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COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

CENTER FOR FOOD SCIENCE AND NUTRITION

**Physicochemical and Techno-Functional Properties of Recently Released
Ethiopian Bread Wheat (*Triticum aestivum*. L) Varieties Grown in Kulumsa,
Arsi, Ethiopia**

By: Cherinet Kasahun

Advisors: Paulos Getachew (PhD)

Workineh Abebe (PhD)

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Addis Ababa University
College of Natural and Computational Sciences
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Ethiopia

Prepared by: Cherinet Kasahun

Approved by	Signature	Date
1. Dr. _____ (External Examiner)	_____	_____
2. Dr. _____ (Internal Examiner)	_____	_____
3. _____ (Chairman)	_____	_____
Advisors		
4. Dr. Paulos Getachew	_____	_____
5. Dr. Workineh Abebe	_____	_____

Declaration

I the undersigned, declare that this is an original work and has never been presented in this of any other University and all the sources materials used for this thesis have been fully acknowledged.

Name: Cherinet Kasahun

Signature: _____

Date: _____

This thesis has been submitted for examination with my approval as advisors

Name: Paulos Getachew (PhD)

Name: Workineh Abebe (PhD)

Signature _____

Signature _____

Date _____

Date _____

Date and place of submission: Center for Food Science and Nutrition of Addis Ababa
University

Addis Ababa University

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List of Acronyms

AACC	American Association of Cereals Chemists
AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of variances
AOAC	Association of Official Analytical Chemists
BD	Bulk density
BDL	Below Detection Limit
CIMMYT	International Center for Maize and Wheat Improvement
CRD	Completely randomized design
CSA	Central Statistic Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
GI	Gluten index
HI	Hardness Index
ICARDA	International Center for Agricultural Research in the Dry Areas
KARC	Kulumsa Agricultural Research Center
MOA	Ministry of Agriculture
MT	Metric ton
NAEGA	North American Export Grain Association
NASS	National Agricultural Statistics Service
OAC	Oil Absorption Capacity
SKCS	Single Kernel Characterization System
SNNP	Southern Nations Nationalities and People's
SP	Swelling Power
SPSS	Statistical Product and service solutions
USDA	United State Department of Agriculture,
WAC	Water Absorption Capacity
WAI	Water Absorption Index
WHO	World Health Organization

Abstract

Bread wheat (*Triticum aestivum*. L) is the most common cultivated wheat species-taking up to 95 % of the wheat and staple food for consumers worldwide. Ethiopia is the top wheat producer in Africa and yet is not self-sufficient for the local consumption. Hence, the national wheat breeding programs in Ethiopia are trying to develop improved wheat varieties that mainly focuses on improving grain yield and disease resistance without checking industrial quality. The objective of this study was to investigate the physical characteristics, nutritional composition, techno-functional properties, baking, and sensory quality of recently (2012 to 2018) released bread wheat varieties by the Wheat Improvement Program (WIP) of the Ethiopian Institute of Agricultural Research (EIAR). The Six recently released and promising bread wheat cultivars were, Wane and Daka, Hidasse, Ogolcho, Kingbird, and Lemu, and Pavon earlier released (1982) used as a check were grown at Kulumsa Agricultural Research Center under the same agronomic practice were evaluated. The standard procedures were used for all laboratory analysis and a straight dough baking method was used for bread baking process. The results showed that Thousand Kernel Weight (TKW) of the recently released bread wheat varieties were found to be in the range of 35.0g (Kingbird) to 45.5g (Hidasse) while Pavon scored 42.5g. Hectoliter Weights (HLW) of the varieties followed almost closer trend as TKW and it ranged between 78.4kg/hl (Kingbird) to 86.4kg/hl (Hidasse) while check (Pavon) scored 81.1kg/hl. The single kernel characterization indicated that except for Hidasse soft wheat (32.02%) all the cultivars could be considered as hard wheat which makes them suitable for making leavened baked products. The measured protein content, crude fat, crude fiber, ash, moisture, carbohydrate, energy, starch, color, and minerals content in the wheat flour were significantly different at $p < 0.05$. The protein content of varieties showed that Wane (14.14) % to Ogolcho (9.74)% and gluten index Daka (94.57)% to Hidasse (59.12)% respectively. From this study, it can be concluded that the gluten qualities and quantity, protein content, and bread baking and sensorial quality of the wheat varieties were acceptable except Hidasse and can be utilized for the production of bread. Except for Hidasse, despite the visible differences in some of the measured grain physical qualities, flour qualities and the sensorial attributes bread made from the rest of evaluated wheat varieties were acceptable. Generally, Wane, Daka, and Pavon had superior performance while, Kingbird, Lemu, and Ogolcho had medium quality whereas Hidasse had poor baking quality. However, further researches should be conducted on these varieties on process optimization for better recommendations.

Keywords: Wheat, Functional properties, Bread quality, Nutritional composition

Chapter One

1. Introduction

1.1. Background and justification

Wheat is the most important cereal crop and staple food for about two billion people around the world (FAO,2016). Today, it is widely grown cereals in Ethiopia, both as a source of food for consumers and as a source of income for farmers, however, for a long time new wheat variety development in the country focused on yield and disease resistance improvement, while the quality aspect was given less attention. As a result, farmers get very low income from the production of wheat and the country is a net importer of wheat due to quality problems in the local harvest for bakery/other industries. Globally, the crop provides about 20% of all calories and proteins consumed by people on the globe and played a central role in combating hunger and improving global food security (Shiferaw *et al.*, 2013).

In Ethiopia, it is the fourth most widely grown crop next to tef, maize, and sorghum (CSA, 2018). It is an important staple food in the diets of many Ethiopians, providing an estimated 12% of the daily per capita caloric intake for the country's over 90 million populations and covering 1.7 million hectares of land, which is 13.38% of the total area of land used for cereal production (CSA, 2018). In Ethiopia, wheat is used for the preparation of bread, biscuits, and pasta products such as macaroni, spaghetti, and noodles that are some of the industrial products. Traditionally, wheat is used for making of local food recipes such as local bread(dabo), roasted grain(kolo), boiled grain (nifro), porridge(genfo) and other types of local beverages (local beer). The byproducts of wheat are useful for livestock and poultry feed.

There are different species of wheat however; *Triticum aestivum* (bread wheat) and *Triticum durum* (macaroni wheat) are the most cultivated worldwide(Wiseman,2001). Bread wheat (*T. aestivum*) is the most common cultivated crop taking a share of up to 95 % (Fuad and Prabhasankar, 2010). Wheat is a rich source of carbohydrate, it also contains, protein, fat, ash, fiber, and vitamins as well as minerals such as sodium, potassium, calcium, magnesium, iron, phosphorus, copper, zinc, (Kumar *et al.*, 2011).

