered an effective instrument in preventing unfair competition and brand creation. Traditional foods are unique to the location in which they are created in terms of taste, scent, and composition [42]. It allows job creation, especially increasing women's economic contribution [43]. Albayrak and Erdo Gunes [42] suggest that traditional food ensures compliance with food safety regulations and helps to promote a country. Traditional foods are healthier since they are prepared to last longer through processing with domestic technology. The production and marketing of traditionally produced foods on an industrial scale are usually difficult due to the difficulty of preservation of original features and the different labor-intensive production methods used. Yet, industrial production of traditional food is encouraged not to lose these tastes and to enable their consumption by more people. Hygiene is as important as the test of traditional foods [44] [42]. Also, according to Shweta and Tech, [45] traditional food products are dried under slow or rapid drying with unregulated drying temperature and air velocity (the sun), which often takes about two days for its drying, may impair the crust structure which leads to an undesirable structure of the product. So, mechanical drying offers a promising alternative to maintaining uniformity in product quality. There is untapped traditional knowledge about food plant production, preservation, and consumption among Ethiopians from various regions [46]. However, there have been limited efforts to integrate this local knowledge into the agricultural and food security systems or to disseminate it from one ethnic region to another.

2.2. Standardization of Traditional Food

The traditional food product-making process is labor-intensive, extremely sluggish, limited capacity and poor efficiency, and produces a product with inconsistent quality in batch-wise [47][48]. But the processing techniques constitute simple and low-cost indigenous methods obtained through time immemorial experience, allowing the seasonal availability of many foods

[49]. Nevertheless, this essential body of indigenous knowledge is progressively being lost due to modernization's impact on changing lifestyles, food preparation techniques, and food preferences [50]. The beneficial effects of these techniques in improving nutritional quality by preserving sensitive nutrients and minimizing the effects of antinutrients cannot be overemphasized. Furthermore, the methods are cheaper, acceptable, economically feasible, and sustainable means of improving foodstuff nutrients [51].

Conversely, some traditional techniques are time-consuming, difficult, and often non-standardized, making them unsuitable for export [52] and large-scale production [51]. According to Okafor et al. [53], to ensure the supply of food products to high-demand areas in a shelf-stable form, effective processing methods that can be replicated to give a high quality product needs to be established. This requires standardization of the existing methods, which will generate fundamental data that can serve as a basis for large-scale processing. A standardized recipe is a set of written directions used to reliably produce food for a certain place in a defined quantity and quality. No matter who follows the instructions, a standardized recipe will deliver a product nearly equal in taste and yield every time it is manufactured [54] [55]. Standardization of recipes is the most significant control tool for ensuring that food wastage is reduced. A recipe is said to be standardized when it has been tried, tested, evaluated, and adapted for use by a food service under controlled conditions [56] [55]. Although traditional foods are upgraded and produced on an industrial scale in many other nations, including Japan, India, and China [57][58]), traditional foods are still primarily produced at households levels by the unregulated informal food sector with little advancement in quality and processing methods [50]. Furthermore, traditional foods are usually prepared using rudimentary tools and processing methods, often prone to microbial and physical contaminations, thus leading to potential cases of acute diarrhea, cholera, typhoid fever, and even death [59]. Given the shortcomings of the conventional approach, mechanization is the best course of action that could produce traditional food products at a bigger scale and with greater acceptability and quality attributes. This may also reduce the cost of energy and labor per unit production of the item [60]. Mechanization also increases processing capacity and efficiency and improves the quality and safety of the products [50] [61]. Improving traditional food processing technologies is critical to improving the fortunes of small-scale food processing industries that are crucial to rural development and agro-industrialization in developing countries. Small-scale food industries provide employment in rural areas, reduce rural-urban migration and the associated

social problems, reduce post-harvest losses, increase farmers' incomes, and contribute to food security [48] [50][62].

The handling, preparation, and preservation methods of Ethiopian traditional food are transmitted to the present generation as indigenous knowledge, which is a valuable intangible asset that has been developed over many generations through persistent research and practical experimentation [63]. However, the role of indigenous knowledge in food processing is ignored in the country, and its documentation and dissemination remain a big challenge. Therefore, since they contain information that may be particularly useful during times of crisis or during adaptation to new circumstances, documentation and transmission of this knowledge and practice demand special attention [63]. In addition, the lack of pilot plant facilities for scaling up research from the bench stage to large-scale commercial production is one of the most important constraints to commercializing research findings and upgrading traditional African foods [48].

2.3. Haricot Bean (*Phaseolus Vulgaris L.*) Processing

Pulses are grown and used for food in nearly all the temperate and tropical areas of the world [64]. Bean (*Phaseolus Vulgaris L.*) seeds are a common human food low in fat and rich in proteins, vitamins, complex carbohydrates, and minerals. Beans as legumes are good sources of slow-release carbohydrates, mainly due to their higher soluble dietary fibre when compared to other fibre-rich plant foods such as cereals and tubers [65]. Since they are now a more readily available option for the scarce and expensive animal sources of proteins among the resource-poor rural and urban consumers, they are attractive supplements to the predominantly starchy cereals and tuber-based diets. Thus consumption of beans is essential among all classes of consumers: the wealthy and the poor, infants, teens, and pregnant and nursing women, as a unique remedy to prevalent micronutrient malnutrition and the associated physical and mental development impairments [66]. Therefore, pulses and their products become important constituents in the human diet. Since pulses in processing resources are crucial, attempts have been made to improve grain yield, nutritional quality, digestibility, storage, and processing technology [64]. Common beans are highly nutritious and have been reported as a good source of polyphenols with antioxidant and anticarcinogenic activities, and their consumption has been associated with health benefits such as reducing the risk of cardiovascular diseases, obesity, and diabetes[67][68].

Legumes have been underutilized because of anti-nutritional factors such as enzymes (trypsin, chymotrypsin, &-amylase) inhibitors, phytic acid, flatulence factors, saponins and toxic factors are the need for prolonged cooking. These factors negatively affect the nutritive value of beans through direct and indirect reactions; they inhibit protein and carbohydrate digestibility, induce pathological changes, inhibit a number of enzymes and bind nutrients, making them unavailable [9]. Consequently, it is desirable to develop transformation processes that could improve legumes' nutritional quality and provide new derived products for consumers. Different processing techniques, such as germination, roasting, and extrusion cooking, have been reported to reduce the level of antinutrients and improve cooking characteristics and physicochemical properties, thus improving the nutritive value of beans [69].

In addition, Consumers view the conventional bean preparation procedure, which calls for lengthy soaking and cooking times, as tedious and time-consuming, which results in the underutilization of these beans. One alternative to improve the consumption of dry beans is using bean flour. Including legumes, especially beans, in cereal-based products could be a good option for increasing the nutritional intake of people. Legumes are rich in lysine and deficient in sulfur-containing amino acids, whereas cereal proteins are deficient in lysine but have adequate amounts of sulfur amino acids. Therefore, combining grain with legume proteins would provide a better overall essential amino acid balance, helping to overcome the world protein-calorie malnutrition problem [70]. As an illustration, bean flour has been added to composite flours to raise the amount of resistant starch and enhance the protein quality [71]. Similarly, incorporating common bean (*Phaseolus vulgaris* L.) flour into semolina spaghetti decreased the starch digestibility and increased spaghetti's protein and fibre content [72]. Bean flour can also be used in the development of gluten-free products, which in turn is one of the most prosperous markets in the field of the food industry [73].

2.3.1. Soaking

Soaking lowers the number of toxins and anti-nutrients that are water-soluble and heat-sensitive, such as tannins, saponins, digestive enzyme inhibitors, and lectins. Moreover, it partially breaks down phytic acid, a powerful inhibitor of the absorption of minerals. Thus improves the digestibility and nutritional value of legumes [74]. Beans processing requires a relatively long time, which is not suitable for the current lifestyle of society. In the modern world, individuals

lead hectic lives and move quickly, including preparing daily meals [75]. Therefore, it is important to develop a way to process it to shorten the processing time of beans into the product. According to Balasubramanian and Borah [76], soaking before cooking can reduce cooking time. Soaking grains can result in larger grains due to increased water diffusion from increased hydration, causing the starch granules to swell and grain cracks to widen, which in turn produces more puffed kernels. Cooking and drying the soaked grains can further expand the kernels through water vapor expansion, but case hardening during the drying process can prevent water vapor release, causing the grain to expand and become larger in the middle, which simplifies the rehydration process [77]. Additionally, soaking has an impact on the nutritional value of grains by lowering their protein content while increasing their bioavailability and lowering their vitamin queuing content [78]. The soaking procedure is excellent for producing kid-friendly food products with good protein digestibility and mineral availability [79]. Some studies found a greater reduction in the content of tannins, phytates and oligosaccharides in beans that were soaked and cooked without the soaking water [80] [78].

2.3.2. Autoclaving

Autoclaving (cooking with pressure) is a thermal process usually undertaken by the food industry in an autoclave to prepare pulses for human consumption. It serves as an alternative to boiling legumes, which must be prepared in water for an extended period. This processing affects the nutritional and antinutritional composition of legumes in different ways. After being treated at 116 °C for 42 min, Pedrosa et al. [93] found significant differences in the nutritional composition of two industrial autoclaved bean varieties (*P. vulgaris* var. Almonga and var. Curruquilla): increasing protein (>7%) and dietary fibre (>5%); decreasing fat (>16%), carbohydrate (>15%), and, generally, mineral content (P, Mg, Ca, Fe, and Zn). In autoclaved (121°C) chickpeas for 35 min and faba bean for 30 min [81], similar effects on nutritional composition were observed, except on protein content, which did not change, nor their amino acid composition. Autoclaving was the most efficient method for decreasing or even eliminating allergenicity in lentils, chickpeas, and lupin, according to Alvarez-Alvarez J. et al. [82]. The increment of protein digestibility by autoclaving may be due to the heat-denaturation of protein and reduction or even abolition of bioactive compounds/anti-nutritional factors such as a trypsin inhibitor, tannins and phytic acid [83] [81]. Consumption of autoclaved beans reduces metabolic risk factors associated with obesity [84] and may be used in a renal patient diet [85].

2.3.3. Germination

Sprouting is one of the oldest and most important traditional food processing techniques. It is an extremely inexpensive traditional method of processing for enhancing proteins, vitamins, minerals and enzymes in the diet [74]. Germination increases pulses' palatability and nutritional value, particularly through the breakdown of certain antinutrients [68] and enhances the pulses' vitamin C and niacin content. Iron is released from its bonded state and is now readily accessible. Because the cell walls containing the proteins and carbs are broken down during the sprouting process, the digestibility of the products is improved. During germination, much of the starch in the grains is broken down into simple sugars such as glucose and sucrose by the action of an enzyme called Amylase. This enzyme hydrolyses the amylose and amylopectin to dextrans and maltose, thus increasing the nutrient bioavailability [74]. In addition, this causes a significant change in the physico-chemical characteristics of the legumes, including the modification of antioxidant activities [65]. According to Mubarak, [86] germination retains the minerals found in the seeds of chickpeas.

2.4. Pumpkin Processing

Pumpkin (*Cucurbita pepo*) belongs to the herbaceous vines of the Cucurbitaceae family, a group that includes several economically and nutritionally important vegetable crops cultivated worldwide [87]. Pumpkin is scientifically a fruit due to its seed content though it is regarded as a vegetable with high vitamins and minerals, a source of antioxidants, beta-cryptoxanthin, and beta and alpha-carotene [87]. The yellow-to-pink fruit pulp makes it a rich source of vitamin A [88]. Due to the lack of major scientific, technological, and cultural research efforts to improve pumpkin production, use, and value additions that would allow them to improve food security and alleviate poverty significantly, the crop now remains an “orphaned crop” [89]. The main obstacles to the development of pumpkins in terms of production and use must therefore be identified and removed to reach their full potential. This is true even though the crop has valuable nutritional and therapeutic properties and can be grown in favorable ecological settings [90]. Regrettably, traditional techniques and indigenous knowledge needed to improve the status of this traditional crop are not extensively documented, even though pumpkins have been grown and maintained in East Africa for many centuries utilizing indigenous knowledge. Most farmers in the region regarded it as supplementary food for the domestic consumption of pumpkins. This indicates that

the pumpkin is not considered a priority food crop, and future efforts in the region should focus on diversifying food crops to include pumpkins. Therefore, to combat the undernourishment issues and contribute to food poverty, it is highly desirable to cultivate such high-yielding, multipurpose, and nutrient-rich food crops [90].

Consuming fruits and vegetables have long been associated with a reduced risk of many lifestyle-related health conditions. In terms of health, a pumpkin is a good source of vitamins, proteins, oils, and minerals that are used to strengthen the body's defenses and treat malnutrition-related illnesses [90]. Numerous studies have recommended that increasing the consumption of plant foods like pumpkin reduces the risk of obesity and overall mortality, diabetes, and heart disease and promotes a healthy face and hair, increased energy, and overall lower weight [91]. While dietary fibre from cereals is more commonly consumed than fibre from vegetables, it is generally recognized that vegetable fibres are of higher quality. They can be used in the food industry as functional ingredients because they have higher levels of soluble dietary fibre, better water-holding capabilities, and lower phytic acid content. Besides these, vegetables contain various bioactive substances such as antioxidants, polyphenols and carotenoids [89]. They are considered as good examples of functional foods [92]. Pumpkin is a well-known source of beta-carotene, a powerful antioxidant that creates the vibrant orange color in many fruits and vegetables and is converted to vitamin A in the body. Consuming foods high in beta-carotene may offer protection against asthma and heart disease, postpone aging and bodily deterioration, and lower the risk of getting some cancers [91].

Pumpkin fruits are processed into flour, having extended shelf-life, highly desirable flavor, sweetness, and deep yellow-orange color. Even if pumpkin flour could replace cereal flour in baked goods, soups, and instant noodles and as a natural coloring agent in pasta and flour mixes [34], its consumption in Ethiopia is still restricted to the traditional rural pattern despite the opportunities for value addition. According to Joy, Chidinma, and Akusu [88], producing flour-based snacks will increase public awareness of the crop's nutritional and health benefits, particularly among urban dwellers. This will also increase demand for the crop, which will increase crop production and farmers' income. The flour will also find wider domestic and industrial applications, substitute wheat, and become a source of essential phytonutrients.

2.4.1. Pre-drying Treatment

Due to their high water content, fruits and vegetables are highly perishable foods typically processed into dried products for various reasons, including increasing storage stability, extending the shelf life, allowing for consumption outside of the growing season, and decreasing transport weight [93]. On the other hand, the process used for drying has a big impact on the dried product's quality, including its ability to rehydrate, color, and nutritional characteristics. The best way to preserve the chemical and physical characteristics of fruits and vegetables is through freeze-drying. However, it has drawbacks, such as high cost and prolonged drying time [94]. To minimize the loss of thermolabile substances or oxidizable substrates, such as carotenoids and tocochromanols, which can occur during oven drying - the most common dehydration method, pretreatments are often utilized to preserve product quality, reduce drying time, and lower energy consumption [95][96]. The differences are evident in many properties, including color and rehydration rate [97] [98].

Due to its major benefit in minimising the quality deterioration of agricultural goods, non-thermal processing techniques have attracted increasing interest from the food sector [99]. Ultrasonic waves have enhanced mass transfer by creating microscopic channels in solid material through unique mechanical fluctuation and cavitation effect, making moisture transport easier [100]. Several studies have confirmed that water might diffuse more effectively in plant tissues after ultrasonic wave pretreatment and reduce drying time by 10%–30% [101] [102]. Furthermore, ultrasonic can be conducted at ambient temperature due to its low heating effect, and the heat-sensitive compounds of food can be well protected [103]. The ultrasound pretreatment reduced the drying time by 31% compared to untreated apple cubes, the dried products treated by ultrasound exhibited 6%–20% lower density and porosity of 9%–14% higher than untreated samples [104].

Thermal blanching pretreatments, such as hot water, steam, and microwave blanching, are widely applied to inactivate the enzymes (polyphenols, polyphenol oxidase (PPO), and peroxidase (POD) responsible for unacceptable darkening and off-flavors, thus preserving products' color [105][106]. In addition, it is used to reduce the microbial load of products to improve their conservation, to soften tissues to facilitate the drying process and eliminate intracellular air to prevent oxidation. Microwave heating involves the absorption of microwave energy by materials, which is then converted into heat through dielectric heating from molecular dipole rotation and the

movement of charged ions within a high-frequency electric field [107], resulting in volumetric heating throughout the product rather than just the surface, in contrast to the slow conduction of heat. [108] [109]. Microwave blanching (MWB) uses microwave energy to heat wet biological materials more quickly than conventional heating methods because microwaves' effective output power grows as they heat the materials [110]. MWB requires lower processing time, has higher heating efficiency and nutrient retention compared to conventional methods [111], and reduces the drying time of agro-products. P. Liu *et al.* [112] reported that hot water blanching, steam blanching, and MWB treatments required 130, 110, and 60 s to reach 90% enzyme activity degradation in purple flesh sweet potato, respectively; MWB reduced the drying time and lightness (L value) of samples by 28.6% and 24.42%–36.66%, compared to SB and HWB, respectively.

In conclusion, pretreatments performed before drying are desired to enhance the retention of the antioxidant compounds. For example, microwave blanching maintained the anthocyanin level of sweet potato [112] and mitigated the ascorbic acid degradation of green asparagus [113]. Ultrasonic pretreatment preserved the phenolic compounds in the mushroom [102].

2.5. Hydrocolloids

Hydrocolloids are polymers of different natures, usually of plant origin, which because of their hydrophilic behavior, can take a solid or semi-solid consistency when hydrated [114]. They are widely used as additives in the food industry, particularly in gluten-free bread and bakery products. The specific action of these polymers is expressed particularly in improving the structure and viscoelastic properties of the dough, slowing down the phenomenon of retrogradation of amylose, facilitating the absorption and retention in their internal water molecules, extending shelf life, and giving softness, smoothness, and stability over time [114] [115]. Many authors examined the impact of hydrocolloids on the gelatinization of starch and discovered that some hydrocolloids could prevent the gelatinization of starch granules because of their high hydrophilic nature [115]. Silva *et al.* [116] found that hydrocolloids with a high water binding capacity, such as hydroxypropylmethylcellulose and xanthan gum, could diminish the gelatinization of starch particles due to the fact that they compete for the available water. Except for the health effects as dietary fibre, most edible gums can be used in pasta and noodles to maintain the dough structure and give a palatable mouthfeel to the products [117]. Because they can create a gel in small amounts with a high consistency at room temperature, hydrocolloids improve the hardness, cutting

force, gumminess, and chewiness of noodles, enhancing the eating experience [118]. According to Raina et al. [119] the incorporation of hydrocolloids into the noodle dough matrix will influence the tenacity of the protein–starch matrix and, thus, affect the cooking and eating qualities of the products. They act as gluten enhancers, resulting in a stronger dough structure and contributing to the noodle texture. The same effect will be achieved in pasta products when using common wheat flour as the raw material by adding certain gums due to the limited production and high price of *durum* wheat (*Triticum durum*).

By taking into account hydrocolloids' ability to improve the technological and sensory properties of gluten-free doughs [120], Kohajdova` and Katovico` va` [121] find a good job in improving the quality of durum wheat bread in which the addition of vegetable flours involves significant changes in the structure. Because hydrocolloids aid in the gelatinization of maize starch to create a stable network that enhances pasta structure, Padalino *et al.* [122] observed that hydrocolloids such as chitosan and carboxymethylcellulose increased sensory qualities (elasticity, adhesiveness, and bulkiness) of maize pasta with oat bran. When increased levels of modified starch, xanthan gum, and locust bean gum were added to mixes of tapioca starch, potato starch, corn flour, and rice flour, according to Huang, Knight, and Goad [123], gluten-free pasta with qualities comparable to those of wheat-based pasta was produced.

2.6. Functional Food

Food is considered a good source of biologically active compounds that greatly improve the overall status of human health [124]. Functional foods are those that produce beneficial health effects to humans beyond nutrition. Functional foods are food substances that have been modified in a way so that they have health-related benefits and may subside the risk of some diseases. They may come from various sources: plants, fruits, vegetables, animals, probiotics, prebiotics, etc., to maintain human health and strengthen the body's defense against diseases [125]. With the increase in awareness of healthy diets, consumers are getting more conscious about their foods. There is a growing demand for foods containing constituents with potential health benefits [126], such as vitamins, polyphenols, carotenoids, essential oils, proteins, and peptides [124]. Plant secondary metabolites such as polyphenols and carotenoids are well-recognized as natural antioxidants linked to the reduction of the development and progression of lifestyle-related diseases [127] [128]. Its consumption seems linked to a reduced risk of gastrointestinal and cardiovascular disorders [129].

Additionally, consumers are increasingly seeking out all-natural goods with the GRAS certification made with environmentally friendly or sustainable technologies [130].

Dry beans (*Phaseolus vulgaris* L.) are an excellent source of chemically diverse components that are associated with protection against oxidative stress, cardiovascular disease, diabetes, metabolic syndrome, and many types of cancer. These components include phenols, resistance starch, vitamins, and fructooligosaccharides [131]. Resistant starch (RS) and the fructooligosaccharides, stachyose, and raffinose compounds present in the dry beans also serve as substrates for bacterial fermentation in the human intestine, thereby influencing the microbial ecology of the gastrointestinal (GI) tract and gut metabolism [132] [133]. Germination, malting, and fermentation are processes that enhance the functional properties of food and are widely used in the daily diet. Due to the growing population and surging demands for healthy foods in the future, it is pivotal to use affordable natural sources of bioactive ingredients to provide functional foods for the vast majority of people. Recent studies show that germination can enhance both the nutritional and medicinal values of seeds, legumes, and cereals and decrease the amount of anti-nutritional and indigestible factors [134]. It has been found to enhance iron absorption due to elevated vitamin C content, reduced tannin or phytic acid content, or both [135] [136]. The applications of germinated ingredients in food preparation are very diverse, such as using germinated legumes and cereals for flour, beverage, and weaning food manufacturing [137]. The bread produced by Gawlik-Dziki et al. [138], who added germinated, dried, and powdered broccoli sprouts to the formulation of wheat bread, was rich in phenolic compounds and enzyme effectors and offered a higher level of free amino groups and resistant starch.

Consuming nutrient-dense foods (fruits and vegetables) that are abundant in bioactive chemicals and are simple to manufacture, store, and ship is becoming more popular as a way to create healthier products [139] [140] [141]. Pumpkin pulp flour (*Cucurbita moschata*) is a potential ingredient for developing healthier foods. Pumpkin pulp flour stood out for its high protein content, dietary fibre and carotenoids, phytosterols, tannins, alkaloids, flavonoids, phenolics, tocopherol, and cucurbitacin [95], low content of sodium, as well as the high antioxidant capacity [142]. Anti-allergic and anti-inflammatory activities were reported in vitro studies [143] by pumpkin's phenolic compounds (0.3 mg/100 g). Phenolics have reactive oxygen scavenging ability because of their electron-donating capability, which is vital in disease prevention in plants and animals, such as Alzheimer, Parkinson and cancer [144].

2.7. Concluding Remark

A national, regional, or local dish may have a historical precedent in traditional cuisines, which are traditional in nature. African traditional foods are still largely prepared in the home and in the unregulated informal food sector. Slow, manual operations characterize their production; the processes are not standardized, and the quality of the products is variable and often poor. Several traditional cuisines from Africa raise major safety concerns, mostly because of the unclean conditions in which they are created, the caliber of the ingredients, and the packaging. Upgrading African traditional food processing techniques would promote sustainable food security. The use of wheat-based products often leads to imbalanced nutrients among consumers as they are rich in starch and have a significantly low concentration of protein dietary fibre and bioactive components. Also as it decreases the importation of wheat flour and promotes the use of locally grown crops as flour, composite flour is viewed favorably in developing nations. Incorporating protein-rich, high-fibre, and bioactive components enhances wheat-based products' nutritional and functional quality. There is a growing demand for foods containing constituents with potential health benefits, such as vitamins, polyphenols, carotenoids, essential oils, proteins, and peptides. Dry beans (*Phaseolus vulgaris* L.) are a rich source of bioactive compounds, which have been found to guard against oxidative stress, cardiovascular disease, diabetes, metabolic syndrome, and many different types of cancer. Recent studies show that germination can enhance both the nutritional and medicinal values of legumes and decrease the amount of anti-nutritional and indigestible factors. There is growing interest in fruits and vegetables rich in bioactive compounds consumption, which can be used to develop healthier products. The pretreated pumpkin pulp flour is a potential ingredient for the creation of healthier foods because it is high in protein, dietary fibre, carotenoids, phytosterols, tannins, alkaloids, flavonoids, phenolics, tocopherol, as well as low in sodium and has a high antioxidant capacity. Hydrocolloids are added to the dough to improve its structure and viscoelastic properties, delay amylose retrogradation, facilitate water absorption and retention, lengthen shelf life, and add softness, smoothness, and stability.

CHAPTER 3: GENERAL MATERIALS AND METHODS

3.1. Sample Preparation and Storage

Common wheat (*Triticum aestivum*) flour, pumpkin, carboxymethyl cellulose, and other chemicals were purchased from a local Addis Ababa, Ethiopia market. Four improved varieties of haricot bean (*Phaseolus vulgaris* L.), namely: Awash-2, SER 119, SER 125, and SAB 632 (see appendix A for Agronomics), were obtained from the Awash Melkassa Agricultural Research Institute of Ethiopia, based on production percentage, disease tolerance, early maturing and easy to adopt in Ethiopia. The techniques and equipment employed and the analytical approaches followed are presented in each study's respective material and methods section. The material and method, which are common throughout all studies, were presented.

3.2. Analysis method

3.2.1. Proximate Composition

The Proximate composition of the flour samples was determined according to the official methods AOAC [145]. Moisture content (MC) was determined by drying the samples in an oven (Model 10-D1391/AD, SCA) at 105 °C for 18 h until constant weight. The percentage crude protein was found using an automatic Kjeldahl analyzer (K1160, Hanon, China), and the percent crude protein (% CP) was used to calculate the using the obtained percentage nitrogen (N) with 6.25 as a multiplication factor. Fat content was determined using the Soxhlet extractor technique. The percent of ash (%) was determined after incinerating the samples in a muffle furnace (MKF-

07,natek, Turkey) at 550°C for 4h and calculating the mass difference. Dilute acid and alkali hydrolysis assessed crude fiber percentage (% CF) (BXB-06Guangzhou, China). Carbohydrate was calculated by difference.

3.2.2. Phytochemical Composition

3.2.2.1. Phytate Content

The phytate content in the samples was determined according to the method described by Deme *et al.* [146]. Extract 100 mg of the sample with 10 mL of 0.2 N HCl in a mechanical shaker for 1 h at room temperature. Centrifuged the extract at 3000 rpm for 30 min. The clarified supernatant was used for phytate estimation. Add 1 mL of Wade reagent (containing 0.03% solution of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ and 0.3% of sulfosalicylic acid in water) to 3 mL of the sample solution (supernatant) and vortexed for 5 s. Absorption readings at 500 nm (Perkin Elmer Lambda 950 UV/Vis/NIR, UK) were taken against a blank solution (3 mL extract solution mixed with 2 mL of 2.4% HCl). The sodium salt of phytic acid (5–36 mg/mL) was used as a standard for the construct calibration curve. Phytate concentration was determined from a standard curve, and results were expressed as phytic acid in mg per 100 g dry matter.

3.2.2.2. Tannin Content

Tannin content was ascertained by the Burns (1971) method modified by Gemed [147], using catechin as the tannin standard. Approximately 1.0 g of each treatment sample was weighed in triplicates in a screw cap test tube and extracted with 10 mL of 1% HCl in methanol for 24 h at room temperature with mechanical shaking. After 24 h of shaking, the solution was centrifuged at 1000 rpm for 5 min. Mix 1 mL of supernatant with 5 mL of vanillin-HCl reagent (prepared by combining an equal volume of 8% concentrated HCl in methanol and 4% Vanillin in methanol). D-catechin was used as a standard for tannin determination. A 0.01 g of D- catechin was measured and dissolved in 50 mL of 1% HCl in methanol, serving as a stock solution. A 0, 0.2, 0.4, 3, 0.6, 0.8, and 1 mL of stock solution were taken in a test tube, and the volume of each test tube was regulated to 1 mL with 1% HCl in methanol. To each test, tube added 5 mL of vanillin-HCl reagent. After 20 min, the absorbance of sample solutions and the standard solution were evaluated at 500 nm (Perkin Elmer Lambda 950 UV/Vis/NIR, UK) zero the spectrophotometer by using distilled

water, and the calibration curve was formed from the series of standard solution as absorbance versus concentration, and the slope and intercept were used for calculation.

3.2.2.3. Total Phenolic Content

The total phenolic content (TPC) was assessed using the Folin Ciocalteu assay and using gallic acid (GA) as the standard, according to Xu & Chang [148]. The mixture of the sample solution (50 μL), distilled water (3 mL), 250 μL of Folin-Ciocalteu's reagents solution, and 7% NaCO_3 (750 μL) was vortexed and incubated for 8 min at room temperature. Then, a dose of 950 μL of distilled water was added. The mixture was allowed to stand at room temperature for 2 h. The absorbance was measured as a blank at 765 nm (Perkin Elmer Lambda 950 UV/Vis/NIR, UK) against distilled water. Gallic acid was used to draw the standard curve of 20–100 $\mu\text{g}/\text{mL}$ ($r = 0.99$). The results were mean \pm standard error of the mean and indicated as mg of gallic acid equivalents/g of extract (GAEs). The total phenolic content of the flour extracts in gallic acid equivalent (GAE) was determined by the following formula:

$$C = \frac{cxV}{m} \quad 3.1$$

where C is the total content of phenolic compounds, mg/g fresh material, in GAE; c is the concentration of gallic acid determined from the calibration curve; V is the volume of extract, L; m is the weight of extract, g.

3.2.2.4. Total Flavonoid Content

Total flavonoid content was determined using the colorimetric method previously described by Xu & Chang[148]. Briefly, 0.25 mL of the flour extract or quercetin standard solution was mixed in a test tube with 1.25 mL of distilled water, followed by 75 μL of 5% NaNO_2 solution. After 6 min, add 150 μL of 10% $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ solution, let stand for 5 min, and then add 0.5 mL of 1 M NaOH. The mixture was adjusted to 2.5 mL with distilled water and mixed well. The absorbance was evaluated immediately against the blank (the same mixture without the sample) using a UV-Visible Spectrophotometer (Lambda 950 UV/Vis/NIR, Perkin Elmer, UK) at 510 nm. Results were calculated and expressed as quercetin equivalents (mg of CE/g sample) using the calibration curve of (+)-catechin. The Linear range of the calibration curve was 25 to 200 $\mu\text{g}/\text{mL}$ ($r = 0.99$). The extraction was conducted in triplicate.

3.2.2.5. Free Radical Scavenging Activity

The effect of methanolic extracts on the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical was estimated according to Woldegiorgis *et al.* [149]. A 0.004% DPPH radical solution in methanol was prepared, and then 4 mL of this solution was blended with 1 mL of various concentrations (2–14 mg/mL) of the extracts in methanol. Finally, incubated the samples for 30 min at room temperature in the dark. Scavenging capacity was read spectrophotometrically (UV/Vis/NIR, Lambda 950 Perkin Elmer, UK) by checking the decrease in absorbance at 517 nm. The absorption maxima were first confirmed by scanning freshly prepared DPPH from 200 to 800 nm by the scan mode of the spectrophotometer. Ascorbic acid was used as a standard without extract and used as the control. Inhibition of free radical DPPH in percent (I%) was then calculated:

$$\text{Radical Scavenging activity} = \frac{A_o - A_1}{A_o} * 100 \quad 3.2$$

where A_0 is the absorbance of the control, and A_1 is the absorbance of the sample. EC_{50} ($\mu\text{g/mL}$) was defined as the half-maximal effective concentration of the amount of sample necessary to decrease the absorbance of DPPH by 50%. It was obtained by interpolation from the linear regression analysis.

3.3 Experimental Research Design and Statistical Data Analysis

This study employed a factorial and D-optimal design, and an analysis of variance was run on the data to identify significant ($p < 0.05$) variations between the samples. All analysis was done in triplicate, and the descriptive categories were converted to numerical scores. The variance analysis findings were then performed on the scores using the SAS statistical software version 9.0 (SAS Institute, Inc., Cary, North Carolina, USA), and the means of the three sets of data were compared using Tukey's Honestly Significant Difference test.

CHAPTER 4: GEOMETRIC CHARACTERISTICS AND MASS-VOLUME-AREA PROPERTIES OF HARICOT BEANS (PHASEOLUS VULGARIS L.): EFFECT OF VARIETY

Abstract

The geometric characteristics and mass-volume-area properties of haricot beans are essential for the design of equipment for harvesting, handling, drying, storing, dehulling, processing, and packaging. This study was conducted to determine the effect of variety on the geometric characteristics and mass-volume-area properties of four improved haricot bean varieties. The moisture content, 1000 seed mass and true density of beans varied significantly ($p < 0.05$) in the range of 9 to 11.28%, 199.9 to 529.93 g and 1127.52 to 1212.40 Kg.m^{-3} , respectively. The dimensional properties of the improved haricot bean were significant ($p < 0.05$) among the varieties indicating that these would require some variation in the processing equipment design. Hydration capacity varied significantly from 0.14 to 0.36 g/seed among the improved haricot bean varieties. The hydration index also displayed significant differences among the varieties. Significant differences among the varieties were observed in hydration coefficient and swelling capacity and varied from 1.71 to 1.77% and 0.28 to 0.81 mL/seed, respectively.

Keywords: Dimensions, Improved varieties, Haricot Beans, Physical properties

4.1. Introduction

Common beans are the most broadly grown legume species in the world, and it is the third most significant bean after soybean (*Glycine max* (L.) Merr.) and peanut (*Arachis hypogea* L.). Common beans have considerable potential now and in the future to contribute to nutrition and

food security [150]. Haricot beans (*Phaseolus vulgaris* L.) are a type of legume that is widely consumed due to their high nutritional value, delicious flavor, and ease of preparation. In Africa's East and Great Lakes regions, haricot beans play an important role in human nutrition [151]. They have a high protein source and are recognized as the “poor man’s meat.” They are nearly 2-3 times higher in protein than cereals [152]. Besides, they are also an important contributor to fibre, prebiotic, vitamin B, and other micronutrients in the human diet [153][154].

Haricot bean (*Phaseolus vulgaris* L.) has been an export crop for Ethiopia for more than 50 years [155]. A wide range of haricot bean types are grown in Ethiopia, including mottled, red, white, and black varieties. The most commercial varieties are pure red and white-colored beans, and they are becoming the most commonly grown types with increasing market demand. Nowadays, a continuous increase in the area and volume of production in the country has been noticed due to the growing demand for the local and export market of these crops [156]. This demonstrates that, while Ethiopia produces a large amount of haricot beans globally, postharvest handling is still inefficient and mostly done by hand. Therefore, it is necessary to have information on the geometric characteristics and mass-volume-area properties of haricot beans to handle them mechanically. As a result, there is an urgent need to investigate the geometric characteristics and mass-volume-area properties of Ethiopia's improved haricot bean varieties.

Information on the physical properties of common beans is important in the design of equipment used for processing, transportation, sorting, separation, and storage. Furthermore, these properties are required during the processing and handling of agricultural materials to set the operational parameters of the equipment for efficient operations [157] [158]. For instance, the size and shape of foods are important physical characteristics used in screening, grading, and quality control [159]. Data on the angle of repose, volume, density, and porosity are also important for the design of processing and storage of particulate material, determining the power required for pumping, and modeling and design of various heat and mass transfer processes such as drying, frying, baking, heating, cooling, and extrusion [159]. The functionality of raw material is the combination of properties that determine product quality and process effectiveness. These properties are relevant to the mechanization of processing to increase its utilization as a food resource. Hence, knowledge of the haricot bean's geometric characteristics and mass-volume-area properties is needed. Thus, this study aimed to explore geometric characteristics and mass-volume-

area properties of improved haricot beans and their dependence on variety, which can help design handling, processing, and packaging machinery for haricot beans production.

4.2. Materials and Methods

4.2.1. Sample

Four improved varieties of haricot bean (*Phaseolus vulgaris* L.), namely: SER 119, SER 125, SAB 632, and Awash -2 were obtained from the Awash Melkassa Agricultural Research Institute of Ethiopia (Fig. 4.1). The choice of exploring these haricot beans varieties was based on the facts that they have shown to have a high production percentage, disease tolerance, short period to ripe and easy to adopt in Ethiopia.

The sample seeds were cleaned from foreign materials such as dust, stones, dirt, immature seed, damaged seeds, and other impurities by manual picking, and for further analysis, the healthy selected seeds were kept at 5°C be placed in an airtight plastic vessel. Before starting a test, the seeds were allowed to warm to room temperature. Throughout the test and experiments, sample selection was randomized.

4.2.2. Physical Properties

4.2.2.1. Moisture Content

Before oven drying, each of the cleaned and selected seeds samples was weighed using an electronic weight of accuracy of 0.001 g (Metler toledo ML303T/00, China). By using small trays, all samples were put in an oven at a temperature of 103 °C as per ISO-665-2020 [160] and weighed every time after cooling the samples in a desiccator until constant mass. The moisture content was then calculated by using

$$\text{Dry basis } mc_d = \frac{M_w - M_d}{M_d} * 100 \quad 4.1$$

where m_d is dried beans mass, m_w is wet bean mass (total mass), and mc_d , is moisture content (dry basis) in percentage.

4.2.2.2. Thousand Seed Weight

The 1000 seed weight was determined using a digital electronic balance (Metler toledo ML303T/00, China) with an accuracy of 0.001 g following the procedure described by Sharma *et al.* [161] with some modifications. To assess the 1000 seed weight, 1000 randomly selected haricot bean seeds were counted and weighed. The reported value is the mean of three replications.



Figure 4.1 Haricot bean variety

4.2.2.3. Bean Weight

The weight of the improved haricot beans was determined using a precision electronic balance reading to an accuracy of 0.01g.

4.2.2.4. Bulk Density, True Density, and Porosity

The bulk density, true density and porosity of the haricot beans were determined using the method of Sharma *et al.* [161]. In brief, the bulk density was obtained by filling 500 mL in a volume of a circular container with the seed from a height of 150 mm to create a tapping effect in the container to mimic the settling effect during storage at a constant rate and then weighing the contents with a digital electronic balance with an accuracy of 0.001 g. No manual compactions were done for each seed variety. The bulk density, ρ_b was calculated as the ratio of the beans' mass to the cylinder's volume.

$$\rho_b = \frac{M_s}{V_c} \quad 4.2$$

where, V_c is the volume of a cylinder (m^3), M_s is the mass of the seed (kg).

The true density of haricot beans was determined using the toluene (C₇H₈) displacement method. The true density was found as an average ratio of their masses to the volume of toluene displaced by the seeds. The volume of toluene displaced was found by immersing a weighted quantity of haricot seed in the toluene. True density was then calculated from the obtained values using the formula:

$$\text{True density: } \rho_t = \frac{M}{V_2 - V_1} \quad 4.3$$

where M is the mass of seeds (kg), V_1 is the initial volume (m³), and V_2 the final volume (m³).

The porosity of haricot beans was determined by using the following equation:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) * 100 \quad 4.4$$

where ε is the porosity (%); ρ_b is the bulk density (kg/m³), and ρ_t is the true density (kg/m³).

4.2.2.5. Angle of Repose

The angle of repose of the sample was determined by filling the seed beans in a topless and bottomless cylinder (with a 10 cm diameter and 15 cm height) placed on a flat surface and allowing it to overflow and form a cone in its natural rest position. The angle of repose was calculated using the formula Aviara et al. gave [162].

$$\theta = \tan^{-1} \left(\frac{h}{r}\right) \quad 4.5$$

where θ = Angle of repose in degrees, h and r = height and the cone radius, respectively.

4.2.2.6. Color measurement

The color of haricot beans was measured with a precision colorimeter (3NH Technology Co., LTD, China). The color readings were displayed as L*, a*, and b* format values where L* represents lightness/darkness dimension, positive and negative a* value indicates redness and greenness, respectively, and b* indicates yellowness for positive and blueness for a negative value. The color measurement was repeated seven times.

4.2.3. Dimensional Properties

The three principal axial dimensions (length (L), width (W), and thickness (T)) of the haricot bean were measured using the method of Sahin and Sumnu [159]. The dimensions of 100 randomly selected haricot beans from each variety were measured using a digital vernier caliper (TA, M5 0-300 mm, China) of 0.01 mm precision. The arithmetic mean diameter (D_a), geometric mean

diameter (D_g), square mean diameter (D_s), and equivalent mean diameter (D_e) of the haricot bean were determined by using the following equations (4.6, 4.7, 4.8, and 4.9) [163].

$$D_a = \frac{(L+W+T)}{3} \quad 4.6$$

$$D_g = (LWT)^{1/3} \quad 4.7$$

$$D_s = (LW+WT+TL)^{1/2} \quad 4.8$$

$$D_e = \frac{D_a + D_g + D_s}{3} \quad 4.9$$

The volume (V) and surface area (S) of the haricot bean were determined using equations 4.10 and 4.11, adopted from Baryeh and Mangope [164].

$$V = \frac{\pi B^2 L^2}{6(2L-B)} \quad 4.10$$

$$S = \frac{\pi B^2 L^2}{2L-B} \quad 4.11$$

where; $B=(WT)^{0.5}$; L is the length of the seeds; W is the width of the seeds; T is the thickness of the seeds in mm.

4.2.3.1. Sphericity, Aspect Ratio, Flakiness Ratio and Percent Roundness

The sphericity and the aspect ratio of the haricot bean were calculated using the following equations 4.12 and 4.13 as per the method of Wani *et al.* [165].

$$\varphi = \frac{D_g}{L} * 100 \quad 4.12$$

$$R_a = \frac{W}{L} \quad 4.13$$

The haricot bean seed's flakiness ratio (R_f) was determined using the following equation (equation 4.14) [166].

$$R_f = \frac{T}{W} \quad 4.14$$

where φ is sphericity, R_a is the aspect ratio, R_f is the flakiness ratio, and L , W , and D_g are the length, width and geometric mean diameter of haricot beans seeds, respectively.

The percent roundness R_p was calculated as follows [167]. The projected area of the seed was measured by an image analysis method. The area of the minimum circumscribing circle was determined by taking the largest axial dimension of the seed at a natural rest position (length of the seed) as the circle's diameter. The process was repeated for 20 seeds selected randomly. The average was taken as the representative value of roundness.

$$R_p = \frac{A_p}{A_c} * 100 \quad 4.15$$

where: A_p is the projected seed area in mm^2 , and A_c is the minimum circumscribing circle in mm^2 .

4.2.4. Functional Properties

4.2.4.1 Hydration and Swelling Capacity

The hydration and swelling capacity of the haricot bean were determined using the method of Shimelis and Rakshit[151] and Kaur and Singh[168].

4.2.4.2. Hydration and Swelling Index

Hydration and swelling index was evaluated using Shimelis and Rakshit [151] method.

4.2.4.3. Hydration and Swelling Coefficients

The percentage increase in mass of haricot bean seeds soaked in distilled water for 24 hours was used to measure the hydration coefficient [151]. The swelling coefficient was calculated as a percentage of the volume of bean seeds after soaking divided by the volume before soaking [151].

4.2.4. Experimental Research Design and Statistical Data Analysis

The results were presented as the mean and standard deviation (SD). The data were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Science (SPSS version 20). Significant differences between means were determined with Tukey at $p < 0.05$.

4.3. Results and Discussions

4.3.1. Physical Properties

Table 4.1 shows the effect of variety on the physical properties of improved haricot bean varieties. According to the result, the moisture content value ranged from 9 % to 11.28 % on a dry basis. The highest was recorded for SER 125 variety, and the lowest was for SER 119 variety. There were no significant differences between SAB 632, SER 119 and Awash 2 varieties, but these three were significantly ($p < 0.05$) different from SER 125 varieties. The present results show that the moisture contents range was within those reported in Shimelis and Rakshit [151] for haricot bean, which was between 9.08 to 11.00 g/100 g (d.b) and Tuned-Akintunde *et al.*[169] for soybean, which was between 6.25 to 11.60% d.b. The moisture content of the seed can indicate its storage stability and ease of the dehulling process [161]. For food researchers and processors, the amounts

of water present in agricultural products are extremely important as they assist in determining certain phases of adaptation and resistance to processing, such as drying, bagging, storing, cooking and even consumption.

The seed mass of improved haricot beans varied from 0.20 to 0.51 g. The highest seed mass was observed in SAB 632 variety. The haricot bean seed is heavier than the soybean, which is between 0.11 to 0.18 g reported by Tunde-Akintude et al. [169] but the mass of the SAB 632 variety was in tune with the observations of Palilo et al. [170] for the common beans Wanja variety grown in Tanzania, which is 0.50 g. According to the classification of bean size adopted by De Barros and Prudencio [171], the haricot beans studied were considered small, except the beans from the SAB 632 variety, which were classified as big.

Regarding the thousand seed mass, results showed significant ($p < 0.05$) differences between the haricot bean varieties. However, SER 119 and SER 125 varieties were not significantly different in their thousands of seed mass from each other. The highest (529.93) thousand seed mass was observed in SAB 632, and the lowest (199.90) in the Awash 2 variety. The data of thousand seeds' mass is a significant factor in the equipment design for cleaning, separation, conveying, and elevating unit operations [162]. It can also be used to estimate the overall bulk mass of haricot bean seeds during bulk handling.

There were significant ($p < 0.05$) differences in the true density values of haricot bean seed varieties. The true density of the haricot bean seed varieties ranged from 1127.52 to 1212.40 $\text{kg}\cdot\text{m}^{-3}$. Data on the true haricot bean seed density is used to design haricot bean seed separation or cleaning processes. A significant ($p < 0.05$) difference exists in the haricot bean varieties' bulk density. SAB 632, SER 119 and SER 125 varieties had no significant differences in their bulk density. Awash 2 variety had the highest bulk density (958.2 $\text{kg}\cdot\text{m}^{-3}$). The bulk density observed was higher than those reported by Altuntas and Demirtola [172] for legume seeds such as kidney bean (*Phaseolus vulgaris*), pea (*Pisum sativum*) and black-eyed pea (*Vigna sinensis*) that were between 426.26 to 503.72 $\text{kg}\cdot\text{m}^{-3}$ measured at different moisture content. Information on bulk density is an important parameter in determining packaging and storage requirements for agricultural materials [159]. It is also practically used to calculate heat transfer problems with thermal properties, identify Reynold's number of materials, and predict the pressures of the stock structures and chemical composition [162].

The porosity and angle of repose were statistically the same for all varieties. The values are lower than that reported for Indian kidney bean cultivars, 33.6% to 37.5% and 15.20 to 18.67° [165], 35 to 40° for common beans grown in Tanzania [170]. Seeds with low porosity take a long time to dry, while seeds with higher porosity have greater aeration and water vapor diffusion during drying. The porosity refers to the percentage of space in bulk seeds not filled by seeds. It is useful for calculating the rate of aeration, cooling, drying, and heating, as well as designing heat exchangers and other similar bean-handling equipment [173]. The angle of repose of the haricot bean measured in the present study is higher than 6.09 to 8.40° for soybean [169]. The angle of repose is important when designing hopper openings, storage bin sidewall slopes, and chutes for bulk seed transport, and it is especially useful when measuring the number of granular materials that can be stored in implied or flat storages [158][173].

Table 4.1. Effect of variety on some selected properties of improved haricot bean varieties

Parameters	SAB 632	SER 119	Awash 2	SER 125
Moisture content, %	9.81±0.52 ^b	9±0.07 ^b	9.33±0.48 ^b	11.28±0.34 ^a
Weights of beans, (g)	0.51±1.83 ^a	0.26±0.65 ^b	0.20±0.83 ^b	0.26±0.07 ^b
Thousand seed mass, (g)	529.93±14.01 ^a	255.15±2.39 ^b	199.90±5.06 ^c	260.10±2.76 ^b
Bulk density (ρ_b), kg/m ³	881.33±3.49 ^b	890.85±13.58 ^b	958.20±8.05 ^a	871.92±13.11 ^b
True density (ρ_t), kg/m ³	1185.28±5.56 ^b	1167.65±0.68 ^c	1212.40±2.96 ^a	1127.52±11.62 ^d
Porosity (p), %	25.64±0.47 ^a	23.71±1.12 ^a	20.97±0.78 ^a	22.66±1.83 ^a
Angle of repose, °	13.11±0.77 ^a	13.46±0.27 ^a	13.14±0.09 ^a	12.90±0.49 ^a

All values are means ± SD, and values in the same row with different superscript letters were significantly different ($p < 0.05$).

4.3.1.1. Color Measurement

Table 4.2 shows the effect of variety on the color of improved haricot bean varieties. The L* value showing the samples' lightness was significantly ($p < 0.05$) different due to variety. The highest 80.91 L* value was recorded for the Awash 2 variety. The L values of different dry bean varieties ranged from 28.823 to 73.937, as reported by Shimelis and Rakshit [151]. Skin color and brightness are some of the most significant quality parameters of the common bean.

The a* and b* values, which indicate the red or green and the yellow or blue color of the improved haricot beans, showed significant ($p < 0.05$) differences due to variety. However, SAB 632, SER 119 and SER 125 varieties were not significantly different in their a* and b* values from each other. These findings are similar to the range reported (1.693 to 14.390 and 5.710 to 25.393

for a* and b* values, respectively) by Shimelis and Rakshit[151] for improved dry bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia. Color values of L*, a*, and b* in the 33.31–38.90, 3.43 to 8.58, and 1.88– 7.32, respectively, have been reported for Indian kidney bean cultivars [165]. Ethiopians favor red color beans as the beans provide attractive red color when cooked with other cereals and legumes [151].

Table 4.2. Color measurement of improved haricot beans as affected by a variety

Parameters	SAB 632	SER 119	Awash 2	SER 125
L*	63.08±1.44 ^b	26.38±1.87 ^c	80.91±1.58 ^a	26.36±3.48 ^c
a*	13.37±1.07 ^a	14.97±6.47 ^a	2.42±0.43 ^b	13.80±10.73 ^a
b*	20.24±1.04 ^a	22.01±3.91 ^a	14.43±1.04 ^b	22.96±3.79 ^a

All values are means ± SD, and values in the same row with different superscript letters were significantly different ($p < 0.05$).

4.3.2. Dimensional Properties

Table 4.3 shows the effect of variety on the dimensional properties of improved haricot bean varieties. The dimensional properties of the improved haricot bean were significant ($p < 0.05$) among the varieties indicating that these would require some variation in the processing equipment design. The average length of the improved haricot beans ranged from 11.12 to 13.09 mm, while the corresponding width ranged from 6.23 to 8.41 mm. Comparisons in terms of length and width indicate that SAB 632 variety is longer and wider than SER 119, SER 125, and Awash-2 varieties, and it is inside the range of 11.39 to 19.96 mm (in length) and 7.61 to 8.97 mm (width) reported by Palilo et al.[170] for common beans cultivated in Tanzania. The thickness of the improved haricot bean is between 4.79 to 7.01 mm; the highest was recorded for SAB 632 variety, while the lowest was for SER 125 variety. Wani et al.[165] reported length, width and thickness in the range of 11.45–16.45 mm, 6.65–7.80 mm and 4.70– 6.13 mm, respectively, for Indian kidney bean cultivars.

The arithmetic and geometric mean diameter of improved haricot beans ranged from 6.76 to 9.50 mm and 6.60 to 9.16 mm, respectively, being this value lower than the length and width and higher than the thickness. The four improved haricot beans' equivalent and square mean diameters were 8.31 to 11.60 mm and 11.57 to 16.14 mm, respectively. SAB 632 reported the highest and Awash 2 the lowest arithmetic, geometric, equivalent and square mean diameters. The equivalent diameter of Indian kidney bean cultivars has been reported to vary from 7.31–9.24 mm [165]. The

geometric mean diameter is useful for the appraisal of the projected area of a particle moving in the turbulent or near-turbulent area of an air stream which is a useful parameter in the design of separation systems for the seeds from extraneous materials [174]

The improved haricot beans have a sphericity and roundness range of 60.23 to 75.37% and 67.33 to 75.18%, respectively. The results showed that the aspect ratio, flakiness ratio, projected and surface area and volume of the improved haricot beans ranged between 0.54 to 0.73°, 0.76 to 0.83, 47.08 to 97.54 mm², 731.95 to 1726.29 mm² and 112.99 to 287.72 mm³, respectively. Sphericity, aspect ratio, seed volume and surface area of Indian kidney bean cultivars have been reported to vary from 52.13% to 63.08%, 0.40 to 0.61, 113.83 to 223.96 mm³ and 137.84 to 224.18 mm, respectively [165]. The nearer the sphericity to 1.0, the higher the affinity to roll about any of the three-axis, and the closer the ratio of thickness to width to 1.0, the higher the tendency to rotate about the major axis [175]. This propensity to either roll or slide is essential in designing hoppers and de-hulling equipment for the seed since most flat seeds slide easier than spherical seeds that roll on structural surfaces [176]. The sphericity and aspect ratio of more than 70 percent implicit that grain was more spherical and tended to roll than slide [177].

4.3.3. Functional Properties

The effect of variety on the functional properties of four improved haricot bean varieties is presented in Table 4.4. Hydration capacity varied significantly from 0.14 to 0.36 g/seed among the improved haricot bean varieties. SAB 632 had the highest, whereas Awash 2 had the lowest hydration capacity. Shimelis and Rakshit [151] reported hydration capacity in the range of 0.081 to 0.194 g/seed for different dry bean varieties.

The hydration index also displayed significant differences among the varieties. This parameter varied from 0.71 to 0.77. SER 125 had the maximum hydration index followed by SER 119, SAB 632 and Awash 2 varieties. The hydration capacity and hydration index of some Indian kidney bean cultivars have been reported to vary between 0.12–0.42 g/seed and 0.48–0.93, respectively [165].

Table 4.3. Size dimensional properties of improved haricot beans as affected by the variety

Parameter	SAB 632	SER 119	Awash 2	SER 125
Length (L), mm	13.09±0.74 ^a	11.12±0.79 ^c	8.76±0.37 ^d	11.76±0.60 ^b
Width (W), mm	8.41±0.45 ^a	6.23±0.46 ^b	6.37±0.29 ^b	6.31±0.30 ^b
Thickness (T), mm	7.01±0.50 ^a	4.91±0.32 ^c	5.16±0.32 ^b	4.79±0.31 ^c
Arithmetic mean diameter (Da), mm	9.50±0.47 ^a	7.42±0.43 ^c	6.76±0.25 ^d	7.62±0.32 ^b
Geometric mean diameter (Dg), mm	9.16±0.46 ^a	6.97±0.39 ^b	6.60±0.25 ^c	7.08±0.30 ^b
Equivalent mean diameter (De), mm	11.60±0.58 ^a	8.94±0.51 ^c	8.31±0.30 ^d	9.13±0.38 ^b
Square mean diameter (Ds), mm	16.14±0.80 ^a	12.42±0.70 ^c	11.57±0.42 ^d	12.68±0.53 ^b
Sphericity (y), %	70.1±2.4 ^b	62.8±2.4 ^c	75.4±2.3 ^a	60.2±1.9 ^d
Roundness (Rp), %	67.4±3.8 ^b	67.3±6.9 ^b	75.2±3.8 ^a	69.7±6.9 ^b
Aspect ratio (Ra). °	0.64±0.03 ^b	0.56±0.0 ^c	0.73±0.03 ^a	0.54±0.03 ^d
Flakiness ratio (Rf),	0.83±0.05 ^a	0.79±0.07 ^b	0.81±0.05 ^b	0.76±0.05 ^c
Projected area (Ap), mm ²	97.54±6.74 ^a	72.83±7.16 ^b	47.08±2.89 ^c	76.52±5.71 ^b
Surface area (S),mm ²	1726.29±269.46 ^a	805.58±137.17 ^c	885.05±95.87 ^b	731.95±95.63 ^d
Volume (V), mm ³	287.72±44.91 ^a	119.40±20.46 ^b	112.43±13.23 ^b	121.99±15.94 ^b

All values are means ± SD, and values in the same row with different superscript letters were significantly different (p < 0.05).

Table 4.4. The effect of variety on the functional properties of improved haricot bean varieties

Parameters	SAB 632	SER 119	Awash 2	SER 125
Hydration capacity ,g/seed	0.36±0.17 ^a	0.19±0.01 ^b	0.14±0.00 ^c	0.19±0.01 ^b
Hydration index	0.72±0.01 ^b	0.75±0.02 ^{ab}	0.71±0.02 ^b	0.77±0.03 ^a
Hydration coefficient, %	1.72±0.01 ^b	1.75±0.02 ^{ab}	1.71±0.02 ^b	1.77±0.03 ^a
Swelling capacity, mL/seed	0.81±0.03 ^a	0.40±0.01 ^b	0.27±0.00 ^c	0.38±0.01 ^b
Swelling index	1.11±0.02 ^a	1.11±0.04 ^a	1.07±0.02 ^a	1.09±0.02 ^a
Swelling coefficient, %	2.11±0.02 ^a	2.11±0.04 ^a	2.07±0.02 ^a	2.09±0.02 ^a

All values are means ± SD, and values in the same row with different superscript letters were significantly different (p < 0.05).

Significant differences among the varieties were observed in hydration coefficient and swelling capacity and varied from 1.71 to 1.77% and 0.28 to 0.81 mL/seed, respectively. SAB 632 showed the highest swelling capacity, while the lowest was found in Awash 2 among the improved haricot bean varieties. A similar trend was reported by Wani et al.[165] in some Indian kidney bean cultivars. The swelling index and swelling coefficient did not differ significantly among the improved haricot bean varieties.