Wheat is ideal raw materials for making bread, due to its absolute baking performance in comparison to all other cereals (Dewettinck *et al.*, 2008). Among cereals, wheat is the only cereal with sufficient gluten content to make a typical loaf of bread without mixed with other grains (Scheuer *et al.*, 2011).

In general, wheat flour containing a high amount of protein (>12%) and high quality of gluten is used for bread making, whereas one with a lower amount of protein (<10%) is mostly used for confectionery or cakes, biscuits (Caballero *et al.*, 2007).

Wheat produced in different parts of the world differs greatly in intrinsic protein qualities and quantities. The protein quality is mainly influenced by the genetic characteristic of the wheat (Bordes *et al.*, 2008). Baking quality wheat is determined by flour water absorption capacity, dough rheological property, bread volume, texture, and the color of the bread. Dough rheological property depends on the quantity and quality of gluten in the flour. Baking properties of bread depends on the flour's ability to form a dough, that indicates after mixing and during fermentation, has appropriate physical properties. The strength thus contributed to the dough is an important part of the bread-making quality of the flour (Menkovska *et al.*, 2002).

Even though Ethiopia is one of the top-ranking producers of wheat in Africa, yet the production is not self-sufficient yet, because of the large population growth and urbanization, which apparently resulted in increased demand. Moreover, the wheat rust epidemics being frequent in the country have also affected a lot in lowering the annual yield. As a result, wheat breeding programs in the country have focused on improving yield and disease resistance, while giving less or no attention to the quality aspect. Thus, until now the country has been importing wheat for several decades (CSA,2018).

According to the USDA (2014), the Ethiopian government imported about 900,000 tons of wheat to satisfy its demands for domestic utilization (i.e.food,industrial use, seed, and feed consumption). In addition to the wheat grain, the country has also been importing wheat flour. The FAOSTAT data of fifteen years (1999-2013) shows that the wheat flour (in wheat grain equivalent) imports are about 2.01% of the total wheat grain imported during the same period (Tadele *et al.*,2018).

In addressing the growing demand, the wheat breeding programs in the National Agricultural Research System(NARS) of Ethiopia have been working on the development of new wheat varieties with high yield potential and resistance to major wheat diseases (Bekele *et al.*, 2018). However, the efforts were more bulk oriented than catering for the quality needs of various end-users, especially the milling and baking industries in the country. Hence, in recent years, the research system is pressured to revise its priority and to include quality as one of the most important traits to be included in the breeding programs nationally.

The qualities of bread obtained from a given bread wheat varieties are affected by wheat variety, composition, method of milling, storage conditions, techno-functional properties, kneading techniques, and baking method (Siddique, 1989). However, there is still limited information available on physicochemical, techno-functional properties, baking quality, sensory quality, and bread characteristics of released Ethiopian bread wheat varieties so far.

Therefore, the purpose of the present study was to investigate the main physicochemical properties, nutritional composition, flour techno-functional properties, and bread baking qualities of recently released(2012 to 2018) Ethiopian bread wheat varieties for end-users.

1.2. Statement of the problem

Ethiopia is the top wheat producer in Africa and yet the production is not self-sufficient for the local consumption let alone serious quality issues. Due to the expansion of urbanization, population growth, and changing lifestyle; there is a high demand for quality wheat to produce good quality bread and other products. In fact, Tef (*Eragrostis Tef*) is a staple and most commonly used ancient tropical cereal crop in Ethiopia and its flour is widely used for making injera, bread (staples for the majority of Ethiopians, a fermented pancake-like, soft, sour, circular flatbread) (CSA,2007). However, compared to wheat, the price escalation of tef and the ease of preparation of wheat and unique properties of wheat flour due to gluten content, most middle, and lower class consumers shifted to consume wheat-based food products (FAO, 2017).

In Ethiopia, almost 90 % of the total wheat produced in the country is used for bread production. However, local wheat processing industries are still dependent on imported wheat because of insufficient local wheat production and inadequate quality to meet their end-use product quality standards. This is due to the non-uniform quality of wheat from local producers because of small-scale production and less attention given to product quality concept during the variety releasing and distributing process in Ethiopia. The percentage of domestic wheat consumption coming from imports varies between 25 and 35%, depending on the size of the harvest and other factors (FAO, 2014). As a result, the country is forced to undertake a huge wheat import every year despite its recurrent scarcity of hard currency.

Hence, the national wheat breeding programs in Ethiopia are trying to develop improved wheat varieties that mainly focuses on improving grain yield and disease resistance without checking industrial quality. This may influence grain nutritional composition, flour techno-functional properties, and baking characteristics of the products lead to an adverse effect on baked products (Guttieri *et al.*,2001). Despite this fact, breeders have given less emphasis on quality characteristics of wheat varieties during the selection process. Quality is a major feature for selecting the suitability of wheat for a particular type of product which, affects mixing tolerance of dough, water absorption capacity, and bread loaf volume (Shah *et al.*, 2008). Besides, the protein content and quality, flour techno-functional properties with nutritional qualities, and bread baking qualities are as a quality indicator of wheat in addition to grain physical properties.

Thus, the characterization of wheat varieties can play a vital role in identifying the superior quality of wheat for producing bread with acceptable quality for bakery industries and consumers. In Ethiopia, as to our knowledge, there is little information available regarding the characteristics of wheat and its flour milling quality concerning their suitability for bread production. An earlier study by Soboka *et al.* (2017) underlined the presence of variability in the bread-making quality of Ethiopian earlier improved bread wheat varieties. However, holistic information that includes grain physical property, milling quality and flour yield, flour physicochemical and techno-functional properties, and bread-making quality with sensory evaluation is missing. Therefore, the present study is aimed to avail such pertinent information that will help farmers, national bread wheat improvement programs, bread wheat processors, and consumers.

1.3. Objectives

1.3.1. General Objective

To investigate the physicochemical and techno-functional properties of recently released Ethiopian bread wheat varieties for production of quality bread

1.3.2. Specific Objectives

- ❖ To evaluate the grain physical properties of recently released bread wheat varieties
- ❖ To evaluate the nutritional composition of recently released Ethiopian bread wheat varieties

- ❖ To determine the techno-functional properties of the recently released bread wheat varieties
- ❖ To evaluate the baking, sensorial and nutritional quality of bread made from the recently released bread varieties

1.4. Significance of the study

This study provides;

- ❖ Information on the physicochemical, techno-functional properties and baking quality of recently released bread wheat varieties grown in Ethiopia for researchers. With the basis of the above information, bread baking quality of the recently released bread wheat varieties would be identified for the product they meet (bread, biscuits, and others).
- ❖ Thus, this would provide baseline information on new bread wheat varieties for stakeholders like; wheat breeders, agricultural extension workers, farmers, and other concerned bodies, and breeders would also give attention to the maintenance of well-performed and selected bread wheat varieties for further use.
- ❖ This baseline information supports bakery industries to process quality bakery products and would provide information for future related research activities (i.e. new bakery product development, etc.).
- ❖ Contributing to the reduction of imported bread wheat and encourage farmers to cultivate and increasing production of bread wheat based on the final product concept.