4.4. Conclusions

The effect of variety on the geometric characteristics and mass-volume-area properties of improved haricot beans was reported, and the following conclusions were drawn from this investigation. The moisture content, seeds Mass, thousand seed mass, true and bulk density were

significantly different among the varieties. The effect of variety on the dimensional properties such as length, width, thickness, arithmetic and geometric mean diameter of the haricot bean was significant ($p < 0.05$), indicating that these would require some variation in the processing equipment design. In addition, the results showed that the aspect ratio, flakiness ratio, projected and surface area and volume of the improved haricot beans ranged between 0.54 to 0.73°, 0.76 to 0.83, 47.08 to 97.54 mm², 731.95 to 1726.29 mm² and 112.99 to 287.72 mm³, respectively. Hydration capacity varied significantly from 0.14 to 0.36 g/seed among the improved haricot bean varieties. The hydration index also displayed significant differences among the varieties. In conclusion, this paper deals with the geometric characteristics and mass-volume-area properties of improved haricot beans, enlarging the knowledge about these varieties and providing useful data for post-harvest handling and further industrial processing. Further studies should be conducted to explore the moisture-dependent geometric characteristics and mass-volume-area of these improved haricot bean varieties.

CHAPTER 5: HARICOT BEANS (*PHASEOLUS VULGARIS* L.)

FLOUR: EFFECT OF VARIETIES AND PROCESSING

METHODS TO FAVOR THE UTILIZATION OF

UNDERCONSUMED COMMON BEANS

Abstract

Four improved varieties of haricot bean flour prepared by soaking, autoclaving, germination, and germination followed by autoclaving were investigated. The objective was to obtain information on the effect of varieties, processing methods and their interactions on flour quality. The moisture, crude protein, crude fat, crude fibre, ash, and carbohydrate contents of flours were from 8.05 to 9.72%, 23.11 to 27.96 %, 1.33 to 2.87 %, 3.82 to 5.97 %, 3.45 to 5.52%, and 51.79 to 57.14%, respectively. The flour produced through germination followed by the autoclaving method showed a significant reduction in tannin, phytate, and oxalate contents with less acceptability by the consumer, while the one that produced through germination increased in total flavonoids (2.79 to 3.69 mg QE/g), total phenol content (0.72 to 1.04 mg GAE/g) and DPPH scavenging activities (EC50). Germination showed increased foaming and emulsifying capacity; however, autoclaving and germination followed by autoclaving noticeably reduced foaming capacities.

Keywords: Functional properties, Haricot beans flour, Phytochemicals properties, Processing method, Variety

5.1. Introduction

Legume seeds are important staple foods, especially in developing countries, due to their accessibility, relatively low cost, long conservation time, and high nutritional value. Legumes are a major source of cheap protein and minerals compared to animal products such as meat, fish, and egg [178], and the less affluent people in many tropical countries, especially in Africa and Asia, utilize legumes as an alternative to other expensive protein sources. Beans contain various phenolic compounds [182], considered natural antioxidants and an important part of bioactive components in foods, which can inhibit the development of various diseases such as diabetes mellitus, coronary heart disease, and colon cancer [68]. A wide range of haricot bean types are grown in Ethiopia,

including variegated, red, white, and black varieties. The most commercial varieties are pure red beans and pure white-colored beans, which are becoming the most frequently planted varieties as market demand increases. Despite the wide range of varieties available, widespread production is restricted to a relatively small set of commodity varieties. Processing haricot beans into flour would help to increase its use as there is growing interest in the consumption of flour from different legumes [179]. The low consumption of haricot beans for food is partly due to anti-nutritional factors and low community awareness of the nutritional benefit. Therefore, reducing anti-nutritional factors before consumption is a better solution to the problem. Dried beans are nutrient-dense and gluten-free, offering important opportunities to use flour in different food systems. In order to fully utilize the potential of haricot beans in food, it is essential to investigate how processing affects their properties. This will allow for improvements in their nutritional quality by reducing the levels of anti-nutritional factors. Additionally, changing their functional properties will enable their wider use as ingredients in various food products.

The objective of this study was to evaluate the physical, chemical, and functional properties, as well as the taste and smell, of haricot beans flour that had undergone various treatments including soaking, autoclaving, germination, and a combination of germination and autoclaving. The purpose of this investigation was to provide useful information for the optimal usage of the seeds in a variety of food applications, and to generate data that would raise awareness of their potential for consumer food formulations.

5.2. Materials and Methods

5.2.1. Chemicals

Standards and reagents used were gallic acid (97.5-102.5% sigma Aldrich, China), Quercetin ($\geq 98\%$, sigma Aldric, Germany), folic-Ciocalteu's (2N, Sigma Aldrich, USA), (+-) Catechin hydrate ($\geq 96.0\%$, Sigma Aldrich, China), 2,2-Dipheyl-1-picrylhydrazyl (sigma Aldrich, Germany), Phytic acid sodium salt hydrate (sigma Aldrich, Switzerland), Vanillin ($\geq 99.5\%$, UNI-CHEM, Roth, France), Almunium Chloride (99% Loba chemic, India), Sodium carbonate ($\geq 99.5\%$ carl Roth GmbH, Karlsruhe) Methanol (M.wt. =34.02g/mol, Biochem chemopharma, France), and Nitric acid (69% Loba chemic, India). All chemicals used were of analytical grade.

5.2.2. Material Collection and Preparation

Haricot bean (*Phaseolus Vulgaris L.*) varieties (*Awash-2, SER 119, SAB 632, and SER 125*) were collected from Awash Melkasa Agricultural Center. The seeds were cleaned and the extraneous materials were carefully removed by hand sorting. From each variety, the good sample was separated into four parts. One portion was soaked (S) dehulled, and served as control. The others were processed using the following processing methods; germination (G), autoclaving (A), and germination followed by autoclaving (GA). It was set in a 4 × 4 factorial arrangement prior to drying and milling. The resulting flours were sealed, placed in plastic bags, and stored at 4 °C in a desiccator before use.

Soaking: The flour was prepared according to the method of Ugwu & Oranye [180] with some modifications. During preparation, 500 g of seeds free of dirt and other extraneous materials were weighed and soaked in 2 L of distilled water for 24 h at room temperature (25±2 °C). The soaked seeds are drained and dehulled by rubbing between palms to remove the husk. The dehulled seeds were rinsed, spread on the trays, and dried in a hot air oven (Model 10-D1391/AD, SCA) at 60 °C for 10 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using a hammer mill (Model BH24 1DY, Armfield, England) and sieved through a 500-micron mesh sieve. The flour produced was packaged in airtight plastic bags and stored at 4 °C in a desiccator until needed for further analysis.

Autoclaving: It was prepared according to the method of Ugwu & Oranye [180] with some modifications. During preparation, 500 g of seeds free of dirt and other extraneous materials were cleaned, weighed, and soaked in 2 L of distilled water for 24 h at room temperature (25±2 °C). The soaked seeds were drained, rinsed, and manually dehulled by rubbing between palms to remove the husk. Placed the dehulled seeds in a beaker and autoclaved in an autoclave (Model 75xG) at a temperature of 121 °C and a pressure of 6 atmospheres for 40 min. Spread the autoclaved seeds on the tray and dry in a hot air oven (Model 10-D1391/AD, SCA) at 60 °C for 8 h, stirring the seeds occasionally every 30 min to ensure even drying. Dried seeds were milled to flour by a hammer mill (Model BH24 1DY, Armfield, England) and sieved through a 500-micron mesh screen. The flour produced was packaged in airtight plastic bags and stored at 4 °C in a desiccator until needed for further analysis.

Germinating: accurately weighed 1000 g seeds into a large plastic Petri-dishes and soaked in distilled water (1:5 w/v bean to water ratio) for 24 h at room temperature. Petri dishes were covered

with perforated aluminum foil and placed in the darkroom for germination in filter paper-lined Petri dishes for 4 days. Leaching losses were minimized by collecting all drips at the bottom of the petri-dish. Spray the seeds with distilled water for 10 min every 24 h to avoid mold contamination. At the end of the germination period, non-germinated seeds were discarded; one-half of germinated seeds were dehulled manually, dried in an air circulation oven at 60 °C for 12 h (Model 10-D1391/AD, SCA), and milled into flour using a hammer mill (Model BH24 1DY, Armfield, England) then sieved through a 500-micron mesh sieve. The other half was autoclaved, dried, and milled as described above. The flour produced was packaged in airtight plastic bags and stored at 4 °C in a desiccator until needed for further analysis.

5.2.3. Physical Properties

5.2.3.1. Color

Color analysis was performed using Hunter Lab Colorimeter, Minolta. The color readings were displayed as L*, a*, b*, c*, h* format where a* value extends from -100 (greenness) to +100 (redness), the b* value ranges from -100 (blueness) to +100 (yellowness), whereas the l* value, pointing out the degree of lightness, ranges from 0 (black) to 100 (white)[181]. Black and white tiles are used for instrument calibration before color measurement.

5.2.3.2. Water Activity and pH

The water activity of the legume flours was measured by a water activity meter (HD-3A, NanBei, China). Balanced and dissolved 10 g of the sample in a beaker filled with 25 mL of distilled water to form a slurry. It was allowed to stand for 10 min with constant stirring. The pH was then determined with a pH meter (BANTE Multiparameter/China) according to official methods AOAC [182].

5.2.4. Proximate Composition

Proximate composition was determined according to the method described in section 3.2.1

5.2.5. Phytochemical Composition

5.2.5.1. Phytate content

Phytate content was determined according to the method described in section 3.2.2.1.

5.2.5.2. Tannin content

Tannin content was determined according to the method described in section 3.2.2.2.

5.2.5.3. Oxalate content

Oxalate was assessed by the AOAC [145] method. A 1 g of sample was measured in a 100 mL conical flask. A 75 mL of 3 mol/L H₂SO₄ was added, and the solution was stirred intermittently with a magnetic stirrer for about 1 h and then filtered using Whatman No.1 filter paper. The sample filtrate (extract) (25 mL) was collected and titrated with hot (80–90 °C) 0.1 N KMnO₄ solution until a pale pink color was observed for at least 30 s. Results were summarized as mg of oxalate per g of sample, and the concentration of oxalate in each sample was assessed by following the calculation:

$$1 \text{ mL of } 0.1 \text{ N Permanganate} = 0.006303 \text{ g oxalate} \quad 5.1$$

Antioxidant Activities

Samples were extracted according to the procedures previously defined by Ferreira *et al.*[183]. Briefly, 10 g of flour was extracted with 100 mL of methanol using an incubator shaker (ZHWY-103B) at 25 °C, 150 rpm for 24 h, and then passed through Whatman No.1 paper. The sediment was then extracted with two additional 100 mL portions of methanol as described above. The combined methanolic extracts were evaporated to dryness at 40 °C using a rota evaporator (R-300, Buchi, Switzerland), redissolved in methanol at 50 mg/mL concentration, and stored at 4 °C for further use.

5.2.5.4. Total phenolic content

Total phenolic content was determined according to the method described in section 3.2.2.3.

5.2.5.5. Total flavonoid content

Total flavonoid content was determined according to the method described in section 3.2.2.4..

5.2.5.6. Free Radical Scavenging Activity

Free Radical Scavenging Activity was determined according to the method described in section 3.2.2.5.

5.2.6. Functional Properties

Water absorption capacity (WAC) and water solubility index (WSI): Suspension was prepared by adding 10 mL of distilled water to 1 g of flour and stirring for 5 min in centrifuge tubes. The tubes were centrifuged at 3000*g (TGL-16, Sichuan Shoke, China) for 30 min, and the supernatant was collected in an evaporating dish to determine its solid content and the sediment was balanced. The weight of dry solids was recovered by evaporating the supernatant overnight at 105 °C. The weight of solids obtained after evaporation of the supernatant was used to calculate the water solubility index (*Equation.5.3*), and the water absorption index (*Equation. 4.2*) was determined from the amount of water absorbed by the sediments [184].

$$WAC = \frac{\text{Weight of sediment (g)}}{\text{Weight of flour sample (g)}} \quad 5.2$$

$$WSI = \frac{\text{Weight of dissolved solids in supernatant(g)}}{\text{Weight of flour sample (g)}} \quad 5.3$$

Foaming properties: A suspension was prepared by putting on a known weight of the sample to 100 mL of distilled water. The suspension was homogenized for 5 min. The mixture was transferred immediately into a 250 mL measuring cylinder, and the volume was recorded after 30 s. Foam capacity (FC) was expressed as a % increase in volume by the formula (*Eq. 5.4*), and the change in volume of foam after 60 min of standing at room temperature was documented as foam stability(*Eq. 5.5*) [185]

$$FC (\%) = \frac{V_2 - V_1}{V_1} * 100 \quad 5.4$$

$$FS (\%) = \frac{V_2 - V_3}{V_2} * 100 \quad 5.5$$

where FC is the foaming capacity, FS is the foaming stability, V_1 is the volume of the suspension, V_2 is the volume of suspension and foam formed, and V_3 is the volume of the foam formed after it is permitted to stand for 60 min, all volumes measured in mL.

Oil absorption capacity (OAC): The OAC of flour was assayed according to the Niangoran *et al.* [186] method with some modifications. A 1 g of the flour (M_o) was mixed with 10 mL oil in a centrifuge tube and allowed to stand at room temperature for 1 h, followed by centrifugation at 3000 for 30 min. The resulting precipitate (M_1) was weighed and the OAC was calculated as follows:

$$OAC = \frac{M_1 - M_o}{M_o} \quad 5.6$$

Gel formation: Gelation was investigated according to Adebowale et al.[184]. Suspensions of 4, 6, 8, 10, 12, and 14 g sample/100 mL were prepared in distilled water and mixed in a Waring Blender (XTY-767, Starsun, China) at the highest speed for 2 min. A 10 mL of each dispersion was transferred into a test tube. Heated in a boiling water bath for 1 h, then rapidly cooled in a cold bath. The tubes were further cooled at 4 °C for 2 h. The least gel concentration was found. Concentration at which the sample in an inverted test tube did not slip.

Emulsifying Properties: Emulsifying properties (emulsifying capacity and stability) were calculated according to the method defined by Butt & Batool [187]. A 1.8 g flour was added to 25 mL of distilled water (pH 7) and dispersed at maximum speed in a blender (XTY-767, Starsun, China). Corn oil (12.5 mL) was added and unified at high speed for 1 min; the resulting emulsion was equally divided into two 12 mL centrifuge tubes and centrifuged at 5200 rpm for 5 min using a centrifuge (TGL-16, Sichuan Shoke, China). Emulsion capacity was calculated as follows:

$$\text{Emulsion capacity (\%)} = \frac{\text{Height of emulsified layer}}{\text{Height of total content of tube}} * 100 \quad 5.7$$

The evaluation of emulsion stability was similar to that of emulsion capacity, except that the emulsion was first heated in a water bath at 85 °C for 30 min and then cooled to 25 °C before centrifugation.

$$\text{Emulsion stability (\%)} = \frac{\text{Height of emulsified layer after heating}}{\text{Height of total content of tube}} * 100 \quad 5.8$$

Bulk density: The bulk density of each flour sample was determined according to Siddiq *et al.* [181]. Place a 50 g sample in a 100 mL graduated measuring cylinder and tap the cylinder gently several times to a constant volume on a laboratory bench.

5.2.7. Sensory Quality Evaluation

The sensory quality evaluation of flour was conducted using 20 panelists. Preference analysis using a nine (9) point hedonic scale, where 1=like extremely, 5=neither like nor dislike and 9=dislike extremely, was adopted according to Iwe [188]. Color, Odor, texture, and overall acceptability were evaluated.

5.2.8. Experimental Research Design and Statistical Data Evaluation

Statistical data analysis was done using the software package SAS version 9.0 (SAS Institute, Inc., Cary, North Carolina, USA) using two factors analysis of variance (ANOVA). Tukey's test at 5% significance level ($P < 0.05$) was used to determine significant differences among means of samples. Pearson's correlation was calculated to study the relationship between various properties.

5.3. Results and Discussions

5.3.1. Physical Properties

As revealed in Table 5.1, the water activity indicates that a product's shelf-stability exhibited relatively no significant impact on the flour due to processing methods ($p < 0.05$). At the same time, the pH value indicates a sign of acidity or alkalinity ranging from 6.36 ± 0.06 to 6.68 ± 0.00 for flour samples of 125A and 125G, respectively, indicating low acidity. Higher acidic flours ($pH < 4$) are particularly unsuitable for processing into bakery and pastry products compared to the flour produced to nurture a lower acidic property. The pH values of the flour in an aqueous suspension are important because some functional properties, such as solubility and emulsion properties, are highly affected by pH changes [189].

The flour samples' Hunter color L^* , a^* , and b^* values varied significantly ($P < 0.05$) due to differences in varieties and processing methods, as shown in Table 5.1. The L^* and h values were highest for flour produced by the soaking method and the lowest for flour produced by the GA method. As seen in Table 5.1, all flour samples had positive values for a^* and b^* , with the highest value recorded for flour samples of AGA 5.63 ± 0.56 and 19.70 ± 0.76 , indicating a greater degree of redness and yellowness, respectively. The highest value of L^* reflects its lighter black, while the lowest represents a darker black [190]. Soaking and germination processes increased the lightness of haricot bean flour. Germination, autoclaving, and germination followed by autoclaving increased the b^* value of haricot bean flour compared to the flour through the soaking method. The increase in the b^* value was attributed to the breakdown and the formation of new pigments during germination and the Maillard, resulting in the formation of new compounds, including melanoidins, reaction during autoclaving [191]. Chromaticity depicted a similar trend to that observed for b^* values. Flours from the soaking method had the lowest chroma and highest hue angle values: chroma symbolizes 'richness of color', color intensity, and hue angle illustrate

how an average person will recognize that color [181]. Differences in hunter color values may be due to genetic differences among the cultivars [192].

Table 5.1. Effects of interaction between varieties and processing methods on Water activity, pH, and color properties of haricot beans flour

Sample Code	Water activity	pH	L*	a*	b*	C	h
AS	0.50±0.02 ^{ab}	6.49±0.034 ^{cdef}	91.84±0.25 ^a	0.94±0.07 ⁱ	13.19±0.23 ^g	13.20±0.23 ^f	85.97±0.26 ^a
AA	0.51±0.01 ^{ab}	6.37±0.10 ^{fg}	87.41±0.30 ^d	4.00±0.17 ^e	16.48±0.31 ^d	16.95±0.34 ^c	76.37±0.38 ^e
AG	0.51±0.01 ^{ab}	6.501±0.02 ^{cde}	90.60±0.12 ^b	1.03±0.13 ⁱ	14.53±0.12 ^f	14.57±0.13 ^e	85.97±0.49 ^a
AGA	0.53±0.04 ^{ab}	6.41±0.01 ^{efg}	81.66±1.35 ^g	5.63±0.56 ^a	19.70±0.76 ^a	20.50±0.88 ^a	74.08±0.99 ^{fg}
119S	0.44±0.01 ^b	6.49±0.03 ^{cdef}	90.42±0.22 ^b	0.96±0.10 ⁱ	11.88±0.16 ^h	11.92±0.15 ^g	85.36±0.47 ^a
119A	0.44±0.04 ^b	6.40±0.03 ^{efg}	85.68±0.27 ^{ef}	4.66±0.17 ^{cd}	16.15±0.23 ^{de}	16.81±0.26 ^{cd}	73.92±0.39 ^{fg}
119G	0.46±0.012 ^b	6.54±0.00 ^{bcd}	88.54±0.29 ^c	2.57±0.10 ^g	13.99±0.15 ^f	14.22±0.16 ^e	79.58±0.351 ^c
119GA	0.52±0.09 ^{ab}	6.39±0.07 ^{efg}	81.67±0.38 ^g	5.18±0.27 ^b	17.31±0.34 ^c	18.07±0.40 ^b	73.34±0.57 ^g
632S	0.48±0.03 ^{ab}	6.61±0.01 ^{abc}	91.81±0.22 ^a	0.92±0.06 ⁱ	11.69±0.20 ^h	11.73±0.21 ^g	85.47±0.23 ^a
632A	0.57±0.01 ^a	6.43±0.03 ^{defg}	86.52±0.25 ^{de}	3.77±0.09 ^{ef}	16.28±0.28 ^{de}	16.71±0.28 ^{cd}	76.94±0.35 ^{de}
632G	0.47±0.03 ^{ab}	6.64±0.05 ^{ab}	89.28±0.09 ^c	1.94±0.05 ^h	14.21±0.09 ^f	14.35±0.10 ^e	82.21±0.16 ^b
632GA	0.52±0.03 ^{ab}	6.43±0.02 ^{defg}	81.54±0.30 ^g	5.04±0.12 ^{bc}	18.03±0.23 ^b	18.70±0.26 ^b	74.36±0.24 ^f
125S	0.48±0.01 ^{ab}	6.40±0.01 ^{efg}	90.54±0.20 ^b	0.84±0.08 ⁱ	12.20±0.08 ^h	12.23±0.09 ^g	86.05±0.36 ^a
125A	0.46±0.00 ^b	6.36±0.03 ^g	85.33±0.32 ^f	4.50±0.14 ^d	16.13±0.20 ^{de}	16.75±0.21 ^{cd}	74.42±0.34 ^f
125G	0.49±0.02 ^{ab}	6.68±0.00 ^a	86.49±0.19 ^{de}	3.39±0.16 ^f	15.79±0.27 ^e	16.15±0.30 ^d	77.87±0.41 ^d
125GA	0.49±0.05 ^{ab}	6.60±0.01 ^{abc}	81.71±0.19 ^g	4.77±0.14 ^{bcd}	17.57±0.30 ^{bc}	18.21±0.30 ^b	74.81±0.43 ^f
Effect							
Variety(V)	***	***	***	***	***	***	***
Processing method (p)	NS	***	***	***	***	***	***
V*P	***	***	***	***	***	***	***

All values are mean ± standard deviation. Means sharing the same letters in columns are not significantly different from each other (Tukey's HSD test, p < 0.05). *** Significant effect at p < 0.05, NS, Not significant. L*, whiteness; a*, redness; b*, yellowness; c, chroma; h, hue angle. A, Awash-2 Variety; 119, SER 119 Variety; 632, SAB 632 Variety; 125, SER 125 Variety; S, Soaking Processing method; A, Autoclaving processing method; G, Germination processing method; GA, Germination followed Autoclaving processing method

5.3.2. Proximate Composition

The effects of varieties and flour processing methods on haricot bean nutrients are presented in Table 5.2. The highest three levels of moisture and fat were 9.72±0.17, 9.36±0.24, 9.28±0.37, and 2.87±0.34, 2.66±0.21, and 2.50±0.43, respectively, in the 119GA, 632GA, 632A, and 119S, 119A, and 119GA flour samples. On average, flour obtained from the SAB 632 variety had the highest moisture and crude fibre content, while flour obtained from the Awash-2 variety recorded the lowest. The 125GA and 632G flour samples had the highest crude protein and crude fibre contents, 27.96±0.26 and 5.97±0.10, respectively, whereas the AS flour samples had the lowest, 23.11±1.18 and 3.82±0.10, respectively. The crude protein content of the flour in the soaked flour sample was significantly (p<0.05) lower than in the other three flour samples. The flour samples

of AA and AS had the highest carbohydrate content, which were 57.14 ± 1.21 and 56.66 ± 1.88 , respectively, and the difference between them was not significant. On the other hand, the flour samples of 119GA and 125GA had the lowest carbohydrate content, which were 51.79 ± 0.27 and 51.80 ± 0.91 , respectively.

Processing of seeds relatively showed significant variation in crude fat content, while germination significantly ($P < 0.05$) reduced moisture, crude fat, and carbohydrate content; instead, it relatively increased the flour's crude protein, crude fibre, and ash content as compared to soaked flour. Moisture content was below the maximum 15.5% specified for wheat flour [193]. This is an important parameter for flour stability in storage. Products with reduced moisture were generally stored longer due to reduced microbial and chemical activity. The reduction in crude fat content was due to the energy expended by the seeds for germination [194]. Mubarak [86] reported a similar case that sprouting mung bean reduced fat content. These findings are consistent with increased crude fibre content during sprouting in American sweet lupin [195]. The crude fibre content of the flour increased during germination, which is thought to be caused by the breakdown of cell walls and other structural components that occur during sprouting [196]. The increase in protein content on germination was possible because of the degradation of high protein molecules to simple peptides and the use of other seed components during germination and by releasing the bound nitrogenous compounds (e.g.-tannin-protein complexes)[86]. An increase in protein content during high-temperature treatments or autoclaving might be because of the high digestibility of proteins during processing [197]. Additionally, the increase in protein content during autoclaving is possibly because of the alteration of protein structure and the breakdown of protein-bound starch and other carbohydrates, which can make the protein more accessible [198]. Decreased carbohydrate levels of the germinated seeds may be due to increased amylase activity, which breaks down complex carbohydrates into assimilable sugars required for seedling growth in the early stages of germination [199]. These findings are consistent with Hooda & Jood [200] who reported that germination decreased crude fat and total carbohydrates, increasing crude fibre, sugars, and protein levels.

Table 5.2. Proximate composition of haricot bean flour as affected by interactions of variety and processing methods % (g/100 g dry weight basis)

Sample code	Moisture %	Fat %	Protein %	Crude fibre %	Ash %	CHO %
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AS	8.81±0.08 ^{cde}	2.33±0.21 ^{abcde}	23.11±1.18 ^f	3.82±0.10 ^f	5.26±0.88 ^{ab}	57.14±1.21 ^a
AA	8.95±0.04 ^{bcde}	2.21±0.10 ^{bcde}	23.87±1.43 ^{ef}	4.18±0.24 ^{ef}	3.65±0.15 ^c	56.66±1.88 ^a
AG	8.05±0.12 ^f	1.80±0.06 ^{efg}	25.15±0.27 ^{cde}	4.45±0.58 ^{cdef}	5.52±0.42 ^a	55.00±0.76 ^{abcd}
AGA	8.90±0.09 ^{bcde}	2.12±0.11 ^{bcdef}	26.11±0.40 ^{abcd}	4.23±0.47 ^{def}	5.51±0.99 ^a	53.13±1.12 ^{bcde}
119S	8.82±0.06 ^{cde}	2.87±0.34 ^a	24.45±0.98 ^{def}	4.82±0.33 ^{bcde}	3.92±0.31 ^c	55.12±1.85 ^{abcd}
119A	8.58±0.13 ^e	2.66±0.21 ^{ab}	25.16±0.63 ^{cde}	5.03±0.51 ^{bcde}	3.71±0.18 ^c	54.87±0.19 ^{abcd}
119G	8.74±0.05 ^{de}	2.00±0.21 ^{cdef}	26.97±0.57 ^{abc}	5.22±0.19 ^{abc}	4.07±0.21 ^{bc}	53.00±0.29 ^{bcde}
119GA	9.72±0.17 ^a	2.50±0.43 ^{abc}	27.23±0.12 ^{ab}	5.09±0.32 ^{abcde}	3.67±0.23 ^c	51.79±0.27 ^e
632S	8.74±0.17 ^{de}	1.88±0.13 ^{cdefg}	24.69±0.35 ^{def}	5.35±0.31 ^{abc}	3.66±0.31 ^c	55.68±0.73 ^{abc}
632A	9.28±0.37 ^{abc}	1.85±0.03 ^{defg}	25.26±0.45 ^{bcde}	5.57±0.10 ^{ab}	3.61±0.33 ^c	54.43±0.99 ^{abcde}
632G	9.03±0.07 ^{bcde}	1.51±0.16 ^{fg}	26.74±0.47 ^{abc}	5.97±0.10 ^a	3.87±0.19 ^c	52.88±0.46 ^{cde}
632GA	9.36±0.24 ^{ab}	1.83±0.08 ^{efg}	27.06±0.43 ^{abc}	5.62±0.20 ^{ab}	3.45±0.35 ^c	52.68±0.51 ^{de}
125S	8.74±0.14 ^{de}	2.33±0.10 ^{abcde}	24.65±0.43 ^{def}	4.83±0.16 ^{bcde}	3.57±0.60 ^c	55.88±1.17 ^{ab}
125A	8.58±0.37 ^e	2.30±0.08 ^{abcde}	25.58±0.38 ^{bcde}	5.15±0.06 ^{abcd}	3.79±0.29 ^c	54.60±0.43 ^{abcde}
125G	9.16±0.06 ^{bcd}	1.33±0.07 ^g	27.07±0.53 ^{abc}	5.25±0.32 ^{abc}	4.00±0.29 ^{bc}	53.19±0.32 ^{bcde}
125GA	9.23±0.08 ^{abcd}	2.50±0.45 ^{abcd}	27.96±0.26 ^a	5.20±0.33 ^{abc}	3.53±0.27 ^c	51.80±0.91 ^e
Effects						
Variety (v)	***	***	***	***	***	***
Processing method(P)	***	***	***	***	***	***
V*P	***	***	***	***	***	***

All values are mean ± standard deviation. Means sharing the same letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$). ***, Significant effect at $p < 0.05$. V, Variety; P, processing method; V*P, Interaction of variety and processing method. A, Awash-2 Variety; 119, SER 119 Variety; 632, SAB 632 Variety; 125, SER 125 Variety; S, Soaking Processing method; A, Autoclaving processing method; G, Germination processing method; GA, Germination followed Autoclaving processing method.

5.3.4. Phytochemical Properties

The phytate, tannin, oxalate, total phenol contents, and DPPH scavenging (EC_{50}) of all flour samples were relatively significantly influenced by the interaction of variety and processing method ($P < 0.05$) (Table 5.3). The AS flour sample had the highest phytate level (143.21 ± 16.41 mg/100 g), while the flour sample 119GA had the lowest (122.26 ± 98.24 mg/100 g). Likewise, AGA (0.82 ± 0.01 mg/100 g) and 632GA (3.15 ± 0.63 mg/g) flour samples had the lowest tannin and oxalate contents, respectively. The level of phytates observed in this study is lower than phytate content (10 – 60 mg/g) which could pose a health problem to humans [201]. The result showed that all the processing methods significantly reduced phytate, tannin, and oxalate contents in haricot beans, among which germination followed by autoclaving was the most effective. Autoclaving partially affected phytate content due to the thermal stability of phytate.

On the other hand, the breakdown of phytate during germination is attributed to endogenous phytase (enzyme activity) amplification activity. Likewise, the observed reduction in tannin content in germinated seed flour may be because of the leaching of tannins into the water [202]. This result is in agreement with the lower value reported by Mubarak [86] in which tannins and

phytate in mung bean seeds were significantly ($p<0.05$) reduced by germination processes. Similar findings were made by Manez *et al.* [203] for the phytate content of raw haricot beans (0.61–2.38 g/100 g).

Regarding the total flavonoid content (TFC), the table (Table 5.3) demonstrates that there were no significant variations in TFC among the different varieties of flour samples. However, the interaction between the variety and processing method had a significant effect on TFC ($P<0.05$). Additionally, there were notable differences in total phenol content. The highest total flavonoid content (3939.45 ± 787.31 mgQE/100g) was recorded for the flour produced by germination of the Awash-2 variety, but the lowest value (1253.88 ± 419.24 mgQE/100g) belonged to flour produced by the autoclaving method of the SER 119 variety. This shows that the effect of the processing method is better than that of the variety. The top two phenolic compounds contents were 1145.59 ± 73.31 and 1106.61 ± 115.58 mg GAE/100g, which belonged to the AG and 125G flour samples, respectively. Unlike autoclaving, which reduces the flour's total flavonoids and phenolic content, germination improved its content. This indicated that autoclaving had a higher degree of damage to the active phenolic compounds of the flour [204] than the germination treatment. The reason for the reduction of phenolic compounds during autoclaving after germination may be attributed to the fact that germination causes an increase in the levels of phenolic compounds, which then become more vulnerable to degradation during autoclaving [205]. According to Luthria & Pastor-Corrales [206] total phenolic contents among dry beans can be attributed to a variety of factors including genotype, agronomic practices, maturity at harvest, post-harvest storage, and climatic conditions, as well as growing and storage conditions; but not restricted to these once only. In the present study, the total phenolic contents of flour were in the range of 0.39 ± 9.50 to 1.15 ± 73.31 mg GAE/g (Table 5.3); whereas, according to Ombra *et al.*[207] the total phenolic content of the common bean is in the range of 0.14–1.29 mg GAE/g.

Table 5.3. Effects of interaction between varieties and processing methods on phytochemical composition of haricot beans flour

Sample code	Phytate (mg/100g)	Tannin (mg/100g)	Oxylate mg	Total Flavonoids (mgCE/g)	Total Phenol (mgGAE/g)	DPPH Scavenging (EC50 ^a) mg/mL)
AS	143.21±16.41 ^a	2.03±0.55 ^{bcd}	11.35±1.67 ^a	2.58±1175.97 ^{ab}	0.75±193.84 ^{cde}	0.18
AA	141.67±35.57 ^{ab}	1.42±0.14 ^{bcd}	7.98±2.55 ^{bcd}	2.54±1309.33 ^{ab}	0.66±71.39 ^{def}	0.19
AG	135.21±38.95 ^{abcd}	1.34±0.46 ^{bcd}	5.88±0.36 ^{defg}	3.94±787.31 ^a	1.15±73.31 ^a	0.11
AGA	126.82±66.22 ^{abcd}	0.82±0.01 ^d	5.04±0.63 ^{efg}	3.38±1610.63 ^{ab}	1.07±207.31 ^{ab}	0.12
119S	141.05±19.54 ^{abc}	3.49±0.85 ^a	8.61±0.96 ^{abcd}	3.22±288.88 ^{ab}	0.63±80.69 ^{def}	0.18
119A	130.02±51.17 ^{abcd}	2.60±0.37 ^{ab}	6.51±0.36 ^{df}	1.25±419.24 ^b	0.63±188.44 ^{def}	0.19

119G	124.21±124.19 ^{dc}	2.52±0.67 ^{ab}	6.30±0.63 ^{edfg}	3.85±1330.72 ^a	1.08±4.53 ^{ab}	0.11
119GA	122.26±98.24 ^d	2.13±0.63 ^{bcd}	4.62±0.36 ^{fg}	3.27±526.67 ^{ab}	1.00±39.36 ^{abc}	0.13
632S	134.03±19.44 ^{abcd}	2.43±0.36 ^{abc}	10.08±0.64 ^{abc}	2.75±438.20 ^{ab}	0.74±23.18 ^{cde}	0.17
632A	133.79±78.18 ^{abcd}	2.12±0.82 ^{bcd}	5.04±0.63 ^{efg}	2.56±301.11 ^{ab}	0.48±22.67 ^{ef}	0.19
632G	129.78±53.54 ^{abcd}	1.58±0.31 ^{bcd}	4.20±0.36 ^{fg}	3.52±435.56 ^{ab}	0.84±65.86 ^{abcd}	0.11
632GA	124.52±32.02 ^{dc}	1.46±0.04 ^{bcd}	3.15±0.63 ^g	2.89±250.92 ^{ab}	0.79±49.01 ^{bcde}	0.12
125S	135.15±19.77 ^{abcd}	2.31±0.14 ^{abc}	10.29±0.37 ^{ab}	2.61±872.07 ^{ab}	0.73±32.02 ^{cde}	0.14
125A	134.97±35.49 ^{abcd}	1.44±0.24 ^{bcd}	7.98±1.31 ^{bcd}	2.57±483.28 ^{ab}	0.39±9.50 ^f	0.19
125G	132.32±32.79 ^{abcd}	1.42±0.12 ^{bcd}	6.93±1.89 ^{cdef}	3.45±414.74 ^{ab}	1.11±115.58 ^a	0.10
125GA	125.20±49.64 ^{bcd}	1.13±0.03 ^{dc}	6.72±1.89 ^{edf}	2.81±700.99 ^{ab}	0.79±120.55 ^{bcde}	0.11
Effect						
Variety (V)	***	***	***	NS	***	***
Processing method (P)	***	***	***	***	***	***
V*P	***	***	***	***	***	***

All values are mean ± standard deviation. Means sharing the same letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$). EC₅₀^a (mg/ml): effective concentration at which 50% of DPPH radicals are scavenged. ***, Significant effect at $p < 0.05$, NS, Not significant. V, Variety; P, processing method; V*P, Interaction of variety and processing method. A, Awash-2 Variety; 119, SER 119 Variety; 632, SAB 632 Variety; 125, SER 125 Variety; S, Soaking Processing method; A, Autoclaving processing method; G, Germination processing method; GA, Germination followed Autoclaving processing method.

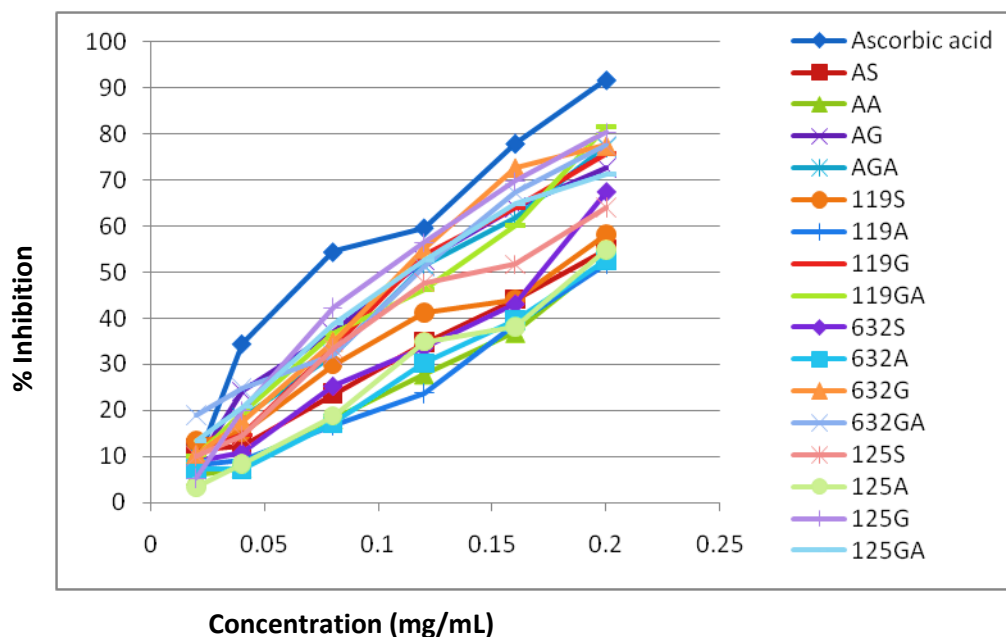


Fig. 5.1. Free radical scavenging of methanolic extract of haricot beans flour and controls for scavenging respectively.

Germinated SER 125 (125G) flour had better antioxidant properties with lower EC₅₀ values of 0.1mg/mL while AA, 119A, 632A, 125A flours had higher EC₅₀ values of 0.19 mg/mL. The synthetic antioxidant (L-Ascorbic acid), used as a positive control, had a superior performance with the least EC₅₀ in all the tests. As can be inferred from Fig. 5.1, on the difference in free radical scavenging activity of methanolic extracts of the flours, the scavenging effect increased with concentration and was the highest for flour 125G with 80% inhibition at 0.2 mg/mL concentration.

In all samples analyzed, flour samples of 119A had the least scavenging power with only 51.8% inhibition at 0.2 mg/mL. The synthetic antioxidant L-ascorbic acid was 90% scavenged at a concentration of 0.2 mg/mL. This study is consistent with other studies in the literature. For example, Oboh [208] reported that the antioxidant activity of legumes was positively correlated with phenolic compounds. From the determination of total phenolic, total flavonoid contents, and antioxidant activity in this study, the content of sprouted flour was higher than that of soaked flour.

5.3.5. Functional Properties

The functional properties determine the application and use of food ingredients in various foods. As shown in the data in Table 5.4, except for bulk density, there were significant differences ($p < 0.05$) in functional properties between all four cultivars (Awash-2, SER 119, SAB 632, and SER 125) and the processing method. The flour samples with the highest water absorption capacities were the 125GA, 119GA, 632GA, and AGA samples, which had capacities of 3.71 ± 0.03 , 3.68 ± 0.01 , 3.59 ± 0.05 , and 3.57 ± 0.00 g/g, respectively. The water solubility indices of the flours ranged from 0.10 ± 0.02 (AA) to 0.31 ± 0.01 g/g (119GA), while their oil absorption capacities ranged from 1.67 ± 0.07 (632GA) to 1.89 ± 0.10 g/g (632G). Flour samples of 125G, 632G, 632S, AG, and 119G had the highest foaming capacity and lowest foaming stability (Table 5.4). Emulsion capacity exhibited a significant difference among the flours with the highest score ($34.72 \pm 2.41\%$) for 119G; and the lowest (16.67%) for the 125S flour sample, but emulsion stability showed that there was no significant difference ($p < 0.05$) between the flour samples except for the AS, AG, and AGA samples. The SER 119 and Awash-2 varieties generally had the lowest foaming and emulsion capacity, while the SAB 632 variety had the lowest emulsion Stability.

The increase in water absorption observed during the autoclaving method may be attributed to the denaturation of proteins upon heating. This leads to an improvement in the flour's water imbibing capacity due to an increase in porosity, better fluid retention, and greater water-binding properties resulting from the exposure of amino acid residues as a consequence of denaturation [194]. According to Aguilera *et al.* [209] in addition to starch gelatinization, the swelling of crude fiber during autoclaving may also contribute to increasing WAC. Autoclaving of germinated seed may lead to denaturation of haricot bean protein, thus, higher water absorption capacity values were obtained in this study. The reason for the increase is thought to be due to the breakdown of cell walls and other structural components during the process. This breaking down of components is

believed to create more surface area and porosity in the flour. This change in structure may help to improve the ability of the flour to soak up water [210].

Sprouting increased the WSI, OAC, FC, and EC of flour compared to soaking. The reduction in water absorption capacity that occurs during germination is said to be caused by the breakdown of cell walls and the release of water-soluble constituents. These processes cause a decline in the flour's capacity to take up water [211]. But the solubility index, related to the presence of soluble molecules like amylose and albumins in the flour, increased during germination, possibly due to increased amylolytic and proteolytic activity [184]. The efficacy of lipid binding in pulse flours mainly depends on the surface hydrophobicity of protein, which can be enhanced by germination as this process increases the exposure of non-polar parts from the interior of protein molecules [212][37]. These findings are consistent with Ghavidel & Prakash [213]. It has been reported that the germination of beans increases oil holding and foaming capacity while reducing the foaming stability of flours. The activation of enzymes that can break down protein molecules into smaller peptides and amino acids is thought to be the cause of the increase in foaming and emulsion capacity of legume flours after germination. These smaller components are thought to be more effective at forming stable foams and emulsions [214]. The more pronounced reduction in foaming capacity in autoclaving samples may be due to protein denaturation and aggregation [215]. It also indicates the precipitation of proteins due to the temperature and time of the heat treatment used in the present study. The higher foaming stability values may be due to the denaturation of proteins present in the flour, which may lead to an increase in viscosity, thereby making the interfacial film rigid and thus stabilizing the foam of flour [216]. Germination leads to partial unfolding and dissociation of proteins, which tend to make proteins more surface-active, especially since it is associated with surface hydrophobicity leading to enhanced emulsification capacity [213]. As suggested by Dzudie *et al.* [189], the high emulsion stability may be related to the globular nature of the major protein of the beans. The significant decrease in LGC values observed in germinated flour may be due to the interaction of amylase and starch in seeds during germination [215]. The higher the LGC, the higher the amount of flour required to form the gel [184]. However, gelation is related to the amount of protein and the type of protein and non-protein components in the flour [217]. The lower the least gelation concentration, the better the ability of proteins to gel, because protein gels are aggregated of denatured molecules [218].

Table 5.4. Effects of interaction between varieties and processing methods on functional properties of haricot beans flour

Sample code	Bulk Density g/cc	WAC g/g	WSI	OAC g/g	FC %	FS %	EC %	ES %	LGC g/100 mL
AS	955.49±10.47 ^a	2.70±0.00 ^{fg}	0.17±0.00 ^{de}	1.83±0.01 ^{ab}	28.12±1.93 ^{bcdef}	82.35±0.33 ^{bc}	19.44±2.41 ^{cd}	13.89±4.81 ^c	14 ^a
AA	955.49±10.47 ^a	3.43±0.01 ^{bcd}	0.10±0.02 ^h	1.81±0.05 ^{ab}	21.87±0.66 ^{cdef}	97.27±0.99 ^a	18.06±2.41 ^d	22.22±9.62 ^{ab}	12 ^b
AG	931.75±10.09 ^a	2.71±0.00 ^f	0.25±0.01 ^b	1.81±0.01 ^{ab}	46.29±2.04 ^{bcd}	80.46±0.16 ^{bcd}	25.00±0.00 ^{abcd}	30.56±4.81 ^a	10 ^c
AGA	1013.89±24.06 ^a	3.57±0.00 ^{abc}	0.14±0.00 ^{ef}	1.83±0.01 ^{ab}	24.74±6.15 ^{cdef}	95.71±0.98 ^a	20.83±4.17 ^{cd}	30.56±9.62 ^a	12 ^b
119S	920.32±9.72 ^a	2.47±0.02 ^g	0.23±0.01 ^{bc}	1.76±0.00 ^{abc}	21.97±3.06 ^{cdef}	85.27±1.06 ^{ab}	22.22±4.81 ^{bcd}	15.28±2.41 ^{ab}	14 ^a
119A	3852.44±49.91 ^a	3.42±0.04 ^{bcd}	0.13±0.01 ^{fg}	1.80±0.09 ^{ab}	10.54±1.27 ^f	96.43±1.79 ^a	25.00±0.00 ^{abcd}	19.44±2.41 ^{ab}	12 ^b
119G	857.20±8.44 ^a	2.55±0.03 ^{fg}	0.31±0.01 ^a	1.88±0.02 ^{ab}	40.55±23.09 ^{bcd}	76.78±12.18 ^{bcd}	34.72±2.41 ^a	27.77±4.81 ^{ab}	10 ^c
119GA	961.78±18.50 ^a	3.71±0.03 ^a	0.13±0.00 ^{fg}	1.83±0.01 ^{ab}	17.55±2.11 ^{ef}	95.03±0.05 ^a	26.39±2.41 ^{abcd}	23.61±2.41 ^{ab}	12 ^b
632S	937.58±10.09 ^a	3.19±0.28 ^c	0.17±0.02 ^d	1.78±0.03 ^{abc}	48.66±12.95 ^{bc}	70.59±1.46 ^{cde}	22.22±4.81 ^{bcd}	16.67±0.00 ^{ab}	14 ^a
632A	986.93±11.32 ^a	3.34±0.08 ^{cde}	0.12±0.00 ^{fgh}	1.83±0.02 ^{ab}	20.70±19.50 ^{def}	96.31±0.39 ^a	25.00±4.17 ^{abcd}	16.66±7.22 ^{ab}	12 ^b
632G	920.73±25.67 ^a	3.19±0.01 ^{de}	0.21±0.01 ^c	1.89±0.10 ^a	53.52±3.44 ^{ab}	69.23±8.60 ^{de}	34.72±2.41 ^a	20.83±7.22 ^{ab}	10 ^c
632GA	961.78±18.50 ^a	3.59±0.05 ^{ab}	0.10±0.01 ^{gh}	1.64±0.07 ^c	27.45±1.96 ^{bcd}	95.90±0.84 ^a	26.39±4.81 ^{abcd}	18.06±2.41 ^{ab}	10 ^c
125S	920.32±9.72 ^a	2.52±0.07 ^{fg}	0.22±0.00 ^c	1.82±0.00 ^{ab}	34.53±9.18 ^{bcd}	81.59±4.80 ^{bcd}	16.67±0.00 ^d	19.44±2.41 ^{ab}	14 ^a
125A	961.78±18.50 ^a	3.35±0.05 ^{bcd}	0.12±0.00 ^{fg}	1.74±0.03 ^{bc}	11.31±0.60 ^f	96.95±1.56 ^a	22.22±4.81 ^{bcd}	25.00±7.22 ^{ab}	12 ^b
125G	887.64±9.05 ^a	2.73±0.06 ^f	0.22±0.01 ^c	1.83±0.09 ^{ab}	78.56±3.65 ^a	59.97±3.76 ^e	31.94±4.81 ^{ab}	27.78±2.41 ^{ab}	10 ^c
125GA	949.45±10.47 ^a	3.68±0.01 ^a	0.11±0.01 ^{gh}	1.76±0.02 ^{abc}	29.47±4.50 ^{bcd}	96.40±0.21 ^a	29.17±4.17 ^{abc}	27.78±4.81 ^{ab}	12 ^b
Effect									
V	NS	***	***	***	***	***	***	***	***
P	NS	***	***	***	***	***	***	***	***
V*P	NS	***	***	***	***	***	***	***	***

All values are mean ± standard deviation. Means sharing the same letters in columns are not significantly different from each other (Tukey's HSD test, p < 0.05). BD, Bulk density; WAC, Water absorption capacity; WSI, Water solubility index; OAC, Oil absorption capacity; EA, Emulsion activity; ES, Emulsion stability; FC, Foam capacity; FS, Foam stability; LGC, Least gelatinization concentration. ***, Significant effect at p < 0.05, NS, Not significant. V, Variety ; P, processing method; V*P, Interaction of variety and processing method. A, Awash-2 Variety; 119, SER 119 Variety; 632, SAB 632 Variety; 125, SER 125 Variety; S, Soaking Processing method; A, Autoclaving processing method; G, Germination processing method; GA, Germination followed Autoclaving processing method

5.3.6. Sensory Quality Evaluation

Sensory quality evaluation is one of the methods of evaluating the quality of a product and can be used to evaluate its acceptance by consumers (i.e., consumer acceptance or preference) [219]. These properties can provide important information about the quality of the flour and its suitability for different food applications. The sensory assessment of flour can help in determining the best processing parameters to provide flour with the desired sensory properties. It can also aid in locating any offensive tastes or odors that the flour might have. Table 5.5 shows the results of the sensory properties of flours due to the interaction between varieties and processing methods. As shown in the data in Table 5.5, there was no significant effect on the sensory evaluation of flours due to variety differences, but the processing methods and the interactions showed some significant differences. The flour samples that were most highly rated for color and overall acceptability were AS (8.60±0.52), 632S (8.50±0.53), 125S (8.40±0.70) and AS (8.40±0.51), 125S (8.40±0.70) and 632S (8.10±0.99) during consumer testing, respectively. The other flour samples did not differ significantly in odor and texture except for 125S, AS, 125G, 125S, and AGA flour samples.

Table 5.5. Effects of interaction between varieties and processing methods on sensory properties of haricot beans flour

Sample code	Color	Odor	Texture	Over all accept
AS	8.60±0.52 ^a	8.20±0.79 ^a	8.20±0.79 ^{ab}	8.40±0.51 ^a
AA	7.40±0.70 ^{abc}	7.90±0.88 ^{ab}	7.50±0.84 ^{ab}	7.70±0.67 ^{abc}
AG	7.10±1.10 ^{abcd}	6.90±1.29 ^{ab}	7.80±0.63 ^{ab}	7.20±1.03 ^{abc}
AGA	5.40±2.22 ^d	6.30±2.11 ^{ab}	6.30±2.21 ^b	6.00±2.36 ^c
119S	7.80±0.42 ^{ab}	7.90±0.99 ^{ab}	7.70±0.67 ^{ab}	7.70±0.48 ^{abc}
119A	7.40±0.97 ^{abc}	7.50±1.18 ^{ab}	7.60±1.07 ^{ab}	7.60±1.07 ^{abc}
119G	7.20±1.03 ^{abcd}	7.40±0.84 ^{ab}	7.80±0.92 ^{ab}	7.50±0.84 ^{abc}
119GA	5.90±1.73 ^{bcd}	6.60±1.58 ^{ab}	6.70±1.49 ^{ab}	6.40±1.43 ^{bc}
632S	8.50±0.53 ^a	7.60±2.12 ^{ab}	8.20±0.63 ^{ab}	8.10±0.99 ^{ab}
632A	7.70±0.82 ^{ab}	8.00±0.82 ^{ab}	7.80±0.79 ^{ab}	7.70±0.82 ^{abc}
632G	7.40±0.52 ^{abc}	7.40±0.97 ^{ab}	7.60±1.07 ^{ab}	7.60±0.84 ^{abc}
632GA	6.20±1.69 ^{bcd}	6.40±1.90 ^{ab}	6.40±1.96 ^{ab}	6.40±1.90 ^{bc}
125S	8.40±0.70 ^a	8.30±0.82 ^a	8.30±0.67 ^a	8.40±0.70 ^a
125A	7.70±0.95 ^{ab}	7.90±1.10 ^{ab}	8.00±0.82 ^{ab}	7.80±1.03 ^{ab}
125G	6.20±1.55 ^{bcd}	5.90±2.18 ^b	6.70±1.49 ^{ab}	6.20±1.75 ^{bc}
125GA	5.70±2.00 ^{cd}	6.30±1.64 ^{ab}	6.40±1.78 ^{ab}	6.00±2.00 ^c
Effect				
Variety (V)	NS	NS	NS	NS
Processing method (P)	***	***	***	***
V*P	***	***	***	***

All values are mean ± standard deviation. This means that sharing the same letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$). ***, Significant effect at $p < 0.05$, NS, Not significant. V, Variety ; P, processing method; V*P, Interaction of variety and processing method. A, Awash-2 Variety; 119, SER 119 Variety; 632, SAB 632 Variety; 125, SER 125 Variety; S, Soaking Processing method; A, Autoclaving processing method; G, Germination processing method; GA, Germination followed Autoclaving processing method

Low odor refers to the fact that the SER 125 variety by germination contributes odor to the food during the manufacturing of this flour. The existence of volatile chemicals, which can be lost or changed during germination, was connected to the reduction in odor qualities. Flour from an autoclaving method doesn't show a significant difference in terms of odor and texture when compared to a soaked one. The sensory evaluation indicated a higher preference for flours produced through soaking methods (control) than other flour samples.

5.3.7. Correlation

Table 5.6 shows the correlation between the physicochemical and functional properties of flours produced by different processing methods. The crude proteins of flour were positively correlated with functional properties but significantly negatively correlated with LGC ($r = -0.605$) ($P < 0.01$ and $P < 0.05$). Crude fibre ($r=0.543$), crude protein ($r=0.695$), and carbohydrate ($r=0.618$)

were strongly associated with emulsion capacity, although carbohydrates were negatively correlated. This might be explained by the protein and fibre molecules' capacity to create stable interfaces between water and oil, which is essential for the creation of stable emulsions [220].

Table 5.6. Correlation between various properties of haricot bean flour

Parameter	WAC	WSI	OAC	FC	FS	EC	ES	LGC	L*	a*	b*
Moisture	0.480*	-0.399*	-0.050	-0.093	0.178	0.203	-0.144	-0.064	-0.580*	0.478*	0.408*
Fat	0.071	-0.220	-0.188	-0.628*	0.511*	-0.357*	-0.184	0.584*	-0.039	0.073	-0.063
Protein	0.368*	0.018	0.023	0.187	0.002	0.695*	0.337*	-0.605*	-0.652*	0.509*	0.492*
Crude fibre	0.183	0.029	-0.150	0.218	-0.197	0.543*	-0.051	-0.370*	-0.171	0.113	0.009
Ash	-0.240	0.264	0.170	0.080	-0.092	-0.183	0.215	-0.048	0.159	-0.175	0.037
CHO	-0.370*	-0.005	0.010	-0.087	0.052	-0.618*	-0.269	0.507*	0.643*	-0.491*	0.485*
WAC		-0.822*	-0.236	-0.387*	0.605*	0.026	0.102	-0.146	-0.746*	0.811*	0.765*
WSI			0.392*	0.392*	-0.698*	0.335*	0.170	-0.186	0.551*	-0.653*	-0.603*
OAC				0.275	-0.317*	0.302*	0.138	-0.100	0.242	-0.202	-0.150
FC					-0.858*	0.444*	0.276	-0.362*	0.229	-0.373*	-0.267
FS						-0.327*	-0.034	0.161	-0.505*	0.607*	0.558*
EC							0.269	-0.657*	-0.206	0.132	0.121
ES								-0.453*	-0.334*	0.290*	0.365*
LGC									0.374*	-0.346*	-0.449*
L*										-0.937*	-0.915*
a*											0.938*

BD, Bulk density; WAC, Water absorption capacity; WSI, Water solubility index; OAC, Oil absorption capacity; EA, Emulsion activity; ES, Emulsion stability; FC, Foam capacity; FS, Foam stability; LGC, Least gelatinization concentration; CHO, Carbohydrate. L*, whiteness; a*, redness; b*, yellowness *Correlation is significant at P < 0.05.

The crude Protein content was negatively correlated with the whiteness ($r=-0.652$) of the flour and positively correlated with redness ($r=0.506$) and yellowness ($r=0.492$) of the flour. This may be due to the presence of pigments, such as flavonoids and carotenoids, which are often associated with protein-rich plant foods [221]. However, carbohydrates were significantly positively correlated with whiteness ($r=-0.643$) and yellowness ($r=-0.491$) but negatively correlated with redness ($r=0.485$). Water absorption capacity was positively correlated with foaming stability ($r=0.605$), and hunter colors (a* and b* value) but negatively correlated with water solubility index ($r=-0.822$), foaming capacity and L* value ($r=-0.746$) ($P < 0.01$ and ($P < 0.05$). This might be as a result of proteins' capacity to bind water and create stable oil-water interfaces, which are essential for the production of stable foams. Foaming capacity was significantly negatively correlated ($P < 0.01$ and $P < 0.05$) with foaming stability ($r = -0.858$) but positively correlated with emulsion capacity. Likewise, negative correlations were observed between oil absorption capacity and foaming stability ($r = -0.317$) as well as WSI and foaming stability ($r = -0.698$).

5.4. Conclusions

The nutritional value and positive effects of common bean (*Phaseolus vulgaris* L.) make it one of the most significant pulses. Based on the findings of this study, the physical, chemical, functional, and sensory properties of processed haricot seeds vary depending on the variety, processing methods, and their interactions. However, the flour produced by the soaking method (control) was brighter, while the flour produced by germination and then autoclaving was darker and less saturated than the other flour samples. Germination significantly increases crude protein, crude fibre, antioxidant content, and functional properties (such as WSI, foaming capacity, emulsion properties, and gelling strength). Nevertheless, compared to the soaking method, the levels of antinutrients are lowered through germination followed by autoclaving. The observed chemical composition and functional properties of flour indicated that sprouted flour has the potential to be used as a nutritional supplement and functional ingredient in the preparation of various food products compared to other flour samples. Except with LGC and whiteness, the crude protein content of flour was significantly positively correlated with functional and hunter color properties. Sensory panelists' ratings indicated all flour samples produced were above the acceptability limit, provided that the flour produced by soaking is more preferred and the one that is produced through germination followed by autoclaving is less preferred. The findings of this research offer valuable information on the potential utilization of haricot bean flour in various food products, which is an underutilized crop.

CHAPTER 6:- PASTING, THERMAL AND STRUCTURAL PROPERTIES OF HARICOT BEANS FLOUR (PHASEOLUS VULGARIS, L.) AS AFFECTED BY VARIETY AND GERMINATION

Abstract

This research aimed to verify how the germination method affects the pasting, thermal and structural properties of haricot bean flours to expand their potential for application in various food products. The pasting properties of flours showed considerable variation due to variety, germination, and interaction between variety and germination. Onset, peak and end of

gelatinization temperature and enthalpy of haricot bean flours ranged with germination from 65.4 to 67.9, 70.6 to 73.3, 77.0 to 79.4 C, and 3.5 to 4.9 J/g, respectively. The Crystallinity index of 632G flour was higher than that of 119G and 125G flour. The data revealed that the soaked and germinated haricot bean flour showed major diffraction peak values of the 2θ at 18.25°, 18.40°, 18.25°, 17.68°, 18.74°, and 18.34°, respectively, for 119S, 119G, 632S, 632G, 125S, and 125G. FT-IR spectroscopy of four samples did not show any variations in spectra, but a change in the intensity of bands was observed. The SEM images reveal that a protein matrix surrounded starch granules.

Keywords: Haricot beans flour, germination, structural properties

6.1. Introduction

Legumes have been considered the most significant food source, especially for low-income groups of people in developing countries [68], containing a relatively high amount of proteins [222]. Dry beans are the dicotyledonous seed of plants belonging to the Leguminosae family, which are widely cultivated worldwide due to their global adaptability and drought tolerance [223]. Among the commonly consumed dry beans, haricot beans (*Phaseolus vulgaris* L.) are significant in human nutrition in Africa's East and Great Lakes regions [224]. However, their role appears limited because of several factors, including anti-nutritional compounds in the seeds, which may adversely affect human nutrition, low protein and starch digestibility [225], and poor mineral bioavailability [226]. Transforming the beans into flour aids in improving the nutritional requirements of consumers, especially in developing countries [227]. The germination processes are easy and cost-effective treatments given to legumes to modify macronutrient structure [228], improve nutritional, functional, and biological properties, as well as removing anti-nutritional factors such as tannin, phytic acid, oxylate, and enzyme inhibitors [229][17]. Grain sprouts have become common among people interested in improving and keeping their health by altering dietary habits. Due to the health benefits of germination, different studies have reported on the incorporation of germinated seeds into various food manufacturing ingredients, such as pasta [230], crackers[231], beverages [232], muffins [233], and yogurt [234]. Depending on the food products, adding legumes in a germinated form has different effects [20]. Eventhough the compositional changes of haricot beans during germination have been investigated to a certain degree, the research performed on changes in the thermal and structural properties of flour during

the germination of haricot beans is limited. Based on this background, this work was undertaken to investigate the effect of germination on the pasting, thermal, morphological, FTIR, and XRD properties of flours from three varieties of haricot bean seeds.

6.2. Materials and Methods

6.2.1. Sample Preparation

Haricot bean (*Phaseolus Vulgaris L.*) varieties (*SER 119, SAB 632, and SER 125*) were collected from Awash Melkasa Agricultural Center based on the facts that they have shown to have a high production percentage, disease tolerance, short period to ripe and easy to adopt in Ethiopia [235]. The soaked and germinated haricot bean flour was prepared according to previously done methods [17]. The resulting haricot bean flours were placed in plastic bags, sealed, and stored at 4 °C in a desiccator until needed for further analysis.

6.2.2. Pasting Properties

The pasting properties of the flours were measured using a Rapid Visco Analyzer (Perten RVA 4800, PerkinElmer, Sweden). An aqueous dispersion of flour on a 14% moisture basis (12.28%, w/w; 28.5 g total weight) was equilibrated at 50 °C for 1 min, heated at the rate of 12.2 °C/min to 95 °C, held for 2.5 min, cooled to 50 °C at the rate of 11.8 °C/min and again held at 50 °C for 2 min. A constant paddle rotational speed (160 rpm) was used throughout the analysis, except for rapid stirring at 960 rpm for the first 10 s to disperse the sample [236].

6.2.3. Thermal Properties

The thermal properties of flours were analyzed using DSC (SKZ1052B, Hunan, China) equipped with a thermal analysis data station. A 10 mg sample was weighed into a 40 µl capacity aluminum pan, and 20 µl distilled water was added with the help of a Hamilton micro syringe. Pans were hermetically sealed and allowed to stand for 1 h at room temperature before heating in DSC. The DSC was calibrated using indium, and an empty aluminum pan was used as a reference. Sample pans were heated at a rate of 10 °C/min from 20 to 180 °C, and thermal parameters viz. onset (T_o), peak (T_p), conclusion (T_c) temperature, and enthalpy (ΔH) were calculated from the DSC curves [236].

6.2.4. Fourier Transform Infrared (FTIR)

The spectra of the samples were recorded using Fourier transform infrared (FTIR) spectrometer system (Nicolet is50 ABX, Thermofisher Scientific, German) coupled to an attenuated total reflection (ATR) accessory. Analyses were carried out at room temperature, and spectra were acquired in the 4000–400 cm^{-1} range at a resolution of 4 cm^{-1} [237].

6.2.5. X-Ray diffractometer (XRD)

Samples were loaded into the XRD sample holder, and XRD pattern was obtained using an X-ray diffractometer (XRD-7000, Shangai Drawel scientific instrument Co., Ltd., China) equipped with a divergence slit, operating at 40 kV and 40 mA at a scan speed of 1°/min. The relative crystallinity (RC) was calculated using the areas of the crystalline and amorphous regions on the X-ray diffractogram [238].

6.2.6. Scanning Electron Microscopy

The flour was placed on an adhesive tape attached to a circular aluminum specimen stub and then coated vertically with gold palladium. The images of samples were captured at an accelerator potential of 10 kV using a scanning electron microscope (JCM-6000 plus, Jeol Ltd., Korea) [236].

6.2.7. Statistical Analysis

All analyses were conducted in triplicates observations except FTIR and SEM analysis, and data obtained were subjected to analysis of variance (ANOVA) using software package SAS version 9.0 (SAS Institute, Inc., Cary, North Carolina, USA). Tukey's HSD test at the significance level of 5% ($P < 0.05$) was used to determine significant differences among means.

6.3 Results and Discussions

6.3.1. Pasting Properties

The pasting properties of the haricot bean four samples are presented in Table 6.1. Significant differences were observed in pasting characteristics of flours due to variety, processing method, and interaction between them. While the non-germinated 119S flour had the highest peak viscosity value (1832 ± 187 cp), flour from germinated SER125 variety had the lowest peak viscosity (564 ± 36 cp). Peak viscosity is indicative of the strength of the paste,

Table 6.1. Effects of interaction between particle size and pretreatment on pasting properties of pumpkin flour

Flour Sample	Peak viscosity (cp)	Trough (cp)	Breakdown (cp)	Final viscosity (cp)	Setback (cp)	Peak time (Min)	Pasting Temp (°C)
119S	1832±187 ^a	1401±166 ^a	430±21 ^a	3516±692. ^a	2114±525 ^a	7.20±0.04 ^a	79.6±0.0.6 ^{abc}
119G	696±288 ^b	654±294 ^b	42±6 ^c	1098±390 ^b	444±96 ^c	6.9±0.1 ^{cd}	77.±2. ^{cd}
632S	1084±448 ^b	863±388 ^{ab}	221±60 ^b	2123±265 ^b	1434±321 ^{ab}	7.1±0.2 ^{ab}	82.3±0.6 ^a
632G	878.±56 ^b	689±55 ^b	190.0±0.8 ^b	1734±616 ^b	871±228 ^{bc}	7.03±0.03 ^{abc}	81.7±0.1 ^{ab}
125S	1176±120 ^b	1062±126 ^{ab}	114±6 ^c	2226±438 ^b	1164±312 ^{bc}	7.0±0.1 ^{bcd}	79.±0.1 ^{bc}
125G	564±36 ^b	522±42 ^b	42±6 ^c	1344±168 ^b	822±210 ^{bc}	6.8±0.1 ^d	75.±2.0 ^d
Effect							
Variety(V)	***	***	***	***	***	***	***
Process (P)	***	***	***	***	***	***	***
Interaction (V*P)	***	***	***	***	***	***	***

All values are mean ± SD. This means that sharing the same superscript letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant. 119S, SER 119 variety Soaked; 119G, SER 119 variety germinated; 632S, SAB 632 variety soaked; 632G, SAB 632 variety germinated; 125S, SER125 variety soaked; 125G= SER125 variety germinated ; cp, centipoise

which is made from gelatinization during processing in food applications. It also reflects the extent of granule swelling [239]. As revealed in Table 6.1, peak and breakdown viscosities decreased with the germination. The decrease in peak viscosity with germination may be attributed to protein and starch degradation or debranching to simpler units by the enzymes activated during the germination [240], similar to Enyinnaya, Adewuyi, & Oneh [241] and Obalolu & Cole [242] report on malted maize and blends of cowpea and soybean flour, respectively. The lower the breakdown viscosity value of germinated legumes, the greater the extent of breakdown of the starch granules and the lower the viscosity of the flour [243]. Low breakdown viscosity for 119G (42 ±6) and 125G (42±6) flour reflects its less resistance to the shear, and the starch granules have more susceptibility to disintegration than starch granules from other flours under study. The breakdown viscosity value measures the ease with which the swollen granules can be disintegrated [244]. Trough viscosity values ranged from 522±42 to 1401±166 cp, with the highest values recorded by 119S and the lowest by 125G flour sample. As reported by Enyinnaya et al.[241] and Liu et al.[245], the decrease in trough viscosity with germination may be attributed to starch degradation, which caused a decrease in viscosity value. Trough viscosity is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of the paste to withstand breakdown during cooling.

There is no significant difference ($P < 0.05$) in the final viscosity among flour samples except for the 119S flour sample with the highest value (3516±692 cp), and also, final viscosity decreases

with germination. The observed low values of final viscosity for the germinated flours might be due to the attendant breakdown of starches, which is associated with the increase in amylase activity during seed germination of the legumes [246]. Final viscosity indicates the ability of a material to form a viscous paste after cooking and cooling [247]. The soaked bean (control) flour had significantly ($P \leq 0.05$) the highest setback viscosity with the highest values attained by the 119S flour sample (2114 ± 525 cp), and the SER119 germinated flour had the least setback of 444 ± 96 cp. The lower setback values of germinated bean flour indicate its lowest rate of retrogradation, which will be useful in the prolonged shelf life of the flour [248]. In line with this finding, Acevedo et al. [249] reported a decrease in setback viscosity of pigeon pea, Dolichos bean, and jack bean flours after germination. The highest setback viscosity of 119S flour indicates its higher tendency to retrograde than other flours. According to Wani, Sogi, & Gill [192], retrogradation results from hydrogen bonding between starch molecules that have hydroxyl and hydrogen acceptor sites.

Table 6.1 shows a significant difference ($p < 0.05$) among flour pasting temperatures. The pasting temperature ranged from 75-82.3 °C, the lowest for 125G and the highest for 632S flour samples. Pasting temperatures of all three flours decreased upon germination. This might be due to the enzymatic degradation of cell wall-wrapped protein and starch in pulse seeds facilitating starch and protein to contact and absorb water, which increases the heat transfer rate [228]. The reduction in pasting temperature during germination agreed with the decrease in T_c of gelatinization. Low pasting temperature translates to low energy cost and other component stability [246]. According to this finding, pasting temperature results are lower than Felker et al. [250] for the raw navy, black, and pinto bean flours (between 80 and 83°C) and higher than 72°C for chickpea flour. Peak time ranged from 6.8 to 7.20 min, with the non-germinated SER 119 variety having the highest peak time (7.20 min) while germinated SER 125 variety had the lowest peak time (6.8 min). The peak time indicates the minimum temperature required to cook the flour. Peak time values reported in this study are higher than the peak time (5.13 to 5.80 min) reported by Adebowale et al. [247], which implies that it needs extended times for forming pastes and hence longer processing times. Generally, the activated amylases and proteases during germination might cause a decline in the pasting viscosity of flours, due to the degradation of starch chains and disruption of disulfide linkages, respectively [251] [240]. Especially the protein degradation and

loss of structural integrity in flours increased the mechanical breakability of the swollen starch granules, which caused a substantial decline in pasting viscosity [240].

6.3.2. Thermal Properties

Table 6.2. Effects of interaction between variety and processing method on thermal properties of haricot bean flour

Flour Sample	To (°C)	Tp (°C)	Tc (°C)	ΔH (J g ⁻¹)
119S	64±1 ^{ab}	69.±2 ^a	78±2 ^a	7.8±0.4 ^a
119G	61±1 ^b	67±2 ^a	78.±2 ^a	5.7±0.3 ^b
632S	66±2 ^a	71.7±0.2 ^a	80±2 ^a	6.8±0.4 ^a
632G	63 ±1 ^{ab}	69±2 ^a	80±2 ^a	4.9±0.3 ^b
125S	65±2 ^{ab}	70.±3 ^a	79±3 ^a	7.3±0.5 ^a
125G	62±2 ^{ab}	68±2 ^a	79±3 ^a	5.3±0.4 ^b
Effect				
Variety (V)	NS	NS	NS	***
Process (P)	***	***	NS	***
Interaction (V*P)	***	NS	NS	***

All values are mean ± SD. Means that sharing the same superscript letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant. 119S, SER 119 variety Soaked; 119G, SER 119 variety germinated; 632S, SAB 632 variety soaked; 632G, SAB 632 variety germinated; 125S, SER125 variety soaked; 125G= SER125 variety germinated ;To, onset temperature; Tp, peak temperature; Tc, conclusion temperature; ΔH, gelatinization enthalpy.

Some thermal properties of haricot bean flour were significantly affected by the varieties and germination as well as by the interaction between varieties and germination ($p < .05$) Table 6.2. But the difference between the temperatures at the beginning and end of gelatinization is not too large, signifying a low variability of the thermal properties of flour molecules. The thermal properties indicated that the hydrogen bond of starch in germinated flour could be broken down at a temperature lower than that of control flours (Table 6.2). To, Tp, Tc and ΔH_{gel} for haricot bean flours ranged between 61±1–66±2, 67.±2–71.7±0.2, 78±2–80±2 °C, and 4.9±0.3–7.8±0.4 J/g, respectively. The value of the onset temperature of 632S flour (66 ±2°C) was significantly higher than that of the other flours. An insignificant change was observed in Tp and Tc of flour with germination. The germinated haricot bean flour samples showed low thermal properties than native flour. The decrease in thermal properties of flour during germination might be due to decreased fat content, which covers the starch granules and thus become easily assessable for swelling [252]. In addition, the reduction in Tc may be linked with the degradation of interactions between starch and protein/lipid during germination [240]. The differences in thermal properties between different cultivars may be attributed mainly to the difference in starch properties, crystallinity, and protein

content [253]. Similar results of a decrease in thermal properties of chickpea and brown rice flour due to germination were reported by Xu et al.[254] and Wu et al.[252], respectively.

Gelatinization enthalpy (ΔH) can predict the energy required to break down the intermolecular hydrogen bonds of starch granules [255]. Flour from soaked SER 119 seeds showed a higher ΔH value than flour from other cultivars. The ΔH of germinated flours decreases, suggesting the reduction of energy required to convert the chemical composition of bean flour from an ordered to a disordered form; also, it indicates that reduction in the number of double helical [256], which may be attributed to the degradation and consumption of starch during sprouting. According to Xu et al.[228], during germination, the partial hydrolysis of starch by the activated enzymes diminishes the intermolecular hydrogen bonds of starch, making them easily detached on heating. This result suggests that the gelatinization enthalpy values obtained were higher than those reported on lentil flours (3.35 to 3.70 J/g) by M. Xu et al. [228] and lower than chickpea flour (15.2 J g⁻¹) by J. Huang et al. [257].

6.3.3. Fourier Transform Infrared (FTIR) Spectroscopy

The soaked (control) and germinated haricot bean flour samples were analyzed by FT-IR spectroscopy to study the change in functional groups upon the interaction between variety and germination. The FT-IR spectroscopy of haricot bean flour samples did not show any variations in spectra, but a change in the intensity of bands was observed (Fig.6.1). The spectra obtained for all samples were similarly based on the form but differed in the intensity of the major peaks as presented in Figure 6.1. All tested flour samples showed high absorption spectra at the wavenumbers 3278.6, 2912.3, 1635.5, 1391.4, 1252.6, and 1008.3 cm⁻¹. The bands observed in the region 3278 cm⁻¹ in the spectra of the flour can be assigned to the stretching vibration of the –OH groups caused by the formation of hydrogen bonds in the [258] starches and starch–proteins interaction and also from various compounds like alcohol, phenols, and carboxylic acid [259]. The literature highlighted that the spectral range between 3000 and 2800 cm⁻¹ corresponds to lipid compounds due to vibration produced by the carbonyl group of triglyceride (C-H) [20]. The signal at 2,912 cm⁻¹ in a sample confirmed the development of more C–H bonds, possibly from unsaturated C-bonds. The spectral range between 1700 and 1500 cm⁻¹ corresponds to the protein content of the samples. The lengthening at 1635 cm⁻¹ indicated the presence of C=O stretching, which may be related to the amide I region [20] [260]. The peaks at 1420 -1380 cm⁻¹ are assigned

to C-H deformation vibrations. The signals between 1200-900 cm^{-1} are ascribed to C—O and C—C stretching vibrations of the polysaccharide molecules [261][262].

6.3.4. X-Ray Diffraction (XRD)

XRD has been widely used to reveal the characteristics of the crystalline structure of starch granules [263]. As exhibited in Table 6.3, the crystallinity index, diffraction peaks, peak intensity, and D-Spacing of all six flour samples ranged from 44-59.1 %, 17.68 -18.49°, 370.43±1.01-537.6±1.0, and 27.4±0.8 – 28.6±0.5 nm, respectively. Both soaked and germinated haricot bean flours showed insignificant changes in diffraction peaks, suggesting no change in the type of crystalline structure due to variety and germination, as well as the interaction between them. It can be seen that the crystallinity index for the 125S flour sample was higher (59.1±0.9) than that of other flours. The variation of the crystallinity index of flour implies the differences in the extent of starch damage. As a result of the breakdown of starch molecules by enzymes during germination, there was a reduction in the crystalline structure of the flour, leading to an increase in the ability of the starch to dissolve in water. This suggests that the starch molecules became more amorphous and soluble due to the changes that occurred during germination [264]. Figure 6.2 reveals that the soaked haricot bean flour showed strong intensities compared to the germinated flour, with the 119S flour being the highest and 632G the lowest.

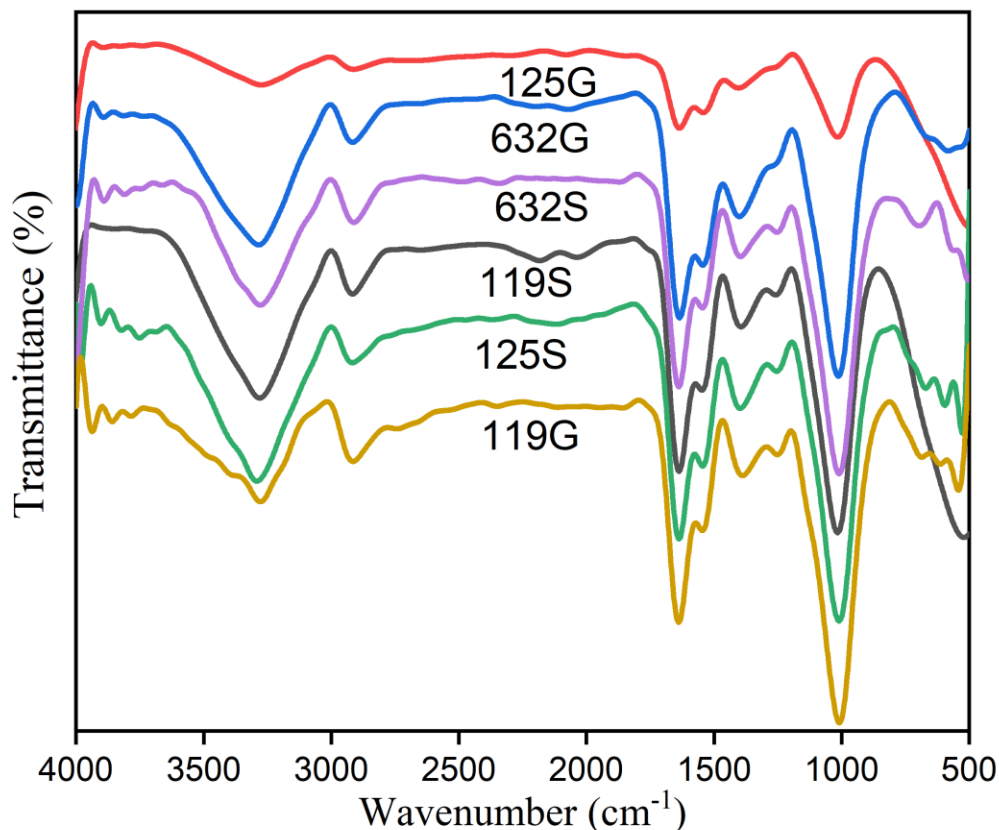


Figure 6.1. FTIR spectra of haricot bean flour: 119S, SER 119 variety Soaked; 119G, SER 119 variety germinated; 632S, SAB 632 variety soaked; 632G, SAB 632 variety germinated; 125S, SER125 variety soaked; 125G= SER125 variety germinated

Table 6.3. Effects of interaction between variety and processing method on XRD parameters of haricot bean flour

Flour Sample	Crystallinity index (%)	Peak diffraction (°)	Peak intensity	D-spacing (nm)
119S	56±1 ^b	18.3±0.8 ^a	537.6±1.0 ^a	27.5±0.3 ^{ab}
119G	44±1. ^d	18.4±0.4 ^a	457.83±0.72 ^b	27.7±0.2 ^{ab}
632S	57.5±0.3 ^{ab}	18.25±0.14 ^a	370.43±1.01 ^e	27.7±0.4 ^{ab}
632G	56.±1. ^b	17.68±0.20 ^a	340.4±0.9 ^f	28.6±0. 5 ^a
125S	59.1±0.9 ^a	18.49±0.30 ^a	437±1 ^c	27.4±0.8 ^b
125G	47.5±0.6 ^c	18.34±0.23 ^a	412.80±1.11 ^d	27.6±0.5 ^{ab}
Effect				
Variety (v)	***	NS	***	***
Processing (p)	***	NS	***	NS
Interaction (v*p)	***	NS	***	***

All values are mean ± SD. Means sharing the same superscript letters in columns are not significantly different from each other (Tukey's HSD test, p < 0.05). *** Significant effect at p < 0.05, NS, Not significant. Values are mean ± SD. 119S, SER 119 variety Soaked; 119G, SER 119 variety germinated; 632S, SAB 632 variety soaked; 632G, SAB 632 variety germinated; 125S, SER125 variety soaked; 125G= SER125 variety germinated

Because starch molecules break down into simpler sugars during germination, a more amorphous and disordered structure can occur. This decrease in peak intensity (crystallinity) was attributed to this [265].

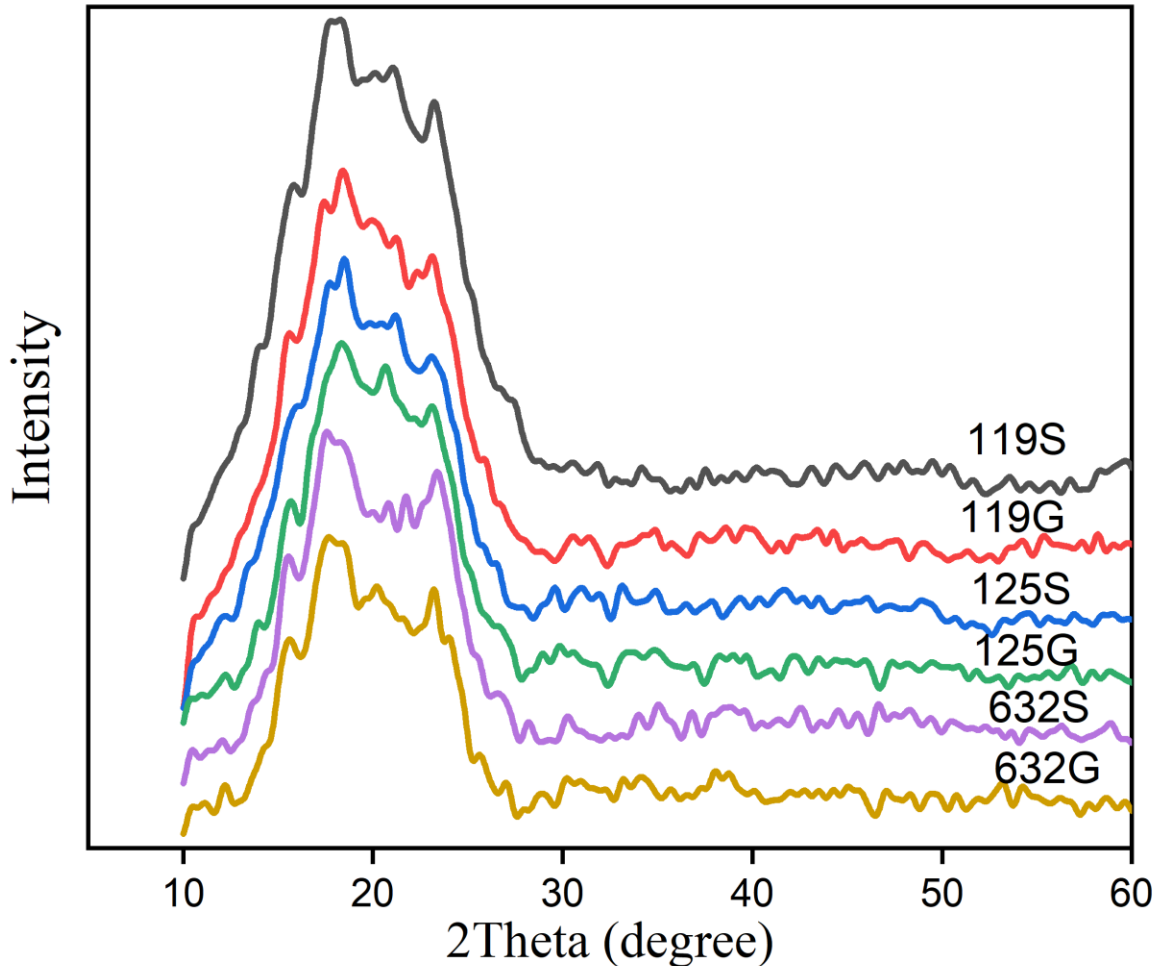


Figure 6.2. XRD patterns of haricot beans flours: 119S, SER 119 variety Soaked; 119G, SER 119 variety germinated; 632S, SAB 632 variety soaked; 632G, SAB 632 variety germinated; 125S, SER125 variety soaked; 125G= SER125 variety germinated

6.3.5. Scanning Electron Microscopy

Microstructures of the soaked and germinated haricot bean flours were examined by scanning electron microscopy (Fig. 6.3). The images reveal some residual proteins deposited or fragments of protein matrix on the granule surfaces, which confirms that starch granules were surrounded by a protein matrix [223]. In addition, it may be included mineral and fibre components, as reported by other workers [236]. There were visible changes observed between the micrographs of the soaked and germinated flour samples of all varieties (Fig.6.3). This indicates that the

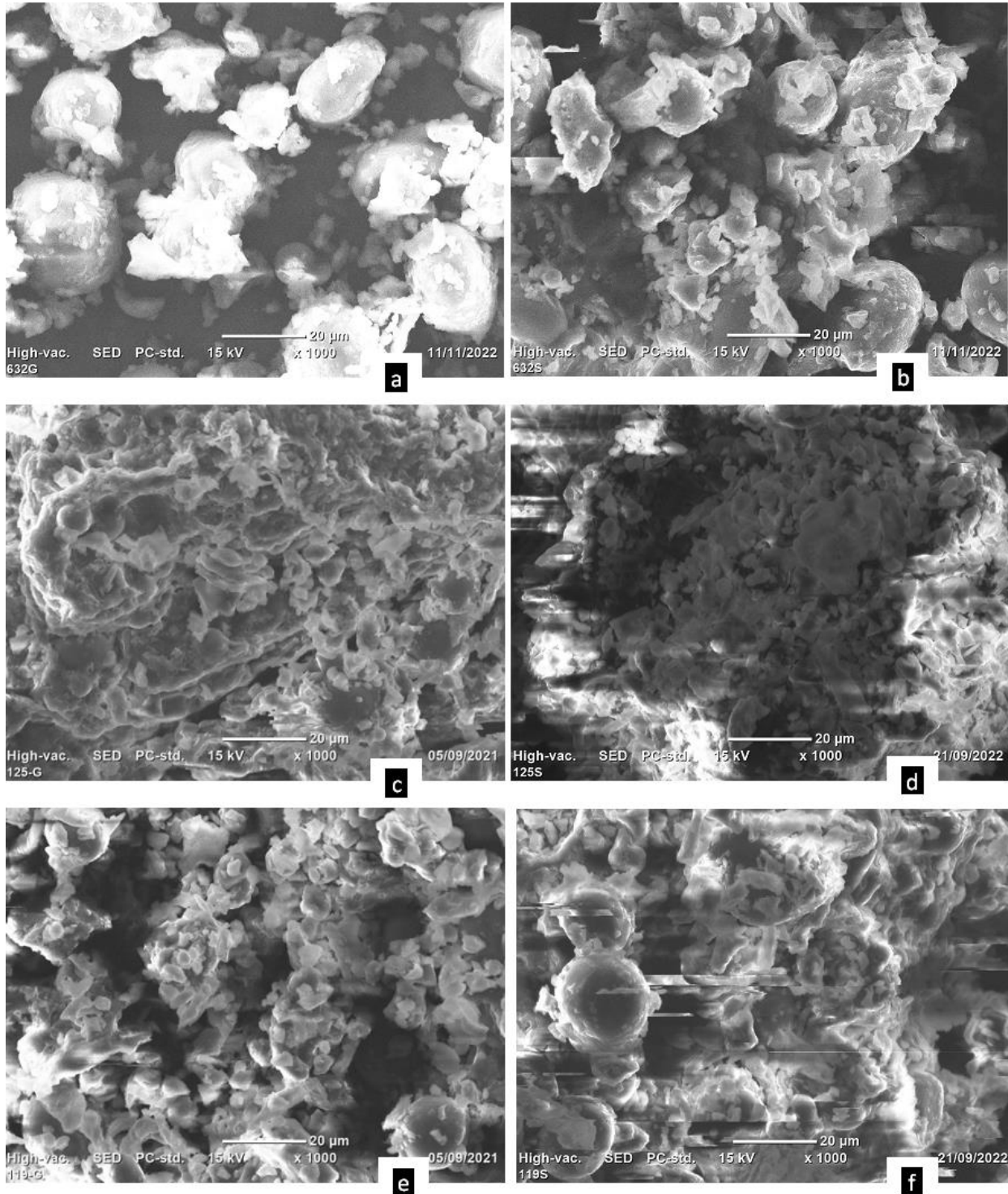


Figure 6.3. SEM of haricot bean flours: a) SAB 632 variety germinated; b) SAB 632 variety soaked; c) SER125 variety germinated; d) SER125 variety soaked; e) SER 119 variety germinated; f) SER 119 variety Soaked

germination could affect the shape of haricot bean flour granules, which was attributed to the breakdown of cell walls and the formation of new tissue[266]. A similar finding on the structural change of sprouted onion powder and sprouted sorghum was observed by Majid, Dar, & Nanda [267] and Yan et al.[268], respectively. The compositional changes during germination account for microstructural changes. This morphological change has an important influence on the flowability behavior of the powders

6.4. Conclusions

The study showed a significant effect of variety and germination on haricot bean flour's pasting, thermal, XRD, FTIR, and SEM properties. The germination process decreases flour's thermal and pasting properties, which could enhance its better utilization in the food industry due to the loosening structure caused by increased amylase activity. So the flour from germinated haricot bean seeds can provide a potential application for producing foods that require low viscosity compared to control flour. It was found that there were significant differences between the onset temperature and gelatinization enthalpy of the flours, with 632S flour showing the highest T_o and T_p , but 125G flour exhibited the lowest ΔH_{gel} . Germinated SER 125 and SAB 632 flour samples had high crystallinity index than other flours. This study may promote haricot bean flour utilization in the food industry.

CHAPTER 7: PUMPKIN FLOUR QUALITIES AS AFFECTED BY ULTRASOUND AND MICROWAVE PRE-DRYING TREATMENT

Abstract

This study aimed to assess the impact of innovative pre-drying treatments (ultrasound and microwave) on pumpkin flour's physical, chemical, and functional properties compared to untreated and freeze-dried (optimal control) flours. The impact was primarily related to improving the flour's nutritional, phytochemical, and functional properties. The pretreated flours were superior to untreated flour and were nearer in quality to freeze-dried flour. The moisture, ash, crude fat, crude protein, crude fibre, and carbohydrate contents of flours ranged from 7.57 to 8.23%, 5.73 to 6.57%, 1.17 to 1.85 %, 8.72 to 11.32 %, 10.92 to 13.11%, and 61.47 to 64.23%, respectively. Among the pre-drying treatment, 20UM depicts the highest color change and retention of the bioactive component in pumpkin flour. The results also showed that the 30UM pre-dried flour had a higher water solubilities index (11.83%), water absorption (9.75 g/g), and oil absorption capacities (2.28 mL/g).

Keywords: Freeze drying, Functional properties, Physical properties, Phytochemical analysis

7.1. Introduction

Fruits and vegetables are consumed worldwide in both fresh and processed forms. Pumpkin is a traditional crop considered an excellent source of provitamin A carotenoids, which are very helpful in preventing vitamin A deficiency [269]. Carotenoids are phytochemicals thought to reduce the risk of certain degenerative diseases and are responsible for the attractive color of many fruits and vegetables [270]. Nevertheless, very little has been done on a pumpkin to overcome undernourishment, food poverty and income generation, even in a favorable ecological conditions throughout East Africa [271]. As such, it remains underutilized and less considered by many households. Due to the high moisture content (90–92%), pumpkins are bulky and difficult to handle and transport. Hence, most pumpkins produced are consumed in the area of production. Processing can transform pumpkins from perishable produce to stable foods with a long shelf-life, facilitating global transportation and distribution [25]. For these reasons, freezing and drying may

be suitable techniques for processing and extending pumpkins' shelf life. Currently, powders are the core processed products of pumpkins.

Air drying is generally favored over freeze-drying due to its low operating costs and shorter drying times. In conventional air drying, high temperatures adversely affect the products' texture, color, and nutritional value [27]. Using pre-drying treatments is a method employed in conventional air drying to enhance the quality of dried products and ensure their high quality [30]. Hence, possible pre-drying treatment methods that reduce drying time while maintaining quality are imperative. Pre-drying treatment helps to reduce undesired changes such as antioxidant activity reduction, color, and textural changes.

In this sense, recent advances in the use of emerging food processing technologies have received considerable attention in reducing various adverse changes in final dried product properties. Among the so-called emerging technologies, ultrasound is a promising non-thermal pre-drying treatment commonly used before drying various agricultural products to improve mass transfer, and drying time, reduce processing costs, and maintain quality properties [272]. Additionally, it reduces drying time by relaxing tissue structure and producing a superior dry product [29]. Ultrasound treatment creates a sponge-like effect on the surface of solid food samples, causing the formation of microspores within the material. This allows for the removal of moisture from solids without causing a liquid phase [28]. Also, ultrasonic pretreatment is a favorite because the process can be performed at low temperatures, which shrinks the probability of food degradation [101]. The utilization of microwave energy has attracted much attention as it is said to improve the drying process by reducing processing time and operating costs [29]. Applying microwave heating as a pre-drying treatment to moist material for drying operations results in internal moisture being heated up and migrating to the surface due to pressure differences for subsequent drying [273]. Therefore, this study aimed to investigate the effect of innovative combined ultrasound and microwave technologies as a pre-drying treatment on the physical, chemical, and functional properties of pumpkin flour qualities.

7.2. Materials and Methods

7.2.1. Chemicals

Standards and reagents used were gallic acids (97.5-102.5% sigma Aldrich, China), phytic acid sodium salt hydrate (Sigma Aldrich, Switzerland), (+-) Catechin hydrate ($\geq 96.0\%$, Sigma Aldrich, China), Quercetin ($\geq 98\%$, sigma Aldric, Germany), Folin-Ciocalteu's (2N, Sigma Aldrich, USA), Vanillin ($\geq 99.5\%$, UNI-CHEM, Roth, France), 2,2-Diphenyl-1-picrylhydrazyl (Sigma Aldrich, Germany), Aluminium Chloride (99% Loba chemic, India), Methanol (M.wt. =34.02g/mol, Biochem chemopharma, France), Nitric acid (69% Loba chemic, India) and Sodium carbonate ($\geq 99.5\%$ Carl Roth GmbH, Karlsruhe). All chemicals were of analytical grade.

7.2.2 Material Collection and Preparation

The fresh, healthy, and ripped pumpkin bought from a local market was washed properly in distilled water, peeled, and cleaned by discarding the seeds. Only the fleshy part was sliced into $(15 \times 15 \times 4)$ mm³ pieces. Slices were washed with distilled water, drained, and mopped with a paper towel. Untreated and freeze-dried (Lablyo plus, Germany) samples were used as a control sample to compare the effect of pre-drying methods; the remaining samples were treated with the following pre-drying methods before drying at 60°C in a fluidized bed drier (TG 200, Germany). Dried slices were milled (Model BH24 1DY, Armfield, England) and then sieved through a standard 500-micron mesh sieve. The obtained flours were wrapped in aluminum foil bags and were kept at 4°C in a desiccator before use.

7.2.2.1. Pre-drying Treatment

Microwave Pre-drying treatment: FA programmable domestic microwave oven (Model-CE107BT, Samsung, Thailand) with a maximum output of 900 W at 2450 MHz was used. For processing, approximately 100 g of sample in slice form was spread evenly on the tissue paper to remove adhering moisture and then placed on the rotatable turntable to confirm the uniformity of microwave energy absorbed by each sample. The microwave oven was allowed to operate at a 300 W power level for 6 min [274], followed by cold water dipping to avoid the residual heating effect.

Ultrasonic pre-drying treatment: A set of experimental pumpkin slice samples were immersed in distilled water and subjected to ultrasonic waves for 10, 20, and 30 min [101],[102].

Experiments were performed in an ultrasonic bath (Model-EU-28, Akin Electronic, Turkey) at ambient water temperature (30°C) without mechanical agitation. The temperature raised during the experiments was lower than $\pm 2^\circ\text{C}$ at each treatment. Keep the water-to-fruit ratio at 4:1 on a weight basis. Experiments were performed in isolated 250 mL Erlenmeyer flasks to keep away from interference among the samples and runs. For the **combined treatment**, other parts were further microwave blanched (Samsung, Model-CE107BT, Thailand) for six (6) min at 300 W power level as above after draining and wiping.

7.2.2.2. Drying Methods

Freeze-Drying: Pumpkin slices were dried using a laboratory-scale freeze dryer (Lablyo plus, Germany), as described by Marques, Prado, & Freire [275]. One hundred grams of each sliced sample was put in the tray, frozen at -18°C for 3 hours, and placed inside the freeze dryer chamber at 52 pa and -52°C . Thermocouple probes were used to regulate and adjust the product temperature on each tray during drying. The dried slices were milled (Model BH24 1DY, Armfield, England), sealed in aluminum foil bags and stored at 4°C until further tests were carried out.

Fluidized bed drying: The slices were drained well and spread for drying using a fluidized bed (TG 200, Germany) drier at 60°C with constant fluidizing drying air velocity set to 1.5 m/s to achieve fluidization [276]. After being subjected to drying, weighing every interval of time until constant weight is achieved. The dried pumpkin slices were then grounded using a laboratory grinder (Model BH24 1DY, Armfield, England) and sieved through a 500-micron mesh sieve to remove coarse fibre. Pumpkin flour was sealed in aluminum foil bags and stored at 4°C for further analysis [276].

7.2.3. Physical Property Analysis

Color: Color analysis was carried out using Hunter Lab Colorimeter, Minolta. The color readings were presented in L^* , a^* , b^* format where a^* value ranges from -100 (greenness) to +100 (redness), the b^* value varies from -100 (blueness) to +100 (yellowness), whereas the L^* value, elucidate the degree of lightness, extend from 0 (black) to 100 (white)[181]. The black and white tile was used for instrument calibration before color measurement. The chroma factor (C^*) was calculated by converting the Cartesian coordinates (b^* , a^*) based on the following formula [277]:

$$\text{Chroma}(C^*) = [(a^*)^2 + (b^*)^2]^{1/2} \quad 7.1$$

The Hue angle showed a relation between a^* and b^* and was calculated according to the formula [277]:

$$H^* = \tan^{-1}(b/a) \quad 7.2$$

Color changes in comparison to the negative control sample are obtained from the following formula:

$$DE = [(Dl)^2 + [(Da)^2 + [(Db)^2]^{1/2} \quad 7.3$$

Water activity, Total soluble solids, and pH: The water activity of the pumpkin flours was measured by a water activity meter (HD-3A, NanBei, China). Total soluble solids (TSS) were determined for each sample according to the AOAC [145] method using a digital refractometer (Model-A670, Hanon, China) at 25°C and expressed as °Brix. A 10 g sample was balanced and dissolved in a beaker containing 25 mL of distilled water to form a slurry. It was placed for 10 min with constant stirring. The pH was then determined according to official methods AOAC [182] with a pH meter (BANTE Multiparameter/China).

7.2.4 Proximate Composition

Proximate values were determined according to the method described in section 3.2.1.

7.2.5. Phytochemical Analysis

7.2.5.1. Phytate Content

Phytate content was determined according to the method described in section 3.2.2.1.

7.2.5.2. Tannin Content

Tannin content was determined according to the method described in section 3.2.2.2.

7.2.5.3. Oxalate content

It was assessed by the AOAC [145] method. One gram of the sample was taken in a 100-mL conical flask. Seventy-five milliliters of 3 mol/L H₂SO₄ were poured, and the solution was stirred occasionally with a magnetic stirrer for about 1 h and then clarified using Whatman No.1 filter paper. The clarified samples (extract) (25 mL) were gathered and titrated against hot (80–90°C) 0.1 N KMnO₄ solution to the point when a faint pink color was observed that persisted for at least 30 sec. Results were outlined as oxalate in mg per g of sample, and the concentration of oxalate in every sample was recorded from the calculation:

1 mL of 0.1 N Permanganate = 0.006303 g oxalate

7.4

Analysis of Antioxidant Activities

Samples were extracted according to previously defined procedures of Ferreira *et al.* [183]. Extract 10 g of pumpkin flour with 100 mL of methanol for 24 h using a temperature shaker incubator (ZHWHY-103B) at 25°C and 150 rpm, then clarify through Whatman No. 1 paper. Again extract the residue with the above two additional 100 mL portions of methanol. The combined methanolic extracts were then evaporated to dry using a Rota evaporator (R-300, Buchi, Switzerland) at 40°C, redissolved in methanol at a 50 mg/mL concentration, and stored at 4°C for further use.

7.2.5.4. Total Phenolic Content

Total phenolic content was determined according to the method described in section 3.2.2.3.

7.2.5.5. Total Flavonoid Content

Total phenolic content was determined according to the method described in section 3.2.2.4.

7.2.5.6. Free Radical Scavenging Activity

Free radical scavenging activity was determined according to the method described in section 3.2.2.5.

7.2.5.7. Total Carotene Content

It was estimated according to the method by de Carvalho *et al.* [278]. Approximately 1 g of the sample was taken in a mortar and crushed by adding 25 mL of acetone. This extract was filtered and collected in a volumetric flask. This extraction procedure was repeated until the sample became colorless. The extract was pooled and transferred to a 500 mL separating funnel containing 40 mL of petroleum ether. Acetone was removed from the extract by the slow addition of distilled water. The addition of distilled water resulted in the separation of two phases. Repeat the process by discarding the aqueous phase until no residual solvent remains. Then the extract was transferred to a funnel containing 15 g of anhydrous sodium sulfate in a 50 mL volumetric flask. Read the sample absorbance at 450 nm after making up the volume to 50 mL with petroleum ether. The total carotenoid content was determined using the following formula:

$$\text{Total carotenoid content} = \frac{A * V * 10^4}{P * A_{1cm}^{1\%}} \quad 7.5$$

where A = absorbance; V =total extract volume (mL); P = Sample weight (g); $A^{1\%}_{1\text{cm}} = 2592$ (Beta carotene extinction coefficient in petroleum ether).

7.2.6. Functional Properties

Bulk density: Bulk density (g/mL) was determined in a graduated cylinder by lightly adding 2 g of pumpkin flour into an empty 10 mL graduated cylinder and holding the cylinder on a vortex vibrator (XH-B, Hinotek, China) for 1 min. The volume was read and recorded. The measurements were made in triplicate. The ratio of the mass of the powder to the volume occupied in the cylinder decides the bulk density value in g/mL using Eq. (3) [279].

$$\text{Bulk density (g mL}^{-1}\text{)} = \frac{W}{V} \quad 7.6$$

where, W = grams of pumpkin powder; V =measuring volume

Water absorption capacity and water solubility index: It was assessed according to Que *et al.*[276]. Pumpkin flour (1 g) and water (10 mL) were vigorously mixed in a weighted 15 mL centrifuge tube, incubated in a 37°C water bath for 30 min, and then centrifuged (3000 * g, 10 min) (TGL-16, Sichuan Shoke, China). The supernatant was collected in pre-weighed aluminum cans, and the residue was weighed after the water was evaporated at 105 °C overnight.

$$\text{Water absorption (g/g)} = \frac{\text{weight of centrifuged precipitate (g)}}{\text{weight of pumpkin flour (g)}} \quad 7.7$$

$$\text{Water solubility (\%)} = \frac{\text{weight of residue}}{\text{weight of pumpkin flour}} * 100 \quad 7.8$$

Oil absorption capacity: It was determined using the method of Que *et al.*[276] with slight modifications. Specifically, it was done by mixing pumpkin powder (1 g) and 6 mL of corn oil in a centrifuge tube and stirring it for 30 s using a vortex mixer (XH-B, Hinotek, China), followed by centrifugation in a benchtop centrifuge (TGL-16, Sichuan Shoke, China) at 8000 rpm for 10 min. The volume of supernatant was recorded, and an average was calculated from triplicate determinations.

$$\text{The oil absorption capacity} = \frac{\text{mL of supernatant}}{\text{grams of pumpkin powder}} \quad 7.9$$

7.2.7. Statistical Analysis

Statistical analysis was carried out using the software package SAS version 9.0 (SAS Institute, Inc., Cary, North Carolina, USA) using analysis of variance (ANOVA). Tukey's HSD test at the significance level of 5% ($P < 0.05$) was used to determine significant differences among samples.

7.3. Results and Discussions

The quality of pumpkin flour exhibits varying responses when subjected to ultrasound, microwave, and combined ultrasound followed by microwave pre-drying treatments. This is attributed to the shortened drying time resulting from improved mass transfer.

7.3.1 Physical Properties

The physical properties of pumpkin flour produced under different types of pre-drying treatment show a significant difference ($p < 0.05$) in all properties except pH and water activity values (Tables 7.1 and 7.2). The data also shows that water activity increased with longer ultrasound exposure time and microwave treatment. However, these increases were not significantly different ($p < 0.05$) except for freeze-dried flour. This difference can be attributed to the sublimation process during freeze-drying, which removes a substantial portion of the free and bound water content, resulting in lower water activity. In line with this finding, Szadzińska *et al.*[280] reported that ultrasound application did not influence the dried potatoes' water activity (a_w). Mothibe *et al.*[281] also reported that microwave pre-drying treatment can reduce the water activity of dried apples more than ultrasound pretreatment. The results show a water activity below 0.6, which indicates it is microbiologically safe [282]. The pH value of the untreated pumpkin flour (6.46 ± 0.16) was higher than that of pretreated and freeze-dried flours, but there was no significant difference among pretreated flours. This finding also showed that the total soluble solids (TSS) of untreated pumpkin flour (3.97 ± 0.06) were lower than that of freeze-dried (4.53 ± 0.21) and microwave pretreated (4.03 ± 0.15) flours but higher than that of ultrasound pretreated flours. As reported in a previous study, the TSS of untreated pumpkin powder and salt pretreated were 7.5 and 8.3 °Brix, respectively [283], which is higher than this finding. The reduction in TSS is reasonable because the longer samples are sonicated, the more soluble solutes are lost. The preservation of food structure during the freeze-drying process contributes to an increase in total soluble solids (TSS). This is because the process minimizes damage to cell walls, allowing for the retention of a higher amount of nutrients and sugars within the food particles.

The drying time was less for the 20UM and 30UM pre-dried flour samples. The faster liquid flow rates through the slice to the edge where micro-channels are formed during ultrasonic application and microwave heating action could be the probable causes. A similar reduction in

drying time was observed for pineapple [284], melon [285] and mulberry [286] due to ultrasonic pre-drying treatment.

Table 7.1. Effects of pretreatment methods on drying time, water activity, pH, and TSS content of Pumpkin flour

Sample code	Water activity	pH	TSS	Drying time (min)
FC	0.43±0.02 ^a	6.46±0.16 ^a	3.97±0.06 ^{bc}	180
FD	0.34±0.02 ^b	6.21±0.07 ^a	4.53±0.21 ^a	540
FM	0.41±0.00 ^a	6.36±0.15 ^a	4.03±0.15 ^b	155
10U	0.43±0.031 ^a	6.38±0.12 ^a	3.77±0.15 ^{bcd}	168
20U	0.44±0.00 ^a	6.24±0.04 ^a	3.43±0.06 ^{de}	138
30U	0.44±0.00 ^a	6.23±0.09 ^a	3.2±0.00 ^e	135
10UM	0.43±0.00 ^a	6.25±0.05 ^a	3.67±0.06 ^{cd}	148
20UM	0.43±0.02 ^a	6.22±0.03 ^a	3.67±0.06 ^{cd}	121
30UM	0.44±0.00 ^a	6.21±0.04 ^a	3.5±0.17 ^{de}	119

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). TSS, Total Soluble Solids; FC, untreated pumpkin flour; FD, Freeze-dried; FM, Microwaved pretreated; 10U, 10min ultrasound pretreated; 20U,20min ultrasound pretreated;30U,30min ultrasound pretreated; 10UM, 10min ultrasound and 6min microwaved pretreated; 20UM, 20min ultrasound and 6min microwaved pretreated;30UM,30min ultrasound and 6min microwaved pretreated pumpkin flour

Table 7.2. Effects of pretreatment methods on color properties of Pumpkin flour

Sample code	L*	a*	b*	C*	H*	DE
FC	79.80±1.59 ^a	5.82±0.24 ^{cd}	39.68±0.56 ^f	40.10±0.54 ^e	81.64±0.40 ^{ab}	0.00±0.00 ^f
FD	71.35±3.05 ^e	23.33±3.00 ^a	48.72±0.79 ^a	54.07±1.22 ^a	64.46±3.07 ^d	21.54±2.39 ^a
FM	77.00±2.01 ^{abc}	6.29±0.55 ^{cd}	41.05±0.45 ^e	41.53±0.48 ^{cd}	81.28±0.72 ^{ab}	3.15±0.85 ^{de}
10U	78.62±1.78 ^{ab}	5.95±0.32 ^{cd}	40.16±1.15 ^{ef}	40.60±1.15 ^{de}	81.58±0.44 ^{ab}	1.46±0.23 ^{ef}
20U	75.82±2.40 ^{abcde}	5.47±0.41 ^d	42.34±0.39 ^c	42.69±0.42 ^c	82.65±0.51 ^a	4.94±1.20 ^{cd}
30U	74.33±2.89 ^{bcde}	5.64±0.25 ^d	42.11±0.44 ^{cd}	42.49±0.45 ^c	82.37±0.31 ^a	6.07±2.07 ^c
10UM	76.18±2.56 ^{abcd}	7.24±0.21 ^{bcd}	41.07±0.13 ^{de}	41.70±0.10 ^{cd}	80.01±0.32 ^{bc}	4.27±1.32 ^{cde}
20UM	72.58±3.12 ^{cde}	7.64±0.29 ^{bc}	44.58±0.71 ^b	45.23±0.74 ^b	80.28±0.26 ^{bc}	9.06±2.04 ^b
30UM	72.31±3.53 ^{de}	8.18±0.42 ^b	43.54±0.21 ^b	44.30±0.21 ^b	79.35±0.55 ^c	8.92±2.46 ^b

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). L*, whiteness; a*, redness; b*, yellowness; C*,chroma; H*, hue angle; DE,color change; FC, untreated pumpkin flour; FD, Freeze-dried; FM, Microwaved pretreated; 10U, 10min ultrasound pretreated; 20U,20min ultrasound pretreated;30U,30min ultrasound pretreated; 10UM, 10min ultrasound and 6min microwaved pretreated; 20UM, 20min ultrasound and 6min microwaved pretreated;30UM,30min ultrasound and 6min microwaved pretreated pumpkin flour

All color parameters for pretreated and untreated flours are shown in Table 7.2. Color is the first parameter customers use to judge the quality of dried products. The study revealed that the color parameters of pumpkin flour were affected by ultrasound, microwave, and combined pre-drying treatments, as shown in Table 7.2. Pumpkin is a good source of carotene, especially β -carotene, used as a coloring agent [287]. This study indicated that freeze-drying reduced discoloration and preserved the yellowness of pumpkin powders compared to other flours. L* values representing brightness were lower in ultrasound-pretreated flours than those of microwave-

pretreated flours. This could be because microwave treatment only heats the water molecules in the fruit tissue, not the fruit tissue itself, whereas ultrasonic treatment can mechanically damage the fruit tissue, which could lead to the release of pigments that could color the flour [288]. Microwaved and ultrasonic pretreatment had a lower L^* value than untreated flour (79.80 ± 1.59) but higher than freeze-dried (71.35 ± 3.05) flour. For the ultrasound pretreated flour, the highest L^* value was noted for 10U (78.62 ± 1.78), followed by 30U (74.33 ± 2.89) and 20U (75.82 ± 2.40), respectively. Samples pretreated with ultrasound for 20 min followed by 6 min microwave blanching had the highest b^* value (44.58 ± 0.71), while samples pretreated at 30 min followed by 6 min microwave blanching had the highest a^* value (8.18 ± 0.42). The chroma index of the untreated control flour is significantly different ($p < 0.05$) from the other flour samples. Among the flour samples, FD recorded the highest value of chroma index at 54.0 ± 71.22 , while FC recorded the lowest value at 40.10 ± 0.54 . The findings show that FD has the lowest hue angles, while 20U and 30U exhibit the highest hue angles, highlighting color purity as the average person perceives [277].

The data reveals a significant difference between the color change of pretreated and untreated flours. Among the pretreated flours, while the 20UM flour sample noticed the highest color change, the 10U (1.46 ± 0.23) samples showed the lowest compared to the negative control flour, indicating that colors are not close to one another. Additionally, for 10U duration of the treatment may not be sufficient to cause significant changes in the physical and chemical properties of the fruit. The highest ΔE was likely due to high differences in the L^* (lightness) and b^* (yellowness) values. The possible reasons for these differences are the exposure of cellular-bound yellow pigmentation of the pumpkin slice to the cavitation effect of ultrasound [289]. The flour's color shift during processing may be advantageous for making pastries, extruded snacks, baked goods, and other foods for enhancing its overall appeal to consumers and product differentiation in the market. A similar finding was reported by Wang *et al.* [30] on ultrasound-pretreated carrot samples. In general, the untreated flour had significantly lower b^* values ($P < 0.05$) compared to the pretreated flours. This indicates that the pretreated flours were more orange in color, as the pretreatment helped them to maintain their color [290]. This implies that the samples lost their pigment to become lighter. The findings are consistent with earlier research showing that prolonged drying times might alter the properties of food surfaces or result in more significant pigment losses (carotenoids and other pigments), which can modify the food color [291]. By

lowering drying time, microwave pre-drying treatment can minimize the loss of color pigments and other nutrients. The reason for this enhancement was credited to the microwave energy's selective heating ability, which can efficiently eliminate water from the fruit tissues without causing considerable heat damage [292].

7.3.2. Proximate Composition

Table 7.3 displays the significant ($p < 0.05$) differences in moisture, protein, fat, fibre, ash, and carbohydrate content between the pretreated and untreated flours. The low moisture content of the freeze-dried flours implied that it would have good storage qualities. The decrease in moisture content is caused by sublimation, which removes water molecules from food products directly during freeze drying as opposed to air drying, which relies on evaporation through the product's surface.

Table 7.3. Proximate composition of pumpkin flour as affected by pretreatment methods % (g/100 g dry weight basis).