Chapter Two

2. Literature Review

2.1. Overview of Wheat varieties

There are several different species of wheat, however, *Triticum aestivum* (common or bread wheat) and *Triticum durum* (durum or macaroni wheat) are the most cultivated wheat varieties in the world (Wiseman, 2001). Different wheat varieties have different characteristics that are more or less suited to different types of bakery products. Durum wheat has been found suitable for the manufacturing of pasta production (Wiseman,2001). Bread wheat (*Triticum aestivum*) is common wheat and the most common cultivated crop taking a share of up to 95 % for bread production in the world (Fuad and Prabhasankar, 2010).

2.2. Ethiopian improved wheat varieties

Regular durum wheat breeding activities were started at Debre Zeit Agricultural Research Center when the bread wheat breeding program moved to Holeta with the establishment of the Institute of Agricultural Research in 1966. After that, the bread wheat breeding program moved to Kulumsa Agricultural Research Centre (KARC) with the wheat regional center of excellence(EIAR,2016).

The main aim of the wheat breeding program is to search for widely adapted high yielding and disease resistant varieties through selections from indigenous germplasm, by an introduction from abroad and also through hybridization. However, they were not given attention to the wheat final product qualities. The program started with a mass selection from local and introduced cultivars from abroad through FAO, USDA, and CIMMYT.

In Ethiopia, the national agricultural research system (NARS) is responsible for variety development and generation at the national level. Since the establishment of agricultural research centers in the country, about 100 wheat varieties (67 bread and 33 durum wheat varieties) are released, distributed, and produced (EIAR,2018). The major research centers which were dedicated to wheat research and variety release are presented in Figure 1.

Kulumsa Research Agricultural Center focuses on bread wheat research, and so far it has released 37 varieties of bread wheat. On the other hand, Debrezeit Agricultural Research Center (DZARC) and Sinana Agricultural Research Centers focused on durum wheat research and generated 15 and 10 improved durum wheat varieties, respectively until 2014(MoA,2014).

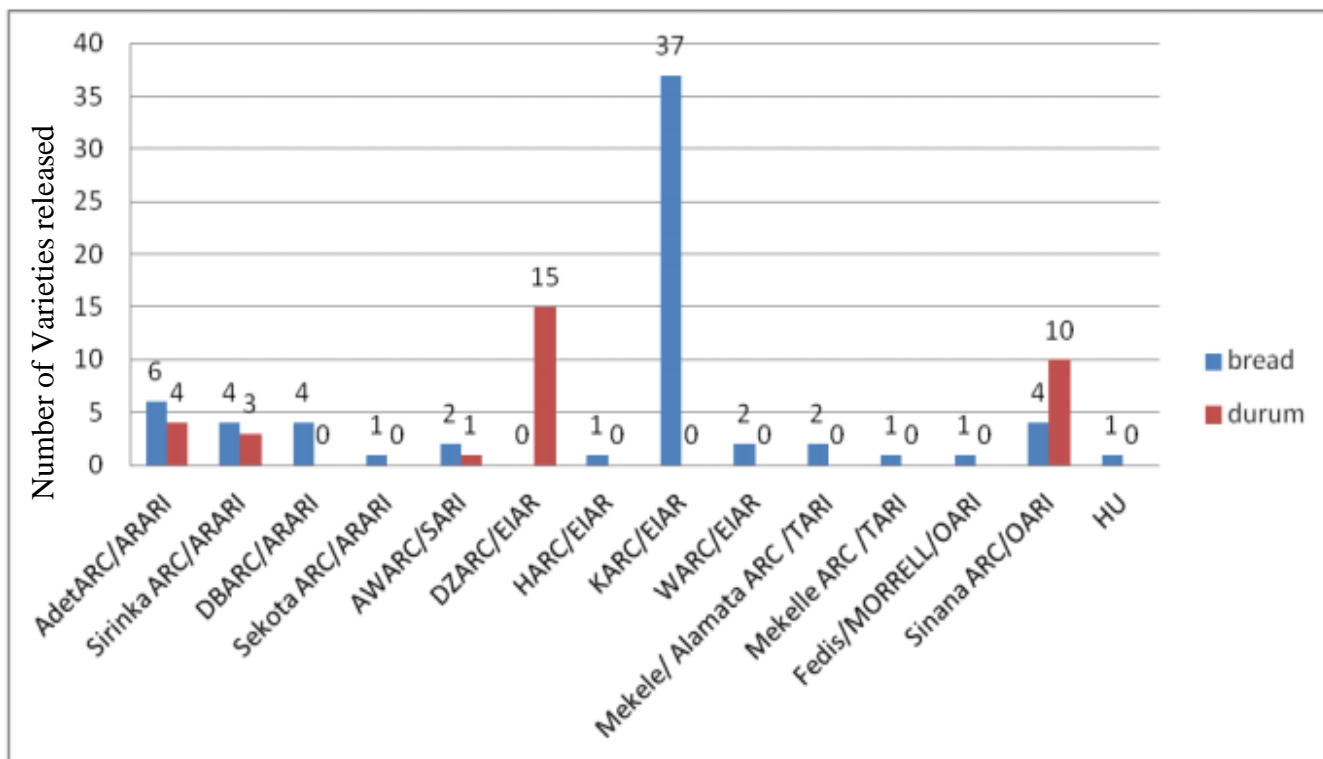


Figure 1: Major research center released wheat varieties(EIAR,2018)

2.3. Wheat Production in Ethiopia

Wheat (*Triticum aestivum. L*) is one of the most important crops in the world in production and nutrition. Annually, wheat is produced on 224.53 million hectares of land, and 672.2 million metric tons of wheat are produced in the world USDA (2010). In Ethiopia, wheat is one of the most important cereal crops widely cultivated. It is cultivated both in bi-modal and uni-modal rainfall areas. Bread wheat (*Triticum aestivum. L*) and durum wheat (*Triticum durum*) are the two species that are mainly cultivated by small scale farmers in Ethiopia. It ranks fourth in area coverage next to tef, maize, and sorghum, respectively (CSA,2018).

Currently, the country produces more than 3 million tons of wheat on 1.7 million hectares. Since the introduction of wheat, more than 100 varieties have been released and more than 65 % of wheat farms

planted with improved cultivars. The average national productivity of wheat is about 2.2 tons per ha while model farmers in the best wheat agro-ecologies of Arsi and the like managed to produce 5-6 tons per ha (EIAR, 2018). In Ethiopia wheat is one of the strategic cereal crops to attain food security although imports of wheat from the world market are still an on-going event.

2.4. Consumption of wheat in Ethiopia

The wheat consumption trend in Ethiopia is gradually increasing in urban areas due to high population growth, migration of people to urban areas, and changes in lifestyles. In most parts of the country, families prefer to use tef to make injera (fermented thin bread) and sometimes to make porridge. Tef can also be used to produce local beer and liquor. Because of the price escalation of tef compared to wheat and of the ease of preparation of wheat and unique properties of wheat flour, most middle and lower class populations are shifting to greater wheat consumption. Over 50% of the average daily caloric intake of an average household is from wheat, sorghum, and corn (FAO, 2014).

Wheat is milled into flour which is processed into various baked products and spaghetti. Unlike other staple grains, wheat is imported in large volumes (FAO, 2014). Due to the importance of the crop and its growing import burden, the government of Ethiopia gives a high priority to efforts to increase wheat productivity and improve wheat marketing efficiency to stop wheat importation from abroad in the coming two years by using irrigated areas in the countries. Therefore, it is critical issues to evaluate bread wheat varieties during the releasing process for industrial quality requirements.

2.5. Impact of wheat varieties on product quality

Wheat quality means different things, depending on that you are in the wheat processing chain. These qualities are wheat physical qualities, nutritional composition, techno-functional properties, rheology, and baking quality and sensorial qualities of bread or pasta production and consumers' acceptance of wheat-based food products. The variation in grain hardness is the single most important trait that determines the end-use quality of wheat and categories products. Grain hardness classification is based primarily on either the resistance of kernels to crushing or the particle size distribution of ground grain or flour (Menegusso *et al.*, 2010).

Grain and flour protein are used as indicators of dough properties and processing performance. The impact of these characteristics on the quality of the produced bread is important. Wheat varieties

should be classified and traded worldwide based on quality parameters and requirements specified by millers, bakers, and end-users (Menegusso *et al.*, 2010).

2.6. Wheat product and quality

Among cereals, wheat is the most important crop in terms of production and consumption. World nutrition mostly depends on wheat and wheat products such as bread, chapatti, biscuit, pasta, and fermented products, as the people all over the world consume the wheat product(s) in one of these forms (Agrawal and Gupta, 2006).

Wheat quality is a very wide subject that will be defined differently by the different stakeholders of the wheat value chains, which makes it an extremely complex and variable concept. For farmers in some countries, wheat quality is considered what allows them to allocate their harvested grain at the grain market and get the highest price for it. This is usually different among countries, where each one has different regulations that may prime farmers for producing better grain quality or not. Good morphological characteristics (grain size and density through test weight) and absence of grain kernel damage are some of the most common traits considered at grain markets to determine the grade and sometimes the price of the produced wheat.

In other countries such as Australia or Canada, there are more complex grading systems, in which protein content is usually an important trait (Blakeney *et al.*, 2009). In other countries, subsistence farmers will mill and process the wheat to feed their families and in these cases, farmers consider wheat quality what allows them to produce a good product with desirable organoleptic properties. For millers, wheat quality is the ability of a wheat variety to produce high levels of flour or semolina during the extraction process. In this process, the level of contamination of the flour/semolina with bran fractions is also important and is linked in most cases to undesirable characteristics for the end-use quality of the product.

For milling quality, the traits probably most important are the grain morphology, grain density (test weight) (Matsuo and Dexter, 1980), and grain hardness (Edwards *et al.*, 2010). Millers prefer large grain with a plump shape which is well filled and not shriveled. These characteristics are also targets for breeders to increase grain yield in the field. On the other hand, food manufactures are more focused on processing quality, the ability of a wheat variety to be processed with minimum cost to give a uniform product, and end-use quality, the ability of a wheat variety to produce a specific

product according to the consumers' preferences. For both types of quality, grain hardness and gluten quality and quantity are very important.

Nutritional quality, the ability of a food to supply nutrients for a complete physical and mental development and a healthy life, is becoming also a big priority for food manufacturers due to the interest of consumers in that issue. Last, but not least, consumers could have very different ideas of what wheat quality means. Some of them will think about the end-use quality of the product, while others could think about the processing conditions (handmade vs mechanized or industrial) or the nutritional quality of food products. End-use consumers vary in terms of quality demands, although there are several traits well-identified among consumers as desired for specific products (soft crumb for bread, yellow color in pasta, the shelf life of products, etc.). The goal of increasing productivity and production of wheat will be realized if and only if the ultimate users, namely farmers, adopt the technologies that are developed by research. Wheat quality means different things, depending on that you are in the wheat processing chain.

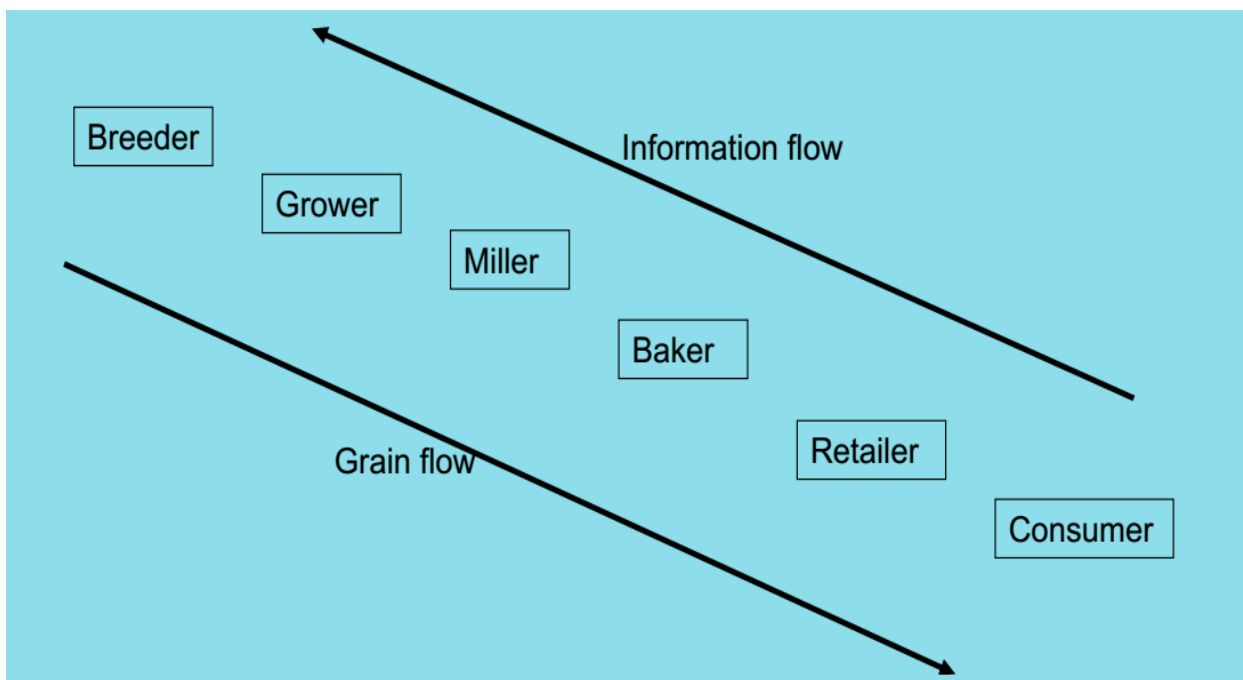


Figure 2: Wheat value chain (Source: Trethowan *et al.*, 2001)

2.7. Bread wheat grain quality

Grain quality is defined by a range of physicochemical characteristics with which threshold requirements are set according to end-use requirements. For staple grains such as wheat, whole grain physical properties such as size and shape influence milling yield and screening losses, which determine the processing efficiency and value of the grain. Whole grain quality incorporates the physical characteristics of grain, such as milling yield, screenings, and test weight which is influenced by both genotype and environment. The quality of wheat grain depends on several characteristics, among which grain hardness, grain size, grain weight, protein content, and composition of high molecular weight gluten subunits are the most important (Salmanowicz *et al.*, 2008).