Sample code	Moisture %	Ash %	Crude fat %	Crude protein %	Crude fibre %	CHO %
FC	8.23±0.21 ^a	5.73±0.06 ^d	1.17±0.29 ^a	8.72±0.70 ^d	10.92±1.31 ^a	62.63±0.95 ^{ab}
FD	5.88±0.05 ^b	6.57±0.06 ^a	1.85±0.38 ^a	11.32± 0.16 ^a	13.11±0.63 ^a	61.47±1.03 ^b
FM	8.17±0.06 ^a	5.97±0.06 ^c	1.25±0.25 ^a	9.04±0.25 ^d	11.34±0.74 ^a	62.40±1.05 ^{ab}
10U	8.18±0.17 ^a	5.80±0.100 ^{cd}	1.23±0.25 ^a	8.93±0.06 ^d	11.15±0.83 ^a	63.84±0.51 ^{ab}
20U	7.99±0.21 ^a	6.27±0.06 ^b	1.45±0.30 ^a	9.68±0.35 ^{cd}	11.57±0.06 ^a	63.05±0.31 ^{ab}
30U	7.78±0.37 ^a	6.30±0.10 ^b	1.50±0.50 ^a	9.81±0.63 ^{bcd}	12.10±0.17 ^a	62.90±0.48 ^{ab}
10UM	8.03±0.31 ^a	6.00±0.10 ^c	1.25±0.25 ^a	9.42±0.16 ^d	11.45±0.23 ^a	64.23±0.23 ^a
20UM	7.64±0.42 ^a	6.40±0.10 ^{ab}	1.60±0.17 ^a	10.88±0.63 ^{abc}	12.40±1.44 ^a	63.03±1.86 ^{ab}
30UM	7.57±0.66 ^a	6.43±0.06 ^{ab}	1.77±0.25 ^a	11.12±0.62 ^{ab}	12.98±0.38 ^a	62.53±0.76 ^{ab}

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). FC, untreated pumpkin flour; FD, Freeze-dried; FM, Microwaved pretreated; 10U, 10min ultrasound pretreated; 20U, 20min ultrasound pretreated; 30U, 30min ultrasound pretreated; 10UM, 10min ultrasound and 6min microwaved pretreated; 20UM, 20min ultrasound and 6min microwaved pretreated; 30UM, 30min ultrasound and 6min microwaved pretreated

No significant ($p < 0.05$) differences were observed between the crude fat and fibre values of the pretreated flours. Excluding moisture content, combined pretreatments improve the nutritional content of flour more than ultrasound and microwave pretreatment independently. Freeze-dried pumpkin flour depicted the highest value in all studied parameters except for moisture and carbohydrate content. While the nutritional value of the 20U and 30U flour samples was higher than that of FM, the nutritional content of the 10U flour was lower since it hardly differed from FC (untreated) flour. So longer (20, 30 min) ultrasound pretreatment time prevents more nutrient loss than a microwave (6 min, at 300W) pretreatment, possibly due to thermal effect. The result obtained indicates that 30min ultrasound pretreated followed by 6 min microwaved blanched flour

(30UM) had the highest protein ($p<0.05$) ($11.12\pm0.62\%$) and crude fibre ($12.98\pm0.38\%$) (not significant) than others, while lower than freeze-dried flour. The highest two flours in carbohydrates content were 10UM ($64.23\pm0.23\%$) and 10U ($63.84\pm0.51\%$), while the lowest two were FD ($61.47\pm1.03\%$) and FM ($62.40\pm1.05\%$). According to Toan *et al.* [293], ash, fat, protein, and crude fibre content of pumpkin flour was 4.51, 0.85, 7.63, and 4.78, respectively, lower than this finding for untreated flour. However, the carbohydrate content was higher, which could be attributed to the high fibre content of these flours. El-Deremy [294], also reported a similar finding. Khandpur & Gogate [295] reported that ultrasound pretreatment enhanced the nutritional quality of carrots, spinach, sweet lime, orange, and juices. The high nutrient retention in freeze-dried samples is not surprising as it has been reported to be one of the chosen drying methods to minimize the loss of nutrients and bioactive compounds [296] [297].

Generally, the higher nutritional values observed in pumpkin flour in the present study were due to pretreatment methods which increased the loss of moisture and preserve nutrients at any given weight. This was also in line with a study conducted by Morris *et al.* [275], who concluded that moisture removal might increase the nutrient content, which was the case in all the flour samples. The mechanical effects of ultrasound were thought to be responsible for this improvement because they can cause cell membrane permeabilization and encourage the diffusion of intracellular components into the extracellular matrix [298]. Products with low moisture were generally stored longer due to reduced microbial and chemical activity. In addition, the reason for an increase in protein content during the ultrasound treatment may be due to its mechanical effect that breaks up the food matrix into smaller particles that form microspores within the food material, thus increasing the surface area, facilitating protein release, and increasing protein yield [299].

7.3.4. Phytochemical Properties

Table 7.4. Phytochemical composition of pumpkin flour as affected by pre-drying treatment methods

Sample code	Phytate (mg/100g)	Tannin (mg/100g)	Oxylate mg	Total flavonoid (mgQE/g)	Total phenol (mgGAE/g)	Total carotenoid ($\mu\text{g/g}$)
FC	142.36 ± 1.43^b	3.55 ± 0.19^b	3.63 ± 0.43^b	0.98 ± 0.05^e	3.43 ± 0.19^d	56.70 ± 0.50^f
FD	189.55 ± 0.00^a	6.48 ± 0.40^a	4.29 ± 0.52^a	2.22 ± 0.22^a	6.52 ± 0.16^a	140.81 ± 1.53^a
FM	134.33 ± 1.11^e	3.28 ± 0.24^{bcd}	2.21 ± 0.29^d	1.31 ± 0.16^{cde}	4.36 ± 0.16^{cd}	87.70 ± 4.56^{de}
10U	139.37 ± 0.90^c	3.45 ± 0.52^{bc}	2.75 ± 0.10^c	1.28 ± 0.16^{de}	4.44 ± 0.23^{bcd}	81.29 ± 20.09^e
20U	138.98 ± 0.22^{cd}	2.83 ± 0.30^{def}	2.16 ± 0.25^d	1.63 ± 0.13^{bcd}	5.58 ± 0.22^{abc}	110.70 ± 7.77^{bcd}
30U	137.60 ± 0.97^d	2.82 ± 0.08^{def}	2.04 ± 0.16^{de}	1.52 ± 0.15^{cd}	5.06 ± 0.15^{abcd}	104.00 ± 4.51^{cde}

10UM	115.91±0.95 ^f	3.02± 0.27 ^{cde}	2.21±0.06 ^d	1.36±0.15 ^{cde}	4.49±0.20 ^{bcd}	93.39±1.88 ^{de}
20UM	110.80±0.81 ^g	2.71±0.03 ^{ef}	1.62±0.04 ^{ef}	1.97±0.14 ^{ab}	6.31±0.23 ^{ab}	131.50±9.84 ^{ab}
30UM	110.26±0.87 ^g	2.51±0.05 ^f	1.58±0.06 ^f	1.73±0.15 ^{bc}	5.43±0.48 ^{abc}	122.51±0.93 ^{abc}

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). FC, untreated pumpkin flour; FD, Freeze dried; FM, Microwaved pretreated; 10U, 10min ultrasound pretreated; 20U,20min ultrasound pretreated;30U,30min ultrasound pretreated; 10UM, 10min ultrasound and 6min microwaved pretreated; 20UM, 20min ultrasound and 6min microwaved pretreated;30UM,30min ultrasound and 6min microwaved pretreated

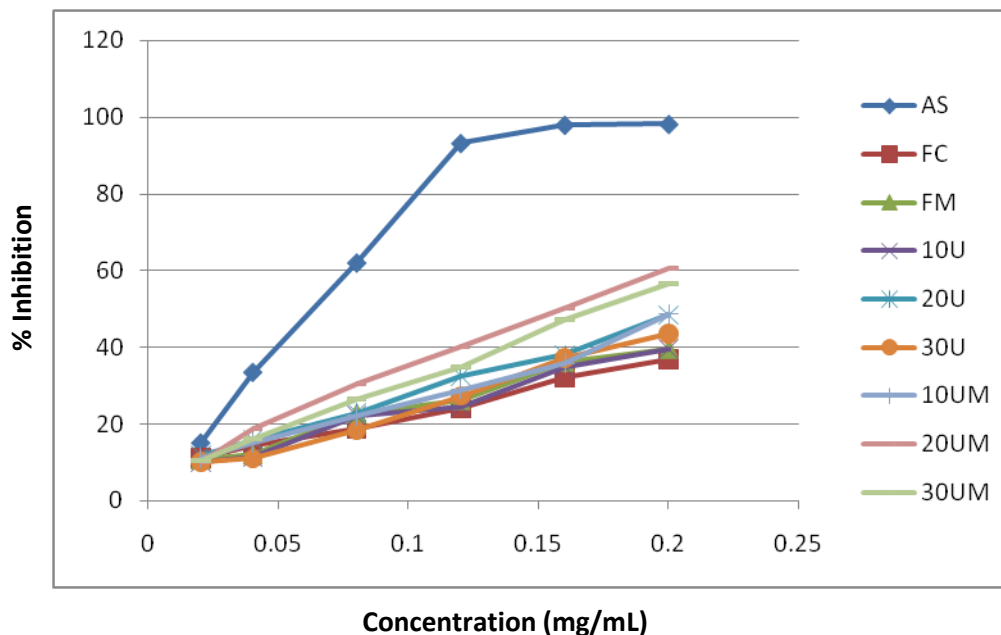


Figure 7.1. Free radical scavenging of methanolic extract of pretreated pumpkin flour and controls. AS, ascorbic acid; FC, untreated pumpkin flour; FM, Microwaved pretreated; 10U, 10min ultrasound pretreated; 20U,20min ultrasound pretreated;30U,30min ultrasound pretreated; 10UM, 10min ultrasound and 6min microwaved pretreated; 20UM, 20min ultrasound and 6min microwaved pretreated;30UM,30min ultrasound and 6min microwaved pretreated flours

As shown in Table 7.4, phytate, tannins, oxylate, total phenols, total flavonoids, and total carotenoids were significantly influenced by pretreatment methods ($P < 0.05$). Food materials' anti-nutrients (phytate, tannin, and oxalate) have been reported to form complexes with several mineral elements, making them biologically unavailable for human absorption and utilization. The phytate, tannin, and oxalate contents of the pretreated and controls flours showed significant variations ($p < 0.05$). The lowest two in phytate content with no significant difference among them were 20UM (110.80±8.12 mg/100g) and 30UM (110.26±8.66 mg/100g), while freeze-dried and untreated flour samples had the highest (189.55±0.00 and 142.36±14.31 mg/100g), respectively.

The finding indicated that microwave and ultrasound pretreatment reduces phytate, tannin, and oxylate content, while combined pretreatment was more effective. With the increase of ultrasonic pre-drying treatment exposure time, phytate, tannins, and oxylate content reduction in flour

increased, but microwave pre-drying treatment was more effective in reducing phytate content (134.33 ± 11.12 mg/100g). So probably due to the chemical degradation of phytate to lower inositol phosphates and inositol or cleavage of the phytate ring itself [300]. Additionally, this is attributed to microwave energy that induces more structural changes in phytate molecules, leading to their degradation and conversion into less complex forms [301]. The study results showed that microwave and ultrasonic pretreatment reduced phytate, tannin, and oxalate content, while combined pretreatment was more effective. The high tannin (6.48 ± 0.40 mg/100g) and phytate (189.55 ± 0.00 mg/100g) content in the freeze-dried flour may indicate both susceptibilities to hot temperatures. Due to differences in the heating mechanisms, temperature profiles and variation in extraction efficiency of the two methods, microwave pretreatment of flour resulted in lower levels of total phenol (4.36 ± 155.36 mgGAE/g), total flavonoid (1.31 ± 160.61 mgQE/g), and total carotenoid (87.70 ± 4.56 g/g) than ultrasonic pretreatment of flour for 20 and 30 minutes. But greater than 10 minutes sonicated and untreated (FC) flour. Kaseke, Opara, & Fawole [290] also reported a similar case, who said microwave pretreatment enhanced total carotenoids, total phenolic content, and DPPH radical scavenging capacity of pomegranate seeds more than the untreated one. Hayat *et al.*[302], also reported that microwave energy could increase the bioavailability of some phenolic compounds by liberating them from the food matrix. These were linked to the microwave treatment's breakdown of cell walls and membranes, which allowed the phenolic compounds to be released from the food matrix and become better absorbed by the body [303]. Among the pretreated flours, the 20UM flour samples had the highest total phenol, total flavonoid, and total carotenoid, which were 6.31 ± 229.99 mgGAE/g, 1.97 ± 135.22 mgQE/g, and 131.50 ± 9.84 μ g/g, respectively. In contrast, the lowest 4.36 ± 155.36 mgGAE/g, 1.28 ± 155.23 mgQE/g, and 81.29 ± 4.56 μ g/g were obtained for FM and 10U flour samples, respectively. It implies that combined pretreatment resulted in higher retention of bioactive compounds than independent ultrasound and microwave pre-drying treatment alone and untreated flour.

According to Muchirah *et al.*[304] and Hussain *et al.*[270], the total phenol and flavonoid content in pumpkin flour were 2.77 mgGAE/g and 2.46 mgQE/g, 1.35 ± 1.24 mgGAE/g, and 0.77 ± 0.63 mgQE/g, respectively, all lower than this finding. In line with these, Roongruangsri & Bronlund [305] also stated that pumpkin powder produced from oven dried at 50°C , 60°C , and 70°C contains about 25.99, 16.42, and 17.66 μ g/g of total carotenoid content, respectively, lower than this finding. As depicted in Table 7.4, 30UM flour had lower TPC, TFC, and TCC than 20UM

flour, and it may be due to the extraction of phenolic compounds by water (phenolics losses) during extended ultrasound treatment time [306]. Opalic *et al.*[307] reported that prolonged sonication reduces dried apples' total phenolic, flavonoid content, and antioxidant capacity. As presented in Table 7.4, the total phenol, flavonoid, and carotenoid content in freeze-dried flour was the highest, followed by 20UM and 30UM pretreated flours. Freeze-dried flour and 20UM flour had the highest total phenolic content, which was 47.46% and 45.72% higher than untreated flour, respectively, while microwave-pretreated flour had the lowest total phenolic content (21.31%).

The lowest two in total carotenoid retention were observed for 10U (30.25%) and FM (35.35%) flour as compared to the best-case control sample (freeze-dried). Microwave treatment of pumpkin pulp, as shown in the study conducted by Dini, Tenore, and Dini [35], enhanced the bioactive components and antioxidant activity. On the other hand, Ren *et al.* [308] found that sonication pretreatment could potentially preserve these components in dried onion slices. Flour with a high carotenoid concentration appears more yellow (20UM). Carotenoids are a significant source of vitamin A, which plays a crucial role in the human body by promoting eyesight, immune system, reproductive system, growth, and development. In contrast, a deficiency of this vitamin is a common cause of infant mortality and blindness [270].

Figure 7.1 illustrates the antioxidant scavenging activities of pretreated and untreated pumpkin flour extract relative to ascorbic acid (control). The combined pre-drying treatment showed a stronger DPPH scavenging activity than single pretreatment alone. DPPH scavenging ability increases with flour's total phenol, total flavonoid, and carotenoid content, among which FD and 20UM flour was the highest, and 10U and FC were the lowest. Because of their conjugated double bonds, carotenoids have a strong antioxidant capacity to scavenge free radicals [309]. Although the total flavonoid contents in pumpkins are lower than total phenols, even small concentrations possess strong antioxidation potential [310]. This result is consistent with the findings of Rodríguez *et al.*[311], who reported that the ultrasonic pretreatment retained higher proportions of antioxidant properties and total phenolic and flavonoid content than apple slices dried without ultrasound pretreatment. According to Titikan and Rungarun [312], the composition of phenolics and carotenoids may also be impacted by the methods used to treat fruits and vegetables. This study revealed that 20 minutes of ultrasound followed by 6 minutes of microwave (300W) pre-drying treatment could be recommended as pre-drying conditions for obtaining the high-phytochemical composition of pumpkin flour.

7.3.5. Functional Properties

Table 7.5 exhibited that bulk density, water absorption capacity (WAC), water solubility index (WSI), and oil adsorption capacity (OAC) of pumpkin flour were affected by ultrasonic, microwave, and combined pre-drying treatment methods before drying. Bulk density was reduced with ultrasound and microwave pretreatment, and the effect was more pronounced with an increased exposure time of ultrasound treatment. The decrease in bulk density was due to alterations in the physical structure and composition of the flour as a result of pre-drying treatments. These changes, which include the disintegration of cell walls and the removal of moisture, can impact the bulk density of the resulting flour [313].

Table 7.5. Functional properties of pumpkin flour as affected by pretreatment methods

Sample code	Bulk density (g/cc)	WAC (g/g)	WSI (g/g)	OAC (g/g)
FC	0.52±0.01 ^a	7.03±0.02 ^d	6.05±2.55 ^{cd}	1.53±0.06 ^c
FD	0.33±0.01 ^e	6.13±0.08 ^e	5.95±0.75 ^d	1.90±0.10 ^b
FM	0.49±0.01 ^b	9.11±0.15 ^{bc}	7.05±0.95 ^{bcd}	1.93±0.12 ^b
10U	0.51±0.01 ^{ab}	8.94±0.32 ^c	6.65±1.15 ^{bcd}	1.53±0.06 ^c
20U	0.44±0.01 ^c	9.47±0.27 ^{abc}	9.80±1.00 ^{ab}	2.00±0.00 ^b
30U	0.42±0.01 ^c	9.69±0.29 ^{ab}	10.05±1.05 ^{ab}	2.00±0.00 ^b
10UM	0.44±0.01 ^c	9.33±0.22 ^{abc}	9.60±1.00 ^{abc}	1.97±0.15 ^b
20UM	0.38±0.01 ^d	9.71±0.05 ^a	11.17±0.76 ^a	2.03±0.06 ^{ab}
30UM	0.36±0.01 ^d	9.75±0.24 ^a	11.83±1.01 ^a	2.28±0.11 ^a

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). WAC, water absorption capacity; WSI, Water solubility index; OAC, oil absorption capacity; FD, Freeze dried; FC, untreated pumpkin flour; FM, Microwaved pretreated; 10U, 10min ultrasound pretreated; 20U, 20min ultrasound pretreated; 30U, 30min ultrasound pretreated; 10UM, 10min ultrasound and 6min microwaved pretreated; 20UM, 20min ultrasound and 6min microwaved pretreated; 30UM, 30min ultrasound and 6min microwaved pretreated

The impact of microwave pre-drying treatment on bulk density was lower than that of ultrasonic and combined pre-drying treatment. Untreated flour had a higher bulk density (0.52±0.01 g/cc), while freeze-dried flour had a lower bulk density (0.33±0.01 g/cc). Lim *et al.* [314] indicated that the bulk density of pumpkin pretreated with Ca(OH)₂ and blanching then air-fried were 0.400 g/cc and 0.358 g/cc, respectively, comparable to this finding. According to Mirhosseini & Amid [315], the low bulk density of freeze-dried flour might be due to increased volume rather than mass, although the solubility of freeze-dried flour may be significantly affected by the low bulk density. Table 7.5 shows that pretreatment of samples with ultrasound, microwaves, or both often led to higher WAC, WSI, and OAC. In comparison, 30UM flour had significantly ($p < 0.05$) the highest WAC (9.75±0.24 g/g), WSI (11.83±1.0 %) and OAC (2.28±0.11 mL/g), but the lowest content was observed for freeze-dried flour (6.13±0.08 g/g, 5.95±0.75 %) expect for OAC on untreated

flour (1.53 ± 0.06 mL/g), respectively. In addition, M. Asif-Ul-Alam *et al.* [316] pointed out that the water-holding capacity of freeze-dried flour was lower than that of hot air-dried flour. The more porous and brittle structure of the freeze-dried flour, which could not retain water as effectively as the hot air-dried flour, was thought to be the cause of its decreased water-holding ability [317]. High water absorption capacity improves yield and consistency, gives the body to food [318], and is an alternative emulsifier for food formulations [287]. Higher water solubility was observed in 30UM, indicating that more starch had been decomposed. The analysis showed that fluidized bed-dried pumpkin flour had higher water solubility and bulk density than freeze-dried flour, consistent with the findings of Que *et al.* [276]. This might be explained by the freeze-dried flour's porous and brittle structure, which could not dissolve as effectively in water as the hot air-dried flour [317]. According to Traynham *et al.* [319], fruit and vegetable flours, which have high water absorption and oil adsorption capacities, can impart water-retention and fat-binding properties essential in bakery products and other select food applications. This study showed that with an increase of ultrasound exposure time, the water solubility, water absorption capacity, and oil adsorption capacity of pumpkin flour also increased.

7.4. Conclusions

Ultrasound combined with microwave pre-drying treatment reduced the drying time than independent pretreatments alone, and the finding indicates that 20UM treatments were more effective (32.78%) in reducing drying time. The present work describes the possibility of producing high-quality pumpkin flour in terms of the physical, chemical, and functional qualities by ultrasound, microwave, and combined pre-drying treatment. Pre-drying treatment decrease lightness due to the increase in the redness and yellowness of all pretreated samples. The high crude protein and fibre levels in pumpkin flour suggest that these raw materials are potential ingredients for developing nutritious foods. The analysis indicates that the flour moisture content and water activity values were within acceptable limits for safe storage. Untreated pumpkin flour showed greater bulk density, WAC, and WSI than freeze-dried flour but lower than pretreated. Ultrasonication pre-drying treatment for 20min followed by microwave (300W) blanching for 6min before drying was the best process for maintaining color, total phenolic content, total

carotenoid content, and DPPH activities during processing. This information is crucial for preparing pumpkin flour, which can be used as an ingredient for coloring and improving food's nutritional and medicinal values.

CHAPTER 8: EFFECTS OF PRE-DRYING TREATMENT AND PARTICLE SIZES ON PHYSICOCHEMICAL AND STRUCTURAL PROPERTIES OF PUMPKIN FLOUR

Abstract

This study aims to determine the effect of pre-drying treatment and particle size on pumpkin flour's compositional, functional, pasting, thermal, and structural properties. The crude fibre, phytochemicals, and functional properties have shown increment with pre-drying treatment and particle size reduction, whereas moisture and color lightness exhibited reduction with pretreatment but improvement with particle size reduction. The pretreated fine-milled flour had the highest viscosities, while the coarsely milled untreated samples had lower viscosities. The pre-drying treatments yielded notable reductions in both gelatinization temperature and enthalpy of the flour

matrix, in comparison to untreated flours. FTIR analysis has indicated that no new functional groups were produced. XRD analysis suggests that while pre-drying treatment leads to decreases in crystallinity index, fine milling leads to increments. The morphological pattern suggested that pretreatment effectively altered the original surface structure of the flour, but particle size reduction did not.

Keywords: Compositional analysis, Particle size, Structural properties

8.1. Introduction

Pumpkins come in a variety of forms, dimensions, and colors. Because of its nutritional and health-protective polysaccharides, agriculture, food processing, pharmaceutical as well as feed industry have all taken an increasing interest in pumpkin fruit and pumpkin-derived products in recent years [320]. Pumpkin is a good source of beta-carotene, fibre, pectin, mineral salts, vitamins, and other substances that are beneficial to health [321]. Because of these facts, pumpkin is processed into a variety of foods. According to Que *et al.* [276], pumpkin flour is the major product of pumpkin fruit in processing since it can be stored for a long time and used in manufacturing formulated foods. However, drying conditions, including high temperature, light, and oxygen exposure, would cause the degradation of carotenoids and thereby affect the final products' attractive color and nutritive value [322].

In contrast, pre-drying can reduce drying times while enhancing quality by preserving color and minimizing nutrient loss and degradation through enzyme action [323]. It is suggested that the drying time be shortened in order to maintain the bioactive components of pumpkin during the flour conversion process. A previous study [324] discovered that ultrasonic, microwave, and combined pretreatment methods had better compositional, phytochemical, and functional qualities than untreated pumpkin flour. Ultrasound and microwave combined pre-drying treatment has been discovered to decrease drying time significantly. It results in a quicker and more effective drying process, while also improving the quality of the dried fruits by maintaining their nutritional properties [324]. Compared to other pretreatment methods, the use of ultrasound and microwave has been found to better retain vitamin C and total phenolic content [325]. Additionally, decreasing the particle size of the flour is an effective option to increase the bioactive availability, as larger particle sizes may be difficult to extract and may require longer heat treatment [326]. In addition, as reported by Lee and Yoon [327] and Zhu *et al.* [328], different variations in particle

size would likewise affect changes in flour color and bioactive chemicals. Reduced particle size has been shown in several studies to increase the antioxidant activities of some food powders, including winter wheat (*Triticum aestivum* L.), red rice (*Oryza sativa* L.), and Qingke (hull-less barley) [329][330][331]. This could be a good way to increase the bioactivity and bioavailability of flour. So, to enhance its use in functional food products, it would be important to look for acceptable particle sizes for pumpkin flour. However, there has been a lack of previous research focused on investigating the combined impact of pre-drying treatment and particle size on the quality of pumpkin flour, which directly influences the overall quality of the flour. Therefore this work aimed to study the interaction effect of pre-drying treatment and particle size on physical, nutritional, phytochemical, functional, thermal, pasting, and structural properties of flours and to provide theoretical support for the application of pre-drying treatment and fine milling in the food industries.

8.2. Materials and Methods

8.2.1. Materials and Chemicals

The fresh, healthy, ripped pumpkin was brought from a local supermarket (Addis Ababa, Ethiopia). The Standards and reagents used were quercetin ($\geq 98\%$, sigma Aldric, Germany), 2,2-Diphenyl-1-picrylhydrazyl (Sigma Aldrich, Germany), gallic acid (97.5-100 % Sigma Aldrich, China), phytic acid sodium salt hydrate (Sigma Aldrich, Switzerland), (+-) Catechin hydrate ($\geq 96.0\%$, Sigma Aldrich, China), Folin-Ciocalteu's (2N, Sigma Aldrich, USA), Vanillin ($\geq 99.5\%$, UNI-CHEM, Roth, France), Aluminium Chloride (99% Loba chemic, India), Methanol (M.wt. =34.02g/mol, Biochem chemopharma, France) and Sodium carbonate ($\geq 99.5\%$ Carl Roth GmbH, Karlsruhe) and Nitric acid (69% Loba chemic, India). All other chemical reagents were purchased locally and were of analytical grade.

8.2.2. Sample Preparations

The pumpkin slice ($15 \times 15 \times 4$) mm³ were pretreated for 20min in ultrasonic followed by microwave blanching for 6 min at 300W and then dried at 60 °C and 1.5m/s airflow by a fluidized bed drier for 121 min [324]. The sliced dried pumpkin was milled coarsely by a hammer mill (Model BH24 1DY, Armfield, England), and then the flours were screened through 500 μm sieves to separate granulates. The resulting coarser flours were micronized using ball-milling (Planetary

type ball mill, PM 100; Restch, Germany) at 300r min⁻¹ for 15 min three times with an interval of 30 min to avoid flour overheating. Using carboxymethyl cellulose as a process control agent, the stainless steel container was filled to around two thirds of its capacity with the pumpkin flour and five times the weight in stainless steel balls ($\Phi = 10\text{mm}$). The milled flour was also split into distinct particle size fractions (250–150, 150–100, 100–75, and <75 μm particle size) using a set of screen sieved with the vibratory sieve shaker for 5 min. The milled flour obtained was stored at 4°C in brown zipped bags until further analysis.

8.2.3 Physical Properties

The sample color was detected via Hunter Lab Colorimeter, Minolta, using the hunter scale of L*, a*, and b* values as indicators. The water activity of pumpkin flour was measured by a water activity meter (HD-3A, NanBei, China) [332]. The pH and Total Soluble Solid were determined according to official methods of AOAC [182] and AOAC [145] using a pH meter (BANTE Multiparameter/China) and a digital refractometer (Model-A670, Hanon, China) at 25°C, respectively.

8.2.4. Proximate Compositions

The Moisture, protein, fat, and ash were determined in triplicates by Association of Official Analytical Chemists (AOAC) official methods 967.19, 920.165, 920–39, and 941.12 [333], respectively. The crude fibre was estimated by 920.169 AOAC [334] method, while Carbohydrate (CHO) was calculated by difference.

8.2.5. Phytochemical Properties

First, the methanol extracts were prepared from pumpkin flour, according to Ferreira *et al.*[183]. Ten grams of pumpkin flour were extracted with 100 mL of methanol at 25°C at 150 rpm for 24 h using a temperature shaker incubator (ZHWHY-103B) and clarified through Whatman No. 1 paper. The deposit was extracted with two additional 100 ml portions of methanol described above. To dryness, the methanolic extracts were evaporated using a Rota evaporator (R-300, Buchi, Switzerland) at 40°C and redissolved in methanol at 50 mg/mL concentration and stored at 4°C for further use. The total phenolic content was then assessed using the Folin-Ciocalteu method in triplicate at a wavelength of 735 nm with gallic acid as a standard, and the total flavonoid concentration was assessed using the colorimetric method at a wavelength of 510 nm with

quercetin as a standard, in accordance with Minuye *et al.*[335]. Antioxidant activities were determined using the DPPH methods [336] using ascorbic acid as a standard without extract or control. Total carotenoid was estimated based on the methodology of de Carvalho *et al.*[278]. Total carotenoids were expressed as μg per g of dry matter. All analysis was carried out in triplicate.

8.2.6. Functional Properties

Bulk density (g/mL) was established in accordance with Goula, Adamopoulos and Kazakis [279], water holding capacity (WHC) and WSI was estimated according to Zhao *et al.*[337], while swelling capacity (SW) and oil absorption capacity (OAC) were assessed based on the procedure outlined by Ye *et al.*[338]. The measurement of each sample was repeated three times.

8.2.7. Pasting Properties

The pasting properties of the flours were evaluated using a rapid visco-analyzer (Perten RVA 4800, Perkins Elmer, Sweden). Pasting parameters were calculated by adjusting moisture to 15% (using the flour's moisture content as a guide, extra distilled water was added to reach 15% moisture) at 250 rpm speed with a starting temperature of 50 °C for 1 minute, raising to 95 ± 0.1 °C in 3 min 42 s, and holding for 2 min 30 s. After the holding time, the temperature was ramped down to 50 ± 0.1 °C in 3 min 48 s by the cooling system [339].

8.2.8. Thermal Properties

Thermal properties were analyzed by differential scanning calorimeter (SKZ1052B, Hunan, china). Using an empty aluminum pan as a reference, eight milligrams of each sample were placed in a hermetic aluminum pan and heated from 20 to 150 °C at a rate of 10 °C/min in a 50 mL/min nitrogen flow. Onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c), and change in enthalpy (ΔH) were assessed [339] from the curve obtained.

8.2.9. Structural Properties

8.2.9.1. Scanning Electron Microscope (SEM)

The morphological characterization of flour particles was studied using a scanning electron microscope (JCM-6000 plus, Jeol Ltd., Korea) to study the effect of grinding and pretreatment on the structure modification. The sample was coated with a thin gold layer to make the samples

conductive, and images were captured at an accelerated voltage of 5 kV at 2000* magnification [267].

8.2.9.2. Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectra were collected using FTIR spectrometer (Nicolet is50 ABX, Thermofisher Scientific, German) over the range 4000–400 cm^{-1} by the potassium bromide (KBr) pellet method with a spectral resolution of 4 cm^{-1} [340].

8.2.9.3. X-ray diffractometer (XRD)

The crystallinity and structural properties of pumpkin flour of different sizes were characterized by an X-ray diffractometer (XRD-7000, Shanghai Drawel scientific instrument co., Ltd., China) operating at 40 kV and 40 mA. The sample was dispersed onto a stub and placed within the chamber of an analytical X-ray diffractometer (wavelength = 1.54 Å, $\text{CuK}\alpha$ radiation). The diffraction data were collected in the 2θ range from 5 to 80° at a 5 °/min scan rate [341].

8.2.10. Statistical Analysis and Experimental Design

Conventional statistical methods were used to calculate means and standard deviations. The software package SAS version 9.0 (SAS Institute, Inc., Cary, North Carolina, USA) using analysis of variance (ANOVA) was applied to the data to determine differences ($P < 0.05$). Tukey's HSD test at the significance level of 5% ($P < 0.05$) was used to determine significant differences among flours. After characterizing their physical, chemical, and functional qualities, notably by looking into their fibre and phytochemical makeup, other flour features, such as pasting, thermal, and structural characteristics, were analyzed with the aim of using the flour for functional foods.

8.3. Results and Discussions

8.3.1. Physical Properties

The physical properties of all flours are presented in Table 8.1. Even though water activity values increased with the increasing particle size of the flour, it was found to be not significant ($P < 0.05$) except for 20UM1 (0.31 ± 0.00) and CON3 (0.41 ± 0.04) flour samples. Food manufacturers and formulators usually employ a_w values to predict moisture migration and evaluate possible effects of moisture migration on product properties during extended storage [342].

Table 8.1. Effects of particle size and pretreatment method interaction on Water activity, pH, TSS, and color properties of flour

Sample code	Water activity	pH	TSS	L*	a*	b*
CON1	0.35±0.04 ^{ab}	6.59±0.32 ^a	4.28±0.13 ^a	83.35±0.56 ^a	4.55±0.40 ^d	37.27±1.42 ^d
CON	0.38±0.03 ^{ab}	6.55±0.30 ^a	4.21±0.01 ^a	82.06±1.15 ^{ab}	5.02±0.60 ^{cd}	38.68±2.00 ^{cd}
CON2	0.39±0.02 ^{ab}	6.53±0.24 ^a	4.13±0.23 ^a	81.00±0.92 ^b	5.67±0.69 ^{bc}	39.17±1.06 ^{cd}
CON3	0.41±0.04 ^a	6.41±0.16 ^a	4.03±0.25 ^a	79.92±0.93 ^b	5.77±0.78 ^{bc}	39.58±1.82 ^c
20UM1	0.31±0.00 ^b	6.42±0.15 ^a	4.07±0.31 ^a	77.13±1.69 ^c	6.03±0.37 ^b	42.14±1.03 ^b
20UM	0.37±0.05 ^{ab}	6.35±0.22 ^a	3.87±0.62 ^a	76.03±2.31 ^{cd}	7.19±0.22 ^a	43.64±0.74 ^{ab}
20UM2	0.38±0.04 ^{ab}	6.31±0.04 ^a	3.76±0.24 ^a	74.78±1.51 ^d	7.56±0.13 ^a	44.13±1.05 ^{ab}
20UM3	0.41±0.03 ^{ab}	6.26±0.04 ^a	3.67±0.44 ^a	73.94±0.95 ^d	7.61±0.20 ^a	44.51±0.91 ^a
Effect						
Pretreatment (P)	NS	***	***	***	***	***
Particle size (Pz)	***	NS	NS	***	***	***
P*Pz	***	NS	NS	***	***	***

All values are mean ± standard deviation. This means that sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant at $p < 0.05$. CON1, control flour, particle size is $< 75 \mu\text{m}$; CON, control flour, particle size is $75 - 100 \mu\text{m}$; CON2, control flour, particle size is $100 - 150 \mu\text{m}$; CON3, control flour, particle size is $150 - 250 \mu\text{m}$; 20UM1, pretreated flour, particle size is $< 75 \mu\text{m}$; 20UM, pretreated flour, particle size is $75 - 100 \mu\text{m}$ and; 20UM2, pretreated flour, particle size is $100 - 150 \mu\text{m}$; 20UM3, pretreated flour, particle size is $150 - 250 \mu\text{m}$; TSS, total soluble solid; L*, whiteness; a*, redness; b*, yellowness.

The water activity of flour can decrease with decreasing particle size due to the increase in surface area-to-volume ratio of the flour particles. When the particle size of flour is reduced, the surface area of the flour particles increases, while the volume decreases. This higher surface area can lead to more water molecules being adsorbed onto the surface of the flour particles, which can result in a lower water activity [343].

The pH, which classifies the samples as acidic or slightly acidic flours, and total soluble solids (TSS) values were slightly increased with decreasing size of the flour but not significant at $P < 0.05$. While CON1 showed higher pH and TSS of 6.59 ± 0.32 and 4.28 ± 0.13 , but 20UM3 flour showed lower pH (6.26 ± 0.04) and TSS (3.67 ± 0.44). The higher TSS in fine particle size could be due to the increased surface area to volume ratio. The bigger surface area makes more contact with the solvent possible, increasing solubility.

Color is an important quality that affects consumer choice of foods [344]. The data indicate that the hunter color significantly differs due to pretreatment, particle size, and interaction between both. While color lightness (L) varied from 83.35 to 77.13, a* and b* values ranged from 7.61 to 4.55 and 44.51 to 37.27, respectively. The lightness increases with particle size reduction and decreases with pre-drying treatment, but b* values were in the opposite direction. According to the information presented in Table 8.1, the untreated flour has a higher lightness value compared to the pretreated flours that have been milled to the same particle size. Additionally, the groups

showed significant differences with a p-value below 0.05, indicating a statistically significant result. The lowest L* value was recorded for the 20UM3 (73.94±0.95) flour, while the highest was obtained for CON1 (83.35±0.56) flour. As particle size decreases, a* and b* values of pretreated and untreated flour decrease, with the highest value noted for 20UM3 flour and the lowest for the CON1 flour sample. The increased lightness of the sample may be due to a combination of factors, including a lower protein content in the smaller particle size [345], resulting in higher reflectance of light, as well as the larger surface area of the particles, which enhances the reflection of light [346] [347]. In another way, while pre-drying treatment preserves the loss of color pigment, the exposure of internal materials during fine milling could contribute to brightness improvement [348] [349]. This implied that the degree of yellowness was lowered in untreated flour as compared to the pretreated sample, which could be due to loss of pigmentation during the drying process, while further decreases of a* and b* values for both pretreated and untreated samples could be possibly due to effects of grinding and sieving. Ahmed, Al-attar and Arfat [346] and Ahmed *et al.* [339] reported a similar case in L*, a*, and b* values for water chestnut flour, lentil flour, and rice flour milled to different particle sizes. Contrary to this study, the lightness (L*) and yellowness (b*) of mango peel powder increased with particle size, but greenness (a*) decreased [350].

8.3.2. Proximate Composition

Table 8.2 demonstrates that while ash, protein, and carbohydrate content decrease as particle size decreases, moisture, fat and crude fibre content increases. Nutritional content was enhanced due to pretreatment except for moisture and carbohydrate content. The lowest moisture content was found in the bigger, pretreated particle size 20UM3 (7.86±0.44%), whereas the highest value was found in the smaller, untreated particle size CON1 (10.61±0.55). The possible reason is that ultrasound pre-drying treatment increases the water permeability due to the formation of microchannels due to expansion and contraction in the food matrix [284]. Also, Önal *et al.* [29] reported that microwave heating penetrates the foodstuff quickly, increasing the product temperature and rapid water evaporation.

Table 8.2. Effects of interaction between particle size and pretreatment on proximate composition of pumpkin flour

Sample code	Moisture %	Ash %	Crude Fat %	Crude protein %	Crude fibre %	CHO %
CON1	10.61±0.55 ^a	5.22±0.33 ^a	1.59±0.26 ^a	6.99±0.85 ^d	12.79±1.08 ^{ab}	62.79±1.29 ^{abc}
CON	10.18±0.35 ^{ab}	5.34±0.49 ^a	1.47±0.21 ^a	7.30±0.81 ^{cd}	12.36±1.08 ^{ab}	63.35±2.38 ^{abc}
CON2	9.22±0.99 ^{abc}	5.45±0.48 ^a	1.33±0.70 ^a	7.88±0.91 ^{bcd}	12.00±0.94 ^b	64.12±1.36 ^{ab}
CON3	8.82±0.79 ^{cb}	5.68±0.41 ^a	1.18±0.32 ^a	8.20±0.49 ^{bcd}	11.03±0.29 ^b	65.10±0.88 ^a

20UM1	9.82±0.31 ^{ab}	5.44±0.58 ^a	1.93±0.19 ^a	9.05±0.44 ^{abc}	14.39±0.40 ^a	59.37±1.06 ^c
20UM	9.25±0.56 ^{abc}	5.57±0.54 ^a	1.78±0.24 ^a	9.56±0.49 ^{ab}	13.12±0.24 ^{ab}	60.72±1.15 ^{bc}
20UM2	8.57±0.49 ^{cb}	5.88±0.43 ^a	1.74±0.18 ^a	10.31±0.46 ^a	12.80±0.65 ^{ab}	60.70±1.53 ^{bc}
20UM3	7.86±0.44 ^c	6.00±0.25 ^a	1.71±0.19 ^a	10.66±0.64 ^a	12.54±0.73 ^{ab}	61.23±1.16 ^{abc}
Effect						
Pretreatment (p)	***	NS	***	***	***	***
Particle size (pz)	***	NS	NS	***	***	***
P*pz	***	Ns	NS	***	***	***

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant at $p < 0.05$. CON1, control flour, particle size is $<75 \mu\text{m}$; CON, control flour, particle size is 75-100 μm ; CON2, control flour, particle size is 100-150 μm ; CON3, control flour, particle size is 150-250 μm ; 20UM1, pretreated flour, particle size is $<75 \mu\text{m}$; 20UM, pretreated flour, particle size is 75-100 μm and; 20UM2, pretreated flour, particle size is 100-150 μm ; 20UM3, pretreated flour, particle size is 150-250 μm ; CHO, Carbohydrate

In addition, smaller particle sizes absorb more moisture from the atmosphere due to higher surface area than larger particle sizes, thus increasing moisture content. The top three flour samples in carbohydrate and protein content were CON3 (65.10±0.88), CON2 (64.12±1.36 %), CON1 (63.35±2.38), and 20UM3 (10.66±0.64), 20UM2 (10.31±0.46), and 20UM (9.56±0.49), respectively. Also, as depicted in Table 8.2, there is no significant difference between flour samples ($p < 0.05$) in ash and fat content due to the interaction between pretreatment and particle size. Pretreated pumpkin slice with a particle size of $<75 \mu\text{m}$ had a crude fibre content that was only significantly ($p < 0.05$) greater than other flours, whereas untreated pumpkin slice with a particle size of 150–250 μm had a lower value (11.03±0.29%). This value was higher than that of Farombi and Oyekanmi [351] and Adelerin, Ifesan and Awolu [352] findings for pumpkin pulp and boiled pumpkin pulp flour, 11.46±0.10% and 13.22±0.03, respectively. The increase in crude fiber content with pretreatment may be due to the breakdown of cell walls and the release of fiber during the drying process [353]. When the size of flour particles is reduced, the surface area of the particles increases and this can result in a greater exposure of the fiber-containing cell walls. As a result, the crude fiber content of the flour increases [354]. Protein content increases with pre-drying treatment, and the possible reason could be increased solvent penetration into cellular material [355]. Pre-drying also enhance the removal of moisture from the fruit before it is ground into flour, which can lead to a concentration of protein in the resulting flour. Also, the smaller the size of a particle, the lower the flour's protein content. The reason for the decrease in protein content during particle size reduction might be that the mechanical forces and heat produced during this process can cause the protein to undergo denaturation and aggregation, resulting in a loss of protein content [354]. Similar findings were reported by Ahmed *et al.* [339] and Ahmed, Al-attar and Arfat [346] in lentil flour and water chestnut flour, respectively.

Carbohydrates increase with an increase in particle size but decrease with pre-drying treatment. Since carbohydrate was calculated by the difference method, their lower value might be due to the higher value of other parameters. The result also aligns with the value observed for water chestnut flour with increased particle size [346]. This study reveals that particle size did not influence the fat content, which is similar to that observed by Ahmed *et al.* [339] for Indian and Turkish lentil flour, contrary to that observed in water chestnut flour [346]. As stated by Luthria, Noel and Vinjamoori [356], the decrease in crude fat extraction in larger particle-size flours could be easily attributed to the lower surface area, which decreases the extraction efficiency. Both pre-drying treatment and milling did not influence the ash content.

8.3.3. Phytochemicals Composition

As shown in Table 8.3, flour total phenol, total flavonoid, and total carotenoid concentrations showed slightly significant differences ($p < 0.05$) due to the interaction between pre-drying treatment and particle size reduction. However, there is a noticeable difference between untreated and pretreated flour at the same particle size, high in content with pre-drying treatment, and smaller particle size. Total phenol and carotenoid contents were not significantly different between the pretreated pumpkin slice milled to different particle sizes.

Table 8.3. Effects of interaction between particle size and pretreatment on phytochemical properties of pumpkin flour

Sample code	Total Phenol (mgGAE/g)	Total Flavonoids (mgCE/g)	Total carotenoid ($\mu\text{g/g}$)
CON1	3.79 \pm 0.15 ^b	1.28 \pm 0.66 ^c	77.93 \pm 8.35 ^b
CON	3.59 \pm 0.59 ^b	1.15 \pm 0.52 ^{cd}	69.85 \pm 2.00 ^{bc}
CON2	3.47 \pm 0.68 ^b	1.04 \pm 0.23 ^d	63.43 \pm 4.03 ^{bc}
CON3	3.43 \pm 0.32 ^b	0.99 \pm 0.79 ^d	57.90 \pm 7.42 ^c
20UM1	6.52 \pm 0.59 ^a	1.92 \pm 0.85 ^a	139.74 \pm 0.96 ^a
20UM	6.39 \pm 0.67 ^a	1.85 \pm 0.95 ^{ab}	133.37 \pm 2.39 ^a
20UM2	6.37 \pm 0.49 ^a	1.74 \pm 0.59 ^{ab}	132.84 \pm 1.83 ^a
20UM3	6.34 \pm 0.88 ^a	1.72 \pm 0.43 ^b	132.03 \pm 8.38 ^a
Effect			
Pretreatment (p)	***	***	***
Particle size (pz)	***	***	***
P*pz	***	***	***

All values are mean \pm standard deviation. This means that sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant at $p < 0.05$. CON1, control flour, particle size is $<75 \mu\text{m}$; CON, control flour, particle size is $75\text{-}100 \mu\text{m}$; CON2, control flour, particle size is $150\text{-}100 \mu\text{m}$; CON3, control flour, particle size is $150\text{-}250 \mu\text{m}$; 20UM1, pretreated flour, particle size is $<75 \mu\text{m}$; 20UM, pretreated flour, particle size is $75\text{-}100 \mu\text{m}$ and; 20UM2, pretreated flour, particle size is $<100\text{-}150 \mu\text{m}$; 20UM3, pretreated flour, particle size is $150\text{-}250 \mu\text{m}$.

According to Tekin and Baslar [357], the strong shear force generated by the cavitation effect of ultrasound treatment damaged the cell walls and promoted the release of active ingredients in the material. Regarding total phenol, flavonoids, and carotenoids, the 20UM1 flour sample had the

highest amount (6.52 mgGAE/g, 1.92 mgCE/g, and 139.79 mg/g), whereas CON3 flour had the lowest (3.43 mgGAE/g, 0.99 mgCE/g, and 57.90 mg/g), respectively. The result agreed with the investigation of Zhao *et al.*[358] for red grape pomace powders. The particle size reduction can alter or destroy the macromolecule matrix, thus releasing or exposing some phenolic compounds, which agreed with this study [331]. Also, it has been noted that particle size reduction increases extraction yield because smaller particles decrease the solvent's path and speed up the process of extracting the sample's functional elements to their fullest extent [342].

Overall, the contents and release rates of carotenoids in samples showed increasing trends with the decrease in particle size. This was suggested that particle size reduction of a matrix by crushing treatment could cause cell wall rupture, promoting carotenoids release into food products [359]. Additionally, the increased surface area of the flour particles can expose more of the outer layers of plant cells that contain carotenoids to the processing environment. Moreover, Speroni *et al.* [360] demonstrated that micronization processing techniques increased olive pomace's polyphenol content and antioxidant capacity. Zhang *et al.*[361] determined that fine grinding improved the accessibility of functional compounds in milled *Lycium ruthenicum* Murray, which increased their antioxidant abilities.

DPPH radical scavenging activity among pretreated and untreated pumpkin flours milled to different sizes was compared (Fig. 8.1). With the pretreatment and particle size reduction, the DPPH scavenging activities of flours rise. The 20UM1 flour showed the highest DPPH scavenging activity, followed by 20UM and 20UM2, while CON3 was the lowest compared to ascorbic acid scavenging activities. It was suggested that DPPH radical scavenging activity was highly related to the amount of total phenols, flavonoids, and carotenoids, which was supported by an investigation of Bai and Li [362]. The increase of antioxidant availability in the pretreated flours with smaller particle sizes (such as <75 and 75-100 μm) might be attributed to finer particles benefiting the dissolution of free-form antioxidant compounds. Besides, particle size reduction broke the protein and fibre matrix structure and thus increased the availability of bound-form antioxidant compounds linked or embedded in the matrix [349].

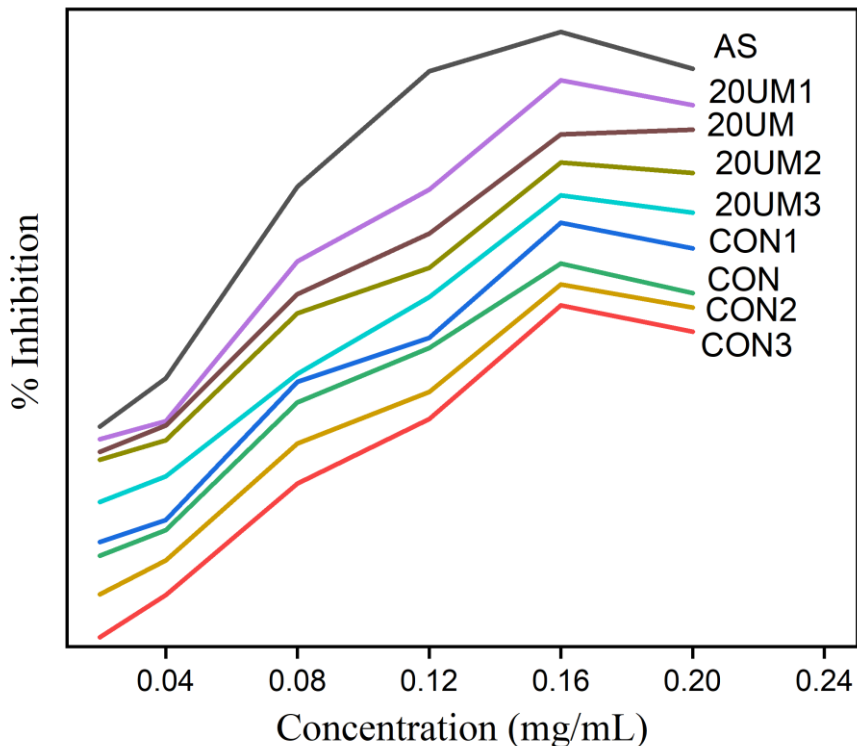


Figure 8.1 Free radical scavenging activities of methanolic extract of pumpkin flour and ascorbic acid: AS, Ascorbic acid, as control; CON1, control flour, particle size is <75 μm ; CON, control flour, particle size is 75 – 100 μm ; CON2, control flour, particle size is 150-100 μm ; CON3, control flour, particle size is 150-250 μm ; 20UM1, pretreated flour, particle size is <75 μm ; 20UM, pretreated flour, particle size is 75 -100 μm and; 20UM2, pretreated flour, particle size is 100-150 μm ; 20UM3, pretreated flour, particle size is 150-250 μm .

8.3.4. Functional Properties

The functional properties of pretreated and untreated pumpkin flour milled to different particle sizes are presented in Table 8.4, and it can be observed that pretreatment and particle size reduction improve the functional properties of flour. Flour sample 20UM1 had the highest values for WAC (11.45 ± 0.58 g/g), WSI (28.53 ± 0.75 %), SC (6.72 ± 0.10 g/g), and OAC (2.23 ± 0.20 g/g), while CON3 had the lowest values for these functional properties (7.55 ± 0.57 g/g, 20.30 ± 0.67 %, 5.05 ± 0.95 g/g, and 1.62 ± 0.15 g/g), respectively. According to Shevkani *et al.* [363] the significant differences in functional properties are probable due to the variation in protein content, which reveals the ability of flour to absorb water. The highest WAC observed in the smallest particle size might be due to the higher fibre content in this sample and its larger surface area, which increases the binding site for water [364].

Table 8.4. Effects of interaction between particle size and pretreatment on functional properties of pumpkin flour

Sample code	WAC(g/g)	WSI %	SC (g/g)	OAC (g/g)
CON1	9.34±0.60 ^{bcd}	24.71±0.79 ^{abc}	5.90±0.53 ^{ab}	2.07±0.20 ^{ab}
CON	8.56±0.45 ^{cde}	23.18±0.48 ^{abc}	5.63±0.15 ^{ab}	1.95±0.14 ^{ab}
CON2	7.93±0.32 ^{de}	21.85±1.43 ^{bc}	5.62±0.23 ^{ab}	1.74±0.17 ^{ab}
CON3	7.55±0.57 ^e	20.30±0.67 ^c	5.05±0.95 ^b	1.62±0.15 ^b
20UM1	11.45±0.58 ^a	28.53±0.75 ^a	6.72±0.10 ^a	2.23±0.20 ^a
20UM	10.89±0.51 ^{ab}	27.30±5.73 ^{ab}	6.13±0.42 ^{ab}	2.18±0.33 ^a
20UM2	10.34±0.72 ^{ab}	25.89±0.60 ^{abc}	5.97±0.64 ^{ab}	2.12±0.19 ^{ab}
20UM3	9.85±0.714 ^{abc}	23.77±0.97 ^{abc}	5.88±0.67 ^{ab}	2.05±0.09 ^{ab}
Effect				
Pretreatment (p)	***	***	***	***
Particle size (pz)	***	***	***	***
P*pz	***	***	***	***

All values are mean ± standard deviation. This means sharing the same letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant at $p < 0.05$. CON1, control flour, particle size is $<75 \mu\text{m}$; CON, control flour, particle size is $75\text{-}100\mu\text{m}$; CON2, control flour, particle size is $150\text{-}100 \mu\text{m}$; CON3, control flour, particle size is $150\text{-}250\mu\text{m}$; 20UM1, pretreated flour, particle size is $<75 \mu\text{m}$; 20UM, pretreated flour, particle size is $75\text{-}100 \mu\text{m}$ and; 20UM2, pretreated flour, particle size is $100\text{-}150 \mu\text{m}$; 20UM3, pretreated flour, particle size is $150\text{-}250 \mu\text{m}$; WAC, water absorption capacity; WSI, water solubility index; SC, swelling Capacity; OAC, oil absorption capacity.

The differences may have also been caused by hydrophilic groups in the cellulose and hemicelluloses of the flour, which resulted in easy integration with water; finally, the value of WAC increased. The increased WSI with decreasing particle size may be attributed to the greater specific surface area, resulting in higher leaching of soluble starch-derived molecules dissolved in water during the WAC assay [337].

The OAC values ranged from 1.62 ± 0.15 to 2.23 ± 0.10 g/g. The oil absorption capacity of flour increased with pre-drying treatment and particle size reduction, similar to the findings of Ahmed *et al.*[339] in lentil flour and Benítez *et al.*[365] in onion fibre concentrate. According to Hitayezu and Kang [342], OAC is linked with the presence of hydrophobic protein, which is helpful in the binding of lipids. Swelling capacity is an important parameter that reflects the hydration ability. The increased surface area, polar groups, and other water-binding sites were exposed to the surrounding water medium, and the increased swelling capacities of 20UM1 and 20UM were potentially related to the flour particle size decreases [366]. This should be because the active sites in starch granules increased due to the structural destruction of flour under intense grinding treatment [367].

8.3.5. Pasting Properties

The pasting properties of the flours obtained from pretreated and untreated pumpkin milled to different particle sizes are shown in Table 8.5; the viscosity increased with both pre-drying treatment and particle size reduction. As reported by Harasym, Satta and Kaim [368], ultrasound

treatment partially disrupts starch granules and facilitates the formation of smaller and more numerous amylose and amylopectin molecules to increase viscosity during the heating process. Further, during microwave pre-drying treatment, the viscosity profile is modified due to the solubilization of the cell wall, causing disorganization and rupture of cellulose, fibre, and pectin, thus forming a firmer gel due to the higher content of linear chains that are responsible for gelatinization [369].

The peak viscosity indicates the starch's ability to swell before breakdown freely. The lowest peak and trough viscosity were recorded for the CON (660.04±9.49 cp, 637.92± 23.58 cp) flour sample, while the highest results were observed for the 20UM1(780.40±36.32, 687.76 ± 20.64 cp) flour sample, respectively. This could be also attributed to the high crude fibre content (14.39%) in 20UM1 flour, which is similar to the case reported by Fila, Itam and Johnson [370] and Adebowale, Adeyemi and Oshodi [371] for watermelon and six mucuna species, respectively. Higher peak viscosity for a 20UM1(pretreated finer particle) indicates a faster water absorption rate, which leads to starch granule swelling [372]. The lower peak viscosity of the CON (untreated coarser particle) sample could be due to lesser WAC [373]. Peak viscosity discrepancies across flours may be caused by variations in amylose content, which would also affect functional characteristics like starch crystallinity, amylose leaching, granule swelling, and structural variations like amylopectin branch chain length [374][375]. The peak viscosity values are significantly lower than that reported by (Promsakha na Sakon Nakhon *et al.*[376] and Ahmed *et al.*[339] for pumpkin flour (340-368 BU) and Indian lentil flour (544-714 BU), which increase with decreasing particle size, respectively.

The breakdown viscosity values of 20UM1, 20UM, CON1, and CON flour samples were 92.64±16.32, 67.80±63.29, 46.52±27.09, and 31.00±26.07 cp, respectively. The results showed that the breakdown viscosity value for the pretreated fine flour was higher than the other flours, indicating that it was less resistant to breakdown.

Table 8.5. Effects of interaction between particle size and pretreatment on pasting properties of pumpkin flour

Flour Sample	Peak viscosity (cp)	Trough (cp)	Breakdown (cp)	Final viscosity (cp)	Setback (cp)	Peak time (Min)	Pasting Temp (°C)
CON	660.4±9.49 ^b	629.4±19.21 ^b	31.0±26.07 ^a	780.08±10.32 ^d	150.68±26.93 ^a	6.77±0.06 ^a	00.00 ^a
CON1	684.44±3.56 ^b	637.92±23.58 ^{ab}	46.52±27.09 ^a	817.56±12.73 ^c	179.64±36.18 ^a	6.02±0.11 ^b	00.00 ^a
20UM	721.32±39.62 ^{ab}	653.52±23.88 ^{ab}	67.80±63.29 ^a	856.00±8.53 ^b	202.48±31.23 ^a	5.64±0.03 ^c	00.00 ^a

20UM1	780.40±36.32 ^a	687.76±20.64 ^a	92.64±16.32 ^a	917.32±16.78 ^a	229.56±36.65 ^a	5.17±0.02 ^d	00.00 ^a
Effect							
Pretreatment (p)	***	***	NS	***	***	***	NS
Particle size (pz)	***	***	NS	***	***	***	NS
Interaction (p*pz)	***	***	NS	***	NS	***	NS

All values are mean ± SD. This means that sharing the same superscript letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant. CON, control flour, particle size is 75-100 μm ; CON1, control flour, particle size is <75 μm ; 20UM, pretreated flour, particle size is 75-100 μm ; and 20UM1, pretreated flour, particle size is <75 μm ; cp, centipoise.

However, no significant difference was observed in the breakdown viscosities between all flour samples. In line with this study Ghafoor *et al.*[377] also reported increased breakdown viscosity (62%) for sonicated navy bean flour. According to Harasym, Satta and Kaim [368], the degree of breakdown viscosity might also depend on other viscosity contributors such as proteins and fibres. The highest value of setback viscosity was recorded for the 20UM1 (229.56±36.65 cp) flour sample, while the lowest was for CON (150.68±26.93 cp) flour sample. As revealed in Table 8.5, setback viscosity increases with both pre-drying treatment and particle size reduction. Similar patterns were recorded by Ghafoor *et al.*[377] and Zhu and Li [378] in the sonicated navy bean flour and quinoa flour, respectively. The results indicated that smaller particle size flour had a higher setback viscosity, which suggested a greater tendency for retrogradation. This can be attributed to the larger surface area and exposure of starch granules to moisture during processing, which resulted in a higher degree of swelling and more rigid structure during cooling. These findings are consistent with previous studies by Sandhu and Singh [379] on shallot flour and Khushbu *et al.* [373] on corn starch. The lower final viscosity value is obtained for the CON flour sample; comparatively did not easily form a viscous paste. An increase in the final viscosity of the 20UM1 sample might be due to a greater aggregation of amylose molecules in samples, which forms paste after heating and cooling [373]. There are significant differences ($p < 0.05$) in the peak time between both pretreated and control samples, with pretreated fine-milled flour, which took a shorter time (5.17 min) to gelatinize, meaning that the control sample was slower and required more heating to form a paste. No pasting temperature was observed in pretreated and untreated flours, similar to Adelerin, Ifesan and Awolu [352] finding for pumpkin flour. It may be due to the starch granules begin to absorb water and swell gradually over a range of temperatures, rather than at a specific temperature. This was attributed to the presence of fibres and other non-starch components in the flour, which can affect the pasting properties and mask the pasting temperature [380].

8.3.6. Thermal Properties

Table 8.6 presents the thermal properties of pumpkin flour; both temperature and enthalpy are affected by pre-drying treatment and particle size reduction. The findings indicated that applying a pre-drying treatment caused decreases in both temperature and enthalpy. On the other hand, reducing the particle size resulted in a temperature decrease (Table 8.6). While the CON flour sample showed the highest onset gelatinization temperature (69.70 ± 0.54 °C), peak gelatinization temperature (73.74 ± 0.85 °C), and conclusion gelatinization temperature (77.89 ± 0.71 °C), but 20UM1 (treated flour with fine particle) showed the lowest temperatures, 62.92 ± 0.42 , 66.55 ± 0.73 and 70.31 ± 0.80 °C, respectively. According to Chen *et al.* [381] ultrasound treatment can cause the breakdown of starch granules into smaller particles, which increases the surface area of the starch and lowers the gelatinization temperature, requiring less energy to reach the gelatinization point. Furthermore, the ultrasound pre-drying treatment can lead to a decrease in the enthalpy value of the starch, which is attributed to the disruption of the starch granule structure caused by the ultrasound treatment. This disruption leads to a decrease in the amount of ordered crystalline regions within the starch granules. In addition, due to the absorption of the wave by the starch granules, the mechanical impacts of ultrasonic waves cause heat to be produced. Because of this, the temperature of the starch may rise, accelerating the gelatinization process and further disorganizing the starch granules. Microwave radiation can generate heat and boost the temperature by rapidly vibrating the water molecules in the starch. This could result in the starch granules swelling and gelatinizing, which would disrupt the granule structure [369]. The decrease in temperature was attributed to an increase in the surface area of the starch granules, which led to a greater degree of swelling and more rapid gelatinization.

Table 8.6. Effects of interaction between particle size and pretreatment on thermal properties of pumpkin flour

Flour Sample	To (°C)	Tp (°C)	Tc (°C)	DH (J g ⁻¹)
CON	69.70±.535 ^a	73.74±0.85 ^a	77.89±0.71 ^a	4.53±0.05 ^b
CON1	67.12±0.52 ^b	71.00±0.80 ^b	75.00±1.00 ^b	5.23±0.25 ^a
20UM	65.34±0.52 ^c	69.12±0.85 ^b	73.03±1.02 ^b	1.85±0.33 ^d
20UM1	62.92±0.42 ^d	66.55±0.73 ^c	70.31±0.80 ^c	2.85±0.15 ^c
Effect				
Pretreatment (p)	***	***	***	***
Particle size (pz)	***	***	***	***
Interaction (p*pz)	***	***	***	***

All values are mean ± SD. This means that sharing the same superscript letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant. CON, control flour, particle size is 75 – 100 µm; CON1, control flour, particle size is <75 µm; 20UM, pretreated flour, particle size is 75 - 100 µm; and 20UM1, pretreated flour, particle size is <75 µm. To, onset temperature; Tp, peak temperature; Tc, conclusion temperature; DH, gelatinization enthalpy.

Smaller flour particle sizes provide a larger surface area for starch granules to interact with water during gelatinization. This results in quicker and more thorough gelatinization of starch, which in turn leads to a greater amount of energy being released during the process. Therefore, smaller flour particle sizes may need less energy input to reach gelatinization, which can result in a greater overall enthalpy [382]. This is comparable to the results of Majid, Dar and Nanda [267] and Raza *et al.*[383] for unsprouted onion powder and extruded chickpea powder, respectively. According to Khushbu *et al.*[373], it is clear from the results that the 20UM1 sample can be used in the food industry as a thickener, with a low energy requirement for creating a bond in an aqueous solution upon heating.

8.3.7. Structural Properties

8.3.7.1. Fourier Transform Infrared (FTIR)

FTIR was used as a monitoring quality control in the food industries because it rapidly screened and quantified chemical components in samples [384]. Fig. 8.2 shows the FTIR spectra peaks of the pretreated and untreated pumpkin flours with different particle sizes at around 3299, 2896, 1607, 1377, and 1025 cm^{-1} . The findings reveal that the flour's general spectral profile was similar, and no new chemical group bands were created as a result of pre-drying treatment and particle size reduction, demonstrating that the flour's primary structural characteristics were preserved. Interestingly, while the intensity of bands decreased with pretreatment, it was usually increased with the flour particle size reduction. The intensity of the FTIR bands decreased due to the disruption of the granule structure caused by both the heating of the starch granules from the microwave radiation, which led to their swelling and gelatinization [385], and the mechanical force generated by the ultrasonic vibrations, which caused the granules to break apart, contract, and the granule structure to become chaotic [386]. The reason for the decrease in intensity, when starch granules are disrupted, is due to the breakdown of the organized structure of starch molecules, which is normally present in intact granules. Because of the increased surface area of the flour particles, FTIR band intensity may rise with the reduction in flour particle size. This enhanced contact between the flour particles and FTIR radiation due to the larger surface area may increase the radiation's absorption and, in turn, the strength of the FTIR bands [387]. The intensity of bands of fine-milled untreated flour with a particle size of $<75\mu\text{m}$ (CON1) was higher than the other three (20UM1, 20UM, and CON) flours intensity. The bands at 3299 cm^{-1} can be attributed to –

OH stretching vibrations from carbohydrates or other compounds such as carboxyl acid and ketone [384]. The frequency at 2896 cm^{-1} is related to CH and CH_2 stretching vibrations [384]. The absorption bands at 1610 cm^{-1} are due to bound water [388], while that at 1377 cm^{-1} originates from CH symmetric bending. The bands at 1025 cm^{-1} were assigned to esters of lipids [384].

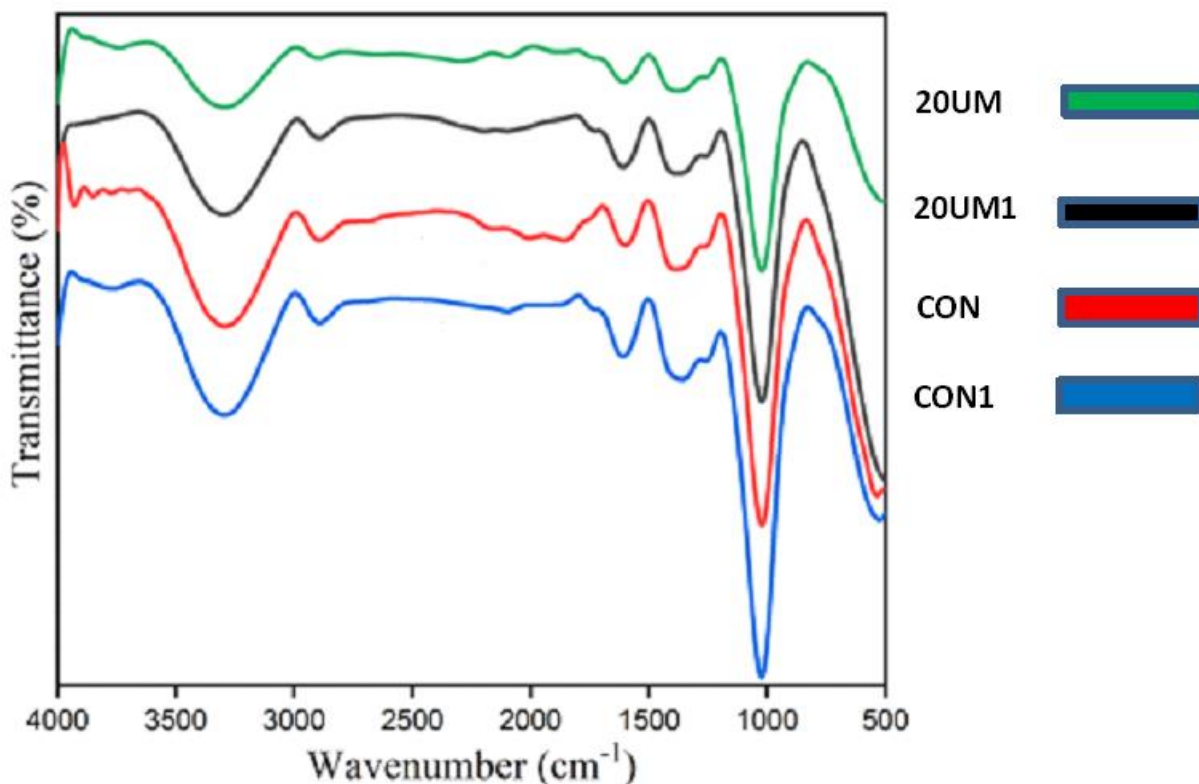


Figure 8.2. Comparison of FTIR spectra of pumpkin flour: CON, control flour, particle size is $75 - 100\ \mu\text{m}$; CON1, control flour, particle size is $<75\ \mu\text{m}$; 20UM, pretreated flour, particle size is $75 - 100\ \mu\text{m}$ and 20UM1, pretreated flour, particle size is $<75\ \mu\text{m}$.

8.3.7.2. X-Ray Diffraction (XRD)

X-ray diffraction patterns of pumpkin flour obtained after pre-drying treatment and size reduction are shown in Figure 8.3. The CON, CON1, 20UM, and 20UM1 flour samples showed a characteristic peak at diffraction angles 2θ of 21.8° , 21.7° , 21.1° , and 21.1° , respectively, with no significantly different at $P < 0.05$ (Table 8.7), suggesting that the peak position of the flour after pre-drying treatment and ball milling were not changed significantly. This could indicate that the interaction effect of pre-drying treatments and particle size did not significantly modify the crystallinity structure. The main difference was a slight reduction in the diffraction intensities, especially in the case of pretreated flour (20UM and 20UM1).

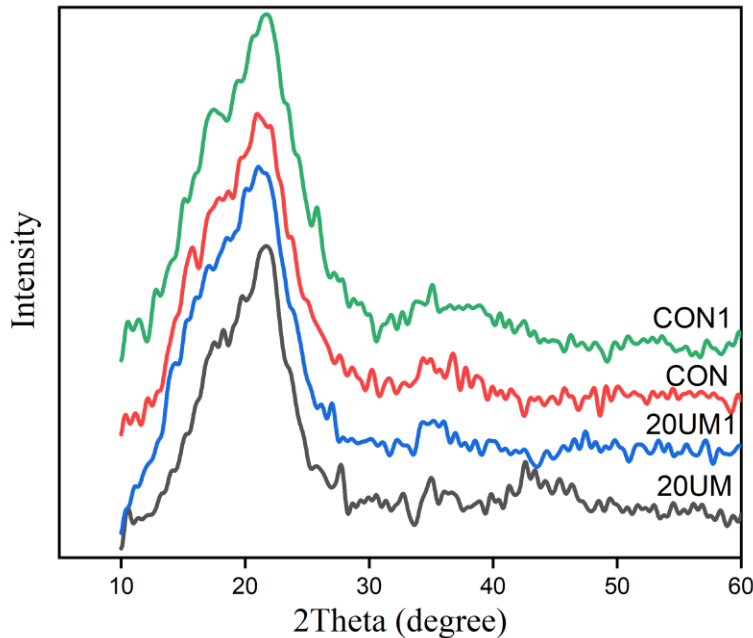


Figure 8.3. XRD patterns of pumpkin flours: CON, control flour, particle size is 100-75 μ m; CON1, control flour, particle size is <75 μ m; 20UM, pretreated flour, particle size is 100-70 μ m; and 20UM1, pretreated flour, particle size is <75 μ m.

The result was in agreement with the conclusion of FTIR. The results were compared based on pretreatment and particle sizes of flour, and it was implied that while the CON1 (untreated fine milled <75 μ m) flour had the highest crystallinity index (61.57%), 20UM (pretreated coarse milled 75 – 100 μ m) flour sample had lowest crystallinity index (45.21%), which is similar to Zhao *et al.*[389] finding for superfine grinding of cellulose fibre structure.

Table 8.7. Effects of interaction between particle size and pretreatment on XRD parameters of pumpkin flour

Flour Sample	Crystallinity index (%)	Peak diffraction ($^{\circ}$)	Peak intensity	D-spacing (nm)
CON	54.99 \pm 0.92 ^b	21.80 \pm 0.42 ^a	319.00 \pm 3.00 ^b	23.23 \pm 0.40 ^a
CON1	61.58 \pm 1.02 ^a	21.70 \pm 0.55 ^a	360.00 \pm 2.75 ^a	23.34 \pm 0.25 ^a
20UM	45.22 \pm 0.72 ^d	21.10 \pm 0.50 ^a	282.00 \pm 3.12 ^d	24.00 \pm 0.05 ^a
20UM1	50.31 \pm 1.12 ^c	21.10 \pm 0.20 ^a	310.00 \pm 3.05 ^c	24.00 \pm 0.45 ^a
Effect				
Pretreatment (p)	***	NS	***	***
Particle size (pz)	***	NS	***	NS
Interaction (p*pz)	***	NS	***	NS

Values are mean \pm SD. This means that sharing the same superscript letters in columns is not significantly different from each other (Tukey's HSD test, $p < 0.05$). *** Significant effect at $p < 0.05$, NS, Not significant. CON, control flour, particle size is 75 – 100 μ m; CON1, control flour, particle size is <75 μ m; 20UM, pretreated flour, particle size is 75 -100 μ m; and 20UM1, pretreated flour, particle size is <75 μ m.

In line with this, while the peak intensity significantly decreases with pretreatment but it increases with particle size reduction (Fig. 8.3). The starch granules break apart and became disordered as a result of the combined mechanical force and heat impacts produced by the ultrasonic and microwave treatments [390]. The average distance between particles in a crystal lattice for CON, CON1, 20UM, and 20UM1 was 23.2, 23.31, 24.00, and 24.00 nm, respectively, with no statistically significant difference ($P < 0.05$) between them. The decrease of crystallinity peaks of pretreated flours is due to disorganization in the structure of starch caused by the effect of ultrasound waves and microwave temperature. According to Trancoso-Reyes *et al.*[369], microwave heating generates greater movement of water molecules within the flour, producing major disorganization in the starch granules. Bashir and Aggarwal [391] found similar results, observing decreases in relative crystallinity linked to decrease in FTIR band intensities of irradiation chickpea starches. The lower DH value indicates greater crystalline starch structure disorganization [392].

8.3.7.3. Scanning Electron Microscope (SEM)

The surface morphology of pumpkin flour was observed using SEM at a magnification of 2000*, and the surface structure was changed with pre-drying treatment but not with particle size reduction (Fig. 8.4). More swollen starch granules were observed for pretreated (20UM and 20UM1) flours, but agglomeration was observed on the untreated (CON and CON1) flours, which is in line with Trancoso-Reyes *et al.*[369] finding for 6 min microwave pretreated sweet potato starch granules. Pre-drying treatments caused gelatinization and swelling of the starch granules, creating a more uniform and stable structure that prevented agglomeration. Contrarily, because intact starch granules were present in untreated fruit powders, they displayed microscale agglomeration [393]. There are also spaces between starch granules of pretreated flour (Fig.8.4). Untreated flour's agglomerated appearance may be due to its increased moisture content, which caused water to adsorb to the surface or become associated with fibre or other components [267]. The changed morphology can affect the physicochemical properties of the flour.

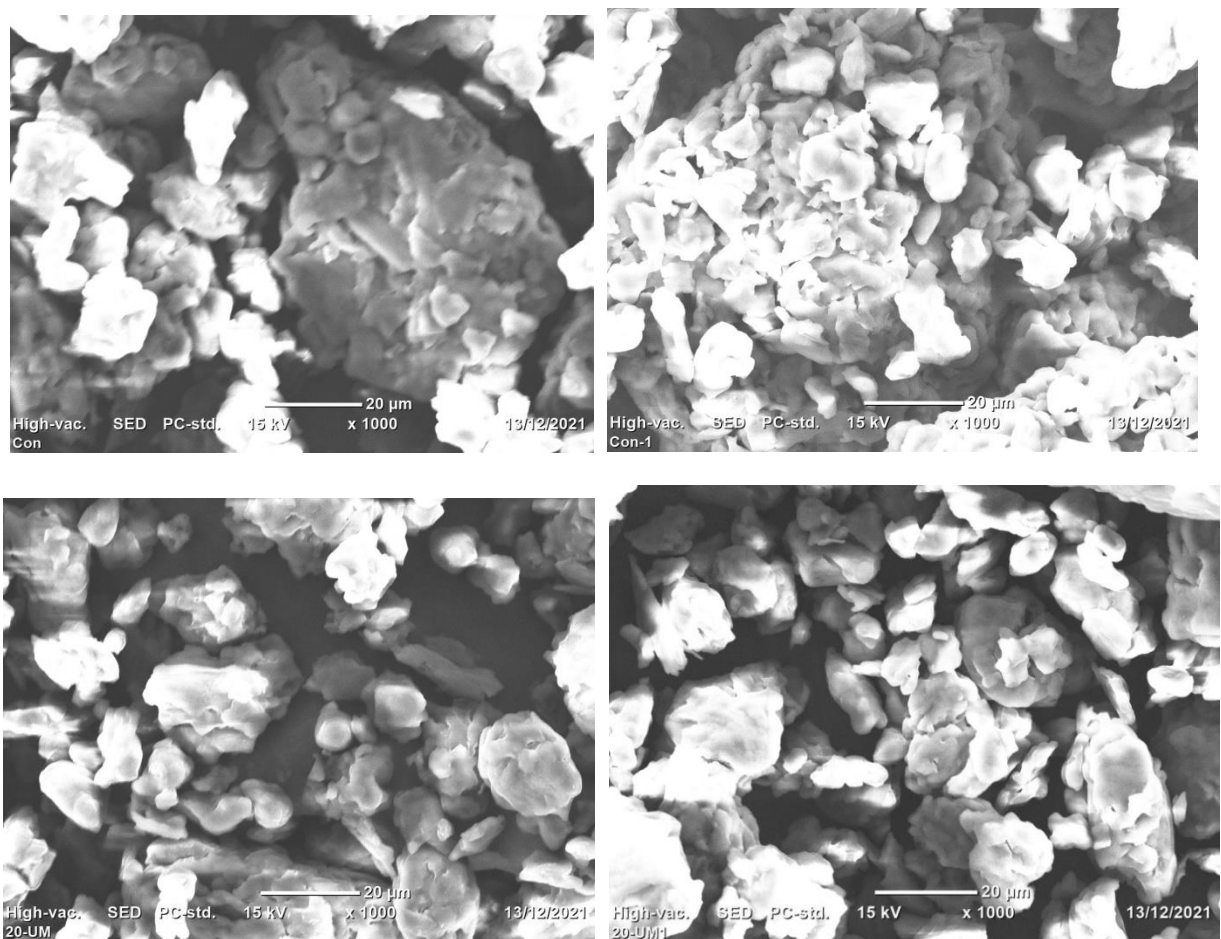


Figure 8.4. SEM of pumpkin flours: CON, control flour, particle size is 75 -100 μm ; CON1, control flour, particle size is $<75 \mu\text{m}$; 20UM, pretreated flour, particle size is 75 - 100 μm , and 20UM1, pretreated flour, particle size is $<75 \mu\text{m}$.

8.4. Conclusions

In conclusion, it has been shown that pre-drying treatment and particle size influence pumpkin flour's physical, chemical, functional, pasting, thermal, and structural properties. Pretreated (20UM1 and 20UM) and untreated (CON1 and CON) pumpkin flour with various particle sizes had protein and crude fibre contents ranging from 9.05 to 10.31%, 6.99 to 8.00%, and 12.4 to 14.39%, 11.03 to 12.79%, respectively. Size reduction increases particles' surface area and consequently improves pumpkin flour's water and oil holding capacity and lightness. The study found that pre-drying treatment and reducing the particle size of the flour increased the extraction of active compounds, potentially resulting in an improvement in antioxidant activity. Both pre-drying treatment and particle size reduction resulted in increasing pasting properties. The results indicated that pre-drying treatment caused a decrease in both the thermal temperature (T_o , T_p , and T_c) and the change of enthalpy (ΔH) values. However, a decrease in flour particle size resulted in

a decrease in thermal temperature (T_o , T_p , and T_c) and an increase in the change of enthalpy (ΔH) values. The FTIR analysis results showed no change in the composition of the functional groups at the macromolecular level. The fine-milled, untreated flour had the highest crystallinity index and strength of noticeable crystal peaks, according to X-ray analysis. Based on examining SEM images of pumpkin flour particles, the flour from the pre-drying treatment contained a swollen starch fragment. It can be concluded that sample 20UM1 is a superior component for increasing the important ingredients in a variety of food formulations due to its better composition, functional, and structural characteristics when compared to others.

CHAPTER 9: STANDARDIZATION, OPTIMIZATION AND CHARACTERIZATION OF FUNCTIONAL *KEMESHA*

Abstract

The objective of this study was to establish a standardized technique for making *Kemesha*, optimize the blending ratio of common wheat (*Triticum aestivum*) flour, germinated haricot bean flour, ultrasonically fine-milled pumpkin flour, and CMC by using a D-optimal mixture design to produce *Kemesha* and assess the quality of the resulting *Kemesha*. The information on the production was acquired from regional *Kemesha* producers in the four districts of Arsi Zone using open-ended and closed-ended questions as well as focus group discussions. Based on a consumer acceptability test, *Kemesha* was standardized and found to be accepted above average in all sensory qualities when dried at 50°C and cooked at 100°C for 6 minutes. Following that, it underwent optimization and a properties study. Protein, fibre, total carotenoid content, and firmness were responses for optimizing *kemesha* formulation. While total carotenoid and fibre increased with an increase in ultrasonicated fine-milled pumpkin proportion, protein, and firmness increased with germinated haricot bean flour and CMC proportion, respectively. The numerical optimization and model validation results indicated that it is feasible to use a flour composition of 63.00 g common wheat flour, 19.01 g germinated haricot bean flour, 14.51 g ultrasonicated fine-milled pumpkin flour, and 3.48 g CMC per 100 g of flour to prepare *Kemesha* with desirability of 0.596. The proximate composition analysis results revealed that the optimized *Kemesha* had higher levels of fibre, ash, and protein compared to the control *Kemesha*, whereas the carbohydrate content was significantly lower. The studies on color estimation revealed that the yellow color of the product was slightly increased during the optimization of *Kemesha* (15.09 to 31.09) while the brightness index was reduced from 89.38 to 74.44. Compared to the control *Kemesha*, the optimized *Kemesha* had a total phenolic, flavonoid, and carotenoid content of 7.47, 3.67, and 149.20 times greater. Also, variations were observed in DPPH scavenging abilities between the *Kemesha* samples. The cooking loss (4.95 %) and water absorption (220.68 %) of optimized *Kemesha* were improved as compared to control *kemesha*. The sensory qualities of raw and cooked *Kemesha* were significantly enhanced by including haricot beans, pumpkin flour, and CMC in terms of surface smoothness, resistance to break, appearance, and texture, color, appearance, general acceptance, respectively.

Keywords:- *Kemesha*, Functional food, Optimization, Traditional food

9.1. Introduction

Age-old food processing techniques still apply in developing countries, especially rural communities. Traditional foods are vital in local identity, consumer behavior, the handover of cultural heritage to upcoming generations, and communicating this heritage with the rest of the world. Traditional food processing methods are important in utilizing locally available raw materials [394]. The household-level *Kemesha* preparation is an indigenous technology developed by various communities from locally available raw materials and equipment. These communities need improved technology to advance *Kemesha* processes for food safety and nutritional value.

Kemesha is traditionally produced and consumed in different parts of the Arsi zone, Ethiopia. It is prepared from common wheat flour and water through traditional processing steps of mixing, sheeting, rolling, cutting, and sun-drying. All age groups of people consume it. *Kemesha* was utilized as dry food for transit, for household consumption, during festive events like festivals and wedding ceremonies, and as a source of revenue for a small minority in the Arsi zone. Presently, the processing and consumption of *Kemesha* are village-based, and it has been underutilized.

The production practices of *kemesha* are not based on scientific knowledge and thus vary from one person to another, which can cause variable quality characteristics. Traditional processing techniques required to produce *Kemesha* are not standardized and are not based on sound scientific principles making it, in its present form, unsuitable for small-scale industrial production. The processes are often laborious and time-consuming, and the quality of the products requires substantial improvements. Since women handle most of the work involved in processing *kemesha*, lessening the tediousness would greatly improve women's lives and positively affect the family and society. Usually, *Kemesha* is dried under the sun, which takes about one to two days to dry. This practice predisposes the food to contamination from microbial, dust, animal dung, leaves, stones, etc. Also, slow or rapid drying with unregulated drying temperature and air velocity may impair the structure, leading to the product's undesirable structure. Mechanical drying offers a promising alternative to maintain uniformity in product drying quality. The traditional most crucial quality factors, such as color and texture (which should not be too firm but should not instantly crumble in the mouth), can be assessed through sensory analysis to determine *Kemesha's* acceptance. Standardization of processing methods ensures consistent use of raw materials in terms of quantity and quality to ensure uniformity in final product quality.

Wheat flour is the raw material most suitable for making *Kemesha* because of its gluten, which is ideal for the development of dough and for preventing its disintegration during cooking [395]. Products made from wheat are typically rich in carbohydrates but poor in fibre, protein, minerals, vitamins, and phenolic compounds, which frequently causes nutrient imbalances in consumers [2]. Consumers worldwide have shown increasing interest in reducing disease risks by consuming health-promoting dietary ingredients [370] and additionally fulfilling their basic nutrition requirements [396]. This is why foods today are expected to do more than just satisfy hunger and deliver essential nutrients; they are also expected to prevent diseases linked to poor nutrition and improve customers' physical and emotional well-being [3][4]. In this regard, functional foods offer an outstanding opportunity to improve the quality of products. In addition to dietary fibre, organic micronutrients like carotenoids, polyphenolics, tocopherols, vitamins C, minerals, organic acids, and others are primarily responsible for the health benefits of plant-based diets [32]. In particular, phenolics and carotenoids can impart health benefits by scavenging reactive oxygen species and protecting against degenerative diseases like cancer and cardiovascular diseases [397]. Consumers have increasingly demanded wheat-based products such as pasta and noodle in the last few decades, considering them added value using animal and plant products [398]. The nutritional status of *Kemesha* can be improved by ingredients that are rich in protein, fibre, and bioactive components, such as haricot bean [10,11][17] and pumpkin flour [324].

Investigations on nutritional, functional, and phytochemical properties of four improved varieties of haricot beans (*Phaseolus vulgaris*) and pretreated pumpkin have highlighted the importance of these crops on the human diet for their high protein, fibre, bioactive component and carbohydrates content, which makes this food a good source of nutrients [70] [17] [324]. As a matter of fact, clinical studies show that eating fruits and vegetables, pumpkin, has positive benefits on the body, acting as a preventative measure for conditions including cataracts, constipation, asthma, cancer, and respiratory (asthma and bronchitis) diseases [114]. For this purpose, the development and studying of new *Kemesha* products with good nutritional, functional, and acceptability is inevitable work. The proportion of alternative flours (germinated haricot bean, ultrasonicated fine-milled pumpkin, and CMC) that can substitute common wheat flour in the *Kemesha* recipe should strike a balance between achieving nutritional enhancement and maintaining satisfactory sensory characteristics. In order to reduce the price of *Kemesha* and make it more accessible to low-income people, it is also necessary to partially substitute wheat

with less expensive food crops like pumpkin and haricot bean. Including germinated legumes, especially beans, in cereal-based products could be a good option for increasing the nutritional intake of people [70]. They have a significant role in human nutrition, especially in the diets of low-income populations in developing nations, since they are affordable protein sources [399]. Haricot beans contain about 23.11–27.96 % protein which is about two-fold higher than wheat and is also reported to be a good source of bioactive components [17].

It is well recognized that reducing the amount of gluten in a product made from wheat by adding more haricot and pumpkin flour does not improve *Kemesha's* sensory or cooking qualities. As a result, carboxymethyl cellulose, a hydrocolloid, must be added to successfully substitute the gluten in *Kemesha*. In the literature, it has also been reported that a substance suitable to produce a cohesive structure can overcome the absence of gluten [114]. Generally, using structuring agents may yield acceptable products with good texture and minimum cooking loss [400]. Despite several research attempts to promote the partial substitution of common bean flour in pasta and noodles, no available information exists on the use of germinated haricot bean flour and ultrasonicated fine-milled pumpkin flour in *Kemesha* processing. Therefore, this study aimed to document the existing production methods and establish standardized process technology for the preparation of traditional *Kemesha*. Furthermore, it sought to optimize the functional *Kemesha* variant with high nutritive value, incorporating key ingredients such as germinated haricot bean, ultrasonicated fine-milled pumpkin flour, CMC, and common wheat flour using D-optimal mixture design. The study also involved evaluating the physicochemical, nutritional, functional, textural, and acceptability properties of the resulting *Kemesha* products.

9.2. Materials and Methods

9.2.1. Material Collection and Preparation

Common wheat (*Triticum aestivum*) flour, pumpkin, and carboxymethyl cellulose were procured from the local market in Addis Ababa, Ethiopia. Haricot bean seeds (SAB 632 variety) were brought from Awash Melkassa Agricultural Research Center. Germinated haricot bean and ultrasonicated fine-milled pumpkin flour were prepared as per the method used by Wodajo and Emire [17] and section 8.2.2., respectively. All chemicals were analytical grade.

9.2.2. Survey and Standardization of Processing Methods

The four districts of Arsi Zone (Arsi Robe, Amigna, Bele Gesgar, and Sude weredas) were surveyed to determine the traditional methods for preparing *Kemesha* depending on the product's availability. From the four districts, 20 respondents who often produce *Kemesha* were chosen randomly for an interview and sample gathering. Information on *Kemesha* preparation techniques, raw materials, and cooking methods was gathered through interviews, focus group discussions, questionnaires, and on-site video recording. The questionnaire was used to gather issues related to traditional processing techniques, proportions of raw materials, economic importance, and desirable quality attributes of *Kemesha*. Also, the responders were asked to list the main issues that came up during the production and consumption of *Kemesha* and to offer any solutions they may encounter.

To preserve the study's homogeneity, the appropriate materials and equipment were purchased and given to all 20 volunteers to prepare the *Kemesha* based on the data collected during data collection. Afterward, the quantity of components and the procedures used by the 20 volunteers who participated in the preparation of *Kemesha* were merged and standardized to a set recipe and processing parameters. The means of the recipes were then calculated to obtain the amounts of each ingredient used for the standardized recipe. For the purpose of tracking process parameters, the processes were methodically watched and investigated in the lab in relation to the quantity of components and processing time. The process parameters were specified and quantified, and the processes were then standardized. The processes were repeated in the laboratory until identical products were obtained. Ingredients used to prepare the *kemesha* were purchased from the most popular local markets in Addis Ababa, Ethiopia. The main utensils used for *kemesha* preparation (standardization) were: stainless steel pots, weighing scales, teaspoons, measuring cups, Serving spoons, etc. Traditionally *kemesha* is prepared manually from wheat flour through traditional processing steps of mixing, sheeting, rolling, cutting, and sun-drying.

Standardized traditional *Kemesha* were produced by blending common wheat flour (100 g) with water (33 mL). The mixtures were thoroughly worked to form a consistency dough. The formed dough was allowed to rest for 15 min in a closed plastic bag, then passing small portions (50 g) of kneaded flattened sheets of dough were through the pasta machine (Imperia Tipo Lusso SP150, Torino, Italy) at decreasing thicknesses (numbers 2, 3, and 4, respectively). The dough was

folded into thirds and sent through again. It was then folded in half, run through, and cut into small manageable lengths. The thin, flattened sheets were passed through the fettuccine cutter to form *Kemesha* strands, which were 1.5 cm in length and 1.6 mm in thickness. In order to compare the acceptability of high and low drying temperatures, the slit and cut strands were placed in clean aluminum trays and oven dried (at 50° C for 2:30 h or 70° C for 1:25 hours) to a safe moisture content (<12%). The dried pasta was stored in Ziploc bags at room temperature until further use.

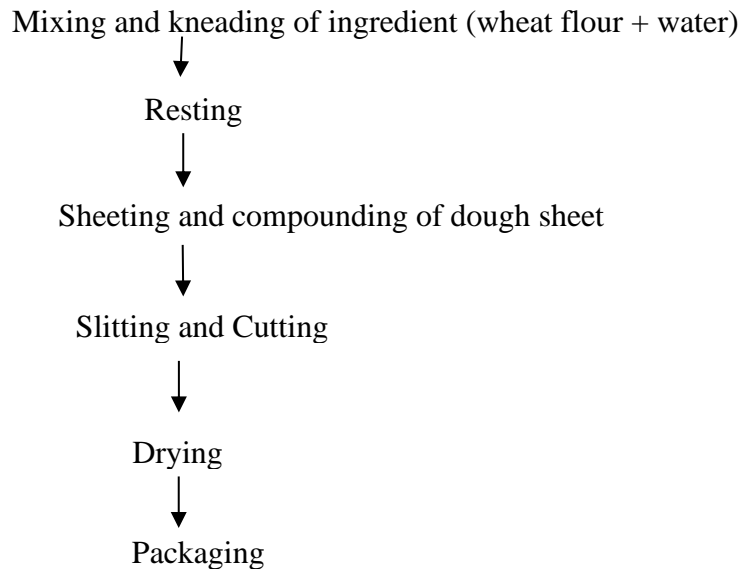


Figure 9.1. Flowchart of *kemesha* processing methods

9.2.3. Experimental Design

This study was conducted to find an appropriate ratio of four components: common wheat flour, germinated haricot bean flour, ultrasonicated fine-milled pumpkin flour, and carboxymethyl cellulose to prepare functional *Kemesha* with optimum nutritional content and acceptability attributes. A total of twenty treatment combinations were generated using a D-optimal mixture design that was used to find the appropriate ratio. The percentage of the lower and upper range of the ingredients includes 61%–80% for CWF, 10%–30% for GHBF, 5%–20% for UFPF, and 2-4% for CMC. Table 9.1 displays the composition of each blend calculated from the experimental design. The amount of components was selected based on similar available literature as well as by preliminary tests. Effects of wheat flour, germinated haricot bean flour, ultrasonicated fine-milled pumpkin flour, and carboxymethyl cellulose on the protein (Y_1), fibre (Y_2), total carotenoid content (Y_3), and firmness (Y_4) of the *Kemesha* were investigated, and the optimum mixture was selected. The statistical parameters used in evaluating and selecting the best-fitted model were

coefficient of determination (R^2), adjusted coefficient of determination (adjusted- R^2), coefficient of variation (C.V), standard deviation, predicted coefficient of determination (predicted R^2), predicted residual sum of squares (PRESS), regression data (P value and F value) and lack-of-fit. The analysis of variance (ANOVA) was used to determine the significant difference between linear, quadratic, and interaction terms of independent factors. A contour plot was created to visualize the concept more clearly by putting a single factor constant at the central point while changing the other three variables within the experimental range. Also, a three-dimensional response surface graph for the model's desirability was generated by Design-Expert Software Version 13.0 for a better explanation. The optimal *Kemesha* preparation was achieved by combining set goals of all quality parameters into an overall desirability function. To confirm the model's validity, the experiment was conducted at optimum values of processing variables, and obtained responses were then compared with predicted values of the responses.

$$Y = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{34}X_3X_4 \quad 9.1$$

Where Y= the predicted variable, $X_{1,2,3,4}$ = the proportion of the four flours in the mixture, β 's =the coefficient of the linear and quadratic terms of the model

Also, for verification of the model, the difference between the predicted and actual values or the relative standard error (RSE) can be calculated by using the following equation (Equation 9.2):

$$RSE \% = \frac{\text{Actual value} - \text{Predicted value}}{\text{Predicted value}} \quad 9.2$$

After selecting the optimal *Kemesha* (OK) based on protein (Y_1), fibre (Y_2), total carotenoid content (Y_3), and firmness (Y_4), its physicochemical properties, nutritional value, phytochemical activity, cooking, textural and sensory attributes were compared with the control sample.

Table 9.1 Experimental design showing the doses of each formulated blend and response of each runs

Run	CWF	GHBF	UFPF	CMC	Protein (%)	Fibre (%)	TCC ($\mu\text{g/g}$)	Firmness (g)
1	80	13	5	2	11.71	2.65	5.94	994.93
2	68	10	20	2	9.77	5.35	28.12	882.85
3	68.5909	13.4545	15.5	2.45455	11.02	4.83	21.75	1025.54
4	66	10	20	4	9.68	5.18	28.12	1115.34
5	63	30	5	2	13.64	3.62	8.01	981.77
6	61	30	5	4	13.13	3.42	6.65	1141.34
7	69.3909	16.0545	11.1	3.45455	11.66	4.08	15.67	1187.47

8	74.5909	13.9545	8	3.45455	11.52	3.82	11.23	1224.71
9	80	11	5	4	10.92	2.95	5.12	1260.46
10	65.0909	23.4545	8	3.45455	12.81	3.96	11.54	1176.34
11	66	10	20	4	9.54	5.18	28.12	1116.34
12	61	16	20	3	10.51	5.88	29.21	944.43
13	61	23.5	13.5	2	12.22	4.64	19.86	922.56
14	63	30	5	2	13.58	3.76	7.21	965.77
15	80	13	5	2	11.78	2.69	5.94	995.93
16	70.5	20.5	5	4	12.68	3.08	6.23	1248.32
17	65.0909	16.9545	15.5	2.45455	11.18	4.99	22.12	1010.21
18	73.5	10	13.5	3	10.23	4.44	19.11	1157.25
19	61	16	20	3	10.61	5.78	29.21	943.43
20	61	30	5	4	13.18	3.47	7.21	1141.34

CMC, carboxymethyl cellulose; CWF, Common wheat flour; GHBF, Germinated haricot bean flour; UFPF, Ultrasonicated fine-milled pumpkin flour; TCC, Total carotenoid content

9.2.4. Preparation of Functional *Kemesha*

The composite flours were mixed in stages according to the proportions specified in Table 9.1, with small amounts of each flour added gradually while mixing slowly to prevent aggregation. The mixed flour samples were packed and sealed in brown bags. *Kemesha* was produced by blending flours (100 g) (according to Table 9.1) with water (35 mL). CMC was dispersed in cold water and added to the recipe in the amount given by the design Table 9.1 as a flour blend replacement. The mixtures were thoroughly worked to form a consistency dough. The formed dough was allowed to rest for 15 min in a closed plastic bag, then passing small portions (50 g) of kneaded flattened sheets of dough were through the pasta machine (Imperia Tipo Lusso SP150, Torino, Italy) at decreasing thicknesses (numbers 2, 3, and 4, respectively). The dough was folded into thirds and sent through again. It was then folded in half, run through, and cut into small manageable lengths. The thin, flattened sheets were passed through the fettuccine cutter to form *Kemesha* strands, which were 1.5 cm in length and 1.6 mm in thickness. The slit and cut strands were put in cleaned aluminum trays and then oven dried at 50°C for 2:10 h to safe moisture content (<12%). The dried functional *Kemesha* was stored in brown bags at room temperature until further use.

9.2.5. Sensory Evaluation of the Control and Optimized *Kemesha*

Raw and cooked standardized *Kemesha* samples, which were dried at 50°C and 70°C, were subjected to sensory evaluation to determine consumer acceptability. To conduct the evaluation, panelists who were familiar with *Kemesha*, including students and employees of the University of

Wolkite in Ethiopia, evaluated both the dried and cooked samples using nine-point hedonic scales ranging from 1 (dislike extremely) to 9 (like extremely). To prepare cooked *Kemesha*, a 100 g sample was boiled in 500 mL of unsalted water at a temperature of 98-100°C. The *Kemesha* was then observed until its core disappeared after being compressed between two transparent glass slides after 6 minutes for the control and 5.3 minutes for the optimized *Kemesha*. The extra cooking and cooling water were then drained from the sample. The samples were then stored for not more than 30 min in tightly covered plastic food containers before testing. A group of ten panelists were provided with *Kemesha* samples to evaluate the texture, color, aroma, appearance, and overall acceptability of the cooked *Kemesha*, as well as the surface smoothness, resistance to break, aroma, appearance, and overall acceptability of the raw *Kemesha*. The most preferred sample was then optimized and subjected to additional analysis.

9.2.6. Physical Characteristics

Ten (10) strips of *Kemesha* were taken for thickness and length measurements with a digital vernier caliper (TA, M5 0–300 mm, China) of 0.01 mm precision, and the average was reported. The water activity of the *Kemesha* was measured by a water activity meter (HD-3A, NanBei, China) at room temperature. Before estimating the water activity, *Kemesha* samples were comminuted and homogenized. After letting the produced slurry stand for 10 minutes while being constantly stirred, the pH of the comminuted *Kemesha* was measured by blending 10 g in a beaker containing 25mL of distilled water with a pH meter (BANTE Multiparameter, China) in accordance with AOAC [145].

Color measurements on *Kemesha* samples were carried out according to Mariotti *et al.*[401] using a Minolta colorimeter (3NH Technology Co., LTD, China). The dried *Kemesha* sample (120g) was milled (BH24 1DY, Armfield, England) and sieved through a 500 μm sieve. The flour was then put into plastic petri dishes, where the top was manually leveled to the brim of the dish, and a plastic film was then snugly placed on top. The black and white tile was used for instrument calibration before color measurement. Color coordinates L^* , a^* , and b^* was measured at seven points on the surface. Results were expressed in the CIELAB space as L^* (lightness; 0 = black, 100 = white), a^* (+a = redness, -a = greenness) and b^* (+b = yellowness, -b = blueness) values. Results were also expressed as color differential (ΔE) between the control (*Kemesha* with common wheat flour only) and the optimized *Kemesha*, calculated by using the following equation (Equation 9.3) according to Jayasena and Nasar-Abbas [126]:

$$DE = [(DL)^2 + [(Da)^2 + [(Db)^2]^{1/2}]^{1/2} \quad 9.3$$

Where $DL^* = L_1^* - L_2^*$, $Da^* = a_1^* - a_2^*$ and $Db^* = b_1^* - b_2^*$; while L^* , a^* and b^* values of control were subscripted by 1, but the optimized one was subscripted by 2.

The Chroma and Hue angle was determined using the following equations (Equations 9.4 and 9.5) to demonstrate the relationship between a^* and b^* [277]:

$$\text{Chroma}(C^*) = [(a)^2 + (b)^2]^{1/2} \quad 9.4$$

$$H^* = \tan^{-1}(b/a) \quad 9.5$$

9.2.7. Proximate Composition of the Control and Optimized *Kemesha*

Proximate composition was determined according to the method described in section 3.2.1.

9.2.8. Phytochemical Properties of the Control and Optimized *Kemesha*

First, the methanol extracts were prepared from milled *Kemesha* flour, according to Erbiai *et al.*[402]. A temperature shaker incubator (ZHWHY-103B) was used to extract 10 grams of flour with 100 mL of methanol over the course of 24 hours at 25°C and 150 rpm. The cleared mixture was then passed through Whatman No. 1 paper. The deposit was extracted with two additional 100 ml portions of methanol described above. The methanolic extracts were vaporized using a Rota evaporator (R-300, Buchi, Switzerland) at 40°C until dry, then redissolved in methanol at a 50 mg/mL concentration and kept at 4°C for later use. Then the total phenolic content was determined in triplicate using the Folin–Ciocalteu method at a wavelength of 765 nm with gallic acid used as a standard. At the same time, the total flavonoid concentration was determined using the colorimetric method with quercetin used as standard at a wavelength of 510 nm, as described by Minuye *et al.*[335]. By employing ascorbic acid as a standard without extract or control, antioxidant activities were assessed using the DPPH techniques [336]. For the quantitative analysis of antioxidant activities, a calibration curve was obtained by injection of known concentrations of ascorbic acid standards ($y=474.36x+16.73$, $R^2=0.91$). The amount of total carotenoid was calculated using the de Carvalho *et al.* [278] approach and expressed as μg per g of dry matter. Expect DPPH; all analysis was carried out in triplicate.

9.2.9. Evaluation of the *Kemesha* Cooking Qualities

Water absorption, cooking loss, and volume increase of *Kemesha* were measured according to the AACC methods [403] by using the following equations (Equations 9.6, 9.7, and 9.8),

respectively. After cooking 10 g of fresh *Kemesha* for the appropriate amount of time in 100 mL of distilled water, cooling for 1 minute with cold water, and removing the water for 30 seconds, the water absorption rate was determined. After determining the water absorption rate, the cooking loss was calculated following a 24-hour drying period at 105°C with the leftover water. The volume rise rate was determined by adding 10 g of fresh *Kemesha* and 10 g of cooked *Kemesha* to a 500 mL measuring cylinder filled with 200 mL of distilled water. All the analyses were conducted in triplicate. The respective formulae used in the calculations are as follows:

$$\text{Water absorption(\%)} = \frac{\text{Weight of cooked Kemesha(g)} - \text{Weight of fresh Kemesha (g)}}{\text{Weight of fresh Kemesha (g)}} * 100 \quad 9.6$$

$$\text{Cooking loss(\%)} = \frac{\text{Remaining solid content after drying (g)}}{\text{Weight of fresh Kemesha (g)}} * 100 \quad 9.7$$

$$\text{Volume increase(\%)} = \frac{\text{Volume of cooked kemesha (mL)} - \text{Volume of fresh Kemesha (mL)}}{\text{Volume of fresh Kemesha (mL)}} * 100 \quad 9.8$$

9.2.10 *Kemesha* Texture Profile Analysis

According to Larrosa et al. [404], a 36 mm diameter flat-ended cylindrical probe (P/36) was used in two compression cycle tests to measure the texture of cooked *Kemesha*. *Kemesha* (10 g) was cooked in 100 g of water using an induction oven (RBE-22H, Rinnai, Incheon, Korea) to optimum cooking time (6 min for control and 5.3 min for optimized *Kemesha*). After cooling in a sieve for 30 seconds, the cooked *Kemesha* was left in there for two to three minutes to drain off the remaining water. *Kemesha* of 1.6 mm thickness and 1.5 cm length were prepared for texture profile analysis using a texture analyzer (TA-XTplus, Stable Micro Systems Ltd., Godalming, UK). The test conditions were as follows: 1 mm/s pre-test speed, 1 mm/s test speed, 5mm/s post-test speed, 80% strain, and 20 g trigger force. From the force-time curve, the parameters calculated were firmness, adhesiveness, springiness, cohesiveness, and chewiness [405]. Measurements were replicated 10 times for each treatment.

9.3. Results and Discussions

9.3.1. Consumer Acceptability Test of Standardized *Kemesha*

Table 10.2 presents the average scores for the sensory characteristics of standardized *Kemesha*. The results indicate that there were differences between the raw and cooked samples in terms of various sensory parameters. For the raw *Kemesha* samples that were dried at 50°C and 70°C, there were differences in surface smoothness, resistance to breakage, odor, and general acceptability.

For the cooked *Kemesha* samples, there were differences in texture, color, odor, appearance, and general acceptability.

Table 9.2. Acceptability of raw and cooked kemesha dried at 50°C and 70°C temperature

Activities	Dried to 50 °C	Dried to 70 °C
Raw <i>Kemesha</i>		
Surface smoothness	7.40±1.07 ^a	6.9±0.63 ^a
Resistance to break	7.10±1.20 ^a	6.4±0.42 ^b
Odor	8.20±0.92 ^a	8.1±0.52 ^a
Appearance	7.50±0.85 ^a	6.5±0.67 ^b
OVA	7.30±0.67 ^a	6.50±0.54 ^b
Cooked <i>Kemesha</i>		
Texture	7.40±0.97 ^a	7.00±0.47 ^a
Color	7.30±0.95 ^a	7.20±0.48 ^a
odor	8.10±0.57 ^a	8.0±0.71 ^a
Appearance	7.3±0.82 ^a	6.50±0.53 ^b
OVA	7.20±0.79 ^a	6.60±0.42 ^b

All values are mean ± standard deviation. This means sharing the same letters in columns are not significantly different from each other student-t-test, $p < 0.05$). ; OVA, Overall acceptability

The fresh *Kemesha* dried at 50 °C had the highest overall acceptability sensory score (7.30±0.67), whereas the *Kemesha* dried at 70 °C had a score of 6.5±0.54. The mean color score of the cooked *Kemesha* dried at 50 and 70 °C was 7.30±0.95 and 7.20±0.48, respectively (Table 9.2), indicating the color of the cooked *Kemesha* was liked moderately and agreed with the observations of Iwe [188] acceptability line. The quality scores for the appearance of both raw and cooked *Kemesha* dried at 50 and 70 °C were 7.50±0.85 and 6.50±0.67, 7.3±0.82 and 6.5±0.53, respectively. The highest temperature resulted in lower appearance scores, as it caused the dried *Kemesha* to become curved. The *Kemesha* dried at 70 °C is slightly slimy than the *Kemesha* dried at 50 °C. It was noted that the texture is preferred to both color and odor among the desirable quality attributes in a cooked kemesha. Cooked *Kemesha* is desired to be not sticky when eaten and exhibit some firmness to the bite. On a 9-point hedonic scale, cooked *Kemesha* dried at 50 °C received the highest score of 7.40±0.97 for texture, while cooked *Kemesha* dried at 70 °C received a score of 7.0±0.47. These indicate that the texture of cooked *Kemesha* dried at 50 °C was preferable to that of cooked kemesha dried at 70 °C. Generally, kemesha dried at 50 °C was preferred based on the acceptance test in Table 9.2.

Then, prior to optimization preliminary investigations were carried out to identify the suitable variables for the response and determine the ranges of these variables in the *Kemesha* formulation. The preferred *Kemesha* from the acceptability test was used as a control. CMC is selected as the structuring agent. According to Liu *et al.* [406] and Hu *et al.*, [407] adding CMC greatly improved the texture and cooking quality of the noodles by increasing their firmness, reducing their stickiness, improving their chewiness, and increasing their elasticity.

Table 9.3. Chemical composition of raw materials

Activities	CWF	GHBF	UFPF
Protein	9.61±0.36 ^b	26.74±0.72 ^a	9.05±0.38 ^b
Crude fibre	1.83±0.08 ^c	6.20±0.32 ^b	14.22±0.24 ^a
Total Carotenoids µg/g	0.14±0.04 ^b	1.12±0.05 ^b	139.41±0.88 ^a
Total phenols mgGA/g	0.17±0.03 ^c	0.84±0.05 ^b	6.47±0.29 ^a
Total flavonoids mgCE/g	0.25±0.05 ^c	3.53±0.05 ^a	1.91±0.04 ^b

All values are mean ± standard deviation. This means sharing the same letters in raw are not significantly different from each other (student-t-test , $p < 0.05$); CWF, common wheat flour; GHBF, germinated SAB 632 haricot bean flour, UFPF, Ultrasonicated pumpkin flour milled to $<75\mu\text{m}$

9.3.2. Nutritional and Phytochemical Composition of Raw Materials

Table 9.3 shows the chemical composition of the raw materials of *Kemesha*. According to the investigation, while germinated haricot bean (SAB 632 variety) flour had the highest protein content (26.74±0.82), ultrasonicated fine-milled pumpkin flour had the highest levels of bioactive components and fibre, which improve the functional qualities of a food product. CMC was very effective on texture due to its network-forming capacity [401].

Table 9.4. ANOVA showing the linear, quadratic, and lack of fit of the response variables

	Protein	Fibre	Total carotenoid	Hardness
Model (P value)	<0.0001	<0.0001	<0.0001	<0.0001
Model (F value)	397.39	397.23	3619.69	566.71
R ²	0.97	0.99	0.99	0.99
Adjusted R ²	0.97	0.99	0.99	0.99
Predicted R ²	0.96	0.98	0.98	0.98
C.V%	0.820	1.75	2.46	0.6692
Lack-of-fit (P value)	0.1010	0.2061	0.2560	0.1285
Lack-of-fit (F value)	3.43	2.18	1.86	2.97
Standard deviation	0.095	0.0732	0.3894	7.17

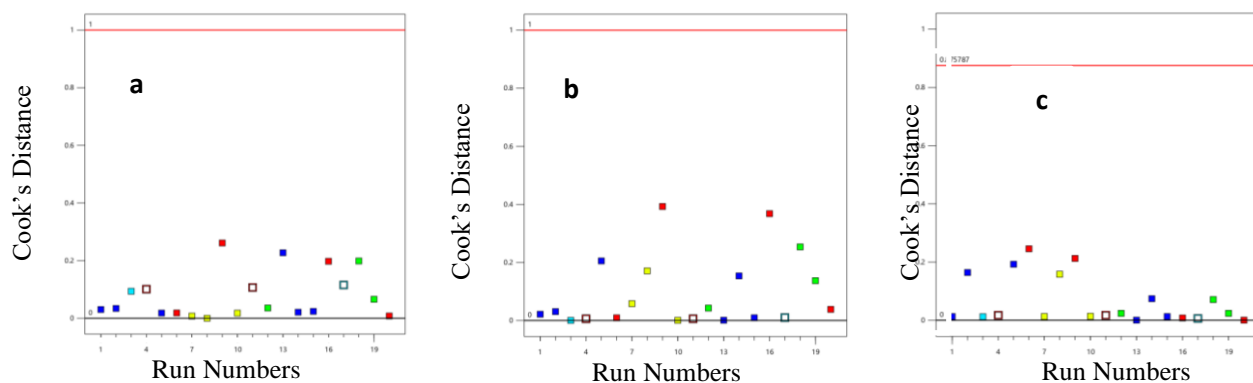
Press	0.287	0.1969	3.80	1663.00
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P<0.05 is significant, P> 0.05 is not significant; PRESS, predicted residual sum of squares; C.V, coefficient of variation

9.3.3. Fitting for the Best Model

Experimental results for the response variables of *Kemesha* preparation are shown in Table 9.1. The best model was selected based on a low standard deviation, a low predicted sum of squares, and a high R-squared [408]. While the total amount of carotenes could be explained by a linear model, protein, fibre, and sample firmness could all be explained by quadratic models. The ANOVA showed that lack of fit was insignificant for all the D-optimal mixture designs at a 95 % confidence level. The lack of fit test measures how well a model captures experimental domain data during times when such data were not included in the regression [409]. The CV indicates the relative dispersion of the experimental points from the model's prediction. According to Gull, Prasad and Kumar [410], the model was considered adequate when the multiple coefficients of correlation (R^2) were more than 93%, and the lack of fit test was non-significant.

The (R^2) values for the responses, i.e., protein, fibre, total carotenoid, and firmness, were 0.97, 0.99, 0.99, and 0.99. A high proportion of variability ($R^2 > 0.97$) in the response models was obtained (Table 9.4). Adding a variable to the model always increases R^2 , regardless of whether the additional variable is statistically significant or not, so a large value of R^2 does not always imply that the regression model is good.