Test weight is one of the simplest criteria used to determine the quality of grain and measure of grain bulk density. The test weight of wheat is considered the most common and easiest way to quantify wheat grain physical quality. It is an indicator of general grain quality and primary grain specification, normally the higher the test weights the higher the quality, and the lower the test weight the lower. The grain quality decreases dramatically as grain deteriorates (Bern and Brumm, 2009). Therefore, grain physical qualities are important for end-products qualities.

2.7.1. Wheat grain kernel size

The most significant indirect way of expressing grain size remains the thousand-kernel weight. However, knowing the size composition is very important. First, it helps in choosing cleaning screens that eliminate impurities larger than the largest kernel and impurities smaller than the smallest kernel. Second, the cylinder gap of the first grinding break roll can be diminished or enlarged depending on the lots' grain size. Third, the adjustment of the rate of grain feed at the beginning of the equipment chain can be changed accordingly. Wheat is generally oval-shaped, although different wheat has grains that range from almost spherical to long, narrow, and flattened shapes. The grain is usually between 5 and 9 mm in length, weighs between 35 and 50 mg. The wheat grain kernel contains 2-3% germ, 13-17% bran, and 80-85% mealy endosperm (Australia wheat grain quality standard).

Thousand kernel weight of any crop depends on its size. Usually grain weight increases with the increase of grain size. Sharma (2000) evaluated four wheat varieties and reported that thousand kernel weight ranged from 33.0 to 42g. Kaur *et al.* 2000 reported that compared two wheat varieties and found that variety had thousand kernel weights 34 to 45g.

Dhingra and Jood, (2004) observed that physical characteristics of wheat and reported that 1000 kernel weight is 41g. Singh *et al.* 2006 worked on 47 commercial wheat varieties and reported that 1000 kernel weight, grain length, and width ratio in the range of 30 to 57 g, 6.0 to 8.0 mm, and 2.9 to 3.7 mm respectively.

2.7.2. Hectoliter weight

Hectoliter weight, which is dependent on both grain size and shape is considered to be one of the important physical criteria in all wheat grading systems as it highly influences flour yield and other quality parameters (Soboka *et al.*,2017). Weight per unit volume, or test weight, is the quantity of grain that packs into a fixed volume. High values greater than (80kg/hl) indicate a good variety having plump kernels undamaged by disease or environmental stress. Hectoliter weight is widely used as primary wheat grading specification and milling quality indicator. Studies made by (Dexter *et al.* (2000) have shown that the test weight of Canadian wheat is strongly related to semolina yield.

2.7.3. Thousand kernel weight

TKWs is Closely associated with test weight is the weight of 1000 kernels called thousand kernel weights. wheat test weight is a good predictor of flour milling potential because it exhibits a strong linear relationship to the kernel weight (Dexter *et al.*, 2000). Generally considered as a guide to flour milling yield potential, test weight is a globally-used measurement of bulk density. It reflects the weight of kernels relative to their size and grain packing capacity (AACC, 2010).

Wheat milling performance is related to kernel plumpness. Thin, shrunken, and damaged kernels cause reduced yield of flour. In addition to specifying the minimum test weight, millers often will specify the minimum proportion of kernels that must be held on a sieve with a carefully defined aperture to avoid excessive amounts of thin kernels. Studies made show that the test weight of the Ethiopian released wheat cultivars ranges from 76kg/hl to 86 kg/hl and thousand kernel weight ranges from 33g to 50 g (Efrem *et al.*,2000; Bemnet *et al.*, 2003; DZARC, 2003). Nitika *et al.* (2008) worked on five varieties of organic and inorganic wheat and found that inorganically grown varieties had higher 1000 kernel weight (42g) and Anand *et al.* (2013) compared two Indian wheat varieties and found that a variety of grain weights ranged from to (35 g) to (42 g).

2.7.4. Wheat grain hardness

Wheat grain hardness is one of the most important characteristics of wheat quality. The hardness of the wheat grain influences the ease with which the endosperm is separated from the bran during the milling process and also controls some of the properties of the flour produced. The wheat hardness is strongly associated with flour yields (Hruskova *et al.*,2009). Soft-textured wheat genotypes showed the least value for grain hardness and higher break flour and lesser reduction flour yield. Genotype, environment and their interaction play an important role in the final expression of grain yield and quality attributes (Kaya and Akcura,2014). Wheat grain hardness is an important parameter that is considered while determining milling and baking properties (Pomeranz and Williams, 1990, Belderok, 2000, Shewry and Jones, 2005,) of wheat. Two distinct categories of wheat varieties are based on grain hardness; namely, “hard” grains and “soft” grains. The kernels of hard grains generally have a dark, shiny appearance, whereas, soft grain kernels have an opaquer and floury look. During the milling process, starch damage is higher in hard wheat varieties and this damage is favorable as it contributes to the soft texture and mouth-feel of the crumb of bread. Hard wheat varieties grains are more suited for yeast-leavened bread-making due to their tolerance to fermentation (Pomeranz and Shellenberger, 1971, Belderok, 2000).