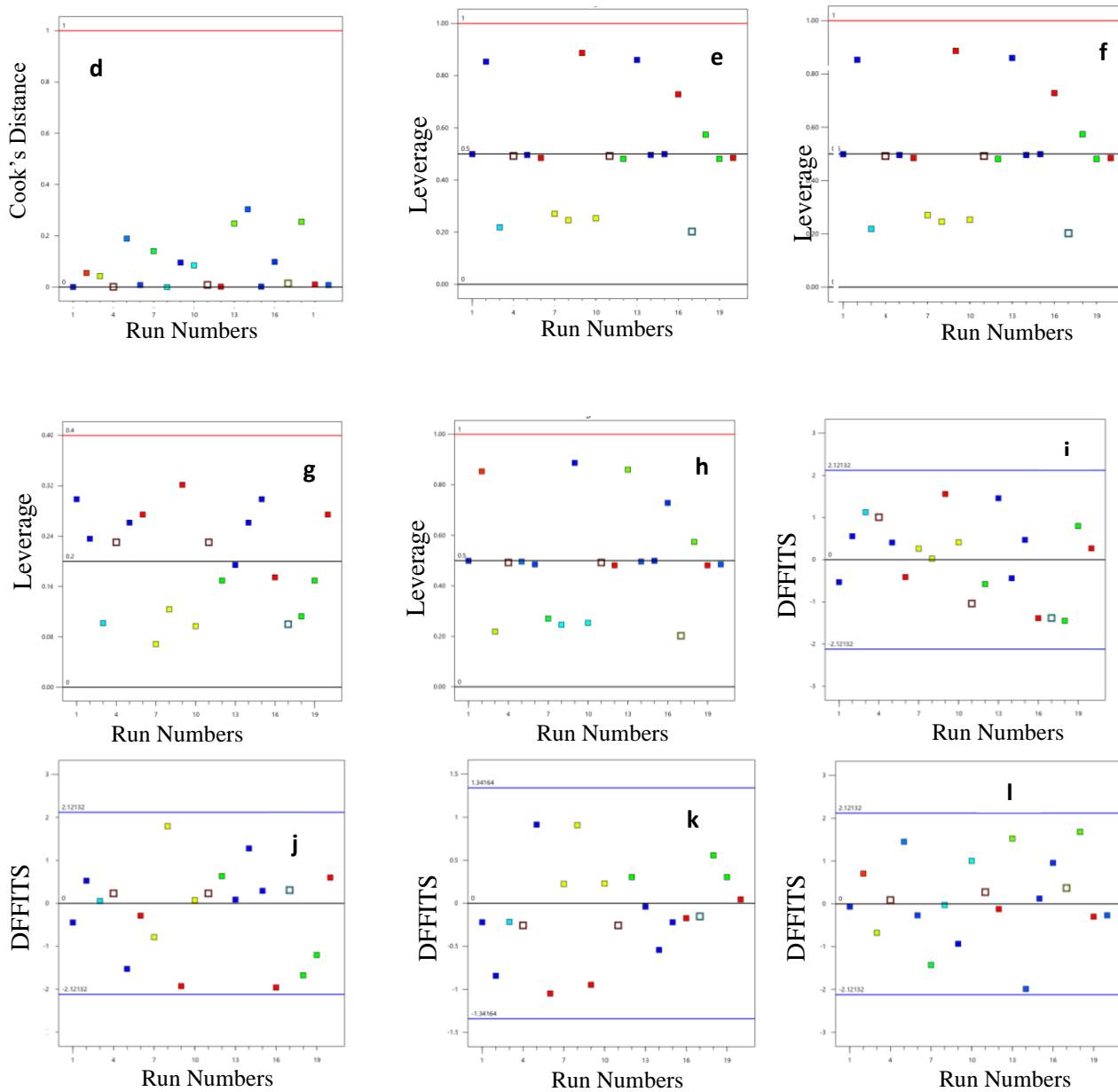


Figure 9.2. Cook's distance, Leverages, and difference in fits (DFFITS) for protein (a, e, and i), fiber (b, f, and j), total carotenoid content (c, g, and k), and hardness (d, h, and l) models

Thus, it is preferred to use an adj-R^2 to evaluate the model adequacy, and it should be over 90 % [409]. Table 9.4 shows that R^2 and adj-R^2 values for the models did not differ dramatically, indicating that non-significant terms have not been included in the model. The models' sufficiency precision values were greater than 4, and it may be inferred that they can be used to track the design space [411]. Thus all four responses were considered adequate to describe the effect of variables on the quality of *Kemesha*. Figure 9.2(a-l) indicates the difference in fits (DFFITS), Leverages, and Cook's distance for firmness, fibre, protein, and total carotenoid contents. There are no outliers

or unforeseen mistakes in the model because, as can be shown, all of the leverage values are inside the range. Also, the cook's distance and DFFITS plots confirmed the model's reliability because the values are within the specified range [408]. The estimated regression coefficients of the proposed models for each response are given in Table 9.5.

Table 9.5. The Estimated regression coefficients of the proposed models for each response

Variable	Protein	Fibre	TCC	Firmness
A	10.96 ^a	2.55 ^a	5.80 ^a	969.66 ^a
B	13.54 ^a	3.85 ^a	7.69 ^a	953.77 ^a
C	8.79 ^a	7.01 ^a	39.27 ^a	615.13 ^a
D	11.97 ^a	-197.74 ^a	2.15 ^a	-5256.75 ^a
AB	3.71 ^a	-0.4139 ^d	-	235.92 ^a
AC	1.31 ^c	-1.15 ^c	-	710.21 ^a
AD	-5.10 ^d	225.33 ^a	-	10335.45 ^b
BC	2.09 ^c	-1.82 ^b	-	413.05 ^a
BD	-2.87 ^d	216.77 ^a	-	9119.22 ^b
CD	-0.9046 ^d	214.64 ^a	-	10153.58 ^b

Note: Common wheat flour (A), Germinated haricot bean flour (B), ultrasonicated fine-milled pumpkin flour (C), Carboxy methyl cellulose (D), total carotenoid content (TCC); a, Significant at .0001 levels, b, Significant at 0.01 levels, c, Significant at 0.05 levels, d, Not Significant at 0.05 levels

The estimated regression coefficients shows the severity of one factor when all other variables are held constant by estimating the expected change in response per unit change in factor value [399].

9.3.4. Effect of Variables on the Protein Content of *Kemesha*

According to Figure 9.3 (a), the greatest effect on protein content was related to GHBF. A quadratic model effectively explained how the protein content and blend proportions relate to one another ($R^2= 0.97$ and $\text{adjust-}R^2= 0.96$). The linear blends significantly affected the protein content. In contrast to the wheat-pumpkin flour blends, the binary (wheat-haricot bean flour) mix was synergistic and positively affected the volume for a maximal response of protein content (Figure 9.3 a). As demonstrated in Table 9.1, the protein content ranged from 9.54% to 13.64%. The maximum protein content in the formulation consisted of 66% CWF, 30% GHBF, 5% UFPF flours, and 2% CMC (run 5, protein content: 13.64). According to the findings, the mixture of these ingredients improved the protein content of *Kemesha* by 53.25 % compared to the control

Kemesha. Protein content increased significantly when the proportion of GHBF flour increased; however, it fell slightly when the fraction of UFPF flour increased. Previously similar reports were done on pasta and noodle protein enhancement using common bean flour [412][413]. Moreover, Shogren, Hareland, and Wu [414] revealed that the protein content of pasta increased by 54% when soy was added to it (at a level of 50%) compared to the control sample. The greater protein level of the sprouted haricot bean flour used in preparing composite flour may be responsible for the rise in protein content in *Kemesha*.

9.3.5. Effect of Variables on the Fibre Content of *Kemesha*

The fibre content of *Kemesha* ranged from 2.65% to 5.88%, as shown in Table 9.1. In comparison to the control, *Kemesha* from a blend of 61% CWF, 16% GHBF, 20% UFPF, and 3% CMC (run 12) showed a considerably ($p < 0.05$) higher fibre content. These combinations increased the amount of fibre by 7.35 fold compared to the control sample. The analysis of fibre content indicated that UFPF had a significant impact on the *Kemesha* fibre content, with a decrease in wheat flour percentage leading to an increase in fibre content. The relationship between the blend proportions and the fibre content was adequately described by a quadratic model Table 9.5 with $R^2=0.99$ and $\text{adj-} R^2= 0.99$. The fibre content is significantly ($P > 0.05$) affected by the linear mixes (Table 9.5) and (Figure 9.3 b). With the exception of the binary (wheat-haricot bean flour) blend, which had a minimal effect on fibre content, the other blends had a favorable impact on fibre content Figure 9.3. (b). The fibre content of *Kemesha* showed an increasing trend with a parallel increase in the proportion of ultrasonicated fine-milled pumpkin flour due to its high fibre content (14.22 ± 0.30) as compared to GHBF (6.2 ± 0.40) and common wheat flour (1.83 ± 0.10). Figure 9.3 (b) shows that the amount of fibre significantly increased when the ratio of pumpkin and haricot bean flour was increased but reduced when the ratio of wheat flour was increased. Also, a similar trend of rising fibre content together with rising legume content for composite flour has been documented [415]. According to Khan et al. [416], adding pumpkin flour to wheat flour increases the fibre content of biscuits. According to Gull, Prasad and Kumar [410], incorporating high-fibre material enhances pasta's nutritional and functional quality. Since *Kemesha* is regarded as a traditional cuisine made primarily from common wheat flour, this is crucial to improving the fibre content from underconsumed pumpkin and haricot bean for producers.

9.3.6. Effect of Variables on the Carotenoid Content of *Kemesha*

The carotenoid content of developed *Kemesha* products ranged from 5.12 to 29.21 μ g/g. The statistical analysis suggested a linear model with $p < 0.001$. The model shows the goodness of fit because it was considerable, and lack-of-fit was insignificant (Table 9.4). The highest carotenoid content was observed in the combination of 61% CWF, 16% GHBF, 20% UFPF, and 3% of CMC (Table 9.1), and the lowest was found in the control (0.14 μ g/g) (Table 9.7). The total carotenoid content was positively impacted by UFPF flour, followed by GHBF flour, but negatively impacted by common wheat flour, as shown in Figure 9.3 (c), where the linear blend coefficients significantly ($p < 0.05$) affected the score. As previously mentioned, this is owing to the pumpkin's high carotenoid concentration [324], and its integration into *Kemesha* at various degrees considerably boosted the carotene content. With the economically effective utilization of underutilized greens, enriching low-carotenoid content foods with high-carotenoid foods like pumpkin may help fight blindness issues [417]. Also, adding more pumpkin flour improved the food's functional qualities regarding its phytochemical content [418]. In a related study, Khan et al. [416] found that adding pumpkin flour to biscuits raises their carotenoid concentrations. But as depicted in Figure 9.3 (d), adding carboxymethyl cellulose to the *Kemesha* did not significantly affect total carotenoid content.

9.3.7. Effect of Variables on the Firmness of *Kemesha*

Firmness is among the most crucial qualities of *Kemesha*. According to Table 9.4, while the lack-of-fit is insignificant, the model is significant. This means that the possibility of an error occurring is low. Table 9.1 displays that the firmness of the *Kemesha* varied between 882.85 g (run 2) and 1260.46g (run 9). The hardness of run 9 was 1.39 times higher than the control sample. As shown in Figure 9.3 (e and f), firmness decreases as a proportion of both UFPF and GHBF increases, but with an increase of CMC percentage in the blends, the *Kemesha* gets harder and harder. Regression coefficient Table 9.5 showed that the firmness of *Kemesha* samples was significantly affected ($p \leq 0.05$) by the CMC at a quadratic level. In general, firmness is reduced by replacing common wheat flour with pumpkin and haricot bean flour by keeping CMC constant (Figure 9.3 (e)). The general trend observed is a progressive reduction in *Kemesha* firmness with increasing fibre concentration. The disruption of the protein starch matrix within the *Kemesha* microstructure by fibre, as it does in pasta, may be responsible for the drop in hardness [419]. It

could be associated with a weakening gluten network [418] and as well as poor availability of water to develop the gluten network [420]. According to Gatta et al. [421], foreign proteins that prevent the development of gluten-starch complexes may lessen the stiffness. In addition, the firmness response of the *Kemesha* reached the maximum value when the proportion of CMC increased. The formation of complexes may cause this due to the interaction of hydrophilic groups on starch, CMC, fat, and protein, thereby improving the structure of *Kemesha* [422][423]. Similar experiments showed that adding xanthan gum and locust bean gum at 2.5–10% significantly increased the stiffness of pasta [126]. As Widelska et al. [397] stated, hydrocolloids' binding effect of water-soluble starch improved the texture of gluten-free pasta. CMC can increase the viscosity of the *Kemesha* dough, which can affect the texture of the final product. Higher viscosity can lead to a firmer and more elastic texture, which is desirable in *Kemesha* products. According to Kamali Roustae *et al.* [408], firmness depends on the level, kind, and interaction of the flours incorporated with the product.

9.3.8. Optimized Level of Ingredients

To produce functional *Kemesha*, Design-Expert Software (version 13.0) was used to determine the ideal variable level and the extrapolative value of responses per the predetermined goals with maximum desirability function. A good quality functional *Kemesha* should have a high level of fibre, TCC, protein content, and firmness, so the criteria target for responses is maximum. Optimization was done by maximizing the amount of protein, fibre, TCC, and firmness. The numerical response analysis found that optimum values were 63.00 g of CWF, 19.01 g of GHBF, 14.51 g of UFPF, and 3.48 g of CMC with 0.596 desirabilities. Desirability demonstrates the effectiveness of the optimization objective function, displaying the program's capacity to satisfy user wishes per the standards established for the finished output to reach a satisfactory compromise [422].

The numerical optimization finds a point that maximizes the desirability function. Protein, fibre, total carotenoid, and firmness had predicted values of 11.57 g/100 g, 4.70 g/100 g, 20.79 g/100 g, and 1110.04 g, respectively, under the optimal circumstances. The amount of protein and fibre in the optimal sample was 1.30 and 3.76 times higher than in the control sample. The validation findings showed good agreement between experimental and predicted response values and no statistically significant difference between them, proving the model's applicability (Table

9.4). Also, if the relative standard error (RSE) or the difference between the predicted and actual values derived from the optimal conditions is less than 2% (Table 9.6), it demonstrates the validity of the suggested model based on the D-optimal design [424] [425].

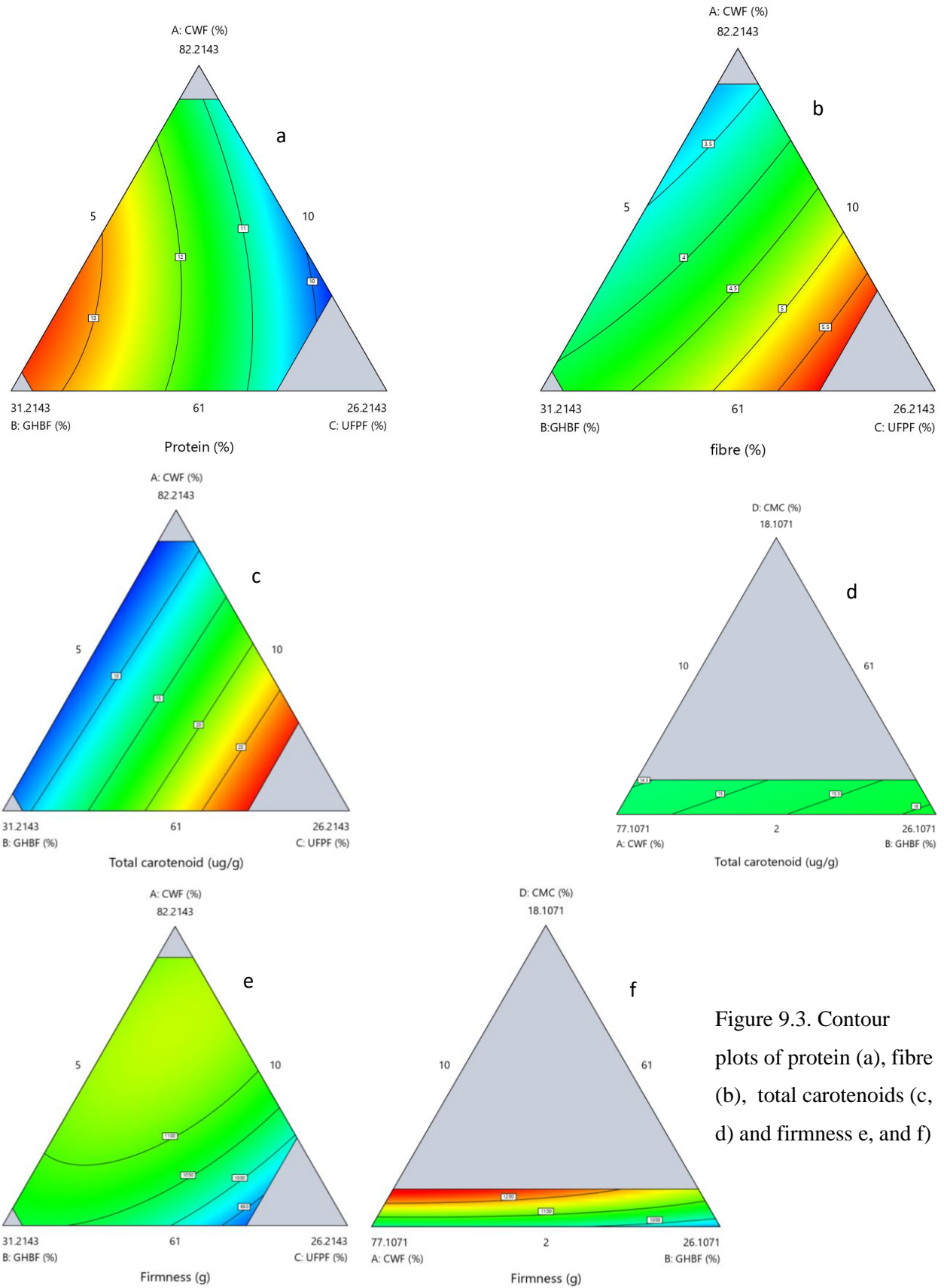


Figure 9.3. Contour plots of protein (a), fibre (b), total carotenoids (c, d) and firmness e, and f)

Therefore, the finalized equation for each variable generated by Design-Expert 13.0 software is acceptable for use in the *Kemesha* formulation.

Table 9.6. actual and predicted values of protein, fibre, TCC, and firmness of optimal formulation

Independent variable				Protein			Fibre			Total carotenoid			Hardness		
CWF (%)	GHBF (%)	UFPP (%)	CMC (%)	Actual value	Predicted value	RSE (%)	Actual value	Predicted value	RSE (%)	Actual value	Predicted value	RSE (%)	Actual value	Predicted value	RSE (%)
63.00	19.01	14.51	3.48	11.64	11.57	0.61	4.81	4.75	1.26	20.89	20.78	0.53	1114.52	1110.57	0.36

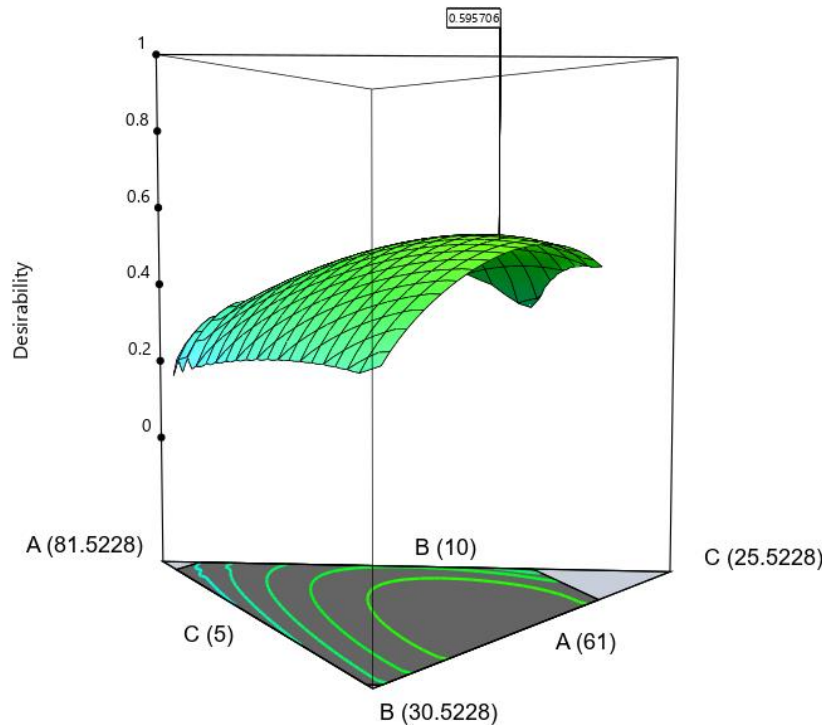


Figure 9.4. A 3D plot of the desirability function

9.3.9. Chemical Properties of Control and Optimized *Kemesha*

Table 9.7 indicates that the moisture content of the optimized *kemesha* sample (10.03 ± 0.24) was found to be slightly but not significantly higher ($P < 0.05$) than that of the control *kemesha* sample (9.22 ± 0.85). The higher moisture content in optimized *Kemesha* may be due to the higher water-holding capacity of fibres in pumpkin and haricot beans during dough formation. Understanding how a product's water content influences its shelf life is critical since abundant water could encourage the development of harmful microbes [426]. In similar studies, the increase in moisture content with the addition of gums in noodles was also reported by Shere, Devkatte and Pawar [427].

Table 9.7. Proximate and phytochemical composition of control and optimized *Kemesha*

Activities	Control	Optimized
Moisture (%)	9.22±0.85 ^a	10.03±0.24 ^a
Ash (%)	2.41±0.27 ^b	2.95±0.09 ^a
Fat (%)	2.13±0.14 ^a	1.75±0.18 ^b
Protein (%)	8.90±0.62 ^b	11.64±0.12 ^a
Fibre (%)	1.25±0.15 ^b	4.81±0.39 ^a
CHO (%)	76.08±1.36 ^a	68.82±0.06 ^b
TCC (µg/g)	0.143±0.02 ^b	20.89±1.49 ^a
TPC (mgGA/g)	0.150±0.03 ^b	1.12±0.10 ^a
TFC (mgCE/g)	0.210±0.10 ^b	0.77±0.21 ^a

Values are mean ± standard deviation. This means sharing the same letters in raw are not significantly different from each other (student-t-test, $p < 0.05$; CHO; Carbohydrate; TCC, Total carotenoid content; TFC, Total flavonoid content; TPC, Total phenol content)

Table 9.7 depicted that while protein content increased (8.90±0.62 to 11.64±0.12) but fat content slightly decreased (2.13±0.14 to 1.75±0.18) with the incorporation of germinated haricot bean and ultrasonicated fine-milled pumpkin flour in *kemesha*. This might be due to a lower fat percentage in haricot bean and pumpkin flour and a higher percentage of protein in GHBF (Table 9.3). This low-fat level is also appropriate for customers who demand a low-fat diet. The fibre content of haricot bean and pumpkin flour-supplemented *Kemesha* was much higher than those prepared from common wheat flour only. As shown in Table 9.7, there was a prominent increment in fibre by 3.85 times as compared to the control *Kemesha*. The addition of haricot bean flour and ultrasonicated fine-milled pumpkin flour, which have higher fibre contents than regular wheat flour, is what caused the increase in fibre levels. There was a significant difference in carbohydrate content of optimized *Kemesha* and control. In general, carbohydrate content decreased progressively with adding haricot bean and pumpkin flour to *Kemesha*. The considerable reduction may be due to supplementing other nutrients by haricot bean and pumpkin flour. Ash content was also found to be increased significantly from 2.41±0.27 to 2.95±0.09 in optimized *Kemesha*. Another research showed that adding dried pumpkin powder to noodles raised their ash level [428].

9.3.10. Phytochemical Composition of Control and Optimized *Kemesha*

The rise in degenerative diseases, bad lifestyles, inactivity, and excessive consumption of foods high in fat and sugar are among the current social debates. The development of healthy food products has expanded in response to escalating consumer demand. The communities recognize

that the value of food intake should be nutritional and provide more advantages to overall health. One of the most important aspects of functional food research is examining the properties of naturally occurring active components (such as antioxidants like polyphenols) in extracts derived from particular food sources. High levels of active ingredients improve food's ability to promote health and improve consumers' quality of life [429][430][431]. In addition to their basic nutrients, pumpkin and haricot bean flour also include phytochemicals that may have positive health effects (chapter 8) and [17].

Tables 9.2 and 9.7 present the phytochemical compositions of flour and *Kemesha* samples, respectively. Common wheat flour's total phenolic and flavonoid contents were significantly lower ($p < 0.05$) than germinated haricot bean and ultrasonicated fine-milled pumpkin flour. *Kemesha* that has been modified had considerably greater levels of total phenolic (1.12 mg GAE/g), total flavonoids (0.770.21 mgCE/g), and total carotenoids (20.891.49 g/g) than control *Kemesha*. Figure 9.5 illustrates how optimized *kemesha* has a higher scavenging ability than unimproved *Kemesha*.

The increment in total phenolic and flavonoid content of optimized *Kemesha* samples may be due to higher phenolic content in ultrasonicated fine-milled pumpkin flour (Table 9.3). In general, the values of total phenolic content found in the present work were lower than those reported by Gallegos-Infante *et al.* [67] for pasta made with semolina and common bean flour, respectively. According to a related study, bean flour boosts the amount of phenolic acids and the antioxidant power of pasta dough. Faba seeds are rich in pro-health phytochemicals such as phenolic compounds, which increase the pro-health qualities of functional foods, according to Karkouch *et al.* [432]. According to research by Fernando-Panchon *et al.* [433] and Luo *et al.* [434], field beans' beneficial effects on health are directly related to their high antioxidant content. Given this, common wheat-germinated haricot bean- ultrasonicated fine-milled pumpkin *Kemesha* with the addition of CMC can be an important source of natural bioactive compounds. Phenolic compound-rich foods have been shown to possess antioxidant properties [429].

The addition of haricot bean and pumpkin flour, which are well-known to be effective sources of antioxidant components, may have contributed to the enhanced antioxidant activity in the case of the optimized *kemesha* Figure 9.5. Due to the contribution of antioxidant activity from both flours, as shown in Figure 9.5, the antioxidant activity of optimized *Kemesha* samples increased

significantly. According to the findings, mixing haricot bean and pumpkin flours into kemesha would be a practical strategy to market this product rich in phenols. According to Alberto et al. [429] study similar to this one, the DPPH test spaghetti manufactured with common bean flour had a higher value than the control spaghetti.

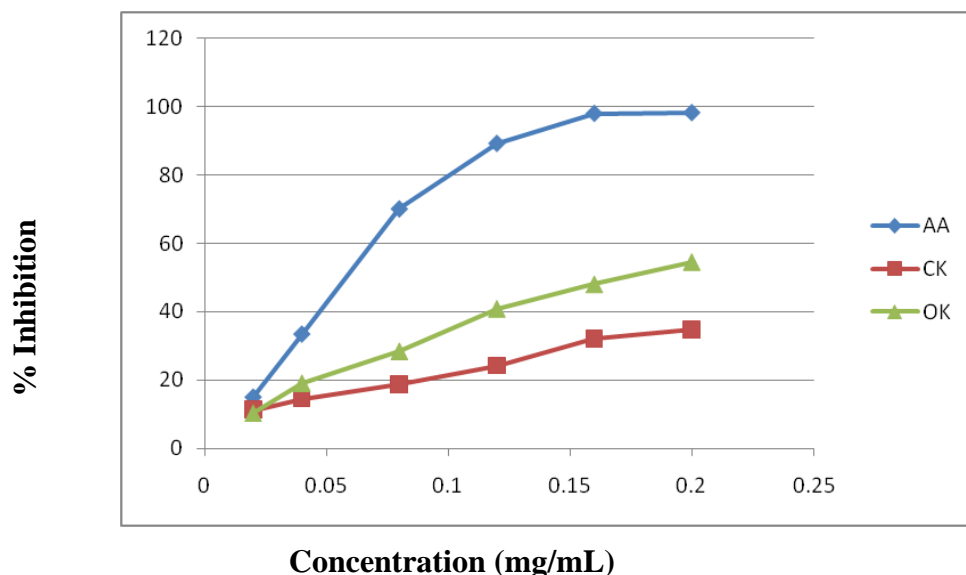


Figure 9.5. Free radical scavenging of methanolic extract of kemesha samples and controls (ascorbic acid). AA, Ascorbic acid; CK, Control *Kemesha*; OK, Optimized *Kemesha*

9.3.11. Physical Properties Control and Optimized *Kemesha*

Table 9.8. Physical properties control and optimized *Kemesha*

Sample	Control	Optimized
L*	89.38±2.24 ^a	74.44±2.50 ^b
a*	0.35±0.20 ^b	3.62±0.35 ^a
b*	15.09±2.24 ^b	31.09±1.84 ^a
C*	15.09±2.24 ^b	31.30±1.84 ^a
H*	88.65±0.76 ^a	83.35±0.70 ^b
DE	0.00±0.00 ^b	22.31±2.63 ^a
Water activity	0.46±0.01 ^a	0.49±0.02 ^a
pH	5.88±0.06 ^a	5.91±0.07 ^a

All values are mean ± standard deviation. This means sharing the same letters in columns are not significantly different from each other (student-t-test, p < 0.05). L*, whiteness; a*, redness; b*, yellowness; c, Chroma; h, hue angle.

Color is crucial when evaluating food goods' aesthetic appeal and market worth. Color values were measured for both raw optimized and control *Kemesha* samples. Control *Kemesha* displayed the highest lightness L* value (89.39±2.24), while optimized *Kemesha* revealed the lowest (74.44±2.50). This decrease in lightness may be due to color contribution from another component,

haricot bean and pumpkin flour. That means both flour samples were darker and red because of the natural pigment color of the flour. Also, as stated by Han *et al.* [435] and Gull, Prasad and Kumar [400], the decline in whiteness may be attributed to increased fibre content. Slightly higher values of L^* were obtained for a product prepared from common wheat flour comparable to a product made from durum wheat semolina [436]. Noodles made from semolina flour had a higher yellow hue but were darker compared to the Control *Kemesha*, as evidenced by the respective color parameter values of 68.9 ± 1.5 , 1.6 ± 0.4 , and 20.8 ± 1.1 for L^* , a^* , and b^* [437]. Optimized *Kemesha* showed the highest a^* value (3.62 ± 0.35) compared to control (common wheat flour) *Kemesha* (0.35 ± 0.20). This could be due to the red color contribution of the haricot bean flour [17] and pumpkin flour [428]. As depicted in Table 9.8, optimized *Kemesha* showed a higher b^* value or yellowness (31.09 ± 1.84) than control *Kemesha* (15.09 ± 2.24). This may be due to the carotenoids present in pumpkin flour [416][324]. Incorporating natural pigment not only promotes the sensory features of food but also functionally enhances the nutritional quality of food [438]. The chroma index and hue angle for the optimized *Kemesha* (31.30 ± 1.84 and 83.35 ± 0.70) were significantly different ($p < .05$) than *Kemesha* prepared only from common wheat flour (15.09 ± 2.24 and 88.65 ± 0.76). Results obtained for color change indicated that colors are not close to one another, with a relative difference of 22.31 ± 2.63 . This difference was associated with using common bean and pumpkin flour, which produced a darker color. The outcomes were better than those found in Gallegos-Infante *et al.* [67] study on pasta made with common bean flour. Also, it was discovered by Setady *et al.* [439] that the addition of various additives to pasta noodles improved the color shift.

The water activity and pH of optimized and control *Kemesha* were not significantly ($p > 0.05$) different from each other (Table 9.8). Water activity refers to the amount of water available for microbial growth and chemical reactions, while pH affects the acidity or alkalinity of the noodles. Water activity, however, changed insignificantly from 0.46 ± 0.01 and 0.49 ± 0.02 with optimized *Kemesha* (higher moisture content); these data indicate that CMC binds water within the system. The pH is also increase insignificantly from 5.88 ± 0.06 to 5.91 ± 0.07 . This might be attributed to when dry beans are germinated, they tend to have a higher pH compared to conventional wheat flour. This is because the enzymes activated during germination break down complex carbohydrates into simpler sugars, which can create a more alkaline environment. As a result, this

could potentially lead to an increase in the pH of the *Kemesha* if germinated dry beans are used as an ingredient [440].

9.3.12. Texture and Cooking Properties of Control and Optimized *Kemesha*

The test consists of compressing bite-size pieces of food two times in a motion that simulates the jaw’s action and extracting several textural parameters from the resulting force-time curve. Consumer acceptance of cooked *Kemesha* is greatly influenced by its firmness and stickiness. The textural properties of control and optimized *Kemesha* were presented in Table 9.9. The control *Kemesha* displayed the maximum cohesiveness (shows the strength of the internal link) and adhesiveness (24.94 ± 5.22 g*s), whereas the optimized *Kemesha* exhibits the highest firmness, a force required to compress a substance between molar teeth [405], (1110.05 ± 59.93), springiness (0.54 ± 0.07), and chewiness (181.80 ± 42.88), in that order. Because it takes more effort to chew before swallowing, *Kemesha*, with a higher degree of firmness, also tends to have higher chewiness values. The optimized *Kemesha* adhesiveness was insignificantly lower than the control *Kemeshas*’.

Table 9.9. Texture and Cooking properties of control and optimized *Kemesha*

Activities	Control	Optimized
Hardness (g)	904.94 ± 68.91^b	1110.05 ± 59.93^a
Springiness	0.28 ± 0.06^b	0.54 ± 0.07^a
Cohesiveness	0.45 ± 0.09^a	0.31 ± 0.08^b
Adhesiveness (g*s)	24.94 ± 5.22^a	22.33 ± 2.70^a
Chewiness (g)	114.40 ± 33.00^b	181.80 ± 42.88^a
Water absorption (%)	180.62 ± 12.70^b	220.68 ± 8.33^a
Cooking loss (%)	7.25 ± 0.63^a	4.95 ± 0.18^b
Volume increase (%)	216.50 ± 10.98^b	250.55 ± 6.78^a
Cooking time (min)	6	5.3

All values are mean \pm standard deviation. This means sharing the same letters in rows are not significantly different from each other (student-t-test, $p < 0.05$).

According to Oduro-Obeng, Fu and Beta [441], adhesiveness is related to the number of starch granules that exudate from the pasta matrix into the cooking water and coat the product’s surface. Similar research on pasta by Widelska et al. [442] with the addition of xanthan gum led to the formation of a continuous protein matrix and a stiff protein network that avoids excessive material leaking during cooking and lowers pasta adhesiveness. Also, Padalino *et al.* [443] reported a similar finding on gluten-free spaghetti; as hydrocolloids were added, adhesiveness was lowered.

Optimized *Kemesha* samples showed a significant increase in springiness compared to the control. Springiness indicates the ability of the *Kemesha* to return to its original shape after deformation. This could also be improved by using CMC because the interactions among their polymer chains (hydrophobic interactions, hydrophilic interactions, as well as H-bonding) could provide elasticity or flexibility in the *Kemesha*[444].

In Table 9.9, cooking loss, water absorption, and volume gain are some of the qualities of the *kemesha* cooking process that are shown. It is preferable for *Kemesha* to have little leached solid in cooked water, indicating *Kemesha* with a compact texture. During cooking, the solid leached is widely used to indicate the overall cooking performance; the low amounts of residue indicate high-quality cooked *Kemesha*. Cooking loss is undesirable, and according to Ugarčić-Hardi *et al.*[445], it should not exceed 10% of the dry weight. A significant decrease ($p < 0.05$) in the cooking loss was reported on the optimized *Kemesha*, containing 3.48% carboxy methyl cellulose, compared to the control *Kemesha*. While the cooking loss of optimized *Kemesha* was 4.95% but that of the control *Kemesha* was 7.25%. The degree of *Kemesha* hydration can be measured as the water absorption capacity index. The optimized *Kemesha's* capacity to absorb water was higher than the control *Kemesha's*, at 220.68% versus 180.62%, respectively. Comparing the functional *Kemesha* to the control, the volume rise increased significantly ($p < 0.05$), from 216.50 to 250.55%. According to Cristina, Paes and Pereira [6], an ideal volume increase is found between 200 and 300%, so the pasta is considered good quality. With regard to this classification, all the samples presented good quality (Table 9.9). The *kemesha's* ideal cooking time was reduced from 6 minutes for the control to 5.3 minutes. Most probably, due to the dilution of gluten, the starch-protein network will be weakened, and it facilitates water diffusion through the food matrix, reducing the time that the water needs to reach the food center during the cooking process [446]. Furthermore, the inclusion of carboxymethyl cellulose can augment the dough's ability to retain water, consequently leading to accelerated hydration of the *Kemesha* while it is being cooked. This expedited hydration process ultimately reduces the required cooking time. Additionally, carboxymethyl cellulose have the potential to enhance heat transfer during cooking by facilitating improved contact between the *Kemesha* and the surrounding hot water. This heightened heat transfer further contributes to a swifter cooking process.

According to Gull, Prasad and Kumar [400], during cooking, soluble starch and other soluble components, including nonstarch polysaccharides, leach out into the water, and as a result, the cooked water becomes thick. According to Larrosa *et al.*[404], a high loss could be due to the absence of a protein reticule with a well-structured structure, which would prevent the excessive swelling of the starch granules and the ensuing dispersion of ingredients in the cooking water. But including carboxymethyl cellulose, which enhanced the gluten network and formed a matrix with the gluten proteins where starch granules were embedded and reduced the solid loss, may be responsible for this decrease in cooking loss [400] [419]. Moreover, this might result from the strong network between gum and starch, with the starch granules strongly adhering to the gum's surface [442]. Due to the inclusion of CMC, it was also reported by Chillo *et al.* [446] and Shiau [447] that the cooking loss of spaghetti decreased. Hydrocolloids can make pasta with a decent texture and less cooking loss, which is acceptable, according to Gull, Prasad, and Kumar [410]. So, these studies agree with the above finding and reported a positive effect of CMC addition on the cooking loss indicating a good *Kemesha* quality. The hydrophilic properties of CMC may be the cause of the enhanced water absorption in the improved *Kemesha* [448][449][442]. Similarly to this, it has been suggested by Kraithong and Rawdkuen [450] that hydrocolloids may improve the rehydration of noodles because of their strong capacity to bind or engulf water molecules via the hydroxyl groups of their polymer chains. In addition, the increased cooked weight may be due to water binding and water holding capacity of carboxy methyl cellulose and both the haricot and pumpkin flours. In similar studies on pasta by Cristina *et al.* [6], if the minimum values of weight gain or water absorptions are 100%, it is characterized as a good quality pasta; therefore, both optimized and control *Kemesha* presented a satisfactory water uptake.

9.3.13. Sensory Properties of the Control and Optimized *Kemesha*

All the panelists have detected *Kemesha* characteristics based on different properties in Table 9.10. An insignificant reduction in scores of the odor was observed for optimized *Kemesha* samples. The results of the sensory evaluation of dry uncooked samples indicate that optimized *Kemesha* significantly increased the scores of surface smoothness and resistance to break from 7.40 ± 1.07 to 8.40 ± 0.52 and 7.10 ± 1.20 to 8.20 ± 0.79 , respectively. There was a significant difference between the control and the optimized *Kemesha* in terms of appearance and overall acceptability. The color, homogeneity, and resistance to breaking seem to be the main ones responsible for the increase in the sample's overall quality. This result can be due to the fact that

CMC had a synergistic effect when blended with wheat flour by providing a considerable increase in viscosity [395].

Table 9.10. Sensory properties of raw and cooked control and optimized *Kemesha*

Activities	Control	Optimized
Surface smoothness	7.40 ±1.07 ^b	8.40±0.52 ^a
Resistance to break	7.10±1.20 ^b	8.20±0.79 ^a
Odor	8.20±0.92 ^a	7.50±0.97 ^a
Appearance	7.50±0.85 ^b	8.30±0.67 ^a
OVA	7.30±0.67 ^b	8.20±0.92 ^a
Cooked <i>Kemesha</i>		
Texture	7.40±0.97 ^b	8.20±0.63 ^a
Color	7.30±0.95 ^b	8.20±0.92 ^a
odor	8.10±0.57 ^a	7.40±0.97 ^a
Appearance	7.30±0.82 ^b	8.10±0.57 ^a
OVA	7.20±0.79 ^b	8.10±0.74 ^a

All values are mean ± standard deviation. This means sharing the same letters in columns are not significantly different from each other (student-t-test, $p < 0.05$). ; OVA, Overall acceptability

Cooked optimized *Kemesha* was perceived to have higher textural (8.20±0.63), color (8.20±0.92), and appearance (8.10±0.57) acceptability than *Kemesha* prepared only from common wheat flour. The optimized *Kemesha* was perceived as having more yellow than the control *Kemesha*. A noticeable difference was observed in the appearance of optimized *Kemesha* as the color was yellowish, and surface smoothness was higher in correlation to the control. Optimized *Kemesha* had higher scores in terms of overall liking as compared with the control due to the consequence of the pumpkin color and improvement in texture. The beany odor was not perceivable in control, whereas it was somewhat beany, and pumpkin flavor was perceivable on optimized *Kemesha*. The slight difference in the characteristic aromatic flavor of haricot bean and pumpkin flour to wheat flour could have been the reason for the odor of *Kemesha* samples.

Moreover, the structuring agents did not alter the odor of the samples, which was pleasant [395]. In general, the structuring agent has more affinity to starch and forms a stable polymeric network, which is important for the entrapment of carbohydrates and good *Kemesha* quality. The sensory properties of the spaghetti samples were improved by Chillo *et al.* [446] and (L. Padalino *et al.* [395], discovered that CMC slows down the diffusion of amylose molecules from the internal part to the spaghetti surface. The *Kemesha* samples displayed good elasticity and firmness and low

adhesiveness. Similarly, Yadav *et al.*[451] also observed an increase in overall acceptability with CMC for non-wheat pasta based on pearl millet flour containing barley and whey protein concentrate. In line with this study, Bharath Kumar and Prabhasankar [437] stated that noodles prepared with different cereal flours, vegetables, and pulses showed increased acceptability among consumers, with improved quality characteristics.

9.4 Conclusions

A survey on the production practices and mode of utilization of *kemesha* was conducted to provide information that would be used to improve the product's processing, nutritional quality, and acceptability. As the handling environment, equipment, and facilities are not assessed, it is impossible to guarantee a continuously sterile environment for traditional *Kemesha* production. One method of improving *Kemesha* is to standardize processing conditions for reproducibility and consistency of quality features. According to the acceptance test on the standardized *Kemesha*, the best sample was *Kemesha* dried at 50 °C. The chemical and physical properties of *Kemesha* formulations were effectively improved by including germinated haricot bean, ultrasonicated fine-milled pumpkin flour, and CMC, which improved *Kemesha* as a functional food. D-optimal mixture design was used to optimize the formulation of *Kemesha* with better nutritional, cooking, and sensory characteristics as compared to the control sample. The optimal formulation contained 63.00 g of common wheat flour, 19.01 g of germinated haricot bean flour, 14.51 g of ultrasonicated fine-milled pumpkin flour, and 3.48 g of carboxymethyl cellulose per 100 g of flour. The amount of fibre and protein in the optimal sample was 3.85 and 1.31 times higher than the control *Kemesha*, respectively. Total phenolic, carotenoid, and antioxidant properties of optimized functional *Kemesha* were significantly higher than control *Kemesha* and may offer the inherent health benefits of pumpkin and germinated haricot bean, especially phytochemicals, to the consumer. This could substantially impact increasing consumption of *Kemesha* from underused crops like haricot beans and pumpkin flour, which is both functionally and nutritionally acceptable. Carboxymethyl cellulose (CMC) improved sensory and cooking quality aspects such as cooked loss, water absorption, and volume increase. It also raised hardness and lowered adhesiveness significantly ($P \leq 0.05$). The sensory evaluation results showed that color changes increased the overall liking of the optimized treatment compared to the control sample. This study documented information about *Kemesha* processing methods, which could serve as useful and informative data for further studies

to scale up this product. In addition, this study could also give the food industry vital knowledge on the development of new functional foods and the possible use of underconsumed pumpkin and haricot bean crops in food formulations. In general, this form of *Kemesha* will provide vital nourishment as well as health benefits, although its intake is not yet widespread in the country.

CHAPTER 10: GENERAL CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

This study aimed to produce and assess the quality of haricot bean and pumpkin flour in order to develop a functional *Kemesha*. *Kemesha* is historically made and eaten in a tasty way, but the

processing techniques for preparing it are not yet standardized. Instead, preparation techniques have primarily been passed down orally rather than through written recipes. To be able to provide information that would be used to improve the processing, nutritional quality, and acceptability of the product, a survey on the production methods and mode of consumption of *kemesha*, a traditional Ethiopian cereal-based food product, was done. The existing homemade methods for the preparation of *Kemesha* were studied and standardized through quality characterization to ensure that consistency in product quality and quantity is achieved. The findings confirmed that the sensory attributes of raw and cooked *Kemesha*, surface smoothness, resistance to break, appearance, color, texture, and overall acceptability of the standardized *Kemesha* dried at 50 °C were preferable to *Kemesha* dried at 70 °C.

Consumers are becoming more mindful of their food choices as healthy diets become more well-known. There is a growing demand for foods containing constituents with potential health benefits. But *Kemesha*, a wheat-based food, is also low in protein and health-protective bioactive components such as total phenols (0.15 ± 0.03 mgGA/g), flavonoids (0.21 ± 0.10 mgCE/g), carotenoids (0.14 ± 0.02 µg/g), and antioxidant properties. Thus, adding wheat flour with other inexpensive staples like haricot beans & pumpkins benefits the nutritional and functional status of the *Kemesha*.

Moreover, haricot beans are a valuable source of several nutrients and phytochemicals that guard against various illnesses. Despite their importance, bean consumption is low in Ethiopia. Understanding the physical characteristics of haricot beans is crucial because it furnishes the necessary information for creating different processing machines, procedures, and controls when producing a new consumer product. It is also vital for assessing and maintaining the quality of end products, as well as designing machine components. Eventhough, haricot beans offer various nutritional benefits, they also contain anti-nutritional factors that require processing before consumption. The study discussed highlights the impact of different processing methods, such as soaking, autoclaving, germination, and germination followed by autoclaving, on the chemical composition, physical, and functional properties of haricot beans flour. The findings suggest that germination can positively affect the pasting, thermal, and structural properties of four improved haricot bean varieties. Therefore, processing methods can significantly influence the quality and

nutritional value of haricot beans, and appropriate processing methods should be employed to optimize their nutritional benefits.

Pumpkin is a rich source of total carotenoids, which gives the optimized *Kemesha* its characteristic yellow color. Traditional air drying methods can have a negative impact on the color, nutritional content, and bioactive component of pumpkin flour due to high temperatures used during the process. To address this, pretreatment methods, including ultrasound, microwave, and ultrasound followed by microwave blanching, were employed before drying to shorten the drying time while preserving the quality of the pumpkin flour. The current study has investigated the effects of these pretreatment methods on the physical, chemical, functional, and structural properties of pumpkin flour. The combination of pretreatment with particle size reduction led to highly acceptable pumpkin flour with high bioactive components and a yellow color closer to freeze-dried pumpkin flour. However, freeze-drying resulted in the best quality product in terms of total phenolic, flavonoid, carotenoid content, antioxidant activity, and color values compared to untreated and pretreated prior to fluidized bed drying methods. Overall, the study suggests that pretreatment methods can improve the quality of pumpkin flour, but the choice of drying method can significantly impact the nutritional and sensory properties of the final product.

In conclusion, the study demonstrated that blending germinated haricot bean flour, ultrasonicated fine-milled flour, and carboxymethyl cellulose (CMC) had a significant effect on the compositional, Textural, and cooking properties of *Kemesha*. Increasing the level of both flours in the *Kemesha* formulation resulted in higher protein, fibre, and total carotenoid contents. CMC improved sensorial and textural properties, such as increased firmness and decreased adhesiveness, as well as cooking quality attributes such as cooking loss, water absorption, and volume increase. The use of a D-optimal mixture design enabled the optimization of the response parameters to obtain high-quality functional *Kemesha*. The study also highlighted the positive correlation between carotenoids and phenolics and antioxidant potentials, indicating that these natural antioxidants are present in legumes and pumpkin flours. Overall, the standardized and optimized *Kemesha* possessed a better nutritional profile, textural, cooking, and acceptability attributes compared to solely wheat-based *Kemesha*.

10.2 Recommendations and Perspectives

- It is recommended that Ethiopia launches a national effort to scientifically record traditional regional foods. This will help to create a database that will preserve knowledge about the preparation, preservation, and dietary suggestions for these traditional foods. Such databases will not only help to safeguard the rich cultural heritage of Ethiopia but also provide valuable information for nutritionists, dietitians, and researchers who are interested in studying the nutritional and health benefits of traditional Ethiopian foods. In addition, it will promote the use of locally available and affordable food resources, thereby contributing to food security and sustainable development in Ethiopia.
- To improve the production, handling, and consumption of *Kemesha*, it is imperative to raise awareness among young, educated men and women who are better prepared to understand and appreciate the usage of contemporary food processing.
- It is also vital to produce suitable packaging for the proper presentation of the *Kemesha* in order to boost consumer appeal and client loyalty.
- It is recommended that research efforts be focused on finding ways to use haricot beans and pumpkins more efficiently in order to address problems related to food security, protein deficiency, and the lack of bioactive components in the nation's food supply. This research could include investigating methods to increase the nutritional content of these foods, exploring novel ways to process and preserve them, and finding new applications for them in the food industry. By doing so, we can help to promote the consumption of these nutrient-rich foods and contribute to a more sustainable and secure food system. Additionally, this research could provide valuable information for farmers and food producers, helping to improve the quality and quantity of their harvests and create new economic opportunities in the local food industry.

REFERENCES

- [1] FAO, “The State of Food and Agriculture Rome, FAO,” Rome, 2016.
- [2] Ebru Eyidemir and M. Hayta, “The effect of apricot kernel flour incorporation on the physicochemical and sensory properties of noodle,” *African J. Biotechnol.*, vol. 8, no. 1,

- pp. 085–090, 2009.
- [3] Betoret E., N. Betoret, D. Vidal, and P. Fito, “Functional foods development: Trends and technologies,” *Trends Food Sci. Technol.*, vol. 22, no. 9, pp. 498–508, 2011.
- [4] F. Brouns and C. Vermeer, “Functional food ingredients for reducing the risks of osteoporosis,” *Trends Food Sci. Technol.*, vol. 11, no. 1, pp. 22–33, 2000.
- [5] A. Gull, K. Prasad, and P. Kumar, “Nutritional , antioxidant , microstructural and pasting properties of functional pasta,” *J. SAUDI Soc. Agric. Sci.*, no. March, 2016.
- [6] M. Cristina, D. Paes, and J. Pereira, “Proximate Composition and Technological Characteristics of Dry Pasta Incorporated With Micronized Corn Pericarp,” *Rev. Caatinga*, vol. 30, no. 2, pp. 496–502, 2017.
- [7] Shanthi, Z. Johnkennedy, K. Parvathi, D. Malathi, and et al. Thangavel K, “Studies on wheat based composite flour for pasta products,” *Diet, Indian J Nutr*, vol. 42, pp. 503–508, 2005.
- [8] A. D. Melese and E. O. Keyata, “Effects of blending ratios and baking temperature on physicochemical properties and sensory acceptability of biscuits prepared from pumpkin, common bean, and wheat composite flour,” *Heliyon*, vol. 8, no. 10, p. e10848, 2022.
- [9] Okafor, Enwereuzoh, ; Ibeabuchi, ; Uzoukwu, S. O. Alagbaoso, and C. Udenkwo, “Production of Flour Types From Black Bean (*Phaseolus Vulgaris*) and Effect of Ph and Temperature on Functional Physico-Chemical Properties of the Flours,” *Eur. J. Food Sci. Technol.*, vol. 3, no. 2, pp. 64–84, 2015.
- [10] Y. Maphosa and V. A. Jideani, “The Role of Legumes in Human Nutrition,” in *Functional Food - Improve Health through Adequate Food*, intechopen, 2017.
- [11] L. Azevedo *et al.*, “Black bean (*Phaseolus vulgaris* L.) as a protective agent against DNA damage in mice,” *Food Chem. Toxicol.*, vol. 41, no. 12, pp. 1671–1676, 2003.
- [12] M. Virginia, “Nutritional and health benefits of dried beans,” *Am. J. Clin. Nutr.*, vol. 100, no. SUPPL. 1, pp. 437S–42S, 2014.
- [13] M. Egounlety and O. Aworh, “Effect of soaking, dehulling, cooking and fermentation with *Rhizopus oligosporus* on the oligosaccharides, trypsin inhibitor, phytic acid and tannins of soybean (*Glycine max* Merr.), cowpea (*Vigna unguiculata* L. Walp) and groundbean (*Macrotyloma geocarpa* Ha,” *J. Food Eng.*, vol. 56, pp. 249–254, 2003.
- [14] Hefnawy, T.H., “Effect of processing methods on nutritional composition and anti-

- nutritional factors in lentils (*Lens culinaris*),” *Ann. Agric. Sci.*, vol. 56, no. 2, pp. 57–61, 2011.
- [15] Shang *et al.*, “The Diversity of Four Anti-nutritional Factors in Common Bean,” *Hortic. Plant J.*, vol. 2, no. 2, pp. 97–104, 2016.
- [16] A. M. Nakitto, J. H. Muyonga, and D. Nakimbugwe, “Effects of combined traditional processing methods on the nutritional quality of beans,” *Food Sci. Nutr.*, vol. 3, no. 3, pp. 233–241, 2015.
- [17] D. Wodajo and S. Admassu, “Haricot beans (*Phaseolus vulgaris* L.) flour : Effect of varieties and processing methods to favor the utilization of underconsumed common beans,” *Int. J. Food Prop.*, vol. 25, no. 1, pp. 1186–1202, 2022.
- [18] P. Sarkar, K. D. H. Lohith, C. Dhumal, S. S. Panigrahi, and R. Choudhary, “Traditional and ayurvedic foods of Indian origin,” *J. Ethn. Foods*, vol. 2, no. 3, pp. 97–109, 2015.
- [19] D. Atudorei and G. Gabriela, “Perspectives on the Use of Germinated Legumes in the Bread Making Process , A Review,” *Appl. Sci.*, vol. 10, p. 6244, 2020.
- [20] Denisa Atudorei, S. Stroe, and G. Gabriela, “Impact of Germination on the Microstructural and Physicochemical Properties of Different Legume Types,” *Plants*, vol. 10, p. 592, 2021.
- [21] Martins, Z. E., O. Pinho, and I. M. P. L. V. O. Ferreira, “Food industry by-products used as functional ingredients of bakery products,” *Trends Food Sci. Technol.*, vol. 67, pp. 106–128, 2017.
- [22] D. Mridula and M. Sharma, “Development of non-dairy probiotic drink utilizing sprouted cereals, legume and soymilk,” *Lwt*, vol. 62, no. 1, pp. 482–487, 2015.
- [23] D. H. Mitiku and T. Y. Bereka, “Effects of pumpkin (*cucurbita moschat*)/soybean (*Glycine max*) flour blends on functional, physic-chemical properties and sensory attributes of breads produced from whole wheat (*Triticum aestivum* L). *Carpathian J.*,” *Food Sci. Technol.*, vol. 13, no. 1, 2021.
- [24] Y. Lee, W. Chung, and H. Ezura, “Efficient plant regeneration via organogenesis in winter squash (*Cucurbita maxima*).,” *Plant Sci*, vol. 164, pp. 413–418, 2003.
- [25] F. O. Habwe and K. M. Walingo, “Food Processing and Preparation Technologies for Sustainable Utilization of African Indigenous Vegetables for Nutrition Security and Wealth Creation in Kenya,” *Int. Union Food Sci. Technol.*, no. May 2014, pp. 2–9, 2008.

- [26] See, N. Wan, and A. Noor, “Physico-chemical and sensory evaluation of breads supplemented with pumpkin flour,” *Asian Food J*, vol. 14, pp. 123–130, 2007.
- [27] N. K. Rastogi, “Recent trends and developments in infrared heating in food processing.,” *Crit. Rev. Food Sci. Nutr.*, vol. 52, no. 9, pp. 737–760, 2012.
- [28] M. Mieszczakowska-Frać, B. Dyki, and D. Konopacka, “Effects of Ultrasound on Polyphenol Retention in Apples After the Application of Predrying Treatments in Liquid Medium,” *Food Bioprocess Technol.*, vol. 9, no. 3, pp. 543–552, 2016.
- [29] B. Önal, G. Adiletta, M. Di Matteo, P. Russo, N. Ramos, and C. L. M. Silva, “Microwave and Ultrasound Pre-Treatments for Drying of the ‘Rocha’ Pear: Impact on Phytochemical Parameters, Color Changes and Drying Kinetics,” *Foods*, vol. 10, no. 853, pp. 1–18, 2021.
- [30] L. Wang, B. Xu, B. Wei, and R. Zeng, “Low frequency ultrasound pretreatment of carrot slices: Effect on the moisture migration and quality attributes by intermediate-wave infrared radiation drying,” *Ultrason. Sonochem.*, vol. 40, pp. 619–628, 2018.
- [31] Padalino, M. Mastromatteo, L. Lecce, F. Cozzolino, and M. A. Del Nobile, “Manufacture and characterization of gluten-free spaghetti enriched with vegetable flour,” *J. Cereal Sci.*, vol. 57, no. 3, pp. 333–342, 2013.
- [32] A. Schieber, F. C. Stintzing, and R. Carle, “By-Products of Plant Food Processing as a Source of Valuable Compounds,” *Trends Food Sci. Technol.*, vol. 12, pp. 401–413, 2001.
- [33] S. Ferris and E. Kaganzi, “Evaluating marketing opportunities for haricot beans in Ethiopia,” *Int. Cent. Trop. Agric.*, pp. 1–52, 2008.
- [34] A. K. Dhiman, K. D. Sharma, and S. Attri, “Functional constituents and processing of pumpkin: A review,” *J. Food Sci. Technol.*, vol. 46, no. 5, pp. 411–417, 2009.
- [35] Irene Dini, G. C. Tenore, and A. Dini, “Effect of industrial and domestic processing on antioxidant properties of pumpkin pulp,” *LWT - Food Sci. Technol.*, vol. 53, no. 1, pp. 382–385, 2013.
- [36] MONIKA Thakur, “Underutilized food crops: treasure for the future India,” *Food Sci. Res. J.*, vol. 5, no. 2, pp. 174–183, 2014.
- [37] Albayrak and E. Gunes, “Traditional foods: Interaction between local and global foods in Turkey,” *African J. Bus. Manag.*, vol. 4, no. 4, pp. 555-561., 2010.
- [38] Getaneh, Forsido SF, Y. BT, A. AA, M. AT, and A. Endale, “Traditional Food Processing Practices of Oats (*Avena Sativa*) and Its Contribution to Food Security in Gozamin

- District of Northwest Ethiopia,” *Afr. J. Food Agric. Nutr. Dev.*, vol. 21, no. 5, pp. 18083–18100, 2021.
- [39] V. Ittersum *et al.*, “Consumers’ Appreciation of Regional Certification Labels: A Pan-European Study,” *J. Agric. Econ.*, vol. 58, no. 1, pp. 1–23, 2007.
- [40] A. P. Volpentesta and S. Ammirato, “Networking Agrifood SMEs and Consumer Groups in Local Agribusiness,” *IFIP Int. Fed. Inf. Process.*, vol. 283, pp. 33–40, 2008.
- [41] A. Tregear, F. Arfini, G. Belletti, and A. Marescotti, “Regional foods and rural development: The role of product qualification,” *J. Rural Stud.*, vol. 23, no. 1, pp. 12–22, 2007.
- [42] M. Albayrak and E. Gunes, “Traditional foods : Interaction between local and global foods in Turkey,” vol. 4, no. April, pp. 555–561, 2010.
- [43] I. Ludmila and I. Terziyska, “Characteristics of traditional food – the viewpoint of the tourism business Characteristics of traditional food – the viewpoint of the tourism business In recent years there has been a clear shift in tourism demand from material expressions of culture t,” no. July, 2015.
- [44] J. Jordana, “Traditional foods: Challenges facing the European food industry,” *Food Res. Int.*, vol. 33, no. 3–4, pp. 147–152, 2000.
- [45] Miss Solanke Shweta Bhagvanrao, “Process Standardization of Ready-to-Eat Pearl Millet Snack Food (Kharodi) Master of Technology (Agril. Engineering) in Agricultural Process Engineering,” 2017.
- [46] M. Woube, “Promoting Underutilized Food Plant Species for Food Security in Ethiopia: a Research-Based Training Programme,” *Acta Hortic.*, no. 806, pp. 65–70, 2009.
- [47] Kehinde A. Taiwo, O. W. Oladepo, M. O. Ilori, and C. T. Akanbi, “A study on the Nigerian food industry and the impact of technological changes on the small-scale food enterprises,” *Food Rev. Int.*, vol. 18, no. 4, pp. 243–261, 2002.
- [48] O. C. Aworh, *Food technology and national development: A global perspective*. Ibadan, Nigeria: : Ibadan University Press., 2010.
- [49] M. Walingo, “Indigenous Food Processing Methods That Improve Zinc Absorption and Bioavailability of Plant Diets Consumed by the Kenyan Population,” *African J. Food, Agric. Nutr. Dev.*, vol. 9, no. 1, pp. 141–143, 2009.
- [50] F. Aworh O Charles, “The Role of Traditional Food Processing Technologies In National

- Development : the West African Experience.,” in *In Using food science and technology to improve nutrition and promote national development.*, no. May, J. R. Robertson, G. L. & Lupien, Ed. International Union of Food Science and Technology (IUFoST), 2008.
- [51] Samson A. Oyeyinka and K. O. Ramota, “Upgrading Traditional Food Processing Technologies,” *Food Stud. An Interdiscip. J.*, vol. 3, no. 1, pp. 1–8, 2014.
- [52] J. Dzikunoo, E. Letsyo, Z. Adams, D. Asante-Donyinah, and C. S. Dzah, “Ghana’s indigenous food technology: A review of the processing, safety, packaging techniques and advances in food science and technology,” *Food Control*, vol. 127, no. March, p. 108116, 2021.
- [53] Yusuf H. L, Igwegbe A.O, I. P. Y, and G. U, “Process Standardization of Kamsa: a Smoked Dried Meat Product, Using Sensory Evaluation Method,” *Saudi J. Eng. Technol.*, vol. 5, no. 9, pp. 330–336, 2020.
- [54] Spears MC and M. Gregoire, *Foodservice Organizations: A Managerial and Systems Approach*, 7th ed. New Jersey: Pearson, 2010.
- [55] M. T. Malaza, “The development, standardisation and acceptability of the traditional Tsonga-Shangaan dishes, Xigugu and Xiendla hi vomu for use in ethnic restaurants,” 2012.
- [56] Z. Hussain, “Importance of Standardized Recipes in Food Service Settings Short communication Mathews Journal of Diabetes & Obesity,” *Mathews J. Diabetes Obes.*, vol. 2, p. 2017, 2017.
- [57] S. V. Gokhale and S. S. Lele, “Retort process modelling for Indian traditional foods,” *J. Food Sci. Technol.*, vol. 51, pp. 3134–3143, 2014.
- [58] D. Qin, Y. Hara, V. Raboy, and H. Saneoka, “Characteristics and quality of Japanese traditional fermented soybean (natto) from low-phytate line,” *Plant Foods Hum. Nutr.*, vol. 75, pp. 651–655, 2020.
- [59] F. A. Oguntoyinbo, “Safety challenges associated with traditional foods of West Africa,” *Food Rev. Int.*, vol. 30, pp. 338–358., 2014.
- [60] S. V Anadani, S. H. Akbari, N. Kumar, and A. Ravani, “Processing and mechanization of Indian traditional food products,” vol. 9, no. 1, pp. 2313–2315, 2020.
- [61] Sanni L.O., A. A. Adebawale, T. A. Filani, O. B. Oyewole, and A. Westby, “Quality of flash and rotary dried fufu flour,” *J. Food Agric. Environ.*, vol. 4, pp. 74–78, 2006.

- [62] O. Charles Aworh, "Promoting food security and enhancing Nigeria's small farmers' income through value-added processing of lesser-known and under-utilized indigenous fruits and vegetables," *Food Res. Int.*, vol. 76, no. P4, pp. 986–991, 2015.
- [63] C. G. Kuyu and T. Y. Bereka, "Review on contribution of indigenous food preparation and preservation techniques to attainment of food security in Ethiopian," *Food Sci. Nutr.*, vol. 8, no. 1, pp. 3–15, 2020.
- [64] M. Sv and Syed Ih, "Standardization of process for preparation of Indian heritage food Sandga using pulses and ash gourd," vol. 6, no. 5, pp. 571–573, 2017.
- [65] M. L. López-Amorós, T. Hernández, and I. Estrella, "Effect of germination on legume phenolic compounds and their antioxidant activity," *J. Food Compos. Anal.*, vol. 19, no. 4, pp. 277–283, 2006.
- [66] Michael Ugen, A. Musoni, G. Cheminingwa, P. Kimani, and M. Mucharo, "Utilization of Common Bean for Improved Health and Nutrition in Eastern and Central Africa," *ASARECA- Transform. Agric. Improv. Livelihoods*, pp. 1–11, 2009.
- [67] J. A. Gallegos-infante, N. E. Rocha-guzman, R. F. Gonzalez-laredo, and L. A. Ochoa-martínez, "Quality of spaghetti pasta containing Mexican common bean flour (*Phaseolus vulgaris* L .)," *Food Chem.*, vol. 119, no. 4, pp. 1544–1549, 2010.
- [68] R. N. Tharanathan and S. Mahadevamma, "Grain legumes - A boon to human nutrition," *Trends Food Sci. Technol.*, vol. 14, no. 12, pp. 507–518, 2003.
- [69] M. G. Nkundabombi, D. Nakimbugwe, and J. H. Muyonga, "Effect of processing methods on nutritional, sensory, and physicochemical characteristics of biofortified bean flour," *Food Sci. Nutr.*, vol. 4, no. 3, pp. 384–397, 2016.
- [70] O. A. Olaoye, S. C. Ubbor, and C. J. Okakpu, "Use of composite flours of wheat and white beans (*Phaseolus vulgaris*) in bread making : influence on quality indices," 2016.
- [71] F. Sumargo, P. Gulati, S. A. Weier, J. Clarke, and D. J. Rose, "Effects of processing moisture on the physical properties and in vitro digestibility of starch and protein in extruded brown rice and pinto bean composite flours," *Food Chem.*, vol. 211, pp. 726–733, 2016.
- [72] J. A. Gallegos-Infante, L. A. Bello-Perez, N. E. Rocha-Guzman, R. F. Gonzalez-Laredo, and M. Avila-Ontiveros, "Effect of the addition of common bean (*Phaseolus vulgaris* L.) flour on the in vitro digestibility of starch and undigestible carbohydrates in Spaghetti," *J.*

- Food Sci.*, vol. 75, no. 5, 2010.
- [73] K. A. Bascuñán, M. Catalina, and V. Magdalena, “Celiac disease : understanding the gluten - free diet,” *Eur. J. Nutr.*, 2016.
- [74] K. B. Lakshmi, K. A. Kuna, and M. Prasuna, “Traditional Processes and Methods to Enhance,” vol. 28, no. August, 2018.
- [75] Lista EKA Yulianti, W. Setiaboma, A. N. Hakim, E. Widowati, N. Afifah, and R. Ekafitri, “The effect of beans types and soaking time on the characteristics of Indonesian traditional food ‘ Instant Borse ,’” *Food Sci. Technol*, vol. 2021, pp. 1–7, 2022.
- [76] Subramanian Balasubramanian, A. Borah, K. K. Singh, and R. T. Patil, “Effect of selected dehulled legume incorporation on functional and nutritional properties of protein enriched sorghum and wheat extrudates,” *J Food Sci Technol*, vol. 49, no. 5, pp. 572–579, 2012.
- [77] W. Prasert and P. Suwannaporn, “Optimization of instant jasmine rice process and its physicochemical properties,” *J. Food Eng.*, vol. 95, no. 1, pp. 54–61, 2009.
- [78] A. C. Fernandes, W. Nishida, P. Rossana, and C. Proenc, “Influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris* L .) cooked with or without the soaking water : a review,” no. 2008, pp. 2209–2218, 2010.
- [79] L. Fadlalla, E. Fadlalla, M. Ahmed, and S. Mohamed, “Effect of Soaking on Nutritional Value of Sorghum (*Sorghum bicolor* L),” vol. 6, no. 11, pp. 1360–1365, 2017.
- [80] S. Queiroz *et al.*, “Contents the Common Bean with in a Domestic Preparation but Reduced Did Not Interfere the of Raffinose-Type Oligosaccharides Nutritive Value The common bean is a legume of high economic and social expression , constituting the basic food of various popula,” pp. 283–289, 2002.
- [81] M. M. Pedrosa, E. Guillam, and C. Arribas, “Autoclaved and Extruded Legumes as a Source of Bioactive Phytochemicals : A Review,” pp. 1–34, 2021.
- [82] Alvarez-Alvarez J. *et al.*, “Effects of extrusion, boiling, autoclaving, and microwave heating on lupine allergenicity,” *J. Agric. Food Chem.*, vol. 53, pp. 1294–1298, 2005.
- [83] Alajaji S.A. and T. . El-Adawy, “Nutritional composition of chickpea (*Cicer arietinum* L.) as affected by microwave cooking and other traditional cooking methods.,” *J. Food Compos. Anal.*, vol. 19, pp. 806–812, 2006.
- [84] B. L. Luhovyy, R. C. Mollard, S. Panahi, M. F. Nunez, F. Cho, and G. . Anderson, “Canned Navy Bean Consumption Reduces Metabolic Risk Factors Associated with

- Obesity,” *Can. J. Diet. Pr. Res.*, vol. 76, pp. 33–37, 2015.
- [85] Martínez-Pineda M., C. Yagüe-Ruiz, A. Caverni-Muñoz, and A. Vercet-Tormo, “Cooking Legumes: A Way for Their Inclusion in the Renal Patient Diet,” *J. Ren. Nutr.*, vol. 29, pp. 118–125, 2019.
- [86] A. E. Mubarak, “Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes,” *Food Chem.*, vol. 89, no. 4, pp. 489–495, 2005.
- [87] H. Schaefer, C. Heibl, and S. S. Renner, “Gourds afloat: A dated phylogeny reveals an Asian origin of the gourd family (*Cucurbitaceae*) and numerous oversea dispersal events,” *Proc. R. Soc. B Biol. Sci.*, vol. 276, no. 1658, pp. 843–851, 2012.
- [88] E.-E. Joy, V.-U. E. Chidinma, and M. O. Akusu, “Physicochemical and Functional Properties of Pumpkin (*Cucurbita Pepo*) Pulp Flour and Acceptability of its Inclusion in Cake,” *Asian Food Sci. J.*, vol. 20, no. 7, pp. 57–71, 2021.
- [89] S. Turksoy and B. Özkaya, “Pumpkin and Carrot Pomace Powders as a Source of Dietary Fiber and Their Effects on the Mixing Properties of Wheat Flour Dough and Cookie Quality,” *Food Sci. Technol. Res.*, vol. 17, no. 6, pp. 545–553, 2011.
- [90] A. N. Ondigi and S. O. Oluchiri, “... of production practices and utilization of pumpkins (*Cucurbita pepo* and *Cucurbita maxima*) by smallholder farmers in the Lake Victoria Basin, East Africa Quality of life among Kenyan families. View project Disaster management and sustainable development ,” vol. 2, no. 9, pp. 296–304, 2008.
- [91] H. J. Mohd Mokhlesur Rahman¹, M. H. Islam, M. M. Khandaker, T. M. Ariff, W. Mohd, and N. wan Nik, “Prophetic vegetable Pumpkin, Its impressive health benefits and total analysis,” *Biosci. Res.*, vol. 16, no. 1, pp. 367–374, 2019.
- [92] M. F. de Escalada Pla, N. M. Ponce, C. A. Stortz, L. N. Gerschenson, and A. M. Rojas, “Composition and functional properties of enriched fiber products obtained from pumpkin (*Cucurbita moschata* Duchesne ex Poiret),” *Lwt*, vol. 40, no. 7, pp. 1176–1185, 2007.
- [93] A. Ciurzyńska and A. Lenart, “Freeze-drying - application in food processing and biotechnology - a review,” *Polish J. Food Nutr. Sci.*, vol. 61, no. 3, pp. 165–171, 2011.
- [94] V. R. Sagar and P. Suresh Kumar, “Recent advances in drying and dehydration of fruits and vegetables: A review,” *J. Food Sci. Technol.*, vol. 47, no. 1, pp. 15–26, 2010.
- [95] Simran Kaur *et al.*, “Functional and nutraceutical properties of pumpkin – a review,” *Nutr.*

- Food Sci.*, vol. 50, no. 2, pp. 384–401, 2020.
- [96] Yuanshan, Tony Z.Jin, and Gengsheng Xiao, “Effects of pulsed electric fields pretreatment and drying method on drying characteristics and nutritive quality of blueberries,” *J. Food Process. Preserv.*, vol. 41, no. 6, 2017.
- [97] F. Kaymak-Ertekin, “Drying and rehydrating kinetics of green and red peppers,” *J. Food Sci.*, vol. 67, no. 1, pp. 168–175, 2002.
- [98] A. Arévalo-Pinedo and F. E. Xidieh Murr, “Influence of pre-treatments on the drying kinetics during vacuum drying of carrot and pumpkin,” *J. Food Eng.*, vol. 80, no. 1, pp. 152–156, 2007.
- [99] N. K. Rastogi, “Opportunities and challenges in application of ultrasound in food processing,” *Crit. Rev. Food Sci. Nutr.*, vol. 51, no. 8, pp. 705–722, 2011.
- [100] K. J. Mothibe, M. Zhang, J. Nsor-Atindana, and Y. C. Wang, “Use of ultrasound pretreatment in drying of fruits: Drying rates, quality attributes, and shelf life extension,” *Dry. Technol.*, vol. 29, no. 14, pp. 1611–1621, 2011.
- [101] Azoubel, A. Melo, R. Amorim, S. Sorelly, and B. Oliveira, “Effect of ultrasound on banana cv Pacovan drying kinetics,” *J. Food Eng.*, vol. 97, no. 2, pp. 194–198, 2010.
- [102] R. S. ,eyda Çakmak, O. Tekeo glu, H. Bozkır, A. R. Ergün, and T. Baysal, “Effects of electrical and sonication pretreatments on the drying rate and quality of mushrooms,” *LWT - Food Sci. Technol.*, vol. 69, pp. 197–202, 2016.
- [103] F. Chemat, Zill-E-Huma, and M. K. Khan, “Applications of ultrasound in food technology: Processing, preservation and extraction,” *Ultrason. Sonochem.*, vol. 18, no. 4, pp. 813–835, 2011.
- [104] M. Nowacka, A. Wiktor, M. Śledź, N. Jurek, and D. Witrowa-Rajchert, “Drying of ultrasound pretreated apple and its selected physical properties,” *J. Food Eng.*, vol. 113, no. 3, pp. 427–433, 2012.
- [105] A. C. Araújo, S. M. Oliveira, I. N. Ramos, T. R. S. Brandão, and C. L. M. Silva, “Influence of Pretreatments on Quality Parameters and Nutritional Compounds of Dried Galega Kale (*Brassica oleracea* L. var. *acephala*),” *Food Bioprocess Technol.*, vol. 9, no. 5, pp. 872–881, 2016.
- [106] J. W. Bai, Z. J. Gao, H. W. Xiao, X. T. Wang, and Q. Zhang, “Polyphenol oxidase inactivation and vitamin C degradation kinetics of Fuji apple quarters by high humidity air

- impingement blanching,” *Int. J. Food Sci. Technol.*, vol. 48, no. 6, pp. 1135–1141, 2013.
- [107] G. Spigno, “Microwave Processing: Impact on Food Product Quality Attributes. In Food Processing Technologies: Impact on product attributes,” A. K. Jaiswal, Ed. Boca Raton, FL, USA: CRC Press., 2016, pp. 79–91.
- [108] M. Regier and H. Schubert., “Microwave processing.,” in *Thermal Technologies in Food Processing*, R. P., Ed. Cambridge, England: Woodhead Publishing Limited., 2001, pp. 179–207.
- [109] I. Rahath Kubra, D. Kumar, and L. Jagan Mohan Rao, “Emerging Trends in Microwave Processing of Spices and Herbs,” *Crit. Rev. Food Sci. Nutr.*, vol. 56, no. 13, pp. 2160–2173, 2016.
- [110] L. M. Ruiz-Ojeda and F. J. Peñas, “Comparison study of conventional hot-water and microwave blanching on quality of green beans,” *Innov. Food Sci. Emerg. Technol.*, vol. 20, pp. 191–197, 2013.
- [111] M. K. Krokida, C. T. Kiranoudis, Z. B. Maroulis, and D. Marinos-Kouris, “Effect of pretreatment on color of dehydrated products,” *Dry. Technol.*, vol. 18, no. 6, pp. 1239–1250, 2000.
- [112] P. Liu, A. S. Mujumdar, M. Zhang, and H. Jiang, “Comparison of Three Blanching Treatments on the Color and Anthocyanin Level of the Microwave-Assisted Spouted Bed Drying of Purple Flesh Sweet Potato,” *Dry. Technol.*, vol. 33, no. 1, pp. 66–71, 2015.
- [113] H. Zheng and H. Lu, “Effect of microwave pretreatment on the kinetics of ascorbic acid degradation and peroxidase inactivation in different parts of green asparagus (*Asparagus officinalis* L.) during water blanching,” *Food Chem.*, vol. 128, no. 4, pp. 1087–1093, 2011.
- [114] M. Mastromatteo, A. Danza, M. Guida, and M. A. Del Nobile, “Formulation optimisation of vegetable flour-loaded functional bread Part I : screening of vegetable flours and structuring agents,” pp. 1–8, 2012.
- [115] G. S. Sumnu, M. K. Ndife, and L. Bayindirli, “Effects of sugar, protein and water content on wheat starch gelatinization due to microwave heating,” *Eur. Food Res. Technol.*, vol. 211, pp. 169–174, 2000.
- [116] E. Silva, M. Birkenhake, E. Scholten, L. M. C. Sagis, and E. van der Linden, “Controlling rheology and structure of sweet potato starch noodles with high broccoli powder content

- by hydrocolloids,” *Food Hydrocoll*, vol. 30, pp. 42–52, 2013.
- [117] Brennan C.S. and C. M. Tudorica, “Fresh pasta quality as affected by enrichment of non starch polysaccharides,” *J. Food Sci.*, vol. 72, no. 9, pp. 659–665, 2007.
- [118] S. I. Rafiq, S. M. Rafiq, and D. C. Saxena, “EFFECT of hydrocolloids on the quality evaluation of flour based noodles from Horse Chestnut,” vol. 04005, pp. 1–5, 2016.
- [119] Raina, S. Singh, A. S. Bawa, and D. C. Saxena, “Textural characteristics of pasta made from rice flour supplemented with proteins and hydrocolloids,” *J. Texture Stud.*, vol. 36, pp. 402–420, 2005.
- [120] Man, Z. Ke-Xue, X. N. Guo, K. Brijs, and H. M. Zhou, “Natural additives in wheat-based pasta and noodle products: Opportunities for enhanced nutritional and functional properties,” *Compr. Rev. Food Sci. Food Saf.*, vol. 13, no. 4, pp. 347–357, 2014.
- [121] Z. Kohajdova` and J. Katovico` va`, “Review – Application of hydrocolloids as baking improvers,” *Chem. Pap.*, vol. 63, pp. 26–28, 2009.
- [122] Padalino, M. Mastromatteo, G. Sepielli, and M. A. Del Nobile, “Formulation optimization of gluten-free functional spaghetti based on maize flour and oat bran enriched in β -glucans,” *Material*, vol. 4, pp. 2119–2135, 2011.
- [123] J. C. Huang, S. Knight, and C. Goad, “Model prediction for sensory attributes of non-gluten pasta,” *J. Food Qual.* 24, 495–511., vol. 24, pp. 495–511, 2001.
- [124] Jakubczyk, M. Kara´s, K. Rybczy´nska-Tkaczyk, and D. Zieli´nska, E.; Zieli´nski, “Current Trends of Bioactive Peptides—New Sources and Therapeutic Effect.,” *Foods*, vol. 9, p. 846, 2020.
- [125] F. Hosseini, M. R. Sanjabi, and M. Kazemi, “Bioactive Ingredients in Functional Foods : Current Status and Future Trends,” *IntechOpen*, vol. 2, pp. 123–129, 2015.
- [126] V. Jayasena and S. M. Nasar-Abbas, “Development and quality evaluation of high-protein and high-dietary-fiber pasta using lupin flour,” *J. Texture Stud.*, vol. 43, no. 2, pp. 153–163, 2012.
- [127] Gresele, C. Cerletti, G. Guglielmini, P. Pignatelli, G. DeGaetano, and F. Violi, “Effects of Resveratrol and Other Wine Polyphenols on Vascular Function: an Update,” *J. Nutr. Biochem.*, vol. 22, no. 3, pp. 201–211, 2011.
- [128] L. Wang and T. Bohn, “Health-Promoting Food Ingredients and Functional Food Processing,” *IntechOpen*, 2012.

- [129] Elmaliklis, Liveri A., B. Ntelis, K. Paraskeva, I. Goulis, and A. Koutelidakis, "Increased Functional Foods' Consumption and Mediterranean Diet Adherence May Have a Protective Effect in the Appearance of Gastrointestinal Diseases: A Case–Control Study," *Medicines*, vol. 6, no. 50, 2019.
- [130] P. Putnik and D. B. Kovačević, "Sustainable Functional Food Processing," *Food*, vol. 10, p. 1438, 2021.
- [131] C. R. S. Câmara, C. A. Urrea, and V. Schlegel, "Pinto Beans (*Phaseolus vulgaris* L.) as a Functional Food: Implications on Human Health," *Agriculture*, vol. 3, pp. 90–111, 2013.
- [132] M. Blaut, "Relationship of prebiotics and food to intestinal microflor," *Eur. J. Nutr.*, vol. 41, pp. 111–116, 2002.
- [133] Finley, J. B. Burrell, and P. G. Reeves, "Pinto bean consumption changes SCFA profiles in fecal fermentations, bacterial populations of the lower bowel, and lipid profiles in blood of humans," *J. Nutr.*, vol. 137, pp. 2391–2398, 2007.
- [134] Gan *et al.*, "Bioactive compounds and bioactivities of germinated edible seeds and sprouts: an updated review," *Trends Food Sci. Technol.*, vol. 59, pp. 1–14, 2017.
- [135] K. Tontisirin, G. Mantel, and L. Battacharjee, "Food based strategies to meet the challenges of micronutrient malnutrition in the developing world.," *Proc. Nutr. Soc. 61 243–250.*, vol. 61, pp. 243–250, 2002.
- [136] S. Hemalatha, K. Platel, and K. Srinivasan, "Influence of germination and fermentation on bioaccessibility of zinc and iron from cereals and pulses.," *Eur. J. Clin. Nutr.*, vol. 61, pp. 342–348, 2007.
- [137] M. R. Rusydi, C. W. Noraliza, A. Azrina, and A. Zulkhairi, "Nutritional changes in germinated legumes and rice varieties," *Int. Food Res. J.*, vol. 18, pp. 688–696, 2011.
- [138] Gawlik-Dziki *et al.*, "Anticancer and antioxidant activity of bread enriched with _ broccoli sprouts," *Biomed Res. Int.*, pp. 1–14, 2014.
- [139] Shashirekha MN, M. SE, and R. S, "Status of bioactive compounds in foods, with focus on fruits and vegetables," *Crit Rev Food Sci Nutr*, vol. 55, pp. 1324–1339, 2015.
- [140] H. Westhoek *et al.*, "Food choices, health and environment: effects of cutting Europe's meat and dairy intake," *Glob. Environ. Chang.*, vol. 26, pp. 196–205, 2014.
- [141] E. Stehfest, "Food choices for health and planet," *Nat. 515 (7528)501–502.*, vol. 515, no. 7528, pp. 501–502, 2014.

- [142] C. M. Bemfeito, J. de D. S. Carneiro, E. E. N. Carvalho, P. C. Coli, R. C. Pereira, and E. V. de B. V. Boas, “Nutritional and functional potential of pumpkin (*Cucurbita moschata*) pulp and pequi (*Caryocar brasiliense* Camb .) peel flours,” *J Food Sci Technol*, 2020.
- [143] R. S. Rajasree, P. I. Sibi, F. Francis, and H. William, “Phytochemicals of Cucurbitaceae family – a review,” *Int. J. Pharmacogn. Phytochem. Res.*, vol. 8, pp. 113–123, 2016.
- [144] K. Kumar, M. S.J., P. Sudhakar, and B. V. Sandeep, “Evaluation of biochemical and phytochemical parameters in germinating and nongerminating seeds of *Cucurbita maxima*,” *Int. J. Appl. Sci. Eng. Res.*, vol. 5, no. 4, pp. 341–353, 2016.
- [145] AOAC, *Association of Official Analytical Chemists*, 17th edn. Washington DC, 2005.
- [146] Tesfaye Deme, Gulelat D.Haki, N. Retta, A. Woldegiorgis, and M. Geleta, “Mineral and anti-nutritional contents of niger seed (*Guizotia abyssinica* (l.f.) cass., linseed (*linumusitatissimum* l.) and sesame (*sesamumindicum* l.) varieties grown in Ethiopia,” *Foods*, vol. 6, no. 4, pp. 1–10, 2017.
- [147] Habtamu Fekadu Gemed, “Effects of Boiling Methods on Anti-nutritional Factors of Anchote (*Coccinia Abyssinica* (lam.) Cogn) tubers Grown in Western Ethiopia,” *Food Sci. Qual. Manag.*, vol. 27, 2014.
- [148] B. J. Xu and S. K. C. Chang, “A comparative study on phenolic profiles and antioxidant activities of legumes as affected by extraction solvents,” *J. Food Sci.*, vol. 72, no. 2, 2007.
- [149] A. Z. Woldegiorgis, D. Abate, G. D. Haki, and G. R. Ziegler, “Antioxidant property of edible mushrooms collected from Ethiopia,” *FOOD Chem.*, vol. 157, pp. 30–36, 2014.
- [150] E. N. Wafula *et al.*, “Application of near-infrared spectroscopy to predict the cooking times of aged common beans (*Phaseolus vulgaris* L.),” *J. Food Eng.*, vol. 284, no. March, 2020.
- [151] S. A. Emire and R. S. Kumar, “Proximate composition and physico-chemical properties of improved dry bean (*Phaseolus vulgaris* L.) varieties grown in Ethiopia,” *LWT - Food Sci. Technol.*, vol. 38, no. 4, pp. 331–338, 2005.
- [152] Derese Mekonnen Teshome and S. A. Emire, “Canning Quality Evaluation of Common Bean (*Phaseolus vulgaris* L.) Varieties Grown in the Central Rift Valley of Ethiopia,” *East African J. Sci.*, vol. 6, no. 1, pp. 65–78, 2012.
- [153] M. Lyimo, J. Mugula, and T. Elias, “Nutritive composition of broth from selected bean varieties cooked for various periods,” *J. Sci. Food Agric.*, vol. 58, no. 4, pp. 535–539,

1992.

- [154] C. Anino, A. N. Onyango, S. Imathiu, J. Maina, and F. Onyangore, "Chemical composition of the seed and 'milk' of three common bean (*Phaseolus vulgaris* L) varieties," *J. Food Meas. Charact.*, vol. 13, no. 2, pp. 1242–1249, 2019.
- [155] Ephrem Terefe Lemu, "Review of Haricot bean Value Chain in Ethiopia," *Int. J. African Asian Stud. ISSN*, vol. 24, no. SSN 2409-6938, pp. 65–73, 2019.
- [156] N. Kefelegn, F. Mekibib, and Y. Dessalegn, "Genetic Advancement and Variability of Released Common Bean (*Phaseolus vulgaris* L.) Varieties from 1974–2009 GC in Ethiopia," *Adv. Agric.*, vol. 2020, pp. 1–7, 2020.
- [157] A. P. Khansa and N. Bintoro, "The influence of types and moisture contents of coffee beans (*Coffea* sp) on sphericity and geometric means diameter," in *IOP Conference Series: Earth and Environmental Science*, 2021, vol. 653, no. 1.
- [158] Adebowale Abdul Rasaq, Lateef O. Sanni, H. O. Owo, and O. R. Karim, "Effect of variety and moisture content on some engineering properties of paddy rice," *J. Food Sci. Technol.*, vol. 48, no. 5, pp. 551–559, 2011.
- [159] S. Serpil and S. Servet Gulum, "Size , Shape , Volume , and Related," in *Size, Shape, Volume, and Related Physical Attributes. Physical Properties of Foods*, 2006, pp. 1–37.
- [160] ISO-665-2020, "Oilseeds — Determination of moisture and volatile matter content," 2020.
- [161] V. Sharma, L. Das, R. C. Pradhan, S. N. Naik, N. Bhatnagar, and R. S. Kureel, "Physical properties of tung seed: An industrial oil yielding crop," *Ind. Crops Prod.*, vol. 33, no. 2, pp. 440–444, 2011.
- [162] A. NA, S. Ekaso Jr, and O. U. Nwanja, "Effect of Moisture Content on Some Engineering Properties of African Mahogany (*Azelia africana*) Seed," *Arid. Technol.*, vol. 15, no. 3, pp. 534–553, 2019.
- [163] K. Heidarbeigi, H. Ahmadi, K. Kheiralipour, and A. Tabatabaeefar, "some physical and mechanical properties of khinjuk," *Pakistan J. Nutr.*, vol. 8, no. 1, pp. 74–77, 2009.
- [164] E. A. Baryeh and B. K. Mangope, "Some physical properties of QP-38 variety pigeon pea," *J. Food Eng.*, vol. 56, pp. 59–65, 2002.
- [165] I. A. Wani, D. S. Sogi, A. A. Wani, and B. S. Gill, "Physical and cooking characteristics of some Indian kidney bean (*Phaseolus vulgaris* L.) cultivars," *J. Saudi Soc. Agric. Sci.*,

- vol. 16, no. 1, pp. 7–15, 2015.
- [166] H. Ebrahimzadeh, A. H. Mirzabe, M. Lotfi, and S. Azizinia, “Gamma irradiation effects on physical properties of squash seeds,” *Agric Eng Int CIGR J.*, vol. 15, no. 1, pp. 131–138, 2013.
- [167] T. O. Omobuwajo, E. A. Akande, and L. A. Sanni, “Selected physical, mechanical and aerodynamic properties of African breadfruit (*Treculia africana*) seeds,” *J. Food Eng.*, vol. 40, no. 4, pp. 241–244, 1999.
- [168] M. Kaur and N. Singh, “Relationships between selected properties of seeds, flours, and starches from different chickpea cultivars,” *Int. J. Food Prop.*, vol. 9, no. 4, pp. 597–608, 2006.
- [169] T. Y. Tunde-Akintunde, J. O. Olajide, and B. O. Akintunde, “Mass-volume-area related and mechanical properties of soybean as a function of moisture and variety,” *Int. J. Food Prop.*, vol. 8, no. 3, pp. 449–456, 2005.
- [170] A. A. S. Palilo, B. A. Majaja, and B. Kichonge, “Physical and Mechanical Properties of Selected Common Beans (*Phaseolus vulgaris* L.) Cultivated in Tanzania,” *J. Eng.*, vol. 2018, 2018.
- [171] M. De Barros and S. H. Prudencio, “Physical and chemical characteristics of common bean varieties,” *Semin. Agrar.*, vol. 37, no. 2, pp. 751–762, 2016.
- [172] E. Altuntas and H. Demirtola, “Effect of moisture content on physical properties of some grain legume seeds,” *New Zeal. J. Crop Hortic. Sci.* 35 423-433, vol. 35, no. 4, pp. 423–433, 2007.
- [173] O. Eboibi and H. Uguru, “STATISTICAL ANALYSIS OF THE PHYSICAL PROPERTIES OF VARIETIES OF BEANS (*Phaseolus vulgaris* L.) INFLUENCED BY MATURITY STAGE,” *Niger. J. Technol.*, vol. 37, no. 4, pp. 1176–1184, 2018.
- [174] Gharibzahedi SMT, E. V, M.-R. J, and F. M, “Study on Some Engineering Attributes of Pine Nut (*Pinus pinea*) to the Design of Processing Equipment,” *Res. Agric. Eng.*, vol. 56, no. 3, pp. 99–106, 2010.
- [175] D. I. Akaaimo and A. O. Raji, “Some Physical and Engineering Properties of *Prosopis africana* seed,” *Biosyst. Eng.*, vol. 95, no. 2, pp. 197–205, 2006.
- [176] I. O. Adewumi, I. J. A, S. . Oladimeji, and B. S. Kosemani, “Determination of Some Physical Properties and Terminal Velocity of Locust Beans of *Parkia Specie* (*Parkia*

- biglobosa),” *Science and Engineering Perspectives*, vol. 10, pp. 105–111, 2015.
- [177] S. K. Dutta, V. K. Nema, and R. K. Bhardwaj, “Physical Properties of Gram,” *I. agric. Engng Res.*, vol. 39, pp. 259–268, 1988.
- [178] F. Subuola, Y. Widodo, and T. Kehinde, “Processing and Utilization of Legumes in the Tropics,” *Trends Vital Food Control Eng.*, no. April, 2012.
- [179] A. Mahajan and S. Dua, “Salts and pH induced changes in functional properties of amaranth (*Amaranthus tricolor* L.) seed meal,” *Cereal Chem.*, vol. 79, no. 6, pp. 834–837, 2002.
- [180] F. Ugwu and N. Oranye, “Effects of some processing methods on the toxic components of African breadfruit (*Treculia Africana*),” *African J. Biotechnol.*, vol. 6, pp. 234–246, 2006.
- [181] M. Siddiq, R. Ravi, J. B. Harte, and K. D. Dolan, “Physical and functional characteristics of selected dry bean (*Phaseolus vulgaris* L.) flours,” *LWT - Food Sci. Technol.*, vol. 43, no. 2, pp. 232–237, 2010.
- [182] AOAC, *Official Methods of Analysis*. , Association of Official Analytical Chemist, 15th Editi. Washington D.C, 1990.
- [183] Ferreira Isabel, B. Paula, M. Vilas-boas, and L. Barros, “Food Chemistry Free-radical scavenging capacity and reducing power of wild edible mushrooms from northeast Portugal : Individual cap and stipe activity,” vol. 100, pp. 1511–1516, 2007.
- [184] Y. A. Adebawale, I. A. Adeyemi, and A. A. Oshodi, “Functional and physicochemical properties of flours of six *Mucuna* species,” vol. 4, no. December, pp. 1461–1468, 2005.
- [185] R. Y. Khattab, S. D. Arntfield, and C. M. Nyachoti, “Nutritional quality of legume seeds as affected by some physical treatments, Part 1: Protein quality evaluation,” *LWT - Food Sci. Technol.*, vol. 42, no. 6, pp. 1107–1112, 2009.
- [186] N. Niangoran, A. Marie, D. A. Edmond, F. M. T. Koné, and K. L. Patrice, “Functional Properties of Seed Flours from Different Cultivars of *Citrullus lanatus* (Cucurbitaceae) Cultivated in Côte d ’ Ivoire,” vol. 1, no. 5, pp. 32–38, 2015.
- [187] S. M. Butt and R. Batool, “Nutritional and Functional Properties of Some Promising Legumes Protein Isolates,” *Pakistan J. Nutr.*, vol. 9, pp. 373–379, 2010.
- [188] I. MO, *Handbook of Sensory Methods and Analyysi*. . Rojoint Communication Services Ltd.Enugu, 2010.
- [189] T. Dzudie, J. Hardy, and V. Les Nancy, “Physicochemical and Functional Properties of

- Flours Prepared from Common Beans and Green Mung Beans,” vol. 8561, no. 95, pp. 3029–3032, 1996.
- [190] V. A. Jideani, J. van Wyk, and M. H. Cruywagen, “Physical properties of *Tylosemia esculentum* and the effect of roasting on the functional properties of its flour,” *African J. Agric. Res.*, vol. 4, no. 11, pp. 1208–1219, 2009.
- [191] B.-L. DA, P.-A. JJ, and G.-G. JM, “Germination of common bean (*Phaseolus vulgaris* L.): Effects on physicochemical and nutritional properties,” *LWT - Food Sci Technol*, vol. 69, pp. 1–9, 2016.
- [192] I. A. Wani, D. S. Sogi, and B. S. Gill, “Physicochemical and functional properties of flours from three Black gram (*Phaseolus mungo* L.) cultivars,” *Int. J. Food Sci. Technol.*, vol. 48, no. 4, pp. 771–777, 2013.
- [193] CAC, *Codex Standard for Wheat Flour: Codex Stan 152-1985. Codex Alimentarius Commission*. Italy: CAC Press, 1985.
- [194] P. Sharma, A. Kaur, and M. S. Alam, “Effect of processing on physico-chemical and functional properties of flours from cluster or guar bean (*Cyamopsis tetragonoloba*) varieties,” *J. Appl. Nat. Sci.*, vol. 8, no. 4, pp. 2120–2127, 2016.
- [195] J. Rumiya, A. P., and V. Jayasena, “Effect of Germination on the Nutritional and Protein Profile of Australian Sweet Lupin (*Lupinus angustifolius* L.),” *Food Nutr. Sci.*, vol. 03, no. 05, pp. 621–626, 2012.
- [196] S. S. Kadam and S. S. Salunkhe, “Chemical composition, protein profile and digestibility of mung bean flour as affected by germination,” *J. Food Sci. Technol.*, vol. 56, no. 7, pp. 3519–3527, 2019.
- [197] Rajni Mittal, HPS Nagi, Priyanka Sharma, and Savita Sharma, “Effect of Processing on Chemical Composition and Antinutritional Factors in Chickpea Flour,” *J. Food Sci. Eng.*, vol. 2, no. 3, pp. 180–186, 2012.
- [198] B. K. Tiwari, B. K. O’Donnell, and P. J. Cullen., “Effect of sonication on the solubilization and emulsifying properties of pea and lentil proteins,” *J. Agric. Food Chem.*, vol. 50, no. 7, pp. 1676–1680, 2002.
- [199] S. Mabrouki, B. Omri, and H. Abdouli, “Chemical, Functional and Nutritional Characteristics of raw, autoclaved and germinated fenugreek seeds,” *J. new Sci. Agric. Biotechnol.*, vol. 16, no. 1, pp. 541–551, 2015.

- [200] S. HOODA and S. JOOD, “EFFECT OF SOAKING AND GERMINATION ON NUTRIENT AND ANTINUTRIENT CONTENTS OF FENUGREEK (TRIGONELLA FOENUM GRAECUM L.),” *J. Food Biochem.*, vol. 27, no. 2, pp. 165–176, 2003.
- [201] L. U. Thompson, “Potential health benefits and problems associated with antinutrients in foods,” *Food Res. Int.*, vol. 26, no. 2, pp. 131–149, 1993.
- [202] E. A. Shimelis and S. K. Rakshit, “Effect of processing on antinutrients and in vitro protein digestibility of kidney bean (*Phaseolus vulgaris* L.) varieties grown in East Africa,” *Food Chem.*, vol. 103, no. 1, pp. 161–172, 2007.
- [203] G. Manez, A. Alegria, R. Farre, and A. Frigola, “Effect of traditional, microwave and industrial cooking on inositol phosphate content in beans, chickpeas and lentils,” *Int. J. Food Sci. Nutr.*, vol. 53, pp. 503–508, 2002.
- [204] R. M. Rzepkowska, M. Bieganski, and K. Krygier., “Effect of cooking methods on antioxidant activity and phenolic content of kidney beans,” *J. Food Sci. Technol.*, vol. 54, no. 13, pp. 4159–4166, 2017.
- [205] O. J. Adebawale and O. O. Adebawale., “Effect of germination and pressure cooking on the phytochemical composition and antioxidant activity of cowpea (*Vigna unguiculata*) seeds,” *J. Food Sci. Technol.*, vol. 56, no. 7, pp. 3325–3333, 2019.
- [206] D. L. Luthria and M. A. Pastor-Corrales, “Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties,” *J. Food Compos. Anal.*, vol. 19, no. 2–3, pp. 205–211, 2006.
- [207] M. N. Ombra *et al.*, “Phenolic Composition and Antioxidant and Antiproliferative Activities of the Extracts of Twelve Common Bean (*Phaseolus vulgaris* L.) Endemic Ecotypes of Southern Italy before and after Cooking,” *Oxid. Med. Cell. Longev.*, vol. 2016, 2016.
- [208] G. Oboh, “Antioxidant properties of some commonly consumed and underutilized tropical legumes,” *Eur. Food Res. Technol.*, vol. 224, no. 1, pp. 61–65, 2006.
- [209] Y. Aguilera, R. M. Esteban, V. Benítez, E. Mollá, and M. A. Martín-Cabrejas, “Starch, functional properties, and microstructural characteristics in chickpea and lentil as affected by thermal processing,” *J. Agric. Food Chem.*, vol. 57, no. 22, pp. 10682–10688, 2009.
- [210] A. A. Adebawale, Y. A. Adebawale, and A. A. Oshodi, “Effect of autoclaving on the physicochemical and functional properties of germinated cowpea (*Vigna unguiculata*)

- flour,” *Food Chem.*, vol. 92, no. 4, pp. 675–683, 2005.
- [211] M. O. Oluwamukomi, L. O. Sanni, and A. A. Adebawale, “Effect of germination on functional properties of common bean (*Phaseolus vulgaris* L.) flour,” *J. Food Eng.*, vol. 60, no. 4, pp. 421–427, 2003.
- [212] L. Menon, S. D. Majumdar, and U. Ravi, “Development and analysis of composite flour bread,” *J. Food Sci. Technol.*, vol. 52, no. 7, pp. 4156–4165, 2015.
- [213] R. A. Ghavidel and J. Prakash, “Effect of germination and dehulling on functional properties of legume flours,” *J. Sci. Food Agric.*, vol. 86, no. 8, pp. 1189–1195, 2006.
- [214] A. A. Adebawale, Y. A. Adebawale, and A. A. Oshodi, “Effect of germination and autoclaving on functional properties of pigeon pea (*Cajanus cajan*) flour,” *Food Res. Int.*, vol. 41, no. 2, pp. 162–168, 2008.
- [215] V. A. Obatolu, S. B. Fasoyiro, and L. Ogunsumi, “Effect of Processing on Functional Properties of Yam Beans (*Sphenostylis stenocarpa*),” *Food Sci. Technol. Res.*, vol. 7, no. 4, pp. 319–322, 2001.
- [216] Z. Ma, J. I. Boye, B. K. Simpson, S. O. Prasher, D. Monpetit, and L. Malcolmson, “Thermal processing effects on the functional properties and microstructure of lentil, chickpea, and pea flours,” *Food Res. Int.*, vol. 44, no. 8, pp. 2534–2544, 2011.
- [217] V. A. Jideani, J. Van Wyk, and M. H. Cruywagen, “Physical properties of *Tylosemia esculentum* and the effect of roasting on the functional properties of its flour,” vol. 4, no. 11, pp. 1208–1219, 2009.
- [218] A. Oyewole, T. Abu, and V. Enujiugha, “Emulsification and Foaming Properties of Locust Bean (*Parkia biglobosa*) and Pigeon Pea (*Cajanus cajan*) Seed Flours and their Protein Isolates,” *Nutr. Food Sci. Int. J.*, vol. 2, no. 3, 2017.
- [219] A. V. Mkanda, A. Minnaar, and H. L. De Kock, “Relating consumer preferences to sensory and physicochemical properties of dry beans (*Phaseolus vulgaris*),” *J. Sci. Food Agric.*, vol. 87, no. 15, pp. 2868–2879, 2007.
- [220] G. Cárdenas, C. M. Rosell, and C. Benedito de Barber, “Effect of protein and dietary fiber content on the emulsifying properties of common bean flour,” *Food Hydrocoll.*, vol. 43, pp. 155–161, 2015.
- [221] S. H. Guzmán-Maldonado, M. Morales-de la Peña, and R. Reynoso-Camacho, “Effect of processing on color and functional properties of *Phaseolus vulgaris* flour,” *J. Food Sci.*,

- vol. 68, no. 5, pp. 1622–1626, 2003.
- [222] M. De, J. A. Tavares, D. CARVALHO, L. M. Jaeger, A. C. de M. Vieira, and I. M. de CASTRO, “Scanning electron microscopy and crystallinity of starches granules from cowpea, black and carioca beans in raw and cooked forms,” *Food Sci. Technol.*, vol. 39, pp. 718–724, 2019.
- [223] Hollman Motta and Y. Zhang, “Physicochemical properties and rheological behavior of flours and starches from four bean varieties for gluten-free pasta formulation,” *J. Agric. Food Res.*, vol. 1, no. 149, p. 100001, 2019.
- [224] E. A. Shimelis and S. K. R. Ā, “Proximate composition and physico-chemical properties of improved dry bean (*Phaseolus vulgaris* L .) varieties grown in Ethiopia,” vol. 38, pp. 331–338, 2005.
- [225] A. Negi, P. Boora, and N. Khetarpaul, “Starch and protein digestibility of newly released moth bean cultivars: Effect of soaking, dehulling, germination and pressure cooking,” *Nahrung - Food*, vol. 45, no. 4, pp. 251–254, 2001.
- [226] A. Kamchan, P. Puwastien, P. P. Sirichakwal, and R. Kongkachuichai, “In vitro calcium bioavailability of vegetables, legumes and seeds,” *J. Food Compos. Anal.*, vol. 17, no. 3–4, pp. 311–320, 2004.
- [227] Y. N. Njintang, C. M. F. Mbofung, and K. W. Waldron, “In vitro protein digestibility and physico-chemical properties of dry red bean (*Phaseolus vulgaris*) flour: effect of processing and incorporation of soybean and cowpea flour,” *J. Agric. Food Chem.*, vol. 49, pp. 2465–2471, 2001.
- [228] Minwei Xu, Z. Jin, S. Simsek, J. Rao, and B. Chen, “Effect of germination on the chemical composition , thermal , pasting , and moisture sorption properties of flours from chickpea , lentil , and yellow pea,” *Food Chem.*, vol. 295, pp. 579–587, 2019.
- [229] Sajad Ahmad Sofi, J. Singh, K. Muzaffar, S. Ahmad, and M. B. N. Dar, “Effect of germination time on physico-chemical , functional , pasting , rheology and electrophoretic characteristics of chickpea flour,” *J. Food Meas. Charact.*, vol. 14, pp. 2380–2392, 2020.
- [230] A. Torres, J. Frias, M. Granito, and C. Vidal-Valverde, “Germinated *Cajanus cajan* seeds as ingredients in pasta products: Chemical, biological and sensory evaluation,” *Food Chem.*, vol. 101, no. 1, pp. 202–211, 2007.
- [231] H. Polat, T. Dursun Capar, C. Inanir, L. Ekici, and H. Yalcin, “Formulation of functional

- crackers enriched with germinated lentil extract: A Response Surface Methodology Box-Behnken Design,” *LWT - Food Sci. Technol.*, vol. 123, p. 109065, 2020.
- [232] Chavan Mayuri, Y. Gat, M. Harmalkar, and R. Waghmare, “Development of non-dairy fermented probiotic drink based on germinated and ungerminated cereals and legume,” *Lwt*, vol. 91, pp. 339–344, 2018.
- [233] K. T. Kaczmarska, M. V. Chandra-Hioe, D. Frank, and J. Arcot, “Enhancing wheat muffin aroma through addition of germinated and fermented Australian sweet lupin (*Lupinus angustifolius* L.) and soybean (*Glycine max* L.) flour,” *Lwt*, vol. 96, pp. 205–214, 2018.
- [234] K. B. Park and S. H. Oh, “Production of yogurt with enhanced levels of gamma-aminobutyric acid and valuable nutrients using lactic acid bacteria and germinated soybean extract,” *Bioresour. Technol.*, vol. 98, no. 8, pp. 1675–1679, 2007.
- [235] Derese Wodajo, S. Admassu, and B. Dereje, “Geometric Characteristics and Mass-Volume-Area Properties of Haricot Beans (*Phaseolus vulgaris* L.): Effect of Variety,” *Int. J. Food Prop.*, vol. 24, no. 1, pp. 885–894, 2021.
- [236] I. Ahmed, D. Singh, A. Abas, and B. Singh, “Physico-chemical and functional properties of flours from Indian kidney bean (*Phaseolus vulgaris* L.) cultivars,” *LWT - Food Sci. Technol.*, vol. 53, no. 1, pp. 278–284, 2013.
- [237] Wani Idrees Ahmed, S. N. Andrabi, D. S. Sogi, and F. Hassan, “Comparative study of physicochemical and functional properties of flours from kidney bean (*Phaseolus vulgaris* L.) and green gram (*Vigna radiata* L.) cultivars grown in Indian temperate climate,” vol. 11, 2019.
- [238] C. E. Chinma, J. O. Abu, B. N. Asikwe, T. Sunday, and O. A. Adebo, “Effect of germination on the physicochemical, nutritional, functional, thermal properties and in vitro digestibility of Bambara groundnut flours,” *LWT - Food Sci. Technol.*, p. 110749, 2020.
- [239] X. Liang and J. M. King, “Pasting and crystalline property differences of commercial and isolated rice starch with added amino acids,” *J. Food Sci.*, vol. 68, no. 3, pp. 832–838, 2003.
- [240] Cheng Li, D. Jeong, J. H. Lee, and H. J. Chung, “Influence of germination on physicochemical properties of flours from brown rice, oat, sorghum, and millet,” *Food Sci. Biotechnol.*, vol. 29, no. 9, pp. 1223–1231, 2020.

- [241] C. Enyinnaya, O. Adewuyi, and J. Oneh, “Effect of germination on the chemical , functional and pasting properties of flour from brown and yellow varieties of tigernut (*Cyperus esculentus*),” *Food Res. Int.*, vol. 42, no. 8, pp. 1004–1009, 2009.
- [242] V. A. Obalolu and A. H. Cole, “Functional property of complementary blends of soybean and cowpea with malted or unmalted maize,” *Food Chem.*, vol. 70, pp. 147–153, 2000.
- [243] N. Kaur, R. Singh, H. K. Sharma, and S. K. Jha., “Effect of germination on physicochemical, pasting, and textural properties of chickpea flour.,” *J. Food Sci. Technol.*, vol. 57, no. 4, pp. 1329–1337, 2020.
- [244] M. Kaur and N. Singh, “Studies on functional, thermal and pasting properties of flours from different chickpea cultivars,” *Food Chem.*, vol. 91, pp. 403–411, 2005.
- [245] Yu Liu *et al.*, “Effect of germination duration on structural and physicochemical properties of mung bean starch,” *Int. J. Biol. Macromol.*, vol. 154, pp. 706–713, 2020.
- [246] O. Clifford, O. Chika, I. Jude, and E. Tochi, “Use of Seed Sprouting in Modification of Food Nutrients and Pasting Profile of Tropical Legume Flours,” *Niger. Food J.*, vol. 32, no. 1, pp. 117–125, 2014.
- [247] Adebowale A.A., S. A. Sanni, and F. O. Oladapo, “Chemical, functional and sensory properties of instant yam–bread fruit flour,” *Niger. Food J.*, vol. 26, no. 1, pp. 2–12, 2008.
- [248] Patience C Obinna-echem, L. I. Barber, and P. C. Jonah, “Effect of germination and pre-gelatinization on the proximate composition and pasting properties of maize flour a base ingredient for cereal-based infant complementary food,” *Int. J. Biotechnol. Food Sci.*, vol. 7, no. 3, pp. 30–37, 2019.
- [249] B. A. Acevedo, C. M. B. Thompson, N. S. González Foutel, M. G. Chaves, and M. V. Avanza, “Effect of different treatments on the microstructure and functional and pasting properties of pigeon pea (*Cajanus cajan* L.), dolichos bean (*Dolichos lablab* L.) and jack bean (*Canavalia ensiformis*) flours from the north-east Argentina,” *Int. J. Food Sci. Technol.*, vol. 52, no. 1, pp. 222–230, 2017.
- [250] F. C. Felker, J. A. Kenar, J. A. Byars, M. Singh, and S. X. Liu, “Comparison of properties of raw pulse flours with those of jet-cooked, drum-dried flours,” *Lwt*, vol. 96, no. June, pp. 648–656, 2018.
- [251] Cheng Li, S. G. Oh, D. H. Lee, H. W. Baik, and H. J. Chung, “Effect of germination on the structures and physicochemical properties of starches from brown rice, oat, sorghum,

- and millet,” *Int. J. Biol. Macromol.*, vol. 105, pp. 931–939, 2017.
- [252] F. Wu *et al.*, “Effect of germination time on physicochemical properties of brown rice flour and starch from different rice cultivars,” *J. Cereal Sci.*, vol. 58, no. 2, pp. 263–271, 2013.
- [253] Juliana Aparecida Correia Bento *et al.*, “Functional and pasting properties of colorful bean (*Phaseolus vulgaris* L) flours : Influence of the cooking method,” *J. Food Process. Preserv.*, vol. 45, no. e15899, pp. 1–14, 2021.
- [254] J. Xu, H. Zhang, X. Guo, and H. Qian, “The impact of germination on the characteristics of brown rice flour and starch,” *J. Sci. Food Agric.*, vol. 92, no. 2, pp. 380–387, 2012.
- [255] R. Hoover, T. Hughes, H. J. Chung, and Q. Liu, “Composition, molecular structure, properties, and modification of pulse starches: A review,” *Food Res. Int.*, vol. 43, no. 2, pp. 399–413, 2010.
- [256] T. T. Huang, D. N. Zhou, Z. Y. Jin, X. M. Xu, and H. Q. Chen, “Effect of repeated heat-moisture treatments on digestibility, physicochemical and structural properties of sweet potato starch,” *Food Hydrocoll.*, vol. 54, pp. 202–210, 2016.
- [257] J. Huang, H. A. Schols, J. J. G. van Soest, Z. Jin, E. Sulmann, and A. G. J. Voragen, “Physicochemical properties and amylopectin chain profiles of cowpea, chickpea and yellow pea starches,” *Food Chem.*, vol. 101, no. 4, pp. 1338–1345, 2007.
- [258] F. M. Pelissari, M. M. Andrade-Mahecha, P. J. do A. Sobral, and F. C. Menegalli, “Comparative study on the properties of flour and starch films of plantain bananas (*Musa paradisiaca*),” *Food Hydrocoll.*, vol. 30, no. 2, pp. 681–690, 2013.
- [259] Y. Kumar, V. S. Sharanagat, L. Singh, and S. Mani, “Effect of germination and roasting on the proximate composition, total phenolics, and functional properties of black chickpea (*Cicer arietinum*),” *Legum. Sci.*, vol. 2, no. 1, pp. 1–7, 2020.
- [260] M. Tarahi, F. Shahidi, and S. Hedayati, “Physicochemical, Pasting, and Thermal Properties of Native Corn Starch–Mung Bean Protein Isolate Composites,” *Gels*, vol. 8, no. 11, p. 693, 2022.
- [261] F. Kamarudin and C. Y. Gan, “Molecular structure, chemical properties and biological activities of Pinto bean pod polysaccharide,” *Int. J. Biol. Macromol.*, vol. 88, pp. 280–287, 2016.
- [262] M. Martínez-Castaño, D. P. M. Díaz, J. Contreras-Calderón, and C. G. Cabrera,

- “Physicochemical properties of bean pod (*Phaseolus vulgaris*) flour and its potential as a raw material for the food industry,” *Rev. Fac. Nac. Agron. Medellin*, vol. 73, no. 2, pp. 9179–9187, 2020.
- [263] G. K. Kaptso *et al.*, “Characterization of Morphology and Structural and Thermal Properties of Legume Flours : Cowpea (*Vigna unguiculata* L . Walp) and Bambara Groundnut (*Vigna subterranea* L . Verdc .) Varieties,” *Int. J. Food Eng*, vol. 12, no. 2, pp. 139–152, 2015.
- [264] L. Zhu, Q. Liu, Y. Sang, Y. Guo, and H. Huang, “Changes in physicochemical properties of rice flour during germination,” *J. Agric. Food Chem.*, vol. 62, no. 16, pp. 3547–3553, 2014.
- [265] M. Kweon, L. Slade, H. Levine, and R. Martin, “A rapid viscometric method to determine the degree of starch gelatinization in corn flours,” *J. Cereal Sci.*, vol. 36, no. 3, pp. 261–272, 2002.
- [266] L. A. Bello-Pérez, E. Agama-Acevedo, M. E. Sánchez-Pardo, and O. Paredes-López, “Rheological and microstructural properties of common bean (*Phaseolus vulgaris* L.) flour as affected by germination time.,” *J. Food Sci. Technol.*, vol. 39, no. 6, pp. 642–647, 2002.
- [267] I. Majid, B. N. Dar, and V. Nanda, “Rheological, thermal, micro structural and functional properties of freeze dried onion powders as affected by sprouting,” *Food Biosci.*, vol. 22, no. January, pp. 105–112, 2018.
- [268] Shuping Yan *et al.*, “Properties of field-sprouted sorghum and its performance in ethanol production,” *J. Cereal Sci.*, vol. 51, no. 3, pp. 374–380, 2010.
- [269] M. Young, E. J. Kim, Y. N. Kim, C. Choi, and B. H. Lee, “Comparison of the chemical compositions and nutritive values of various pumpkin (*Cucurbitaceae*) species and parts,” *Nutr. Res. Pract.*, vol. 6, no. 1, pp. 21–27, 2012.
- [270] A. Hussain *et al.*, “Determination of total phenolic, flavonoid, carotenoid, and mineral contents in peel, flesh, and seeds of pumpkin (*Cucurbita maxima*),” *J. Food Process. Preserv.*, vol. 45, no. 6, pp. 1–8, 2021.
- [271] J. W. Kiharason, D. K. Isutsa, and P. N. Ngoda, “Effect of Drying Method on Nutrient Integrity of Selected Components of Pumpkin Fruit Flour,” *J. Agric. Biol. Sci.*, vol. 12, no. 3, pp. 110–116, 2017.