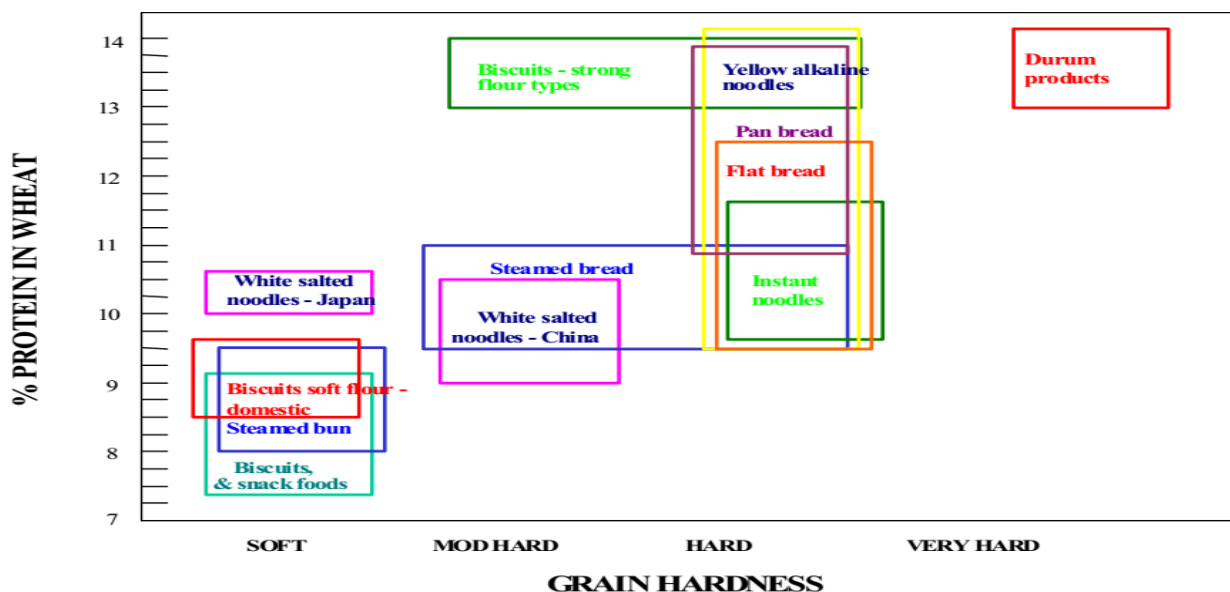


Figure 3: Classification of wheat-based on the hardness

Starch damage is also known to retard the staling of bread (Belderok,2000). Soft wheat, on the other hand, does not undergo extensive starch damage and this property makes it suitable for making

products like cakes, biscuits, etc. Hard wheat varieties grains have higher protein content than soft wheat varieties grains and hard wheat kernels have more resistance to grinding than soft kernels (Belderok,2000).

2.8. Wheat flour quality

The quality of wheat flours can be defined for several parameters including protein, moisture, gluten, enzyme activity, and techno-functional properties, none of which serves as adequate by itself and also the physicochemical tests like ash content, flour color, and falling numbers evaluate important characteristics for the pastry industry (Morris *et al.*,2011). Physico-chemical and techno-functional properties of wheat flour are influenced either by genotype or by other non-genetic factors (Ahmad, 2010).

2.8.1. Wheat flour Protein content and quality

Protein content and quality play a major role in the determination of the quality of the grain, flour, dough, and bread. In resolving of genetics base of grain quality in wheat the main investigations were focused on protein and gluten contents and quality, grain hardness characteristics, which are genetically controlled (Menkovska *et al.*,2002).

A combination of those parameters and the flour protein content can be used as a base for estimation of the technological quality of selected materials. The protein is a primary quality component of cereal grains. The protein concentration is influenced by both environmental and genotypic factors that are difficult to separate. Protein content and protein quality have been also shown to be significant for baking quality.

2.8.2. Gluten content and quality

Gluten is an important constituent of wheat because it provides strength and texture to baked wheat products and makes it capable to form lots of bakery products. Wet gluten content is a plastic-elastic substance consisting of the proteins gliadin and glutenin, obtained after washing out the starch from wheat flour dough.

Gluten forming proteins are primarily responsible for the techno-functional properties of wheat flour. The amount of gluten in the flour is an index of the protein content and physical properties of the

washed-out gluten (i.e. index of flour strength). Wet gluten and dry gluten criteria are as a primary test of flour quality. This is likely due to the simplicity of the test and the quantitative information obtained relating to both gluten content and quality. wet gluten is highly correlated to the protein content which is the most desired quality test parameter (Chinnaswamy *et al.*,2005). The gluten index method provides information on both the quantity and quality of wet gluten. The gluten index value is a criterion defining whether the gluten quality is weak, strong, or normal.

2.8.3. Wheat flour ash content

Ash is the residue that remains after the complete combustion of the organic compounds of the food products. The estimation of the ash content in cereals enables the classification of flours. Gupta *et al.*, (1992) found that ash in flour can affect color, imparting a darker color to finished products. Some specialty products requiring particularly white flour call for low ash content while other products, such as whole wheat flour, have high ash content. Ahmed *et al.*, (2005) reported that the ash content of different varieties of wheat flour was variable in the range from 0.52% to 0.68%. Khan and Zeb, (2007) worked on seven different varieties of wheat and reported that it contains 1.44 to 2.10% ash. Rahman and Kader, (2011) tried to find out the comparative nutritive values and physiochemical properties of five new varieties of wheat seeds. They found that the ash content of the wheat varieties ranged from 1.8% to 2.16 %. Ndife *et al.*, (2011) reported that wheat contained fewer amounts of ash (1.5%).

Ash content shows the mineral content in the wheat. Bran has higher mineral content than the endosperm. Small shivered kernels have more crude fiber and ash than large, plump kernels and consequently yield less flour. Therefore, ash content can be used as a means in comparing the milling value of different cultivars. Previous researchers have reported that several European milling industries consider ash content as an important aspect of durum wheat quality for semolina milling. A highly significant correlation is also found between ash content and the brightness of flour. For any given wheat, higher extraction produces darker flour with higher ash content (Dexter and Matsuo, 1978; Fillet and Dexter, 1996).

2.8.4. Color of wheat flour and products

The color test on the flour sample indicates the whiteness, which is considered as a quality attribute as it affects the appearance of the final product. The color of the flour depends on the extraction rate of

flour, amount of pigments, and flour particle size. The darkness or whiteness of the flour is due to the contamination of bran particles. Higher the flour extractions rate, darker the color of the flour, and vice versa. The coarse flour generally looks dull and darker than its finer counterpart due to the shadow effects of the larger particles.

To carry out a more objective color analysis, color standards (color spaces and numerical values) are often used as reference material which is used to create, represent and visualize colors in two and three-dimensional space (Trusell *et al.*, 2005; León, 2006). The RGB (red, green, and blue), the CMYK (cyan, magenta, yellow, black), and the L*a*b* color space are the three main color spaces that used to define the color.

According to Adobe system (2002), the L*a*b* model has the largest range encompassing all colors in the RGB and CMYK gamut. The L*a*b* values are often used in food research studies. The L*a*b* color space is an international standard for color measurement developed by the Commission Internationale d'Eclairage (CIE) in 1976. The L*a*b* color consists of a luminance or lightness component (L* value, ranging from 0 to 100), a* component (from green to red) and the b* component (from blue to yellow) along with two chromatic components (ranging from -120 to +120). The L*a*b* color is device independent, providing consistent color regardless of the input or output device (Abebe *et al.*, 2015).

2.8.5. Falling number

The Falling Number test (AACC Approved Method 56-81B) provides an index of α -amylase activity in a flour or ground-wheat sample. The procedure relies on the reduction in viscosity of starch paste caused by the action of α -amylase. The method is based on the unique ability of alpha-amylase to liquefy a starch suspension. Gelatinization strength is measured by falling number as “time in seconds” required stirring and allowing the stirrer to fall a measured distance through hot aqueous flour gel undergoing liquefaction.

It indicates the amount of sprout damage that has occurred within a wheat sample. Generally, a falling number value of 350 seconds or longer indicates a low enzyme activity and very sound wheat quality. As the amount of enzyme activity increases, the falling number decreases. Values below 200 seconds indicate high levels of enzyme activity. The falling number measures the viscosity of a mixture of water and ground wheat mixed in a tube and placed in a boiling water bath (100°C).

The falling number is the time in seconds required for stirring(60s) plus the time taken for the stirrer to fall through the heated flour suspension while it is being liquefied by the enzyme. The falling number test is a good indicator of sprout damage in durum wheat and it is used to assess to α -amylase activity in durum wheat. Factors encouraging germination will tend to result in an increased enzyme (α -amylase) activity, which breaks down starch and reduces viscosity and a corresponding drop in falling number. It is, therefore, the indirect measure of starch liquefaction.

Increased α -amylase activity (drop-in falling number) can develop in a standing crop of wheat with a high level of rainfall close to harvest at its physiological maturity or by moisture abuse after harvest. If the crop is lodged in a humid microclimate, germination can be encouraged within the mat of laid straw and ears. An increase in α -amylase activity in the grain is associated with the process of germination. Sprout-damaged wheat is considered undesirable because of inferior pasta-making potential and bread baking (AACC,2000).

2.8.6. Nutritional composition

The nutritional content comparison of durum wheat (semolina) and bread wheat flours contain the percentage of protein (12.70, 10.60); damaged starch (11.50, 8.50); carbohydrate (77.80, 82.00); amylose (27.00, 23.00); fat (1.00, 0.50) and dietary fiber (1.19, 0.91), respectively (USDA, 2016; Steglich, 2013). The three main distinct parts of the wheat kernel are the bran, the endosperm, and the germ. The protein content is a key quality factor that determines the suitability of wheat for a particular type of product as it affects other factors including mixing tolerance, loaf volume, and water absorption Capacity (Shah *et al.*, 2008). Both protein quantity and quality are considered important in estimating the potential of flour for its end-use quality (Farooq *et al.*, 2001).

Quality improvement of wheat involves grain or flour quality, functional properties, and end-use product quality. In the past several decades, dough rheological properties have increased in importance in wheat breeding (Dowell, 2008). Perhaps, because they provide more direct information than grain or flour traits. Additionally, in wheat breeding programs, the end-use quality of many breeding materials can't be directly determined, owing to limited seed quantities, and is often predicted by the evaluation of dough properties (In in Chinese with English abstract, 2006). In recent years, wheat quality research has focused partly on correlations among flour and dough properties and end-use

quality. The large variation in dough rheological properties among some wheat cultivars has been found in different end-use products

The nutritional importance of wheat should not be underestimated, particularly in less developed countries where bread, noodles, and other products may provide a substantial proportion of the diet. According to Adams *et al.* (2002), wheat provides 20% of the food calories. It contains 78.10% carbohydrate, 14.70% protein, 2.10% fat, 2.10% minerals, and considerable proportions of vitamins (thiamine and Vitamin-B) and minerals (zinc, iron).

Among all the nutrients in whole wheat, the bran contains a small amount of protein, larger quantities of the B-complex vitamins, trace minerals, and indigestible cellulose material called dietary fiber. Wheat germ is the embryo of the wheat kernel. The germ or embryo of the wheat is relatively rich in protein, fat, and several of the B-vitamins (Adams *et al.*, 2002). The outer layers of the endosperm and the bran contain a higher concentration of protein, vitamins, and phytic acid than the inner endosperm. The inner endosperm contains most of the starch and protein in the grain. Mepba *et al.*, (2007) reported ash content, crude protein, crude fat, moisture, fiber, and total carbohydrate contents values as 0.46%, 12.86%, 1.40%, 11.31%, 0.82% and 73.15% of wheat flour respectively.

2.8.7. Minerals

The mineral content of flour as such is not related to the quality of a final product but, it does affect the appearance of flour and the product especially color. The minerals are concentrated on the outer part of wheat grain, which is removed during the milling process. However, some contamination does occur in flour. Flour that contains a higher proportion of minerals will have more ash content and it will be darker in color and it may also contain more fine bran particles.

Bran has been shown to have a detrimental effect on the quality of bakery products. Gamal *et al.* (2012) reported that higher amount of calcium, iron, phosphorus, zinc, magnesium, and manganese in wheat bran (76.0, 10.6, 108.0, 7.3, 61.10, and 11.5 mg/100g) and lower in wheat flour (15.0, 1.30, 101.30, 0.6, 20.0 and 0.6 mg/100g, respectively). Most of the seed-zinc is present in the embryo and aleurone layer, whereas the endosperm is very low in zinc concentration (Ozturk *et al.*, 2006).

2.8.8. Anti-nutritional factors

Reducing anti-nutritional factors has become an important criterion of the breeding programs to improve wheat grain quality (Guttieri *et al.*, 2006). According to Hooda, 2002 reported, anti-nutritional factors in wheat found that the polyphenol concentration as 355.11 mg/100 g (dry weight basis) in wheat flour samples. (Sang wan V, Dahiya S, 2002) also evaluated the wheat grains for polyphenol content and found that the polyphenol concentration is 320.4 mg/100 g (dry weight basis). (Varsha S,2003) also evaluated polyphenol content in wheat flour samples and found that it was 465 mg/100 g. (Sikandra, 2005) in 2005 also evaluated the polyphenol content in wheat flour samples and the result obtained was 275-342 mg/100 g concentration of polyphenol.

The bioavailability of key minerals such as iron, zinc, and calcium is known to be significantly affected by the fiber, phytic acid, and tannin content of foods. Ant-nutritional factors cause negative impacts directly or indirectly to consumer's health and hence should be lowered down or removed from wheat grains to improve quality. A balanced food containing enough calories, balanced proteins, and micronutrients with low anti-nutritional components is needed for the proper growth and development. Around three billion people throughout the world face the problem of malnutrition due to micronutrient deficiency (Anonymous,2000). The phytate interferes, iron, and zinc absorption in the gastrointestinal tract with the formation of insoluble phytate-mineral complexes (Manary *et al.*, 2002; Weaver and Kannan, 2002).

Traditional processing technologies (decortications/ removal of the bran, soaking, germination, and fermentation) and milling technology are commonly applied to reduce or remove the levels of anti-nutritional factors (trypsin inhibitor, tannins, and phytates), denatures undesirable enzymes and retains natural colors and flavors of foods (Guy, 2001).