- [272] M. Nowacka, U. Tylewicz, L. Laghi, M. Dalla Rosa, and D. Witrowa-Rajchert, "Effect of ultrasound treatment on the water state in kiwifruit during osmotic dehydration," *Food Chem.*, vol. 144, pp. 18–25, 2014.
- [273] A. A. Adedeji, T. K. Gachovska, M. O. Ngadi, and G. S. V. Raghavan, "Effect of pretreatments on drying characteristics of okra," *Dry. Technol.*, vol. 26, no. 10, pp. 1251–1256, 2008.
- [274] H. Coklar, M. Akbulut, S. Kilinc, A. Yildirim, and I. Alhassan, "Effect of freeze, oven and microwave pretreated oven drying on color, browning index, phenolic compounds and antioxidant activity of hawthorn (*Crataegus orientalis*) fruit," *Not. Bot. Horti Agrobot. Cluj-Napoca*, vol. 46, no. 2, pp. 449–456, 2018.
- [275] L. G. Marques, M. M. & Prado, and J. T. Freire, "Vitamin C content of freeze-dried tropical fruits," *Int. Congr. Eng. Food*, pp. 22–26, 2011.
- [276] F. Que, L. Mao, X. Fang, and T. Wu, "Original article Comparison of hot air-drying and freeze-drying on the physicochemical properties and antioxidant activities of pumpkin (*Cucurbita moschata* Duch.) flours," pp. 1195–1201, 2008.
- [277] A. Mirani and M. Goli, "Production of the eggplant- - fiber incorporated cupcake and evaluating its chemical, textural and colorimetric properties over a ten- - day storage time," no. June 2020, pp. 1–14, 2021.
- [278] L. M. J. de Carvalho *et al.*, "Total carotenoid content, α -carotene and β -carotene, of landrace pumpkins (*Cucurbita moschata* Duch): A preliminary study," *Food Res. Int.*, vol. 47, no. 2, pp. 337–340, 2012.
- [279] A. M. Goula, K. G. Adamopoulos, and N. A. Kazakis, "Influence of spray drying conditions on tomato powder properties," *Dry. Technol.*, vol. 22, no. 5, pp. 1129–1151, 2004.
- [280] J. Szadzińska, J. Łechtańska, S. J. Kowalski, and M. Stasiak, "The effect of high power airborne ultrasound and microwaves on convective drying effectiveness and quality of green pepper," *Ultrason. Sonochem.*, vol. 34, pp. 531–539, 2017.
- [281] K. J. Mothibe, M. Zhang, A. S. Mujumdar, Y. C. Wang, and X. Cheng, "Effects of Ultrasound and Microwave Pretreatments of Apple Before Spouted Bed Drying on Rate of Dehydration and Physical Properties," *Dry. Technol.*, vol. 32, no. 15, pp. 1848–1856, 2014.

- [282] K. Jackson Lim Hwa, F. S. Taip, M. N. Ibrahim, N. A. Aziz, and M. R. I. S. Universiti, “Effect of Pre-Treatment on the Physical Properties of Pumpkin Powder,” *Aust. J. Basic Appl. Sci.*, vol. 10, no. 7, pp. 146–151, 2016.
- [283] Z. Teferi, T. S. Workneh, and K. Woldetsadik, “Thin-layer drying of pumpkin fruit slices,” *Adv. Mater. Res.*, vol. 824, pp. 283–292, 2013.
- [284] F. Fabiano A.N., L. Francisco E., and R. Sueli, “Ultrasound as pre-treatment for drying of pineapple,” *Ultrason. Sonochem.*, vol. 15, no. 6, pp. 1049–1054, 2008.
- [285] G. Dias da Silva, Z. M. P. Barros, R. A. B. de Medeiros, C. B. O. de Carvalho, S. C. Rupert Brandão, and P. M. Azoubel, “Pretreatments for melon drying implementing ultrasound and vacuum,” *Lwt*, vol. 74, pp. 114–119, 2016.
- [286] Y. Tao *et al.*, “Power ultrasound as a pretreatment to convective drying of mulberry (*Morus alba* L.) leaves: Impact on drying kinetics and selected quality properties,” *Ultrason. Sonochem.*, vol. 31, pp. 310–318, 2016.
- [287] N. AZIAH A.A. and C. A. KOMATHI, “Physicochemical and Functional Properties of Peeled and Unpeeled Pumpkin Flour,” *J. Food Sci.*, vol. 74, no. 7, pp. 328–33, 2009.
- [288] A. Quiles, A. Chiralt, and C. Gonzalez-Martinez, “Effect of different drying technologies on the quality of fruit flours,” *Food Bioprod. Process.*, vol. 107, pp. 117–125, 2018.
- [289] R. Osaie *et al.*, “Effects of ultrasound, osmotic dehydration, and osmosonication pretreatments on bioactive compounds, chemical characterization, enzyme inactivation, color, and antioxidant activity of dried ginger slices,” *J. Food Biochem.*, vol. 43, no. 5, pp. 1–14, 2019.
- [290] M. S. Fedha, “Physicochemical Characterization and Food Application Potential of Pumpkin (*Cucurbita* Sp.) Fruit and Seed Kernel Flours,” 2008.
- [291] P. J. Fellows, *Food processing technology: Principles and practice: Third edition*, Second Edi. Woodhead Publishing Limited Abington Hall, Abington Cambridge CB1 6AH, England, 2009.
- [292] D. M. Kadam, B. K. Tiwari, and C. P. O’Donnell, “Effect of microwave pre-drying on quality and uniformity of hot air-dried apple slices,” *J. Food Eng.*, vol. 144, pp. 94–101, 2015.
- [293] N. Van Toan *et al.*, “Production of high-quality flour and the made biscuits from Pumpkin,” pp. 157–166, 2018.

- [294] M. . El-Deremy, "Evaluation of physico-chemical properties of toast breads fortified with pumpkin(*Cucurbita moschata*) flour.," 2011.
- [295] P. Khandpur and P. R. Gogate, "Effect of novel ultrasound based processing on the nutrition quality of different fruit and vegetable juices," *Ultrason. Sonochem.*, vol. 27, pp. 125–136, 2015.
- [296] L. G. Marques, A. M. Silveira, and J. T. Freire, "Freeze-drying characteristics of tropical fruits," *Dry. Technol.*, vol. 24, no. 4, pp. 457–463, 2006.
- [297] R. K. Saini, N. P. Shetty, M. Prakash, and P. Giridhar, "Effect of dehydration methods on retention of carotenoids, tocopherols, ascorbic acid and antioxidant activity in *Moringa oleifera* leaves and preparation of a RTE product," *J. Food Sci. Technol.*, vol. 51, no. 9, pp. 2176–2182, 2014.
- [298] M. Zhang, L. Zhang, H. Chen, H. Yang, and A. S. Mujumdar, "Effect of ultrasound pretreatment on drying kinetics and quality attributes of kiwifruit slices," *J. Food Sci. Technol.*, vol. 55, no. 7, pp. 2596–2605, 2018.
- [299] X. Sun, I. C. Ohanenye, T. Ahmed, and C. C. Udenigwe, "Microwave treatment increased protein digestibility of pigeon pea (*Cajanus cajan*) flour: Elucidation of underlying mechanisms," *Food Chem.*, vol. 329, no. May, p. 127196, 2020.
- [300] A. Verma, A. Sharma, P. K. Rai, and D. Kumar, "Effect of microwave pre-treatment on quality parameters in Indian mustard," *J. Food Sci. Technol.*, vol. 56, no. 11, pp. 4956–4965, 2019.
- [301] M. Zhang, L. Zhang, H. Chen, H. Yang, and A. S. Mujumdar, "Effects of microwave and ultrasound pre-drying treatments on dehydration characteristics, phytate content and antioxidant activity of jujube slices.," *J. Food Sci. Technol.*, vol. 56, no. 1, pp. 425–434, 2019.
- [302] K. Hayat *et al.*, "Effect of microwave treatment on phenolic content and antioxidant activity of citrus mandarin pomace," *Food Chem.*, vol. 123, no. 2, pp. 423–429, 2010.
- [303] E. Gómez-Plaza, R. Gil-Muñoz, J. M. López-Roca, J. I. Fernández-Fernández, and A. Martínez-Cutillas, "Effect of microwave treatment on the extraction of phenolic compounds from grape pomace," *J. Agric. Food Chem.*, vol. 61, no. 41, pp. 10034–10040, 2013.
- [304] P. N. Muchirah, R. Waihenya, S. Muya, L. Abubakar, and H. Ozwara, "Characterization

- and anti-oxidant activity of Cucurbita maxima Duchesne pulp and seed extracts
 Characterization and anti-oxidant activity of Cucurbita maxima Duchesne pulp and seed
 extracts,” *J. Phytopharm.*, vol. 7, no. 2, pp. 134–140, 2018.
- [305] W. Roongruangsri and J. E. Bronlund, “Effect of air-drying temperature on physico-
 chemical, powder properties and sorption characteristics of pumpkin powders,” *Int. Food
 Res. J.*, vol. 23, no. 3, pp. 962–972, 2016.
- [306] E. Horuz, H. J. Jaafar, and M. Maskan, “Ultrasonication as pretreatment for drying of
 tomato slices in a hot air–microwave hybrid oven,” *Dry. Technol.*, vol. 35, no. 7, pp. 849–
 859, 2017.
- [307] M. Opalic, Z. Domitranl, D. Komes, A. Belšcak, D. Horžic, and D. Karlović, “The effect
 of ultrasound pretreatment and air-drying on the quality of dried apples,” *Czech J. Food
 Sci.*, vol. 27, no. SPEC. ISS., pp. 297–300, 2009.
- [308] F. Ren, C. A. Perussello, Z. Zhang, J. P. Kerry, and B. K. Tiwari, “Impact of ultrasound
 and blanching on functional properties of hot-air dried and freeze dried onions,” *LWT -
 Food Sci. Technol.*, vol. 87, pp. 102–22, 2018.
- [309] S. Wilhelm and Helmut Sies, “Antioxidant activity of carotenoids,” *Mol. Asp. Med.* 24,
 vol. 24, pp. 345–351, 2003.
- [310] M. Asif *et al.*, “Antioxidant, antibacterial & antiproliferative activities of pumpkin
 (cucurbit) peel & puree extracts -An in vitro study,” *Pak. J. Pharm. Sci.*, vol. 30, no. 4, pp.
 1327–1334, 2017.
- [311] Ó. Rodríguez, J. V. Santacatalina, S. Simal, J. V. Garcia-Perez, A. Femenia, and C.
 Rosselló, “Influence of power ultrasound application on drying kinetics of apple and its
 antioxidant and microstructural properties,” *J. Food Eng.*, vol. 129, pp. 21–29, 2014.
- [312] L. Titikan and S. Rungarun, “View of Effect of Thermal Treatments on Antioxidant
 Properties of Pumpkin Flesh and Their Stability during in-vitro Gastrointestinal
 Digestion,” *Food Appl. Biosci. J.*, vol. 2019, no. March, pp. 118–130, 2019.
- [313] D. M. Kadam, B. D. Kulkarni, and V. K. Rathod, “Effect of drying methods on
 physicochemical and functional properties of fruit powders: A review.,” *J. Food Eng.*, vol.
 289, p. 110144, 2020.
- [314] J. Lim *et al.*, “Effect of Pre-Treatment on the Physical Properties of Pumpkin Powder,”
 vol. 10, no. 7, pp. 146–151, 2016.

- [315] H. Mirhosseini and B. T. Amid, "Effect of different drying techniques on flowability characteristics and chemical properties of natural carbohydrate-protein Gum from durian fruit seed," *Chem. Cent. J.*, vol. 7, no. 1, 2013.
- [316] S. M. Asif-Ul-Alam, M. Z. Islam, M. M. Hoque, and K. Monalisa, "Effects of Drying on the Physicochemical and Functional Properties of Green Banana (*Musa sapientum*) Flour and Development of Baked Product," *Am. J. Food Sci. Technol.*, vol. 2, no. 4, pp. 128–133, 2014.
- [317] P. Suresh Kumar, M. Pugalenti, V. Vadivel, and K. Janardhanan, "Effect of drying methods on the retention of antinutrients and antioxidant properties of drumstick leaves (*Moringa oleifera*)," *J. Food Sci. Technol.*, vol. 51, no. 11, pp. 3464–3469, 2014.
- [318] O. F. Osundahunsi, T. N. Fagbemi, E. Kesselman, and E. Shimoni, "Comparison of the physicochemical properties and pasting characteristics of flour and starch from red and white sweet potato cultivars," *J. Agric. Food Chem.*, vol. 51, no. 8, pp. 2232–2236, 2003.
- [319] T. L. Traynham, D. J. Myers, A. L. Carriquiry, and L. A. Johnson, "Evaluation of water-holding capacity for wheat-soy flour blends," *JAOCs, J. Am. Oil Chem. Soc.*, vol. 84, no. 2, pp. 151–155, 2007.
- [320] M. Saeleaw and G. Schleining, "Composition, Physicochemical and Morphological Characterization of Pumpkin Flour," in *11th International Congresson Engineering and Food*, 2011.
- [321] M. Bhagya, G. Sanja, and I. Marliya, "EFFECT OF PRETREATMENT METHODS ON THE QUALITY OF DEHYDRATED PUMPKIN SLICES," 2018.
- [322] F. Hasturk Sahin, T. Aktas, H. Orak, and P. Ulger, "Influence of pretreatments and different drying methods on color parameters and lycopene content of dried tomato," *Bulg. J. Agric. Sci.*, vol. 17, no. 6, pp. 867–881, 2011.
- [323] T. S. Workneh, A. Zinash, and K. Woldetsadik, "Blanching, salting and sun drying of different pumpkin fruit slices," *J. Food Sci. Technol.*, vol. 51, no. 11, pp. 3114–3123, 2014.
- [324] Derese Wodajo and S. A. Emire, "Pumpkin flour qualities as affected by ultrasound and microwave pre-drying treatment," *Int. J. Food Prop.*, vol. 25, no. 1, pp. 2409–2424, 2022.
- [325] M. Zhang, M. Zhang, B. Adhikari, and R. Adhikari, "Combined effect of ultrasound and microwave pretreatment on drying kinetics and quality of kiwifruit," *J. Food Process.*

- Preserv.*, vol. 44, no. 5, p. e14454., 2020.
- [326] G. Barbosa-Canovas, E. Ortega-Rivas, P. Juliano, and H. Yan, *Food powders: physical properties, processing, and functionality*. New York: Kluwer Academic/Plenum Publishers, 2005.
- [327] Y. Lee and W. Yoon, “Effects of particle size and heating time on thiobarbituric acid (TBA) test of soybean powder,” *Food Chem.*, vol. 138, no. 2–3, pp. 841–850, 2013.
- [328] K. X. Zhu, S. Huang, W. Peng, H. F. Qian, and H. M. Zhou, “Effect of ultrafine grinding on hydration and antioxidant properties of wheat bran dietary fiber,” *Food Res. Int.*, vol. 43, no. 4, pp. 943–948, 2010.
- [329] Shudong He *et al.*, “Physicochemical and antioxidant properties of hard white winter wheat (*Triticum aestivum* L.) bran superfine powder produced by eccentric vibratory milling,” *Powder Technol.*, vol. 325, pp. 126–133, 2018.
- [330] Q. M. Chen, M. R. Fu, F. L. Yue, and Y. Y. Cheng, “Effect of Superfine Grinding on Physicochemical Properties, Antioxidant Activity and Phenolic Content of Red Rice (*Oryza sativa* L.)” *Food Nutr. Sci.*, vol. 06, no. 14, pp. 1277–1284, 2015.
- [331] F. M. Zhu, B. Du, and B. J. Xu, “Superfine grinding improves functional properties and antioxidant capacities of bran dietary fibre from Qingke (hull-less barley) grown in Qinghai–Tibet Plateau, China,” *J. Cereal Sci.*, vol. 65, pp. 43–47, 2015.
- [332] R. S. Reddy, C. T. Ramachandra, S. Hiregoudar, U. Nidoni, J. Ram, and M. Kammar, “Influence of processing conditions on functional and reconstitution properties of milk powder made from Osmanabadi goat milk by spray drying,” *Small Rumin. Res.*, vol. 119, no. 1–3, pp. 130–137, 2014.
- [333] AOAC, *Association of Official Analytical Chemists*, 18th edn. Gaithersburg, 2006, 2006.
- [334] A. of O. A. C. AOAC, *Official Methods of Analysis of the Association of the AOAC*, 19th edn. Association of Official Analytical Chemists Inc., Gaithersburg, 2012, 2012.
- [335] M. Minuye, P. Getachew, A. Laillou, S. Chitekwe, and K. Baye, “Effects of different drying methods and ascorbic acid pretreatment on carotenoids and polyphenols of papaya fruit in Ethiopia,” *Food Sci. Nutr.*, vol. 9, no. 6, pp. 3346–3353, 2021.
- [336] A. Z. Woldegiorgis, D. Abate, G. D. Haki, and G. R. Ziegler, “Antioxidant property of edible mushrooms collected from Ethiopia,” *Food Chem.*, vol. 157, pp. 30–36, 2014.

- [337] X. Zhao, Z. Yang, G. Gai, and Y. Yang, "Effect of superfine grinding on properties of ginger powder," *J. Food Eng.*, vol. 91, no. 2, pp. 217–222, 2009.
- [338] Y. Fayin, T. Bingbing, J. Liu, and Y. Zou, "Effect of micronization on the physicochemical properties of insoluble dietary fiber from citrus (*Citrus junos* Sieb . ex Tanaka) pomace," *Food Sci. Technol. Int. 0(0)*, pp. 1–10, 2015.
- [339] J. Ahmed, A. Taher, M. Z. Mulla, A. Al-Hazza, and G. Luciano, "Effect of sieve particle size on functional, thermal, rheological and pasting properties of Indian and Turkish lentil flour," *J. Food Eng.*, vol. 186, pp. 34–41, 2016.
- [340] Y. Liu, L. Wang, F. Liu, and S. Pan, "Effect of Grinding Methods on Structural, Physicochemical, and Functional Properties of Insoluble Dietary Fiber from Orange Peel," *Int. J. Polym. Sci.*, 2016.
- [341] M. S. Hunter *et al.*, "X-ray diffraction from membrane protein nanocrystals," *Biophys. J.*, vol. 100, pp. 198–206, 2011.
- [342] E. Hitayezu and Y. Kang, "Effect of particle size on the physicochemical and morphological properties of *Hypsizygus marmoreus* mushroom powder and its hot-water extracts," vol. 28, no. July, pp. 540–549, 2021.
- [343] Wang, Z., J. Huang, Y. Zhang, X. Li, and G. Liu, "Effects of particle size on the physicochemical and functional properties of rice flour," *J. Cereal Sci.*, vol. 77, pp. 74–80, 2017.
- [344] Li Guanghui, W. Guo, X. Gao, Y. Wang, and S. Sun, "Effect of superfine grinding on physicochemical and antioxidant properties of soybean residue powder," *Food Sci Nutr.*, vol. 00, pp. 1–7, 2020.
- [345] M. K. Bolade, I. A. Adeyemi, and A. O. Ogunsua, "Influence of particle size fractions on the physicochemical properties of maize flour and textural characteristics of a maize-based nonfermented food gel," *Int. J. Food Sci. Technol.*, vol. 44, no. 3, pp. 646–655, 2009.
- [346] J. Ahmed, H. Al-attar, and Y. A. Arfat, "Effect of particle size on compositional, functional, pasting and rheological properties of commercial water chestnut flour," *Food Hydrocoll.*, 2015.
- [347] J. Ahmed, S. Al-Jassar, and L. Thomas, "A comparison in rheological, thermal, and structural properties between Indian Basmati and Egyptian Giza rice flour dispersions as

- influenced by particle size,” *Food Hydrocoll.*, vol. 48, pp. 72–83, 2015.
- [348] A. Gani, S. S. Haq, F. A. Masoodi, A. A. Broadway, and A. Gani, “Physico-chemical, Morphological and Pasting Properties of Starches Extracted from Water Chestnuts (*Trapa natans*) from Three Lakes of Kashmir, India,” *Braz. Arch. Biol. Technol.*, vol. 53, no. 3, pp. 731–740, 2010.
- [349] S. Xianbao *et al.*, “Effects of particle size on physicochemical and functional properties of superfine black kidney bean (*Phaseolus vulgaris* L.) powder,” *PeerJ*, vol. 2019, no. 2, 2019.
- [350] M. K. Mahawar, K. Jalgaonkar, V. E. Nambi, B. Bibwe, and V. Thirupathi, “Modelling of rheological properties of mango (cv. Neelum) suspensions: Effect of sample concentration and particle size,” *J. Agric. Eng.*, vol. 55, no. 4, pp. 13–20, 2019.
- [351] A. G. Farombi and A. M. Oyekanmi, “Proximate , Mineral and Anti-Nutrient Evaluation of Pumpkin Pulp (*Cucurbita Pepo*),” vol. 4, no. 5, pp. 25–28, 2013.
- [352] R. O. Adelerin, B. O. Ifesan, and O. O. Awolu, “Physicochemical, nutritional, phytoconstituents, and antioxidant properties of three different processing techniques of pumpkin (*Cucurbita pepo*) pulp flour,” *Ceylon J. Sci.*, vol. 51, no. 1, p. 43, 2022.
- [353] J. Li, W. Zhang, X. Sun, and Y. Liu, “Effect of microwave pre-drying on the physicochemical properties of apple flour,” *J. Food Process. Preserv.*, vol. 44, no. 9, p. e14614, 2020.
- [354] O. O. Awolu, O. O. Adebo, and A. S. Afolabi, “Effect of particle size reduction on physicochemical properties of banana flour,” *J. Food Sci. Technol.*, vol. 52, no. 4, pp. 2261–2268, 2015.
- [355] N. Boukhari, A. Doumandji, F. S. A. Chaouche, and A. Ferradji, “Effect of ultrasound treatment on protein content and functional properties of Spirulina powder grown in Algeria,” *Med. J. Nutrition Metab.*, vol. 11, no. 3, pp. 235–249, 2018.
- [356] D. L. Luthria, K. Noel, and D. Vinjamoori, “Impact of sample preparation on the determination of crude fat content in corn,” *JAOCs, J. Am. Oil Chem. Soc.*, vol. 81, no. 11, pp. 999–1004, 2004.
- [357] Z. H. Tekin and M. Baslar, “The effect of ultrasound-assisted vacuum drying on the drying rate and quality of red peppers,” *J. Therm. Anal. Calorim.*, vol. 132, no. 2, pp. 1131–1143, 2018.

- [358] X. Zhao, H. Zhu, G. Zhang, and W. Tang, “Effect of super fine grinding on the physicochemical properties and antioxidant activity of red grape pomace powders,” *Powder Technol.*, vol. 286, pp. 838–844, 2015.
- [359] F. Lei *et al.*, “Effect of particle size distribution on the carotenoids release, physicochemical properties and 3D printing characteristics of carrot pulp,” *Lwt*, vol. 139, p. 110576, 2021.
- [360] C. S. Speroni *et al.*, “Micronization and granulometric fractionation improve polyphenol content and antioxidant capacity of olive pomace,” *Ind. Crops Prod.*, vol. 137, no. April, pp. 347–355, 2019.
- [361] J. Zhang, Y. Dong, T. Nisar, Z. Fang, Z. C. Wang, and Y. Guo, “Effect of superfine-grinding on the physicochemical and antioxidant properties of *Lycium ruthenicum* Murray powders,” *Powder Technol.*, vol. 372, pp. 68–75, 2020.
- [362] Y. X. Bai and Y. F. Li, “Preparation and characterization of crosslinked porous cellulose beads,” *Carbohyd. Polym*, vol. 64, pp. 402–407, 2006.
- [363] K. Shevkani, N. Singh, A. Kaur, and J. C. Rana, “Physicochemical, Pasting, and Functional Properties of Amaranth Seed Flours: Effects of Lipids Removal,” *J. Food Sci.*, vol. 79, no. 7, 2014.
- [364] C. R. Köhn, A. M. Fontoura, A. P. Kempka, I. M. Demiate, E. H. Kubota, and R. C. Prestes, “Assessment of different methods for determining the capacity of water absorption of ingredients and additives used in the meat industry,” *Int. Food Res. J.*, vol. 22, no. 1, pp. 356–362, 2015.
- [365] V. Benítez, E. Mollá, M. A. Martín-Cabrejas, Y. Aguilera, and R. M. Esteban, “Physicochemical properties and in vitro antidiabetic potential of fibre concentrates from onion by-products,” *J. Funct. Foods*, vol. 36, pp. 34–42, 2017.
- [366] B. Du, F. Zhu, and B. Xu, “Physicochemical and antioxidant properties of dietary fibers from Qingke (hull-less barley) flour as affected by ultrafine grinding,” *Bioact. Carbohydrates Diet. Fibre*, vol. 4, no. 2, pp. 170–175, 2014.
- [367] F. Hofmann, R. J. Harder, W. Liu, Y. Liu, I. K. Robinson, and Y. Zayachuk, “Glancing-incidence focussed ion beam milling: A coherent X-ray diffraction study of 3D nano-scale lattice strains and crystal defects,” *Acta Mater.*, vol. 154, pp. 113–123, 2018.
- [368] J. Harasym, E. Satta, and U. Kaim, “Ultrasound treatment of buckwheat grains impacts

- important functional properties of resulting flour,” *Molecules*, vol. 25, no. 13, pp. 1–15, 2020.
- [369] N. Trancoso-Reyes, L. A. Ochoa-Martínez, L. A. Bello-Pérez, J. Morales-Castro, R. Estévez-Santiago, and B. Olmedilla-Alonso, “Effect of pre-treatment on physicochemical and structural properties, and the bioaccessibility of β -carotene in sweet potato flour,” *Food Chem.*, vol. 200, pp. 199–205, 2016.
- [370] W. Fila, E. Itam, and J. Johnson, “Comparative proximate compositions of watermelon (*Citrullus Lanatus*), squash (*Cucurbita Pepo*’l) and rambutan (*Nephelium Lappaceum*),” *Int. J. Sci. Technol.*, 2013.
- [371] C. S. MARTINEZ, P. D. RIBOTTA, A. E. LEÓN, and M. C. AÑÓN³, “PHYSICAL, SENSORY AND CHEMICAL EVALUATION OF COOKED SPAGHETTI,” *J. Texture Stud.*, vol. 38, pp. 666–683, 2007.
- [372] S. Ragae, Abdel-Aal, and E.-S. M., “Pasting properties of starch and protein in selected cereals and quality of their food products,” *Food Chem.*, vol. 95, no. 1, pp. 9–18, 2006.
- [373] S. Khushbu, C. K. Sunil, D. V. Chidanand, and R. Jaganmohan, “Effect of particle size on compositional, structural, rheological, and thermal properties of shallot flour as a source of thickening agent,” *J. Food Process Eng.*, vol. 43, no. 3, pp. 1–13, 2020.
- [374] I. L. Batey and B. M. Curtin, “Effects on pasting viscosity of starch and flour from different operating conditions for the rapid Visco analyser,” *Cereal Chem.* 77(6), 754–760, vol. 77, no. 6, pp. 754–760, 2000.
- [375] H.-J. Chung, Q. Liu, R. Hoover, T. D. Warkentin, and B. Vandenberg, “In vitro starch digestibility, expected glycemic index, and thermal and pasting properties of flours from pea, lentil and chickpea cultivars,” *Food Chem.*, vol. 111, no. 2, pp. 316–321, 2008.
- [376] P. Promsakha na Sakon Nakhon, K. Jangchud, A. Jangchud, and W. Prinyawiwatkul, “Comparisons of physicochemical properties and antioxidant activities among pumpkin (*Cucurbita moschata* L.) flour and isolated starches from fresh pumpkin or flour,” *Int. J. Food Sci. Technol.*, vol. 52, no. 11, pp. 2436–2444, 2017.
- [377] M. Ghafoor, N. Misra, K. Mahadevan, and B. Tiwari, “Ultrasound assisted hydration of navy beans (*Phaseolus vulgaris*),” *Ultrason. Sonochemistry*, vol. 21, pp. 409–414, 2014.
- [378] F. Zhu and H. Li, “Modification of quinoa flour functionality using ultrasound,” *Ultrason. Sonochemistry*, vol. 52, pp. 305–310, 2019.

- [379] K. S. Sandhu and N. Singh, “Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties,” *Food Chem.*, vol. 101, no. 4, pp. 1499–1507, 2007.
- [380] S. Chaiwanichsiri, M. Supphantharika, and P. Pinthusophon, “Effects of flour particle size and added fibers on the pasting properties of cassava flour.,” *J. Food Sci. Technol.*, vol. 54, no. 11, pp. 3509–3517, 2017.
- [381] Y. Chen, B. Zhang, Z. Tong, and J. Li, “Effect of ultrasound treatment on the physicochemical properties of corn starch.,” *Ultrason. Sonochem.*, vol. 48, pp. 426–433, 2018.
- [382] G. S. V. Raghavan, L. R. V. Ramana, and N. G. Malleshi, “Effect of particle size on thermal properties of wheat flour,” *J. Food Sci. Technol.*, vol. 52, no. 4, pp. 2314–2319, 2015.
- [383] R. Husnain *et al.*, “Effects of ball-milling on physicochemical , thermal and functional properties of extruded chickpea (*Cicer arietinum* L .) powder,” *CyTA - J. Food*, vol. 17, no. 1, pp. 563–573, 2019.
- [384] S. E. Quintana, R. M. Marsiglia, D. Machacon, E. Torregroza, and L. A. Garcia-Zapateiro, “Chemical composition and physicochemical properties of squash (*Cucurbita moschata*) cultivated in Bolivar department (Colombia),” *Contemp. Eng. Sci.*, vol. 11, no. 21, pp. 1003–1012, 2018.
- [385] M. Zhang, H. Zhao, F. Xie, and L. Chen, “Effects of microwave treatment on the structure and physicochemical properties of potato starch.,” *Int. J. Biol. Macromol.*, vol. 167, pp. 1066–1074.
- [386] M. Abdollahi, A. Farahnaky, M. Majzoobi, and G. Mesbahi, “Effect of ultrasound-assisted freeze-drying on the physicochemical properties of potato starch.,” *Carbohydr. Polym.*, vol. 15, pp. 596–604, 2016.
- [387] X. Wang, H. Sun, and X. Li, “Effect of particle size on the Fourier transform infrared spectra of wheat flour.,” *J. Food Eng.*, vol. 121, pp. 129-133., 2014.
- [388] J. Rojas, Y. Uribe, and A. Zuluaga, “Powder and compaction characteristics of pregelatinized starches,” *Pharmazie*, vol. 67, no. 6, pp. 513–517, 2012.
- [389] H. B. ZHAO, J. H. KWAK, Z. C. ZHANG, H. M. BROWN, B. W. AREY, and J. E. HOLLADAY, “Studying cellulose fiber structure by SEM, XRD, NMR and acid

- hydrolysis,” *Carbohydr. Polym.*, vol. 68, pp. 235–241, 2007.
- [390] J. O. Ugwuanyi, C. E. Ofoedu, and R. U. Ofoegbu, “Ultrasound-assisted microwave drying of cassava starch: Effects on physicochemical properties and microstructure.,” *J. Food Process Eng.*, vol. 41, no. 3, p. e12714, 2018.
- [391] K. Bashir and M. Aggarwal, “Physicochemical, thermal and functional properties of gamma irradiated chickpea starch.,” *Int. J. Biol. Macromol.*, vol. 97, pp. 426–433, 2017.
- [392] C. xia Li, Y. ying Liu, H. sheng Feng, and S. zhen Ma, “Effect of superfine grinding on the physicochemical properties of bulbs of *Fritillaria unibracteata* Hsiao et K.C. Hsia powder,” *Food Sci. Nutr.*, vol. 7, no. 11, pp. 3527–3537, 2019.
- [393] S. Garg, P. Rawat, and R. R. B. Singh, “Effect of ultrasound and microwave pre-treatments on the physicochemical and functional properties of peach and pear powders. *Journal of Food Engineering*,” vol. 261, pp. 1–8, 2019.
- [394] M. Albayrak and E. Gunes, “Traditional foods: Interaction between local and global foods in Turkey,” *African J. Bus. Manag.*, vol. 4, no. 4, pp. 555–561, 2010.
- [395] L. Padalino, M. Mastromatteo, G. Sepielli, M. Alessandro, and D. Nobile, “Based on Maize Flour and Oat Bran Enriched in β -Glucans,” pp. 2119–2135, 2011.
- [396] M. Meenu *et al.*, “A Detailed Review on Quality Parameters of Functional Noodles,” *Food Rev. Int.*, vol. 00, no. 00, pp. 1–37, 2022.
- [397] L. Padalino *et al.*, “Functional pasta with tomato by-product as a source of antioxidant compounds and dietary fibre,” *Czech J. Food Sci.*, vol. 35, no. 1, pp. 48–56, 2017.
- [398] D. Alemayehu, G. Desse, K. Abegaz, B. B. Desalegn, and D. Getahun, “Proximate, Mineral Composition and Sensory Acceptability of Home Made Noodles from Stinging Nettle (*Urtica simensis*) Leaves and Wheat Flour Blends,” *Int. J. Food Sci. Nutr. Eng.*, vol. 6, no. 3, pp. 55–61, 2016.
- [399] N. T. Manyatsi, W. K. Solomon, J. S. Shelembe, N. T. Manyatsi, W. K. Solomon, and J. S. Shelembe, “Optimization of blending ratios of wheat-maize- sprouted mungbean (*Vigna radiata* L .) composite flour bread using D-optimal mixture design Optimization of blending ratios of wheat-maize-sprouted mungbean (*Vigna radiata* L .) composite flour bread using D,” 2020.
- [400] A. Gull, K. Prasad, and P. Kumar, “Nutritional, antioxidant, microstructural and pasting properties of functional pasta,” *J. Saudi Soc. Agric. Sci.*, vol. 17, no. 2, pp. 147–153, 2018.

- [401] M. Mariotti, S. Iametti, C. Cappa, P. Rasmussen, and M. Lucisano, “Characterisation of gluten-free pasta through conventional and innovative methods: Evaluation of the uncooked products,” *J. Cereal Sci.*, vol. 53, no. 3, pp. 319–327, 2011.
- [402] E. H. Erbiai, L. Pinto da Silva, R. Saidi, Z. Lamrani, J. C. G. Esteves da Silva, and A. Maouni, “Chemical composition, bioactive compounds and antioxidant activity of two wild edible mushrooms *armillaria mellea* and *macrolepiota procera* from two countries (Morocco and portugal),” *Biomolecules*, vol. 11, no. 4, pp. 1–11, 2021.
- [403] AACC, *American Association for Clinical Chemistry- International approved methods of analysis*, 11th ed. St. Paul, MN, USA, 2010.
- [404] V. Larrosa, G. Lorenzo, N. Zaritzky, and A. Califano, “Improvement of the texture and quality of cooked gluten-free pasta,” *Lwt*, vol. 70, pp. 96–103, 2016.
- [405] A. S. Szczesniak, “Texture is a sensory property,” *Food Qual. Prefer.*, vol. 13, no. 4, pp. 215–225, 2002.
- [406] J. Liu, J. Yin, Y. Zhang, L. Zhao, Y. Li, and X. Zhou, “Effect of carboxymethyl cellulose on rheological and textural properties of instant noodles,” *Int. J. Food Sci. Technol.*, vol. 55, no. 55, pp. 2066–2072, 2020.
- [407] Y. Hu, Y. Huang, W. Tang, and F. Chen, “Impact of carboxymethyl cellulose on cooking and sensory properties of cooked noodles,” *J. Food Eng.*, vol. 251, pp. 46–53, 2019.
- [408] L. Kamali Roustaa, A. Pouya Ghandehari Yazdi, S. Khorasani, M. Tavakoli, Z. Ahmadi, and M. Amini, “Optimization of novel multigrain pasta and evaluation of physicochemical properties: using D-optimal mixture design,” *Food Sci. Nutr.*, vol. 9, no. 10, pp. 5546–5556, 2021.
- [409] L. L. Battaiotto, C. E. Lupano, and A. E. Bevilacqua, “Optimization of Basic Ingredient Combination for Sandwich Cookie Filling Using Response Surface Methodology,” pp. 1847–1855, 2013.
- [410] A. Gull, K. Prasad, and P. Kumar, “Optimization and functionality of millet supplemented pasta,” 2015.
- [411] C. F. Diedericks and V. A. Jideani, “Physicochemical and Functional Properties of Insoluble Dietary Fiber Isolated from Bambara Groundnut (*Vigna subterranea* [L.] Verdc.),” *J. Food Sci.*, vol. 80, no. 9, pp. 1933–1944, 2015.
- [412] G. Kaur, S. Sharma, H. P. S. Nagi, and P. S. Ranote, “Enrichment of pasta with different

- plant proteins,” *J. Food Sci. Technol.*, vol. 50, no. 5, pp. 1000–1005, 2013.
- [413] A. Lorusso, M. Verni, M. Montemurro, R. Coda, M. Gobbetti, and C. G. Rizzello, “Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features,” *Lwt*, vol. 78, pp. 215–221, 2017.
- [414] R. L. Shogren, G. A. Hareland, and Y. V. Wu, “Sensory evaluation and composition of spaghetti fortified with soy flour,” *J. Food Sci.*, vol. 71, no. 6, pp. 428–432, 2006.
- [415] T. Bojňanská, H. Frančáková, M. Lišková, and M. Tokár, “Legumes – the Alternative Raw Materials for Bread Production,” *J. Microbiol.*, vol. 1, pp. 876–886, 2012.
- [416] K. MA, M. C, V. P, S. GK, and S. AD, “Effect of Pumpkin Flour on the Rheological Characteristics of Wheat Flour and on Biscuit Quality,” *J. Food Process. Technol.*, vol. 10, no. 10, 2019.
- [417] B. M. Veena, S. Hb, and U. Ravidra, “Enhancement of nutritional quality of pasta by incorporating underutilized greens,” *J. Pharmacogn. Phytochem.*, vol. 8, no. 4, pp. 3118–3121, 2019.
- [418] D. Çakmakçı, Ü. İ. Konak, and Y. Yavuz Abanoz, “Physical, nutritional, textural and sensory qualities of Turkish noodles produced with siyez wheat (*Triticum monococcum*), kale (*Brassica oleracea* var. *acephala*) and chia seed (*Salvia hispanica* L.),” *Food Heal.*, vol. 8, no. 1, pp. 35–45, 2022.
- [419] C. M. Tudorica, V. Kuri, and C. S. Brennan, “Nutritional and Physicochemical Characteristics of Dietary Fiber,” *J. Agric. Food Chem.*, vol. 50, no. 2, pp. 347–356, 2002.
- [420] T. De Pilli, A. Derossi, and C. Severini, “Cooking quality characterisation of ‘spaghetti’ based on soft wheat flour enriched with oat flour,” *Int. J. Food Sci. Technol.*, vol. 48, no. 11, pp. 2348–2355, 2013.
- [421] B. Gatta, M. Rutigliano, L. Padalino, A. Conte, A. Del Nobile, and A. Di Luccia, “The role of hydration on the cooking quality of bran-enriched pasta Barbara,” *LWT - Food Sci. Technol.*, 2017.
- [422] E. K. Parassih, E. Y. Purwani, and W. El Kiyat, “Optimisation of cassava dried noodle using hydrocolloid and protein isolates: a tropical noodle,” *Futur. Food J. Food, Agric. Soc.*, vol. 8, no. 4, pp. 1–84, 2020.
- [423] C. S. Raina, S. Singh, A. S. Bawa, and D. C. Saxena, “TEXTURAL CHARACTERISTICS OF PASTA MADE FROM RICE FLOUR SUPPLEMENTED

- WITH PROTEINS,” vol. 36, pp. 402–420, 2005.
- [424] İrem Toprakçı, E. Urtulbaş, A. G. Pekel, and S. Şahin, “Application of D-optimal design for automatic solvent extraction of carotenoid from orange peel,” *J. Food Process. Preserv.*, vol. 45, no. 9, pp. 1–8, 2021.
- [425] N. I. Mohamad Zen, S. S. Abd Gani, R. Shamsudin, and H. R. Fard Masoumi, “The use of D-optimal mixture design in optimizing development of okara tablet formulation as a dietary supplement,” *Sci. World J.*, vol. 2015, 2015.
- [426] D. C. Kudake, A. V Pawar, and A. B. Muley, “Enrichment of Wheat Flour Noodles with Oat Flour : Effect on Physical , Nutritional , Antioxidant and Sensory Properties,” vol. 6, no. 12, pp. 204–213, 2017.
- [427] P. D. Shere, A. N. Devkatte, and V. N. Pawar, “Studies on Production of Functional Noodles with Incorporation of Spinach Puree,” *Int. J. Curr. Microbiol. Appl. Sci.*, vol. 7, no. 06, pp. 1618–1628, 2018.
- [428] N. Aukkanit and S. Sirichokworrakit, “Effect of Dried Pumpkin Powder on Physical, Chemical, and Sensory Properties of Noodle,” *Proc. Acad. World 52nd Int. Conf. Los Angeles*, no. 1, pp. 128–132, 2016.
- [429] J. Alberto *et al.*, “EFFECT OF THE ADDITION OF COMMON BEAN FLOUR ON THE COOKING,” vol. 2, no. 2, pp. 730–744, 2012.
- [430] Buttriss JL and C. Stokes, “Dietary fiber and health: an overview,” *Nutr. Bull.*, vol. 33, pp. 186–200, 2008.
- [431] K. N. Pakhare, A. C. Dagadkhair, and I. S. Udachan, “Enhancement of Nutritional and Functional Characteristics of Noodles by Fortification with Protein and Fiber : A Review,” vol. 7, no. 1, pp. 351–357, 2018.
- [432] I. Karkouch *et al.*, “Antioxidant, antityrosinase and antibiofilm activities of synthesized peptides derived from Vicia faba protein hydrolysate: A powerful agents in cosmetic application,” *Ind. Crops Prod.*, vol. 109, no. May, pp. 310–319, 2017.
- [433] M. S. Fernandez-Panchon, D. Villano, A. M. Troncoso, and M. C. Garcia-Parrilla, “Antioxidant activity of phenolic compounds: From in vitro results to in vivo evidence,” *Crit. Rev. Food Sci. Nutr.*, vol. 48, no. 7, pp. 649–671, 2008.
- [434] Y. Luo, J. Li, C. Xu, Z. Hao, X. Jin, and Q. Wang, “Impact of processing on in vitro bioavailability of phenols and flavonoids and antioxidant activities in faba bean (*Vicia*

- faba L.) and azuki bean (*Vigna angularis* L.),” *Legum. Res.*, vol. 37, no. 5, pp. 492–499, 2014.
- [435] W. Han, S. Ma, L. Li, X. X. Wang, and X. L. Zheng, “Application and Development Prospects of Dietary Fibers in Flour Products,” *J. Chem.*, vol. 2017, 2017.
- [436] B. Biernacka *et al.*, “Relationship between the properties of raw and cooked spaghetti - New indices for pasta quality evaluation,” *Int. Agrophysics*, vol. 32, no. 2, pp. 217–223, 2018.
- [437] S. Bharath Kumar and P. Prabhasankar, “A study on starch profile of rajma bean (*Phaseolus vulgaris*) incorporated noodle dough and its functional characteristics,” *Food Chem.*, vol. 180, pp. 124–132, 2015.
- [438] T. Poonsri, S. Jafarzadeh, F. Ariffin, and S. Z. Abidin, “Improving Nutrition , Physicochemical and Antioxidant Properties of Rice Noodles with Fiber and Protein-rich Fractions Derived from Cassava Leaves,” vol. 7, no. 4, pp. 325–332, 2019.
- [439] D. Setiady, M. Lin, F. Younce, and B. A. Rasco, “Incorporation of Minced Trout (*Oncorhynchus Mykiss*) Into Egg-Based Noodles,” vol. 31, pp. 480–491, 2007.
- [440] S. Singh, A. Arora, and B. Singh, “Germination: a vital process to improve the nutritional quality of grains and legumes,” *J. Food Sci. Technol.*, vol. 52, no. 2, pp. 1418-1445., 2015.
- [441] H. Oduro-Obeng, B. X. Fu, and T. Beta, “Influence of cooking duration on carotenoids, physical properties and in vitro antioxidant capacity of pasta prepared from three Canadian durum wheat cultivars,” *Food Chem.*, vol. 363, p. 130016, 2021.
- [442] G. Widelska *et al.*, “Impact of xanthan gum addition on phenolic acids composition and selected properties of new gluten- free maize-field bean pasta,” pp. 587–598, 2019.
- [443] L. Padalino, M. Mastromatteo, P. De Vita, D. B. Maria Ficco, and M. A. Del Nobile, “Effects of hydrocolloids on chemical properties and cooking quality of gluten-free spaghetti,” *Int. J. Food Sci. Technol.*, vol. 48, no. 5, pp. 972–983, 2013.
- [444] S. Kraithong, S. Lee, and S. Rawdkuen, “The Influence of Hydrocolloids on the Properties Organic Red Jasmine Rice Noodles, Namely on Antioxidant Activity, Cooking, Texture, and Sensory Properties,” *Starch/Staerke*, vol. 71, no. 1–2, pp. 1–9, 2019.
- [445] Ž. Ugarčić-Hardi, M. Jukić, D. K. Komlenić, M. Sabo, and J. Hardi, “Quality parameters of noodles made with various supplements,” *Czech J. Food Sci.*, vol. 25, no. 3, pp. 151–

157, 2007.

- [446] S. Chillo, J. Laverse, P. M. Falcone, and M. A. Del Nobile, "Effect of carboxymethylcellulose and pregelatinized corn starch on the quality of amaranthus spaghetti," *J. Food Eng.*, vol. 83, no. 4, pp. 492–500, 2007.
- [447] S. Y. Shiau, "Effects of emulsifiers on dough rheological properties and the texture of extruded noodles," *J. Texture Stud.*, vol. 35, no. 1, pp. 93–103, 2004.
- [448] N. Kaur, S. Sharma, D. N. Yadav, H. Bobade, and B. Singh, "Quality Characterization of Brown Rice Pasta Supplemented with Vital Gluten and Hydrocolloides," *Agric. Res.*, vol. 6, no. 2, pp. 185–194, 2017.
- [449] S. Yalcin and A. Basman, "Original article Effects of gelatinisation level , gum and transglutaminase on the quality characteristics of rice noodle," no. 2001, pp. 1637–1644, 2008.
- [450] S. Kraithong and S. Rawdkuen, "Effects of food hydrocolloids on quality attributes of extruded red Jasmine rice noodle," *PeerJ*, vol. 8, 2020.
- [451] D. N. Yadav, S. Balasubramanian, J. Kaur, T. Anand, and A. K. Singh, "Non-wheat pasta based on pearl millet flour containing barley and whey protein concentrate," *J. Food Sci. Technol.*, vol. 51, no. 10, pp. 2592–2599, 2014.

APPENDICES

Appendix Figure A. Agronomics and Morphological Characteristics of Haricot Beans Variety

A) Variety Awash-2

Adaptation area:	Central Rift Valley, similar lowland areas
○ Altitude (m.a.s.l)	1300 – 1700
○ Rainfall (mm)	400 -750
Seed rate (kg/ha):	90 – 100 for raw planting and 110 – 120 for broad casting
Spacing:	b/n rows 40 and b/n plants 10
Planting date:	End of June to early July
Fertilizer (kg/ha)	P ₂ O ₅ : 50; N: 50
Days to 50% flowering:	38-42
Days to 95% maturity:	85-90
Plant height (cm):	60
Growth habit:	Determinant bush (type I)
Flower color:	White
100 seed weight (gm):	23-25
Seed color:	Red
Crop disease reaction:	Relatively tolerant to CBB, HB, Rust, and drought
Yield Q/ha:	
○ Research field:	28-31
○ Farmer field:	18-22
Year of release:	2013
Breeder/ maintainer:	Melkasa ARC

B) Variety SER 125

Adaptation area:	Central Rift Valley, East, South, West, and North Western bean growing areas of Ethiopia ecologies
○ Altitude (m.a.s.l)	1000 – 1200
○ Rainfall (mm)	350 -1100
Seed rate (kg/ha):	80 – 90 for raw planting and 110 – 120 for broad casting
Spacing:	b/n raws 40 and b/n plants 10
Planting date:	End of June to mid-July
Fertilizer (kg/ha)	
○ DAP:	100
○ Urea:	25-50
Days to 50% flowering:	35-52
Days to 95% maturity:	70-90
Plant height (cm):	40-75
Growth habit:	Indeterminant bush (type II)
Flower color:	White
100 seed weight (gm):	23-25
Seed color:	Red
Crop disease reaction:	Tolerant to the major disease of beans (CBB, Rust, HB, Anthracnose, and ALS)
Yield Q/ha:	
○ Research field:	20-45
○ Farmer field:	18-32
Year of release:	2014

C) Variety SER 119

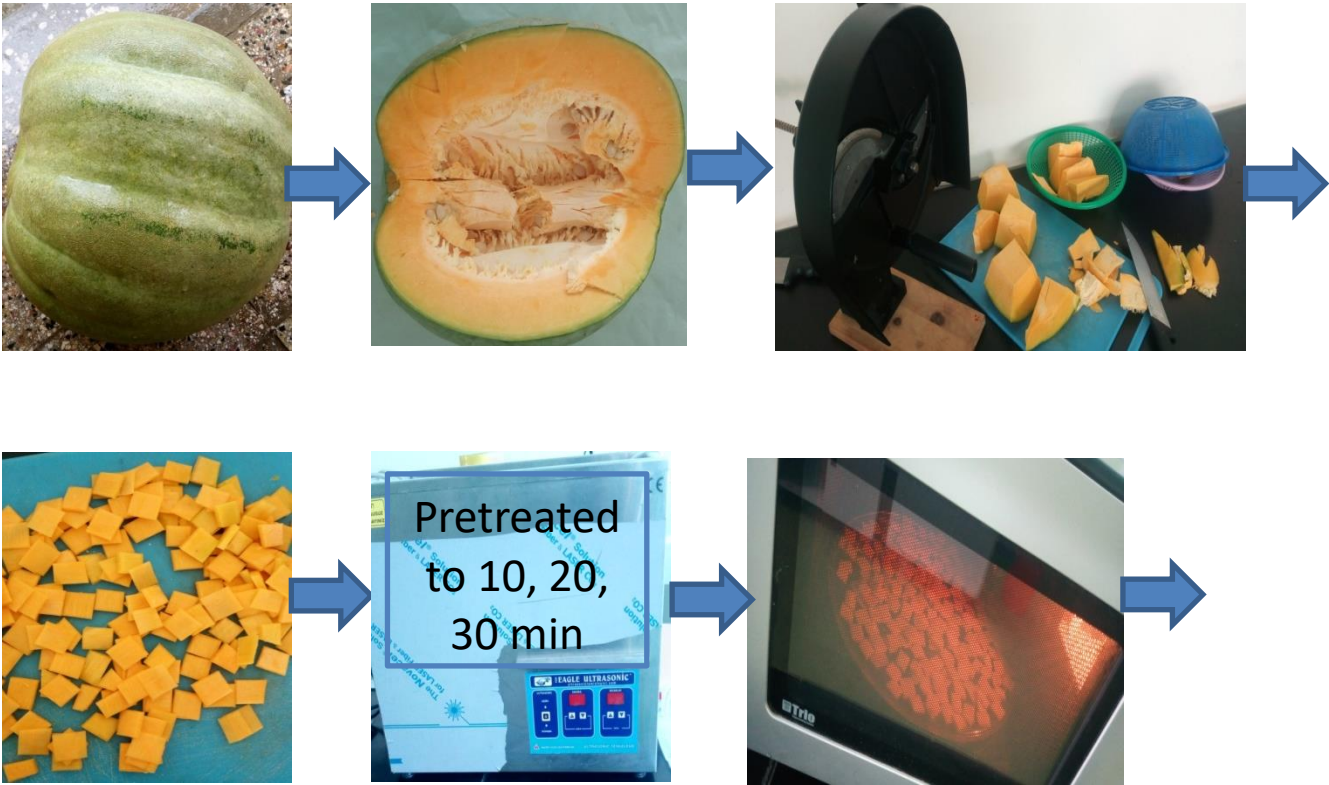
Adaptation area:	Central Rift Valley, SNNPR and Eastern Ethiopia (East and West Hararghe) and West Ethiopia (Jima, Wellega, Illubabor, West Showa), North West (Metekel and Kamashi), and similar agro-ecologies
○ Altitude (m.a.s.l)	1000 – 2200
○ Rainfall (mm)	400 -1100
Seed rate (kg/ha):	80 – 90 for raw planting and 110 – 120 for broad casting
Spacing:	b/n rows 40 and b/n plants 10
Planting date:	End of June to mid-July
Fertilizer (kg/ha)	
○ DAP:	100
○ Urea:	25-50
Days to 50% flowering:	36-52
Days to 95% maturity:	85-105
Plant height (cm):	40-65
Growth habit:	Indeterminant bush (type II)
Flower color:	White
100 seed weight (gm):	23-25
Seed color:	Red
Crop disease reaction:	Tolerant to the major disease of beans (CBB, Rust, HB, Anthracnose, and ALS)
Yield Q/ha:	

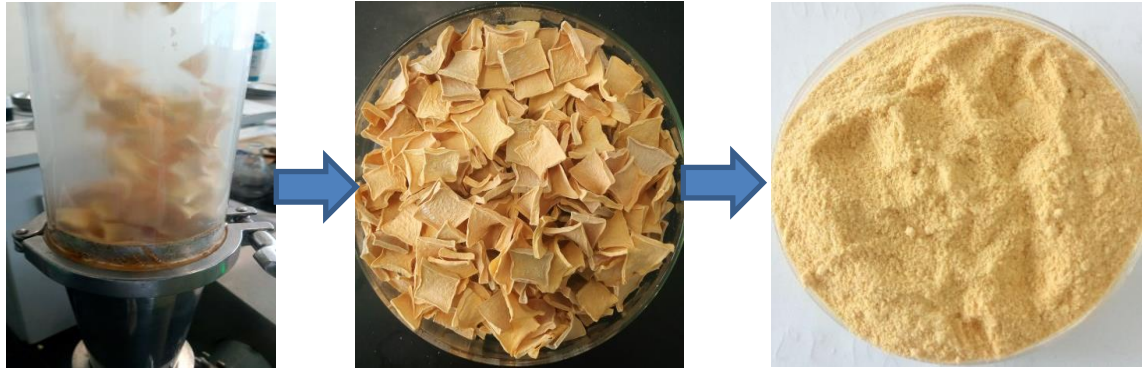
- Research field: 20-50
 - Farmer field: 18-40
- Year of release: 2014

Appendix Figure B. Haricot Beans Processing



Appendix Figure C. Pumpkin Processing





Appendix Figure D. Traditional *Kemesha* Processing



Kneading

Sheeting

Sheeted



Sliting

Spraying with
powdering

Drying

Appendix Figure E. Questionnaires

A. Open-ended questionnaires on *Kemesha* preparation methods, cooking methods, and consumption patterns:

1. Can you describe any techniques used in the preparation and cooking of *Kemesha* dishes in your area?
2. Do you have any family recipes or traditional methods that have been passed down through generations for preparing *Kemesha*? If yes, please share any details or stories associated with them.
3. Are there any challenges or difficulties you face when preparing *Kemesha*? If yes, please describe them.
4. Are there any particular occasions or celebrations in which *Kemesha* dishes hold significance in your area? Please elaborate.
5. Are there any specific regional variations in *Kemesha* preparation techniques that you are aware of? If yes, please provide details.
6. Have you noticed any changes in the consumption patterns of *Kemesha* dishes over the years? If yes, what do you think could be the reasons behind these changes?
7. Are there any efforts being made to promote *Kemesha* cooking methods and dishes in your area? If yes, please provide details.

8. What influences your choice of *Kemesha* dishes? (e.g., cultural heritage, personal preference, availability of ingredients)
9. Are there any efforts being made to promote *Kemesha* preparation methods and dishes in your area? If yes, please provide details.

B. Close-ended questionnaires on *Kemesha* preparation techniques, raw materials, and cooking methods:

1. How familiar are you with *Kemesha* preparation techniques?
 - a) Very familiar
 - b) Somewhat familiar
 - c) Not familiar at all
2. Have you ever personally prepared *Kemesha*?
 - a) Yes
 - b) No
3. If you answered "Yes" to the previous question, please describe your experience in *Kemesha* preparation (e.g., frequency, techniques used).
4. What are the key raw materials used in *Kemesha* preparation? (Check all that apply)
 - a) whole wheat flour
 - b) Refined wheat flour
 - c) Water
 - d) Salt
 - e) Other (please specify)
5. How important is the quality of raw materials in achieving the desired texture and taste of *Kemesha*?
 - a) Extremely important

- b) Somewhat important
 - c) Not very important
 - d) Not important at all
6. What cooking methods are commonly used in *Kemesha* preparation? (Check all that apply)
- a) Boiling
 - b) Baking
 - c) Other (please specify)

Appendix Figure F. Sensory Evaluation Sheet

Based on the provided criteria and your definition of good kemesha, rate the dried and cooked kemesha. Put the 'x' in the scale box that corresponds to the situation the best.

Color	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Dislike extrem ely	Dislike very much	Dislike moderat ely	Dislike slightly	Neither like nor dislike	Like slightly	Like modera tely	Like very much	like extreme ly
Odor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Dislike extrem ely	Dislike very much	Dislike moderat ely	Dislike slightly	Neither like nor dislike	Like slightly	Like modera tely	Like very much	like extreme ly
Texture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Dislike extrem ely	Dislike very much	Dislike moderat ely	Dislike slightly	Neither like nor dislike	Like slightly	Like modera tely	Like very much	like extreme ly
Appearance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Dislike extrem ely	Dislike very much	Dislike moderat ely	Dislike slightly	Neither like nor dislike	Like slightly	Like modera tely	Like very much	like extreme ly
Overall acceptability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Dislike extrem ely	Dislike very much	Dislike moderat ely	Dislike slightly	Neither like nor dislike	Like slightly	Like modera tely	Like very much	like extreme ly
Surface	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