2.9. Wheat milling process

Cleaning removes large impurities and the very small and lightweight impurities. The second process is the conditioning. Wheat is tempered before milling to toughen the bran, thereby reducing the number of bran specks in the flour. The tempering time is short to retain the hard, vitreous nature of wheat thereby, maximizing the release of large endosperm particles and minimizing the yield of flour (Kruger *et al.*, 1998).

The milling process contains breaker, reduction, and purification. The break system is the first step for the wheat milling process and it allows the gradual release of coarse endosperm particles with a minimum yield of flour. Passage through the rolling mills is alternated with sifting phases carried out by the plan sifters and the purifiers. The next step is a reduction process that helps to produce flour with finer granulation (Dexter and Marchylo, 2000).

Wheat Millers want uniformity and consistency to meet wheat flour or semolina specifications demanded by their customers. End-users want uniformity and consistency to make products acceptable to consumers without continually changing processing conditions. Whole grain flours are produced by a variety of techniques and result in flours with widely different particle sizes and functionalities (Kilhberg *et al.*, 2004). Wheat Flour is produced by separating the endosperm from the other components of the wheat kernel and reducing it to a fine powder.

Conventional milling reduces the nutritional content of flour and concentrates them in the milling residues (Cubadda *et al.*, 2009). The milling process indicated that at a low extraction rate (68%), the protein, fat, fiber, ash, iron, zinc, phosphorous, and antioxidant contents of the samples significantly decreased or removed by milling (Heshe *et al.*, 2015). Wheat flour milling is a grinding process that gives different fractions of wheat flour which affect the quality of bakery products (Shekara *et al.*, 2011). During wheat milling, a portion of the starch granules sustains mechanical damage, the level of which depends on the wheat hardness and milling technique. Millers believe that granulation is very important in the production of quality wheat flour. It has been suggested that flour particle size, damaged starch, and protein quality and quantity have adverse effects on the baked products (Guttieri *et al.*, 2001).

2.9.1. Bread baking

The bread-making quality parameters measured for the pup loaf straight-dough procedures baking, water absorption, dough mix time, loaf volume, specific loaf volume, and loaf weight. The bread baking process involves a series of interactions of bread raw materials, equipment, and people in a certain environment. There are numerous activities taking place during the bread-making process. Such activities can be chemical, physical, and biological.

Chemistry of dough has shown that there is an interaction between carbohydrates, lipids, and proteins. The physical science in dough making is rheology and the biological activities involve the

fermentation process by yeast (Pylar and Gorton, 2009). The major ingredients of bread are wheat flour, water, yeast, and salt but, other ingredients also incorporated for different purposes based on the desired products. Water has functions in bread making. It makes possible the formation of gluten. Only when flour proteins are hydrated, gluten is formed. Water controls the consistency of dough and assists in the control of dough temperatures and warming or cooling of doughs can be regulated through the water. It dissolves salts; suspends and distributes non-flour ingredients uniformly.

Water activates enzyme activity and keeps bread palatable longer if sufficient water is allowed to remain in the finished loaf. In bread production, salt is mainly added for taste. It brings out the taste of other ingredients and helps to improve the flavor and characteristics of bread. Salt is toughened and without salt, the dough is wet. It, therefore, improves grain and texture of loaf by strengthening the dough, thus indirectly helping color, grain, and texture. The function of yeast in bread making is to lighten the dough and impart to it a characteristic aroma and flavor. This has been the function of yeast for centuries and remains so even though its activities have been improved over some time through scientific modifications in its manufacture and a broader understanding of bread making methods (AACC, 2000).

The straight dough baking method is a one-step process whereby all the dough ingredients are added together and mixed using a machine or manual mixing in a single batch. At the initial mixing stage, the mixture matrix lacks high cohesion while wet mass chumps appear. As mixing continues, the elastic properties of the dough start to increase causing the chumps to start to pull away from the mixer walls. Adequate mixing is achieved when the dough exhibits smooth appearance, dry surface, and optimum elastic character. Over mixed dough exhibits shewn characteristic and stickiness thus becomes difficult to handle. Usually, mixing temperature during the straight dough method is 26 to 28 °C. Although the higher temperature will accelerate the rate of yeast fermentation, control of fermentation become more difficult and may result in the fermented dough that lacks adequate stability.

Compared to the sponge, and other dough processing methods, the straight-dough method is advantageous because of lower processing time, power, equipment, and labor. Also, losses during fermentation are reduced since shorter fermentation time is required. The product's flavor is also enhanced as a dough ingredient undergoes fermentation treatment (Pylar and Gorton, 2009). The straight dough method is a single-mix process of making bread. The dough is made from all fresh

ingredients, and they are all placed together and combined in one kneading or mixing session. After mixing, bulk fermentation rest about 1 hour or longer occurs before division.

After proofing the dough is subjected to heat in a baking oven. Baking temperature generally varies depending upon oven and product type but, it is generally kept in the range of 220-250 °C. During baking, the temperature of the dough center reaches about 95 °C to ensure that the product structure is fully set. When the dough is placed in the oven, heat is transferred through dough by several mechanisms such as convection, radiation, conduction, and condensation of steam and evaporation of water.

Heat transfer inside dough is said to occur through the mechanism of heat conduction and evaporation/condensation. The baking time of bread may range from 25 to 30 minutes depending upon the size of the bread loaf. After baking, bread is cooled before packaging to facilitate slicing and to prevent condensation of moisture in the wrapper. Bread is prepared as a common bread baking procedure (Ephrem *et al.*, 2000). And the final quality of bread is analyzed to select bread wheat varieties for preferred bread quality production (Straight dough method, AACC, 2000).

2.9.2. Bread quality

The bread-making quality parameters measured for the pup loaf straight-dough procedures baking, water absorption, dough mix time, color, loaf volume, loaf weight, and specific loaf volume. The nutritional value of wheat is extremely important as it takes an important place among the few crop species being extensively grown as staple food sources. For the improvements in physical and sensory properties and shelf life of bread, product and quality are very important. The quality of bread is normally defined based on its volume, color, texture, and flavor of bread (Quilez *et al.*, 2006). Bread sensory analysis demonstrated the effect of the kernel physical characteristics, flour chemical traits, and the dough functional properties on bread quality. Cut-out dough loses weight during the proofing and baking stages of bread making indicated that the bread baking losses. This may be due to both fermentation losses brought about by amylases of starch and utilization of soluble sugar by yeast and also by evaporation of moisture during baking. Loaf volume is used as criteria to measure the quality of fresh bread in research quality control in industry and by consumers.

The specific volume of loaves of bread provides a uniform basis for comparing the results of various studies. Specific volume is an indication of the gluten content of the bread but, other constituents such

as starch and fiber also contribute to the specific volume of bread. Gluten or more precisely glutenin is the main structure-forming protein in wheat flour that is responsible for the elastic and extensible properties needed to produce good quality wheat bread (Bloksma, 1990b; Gallagher *et al.*, 2003). Bread made from soft wheat flour usually yields lower loaf volume.

Baked product quality chain from field to fork

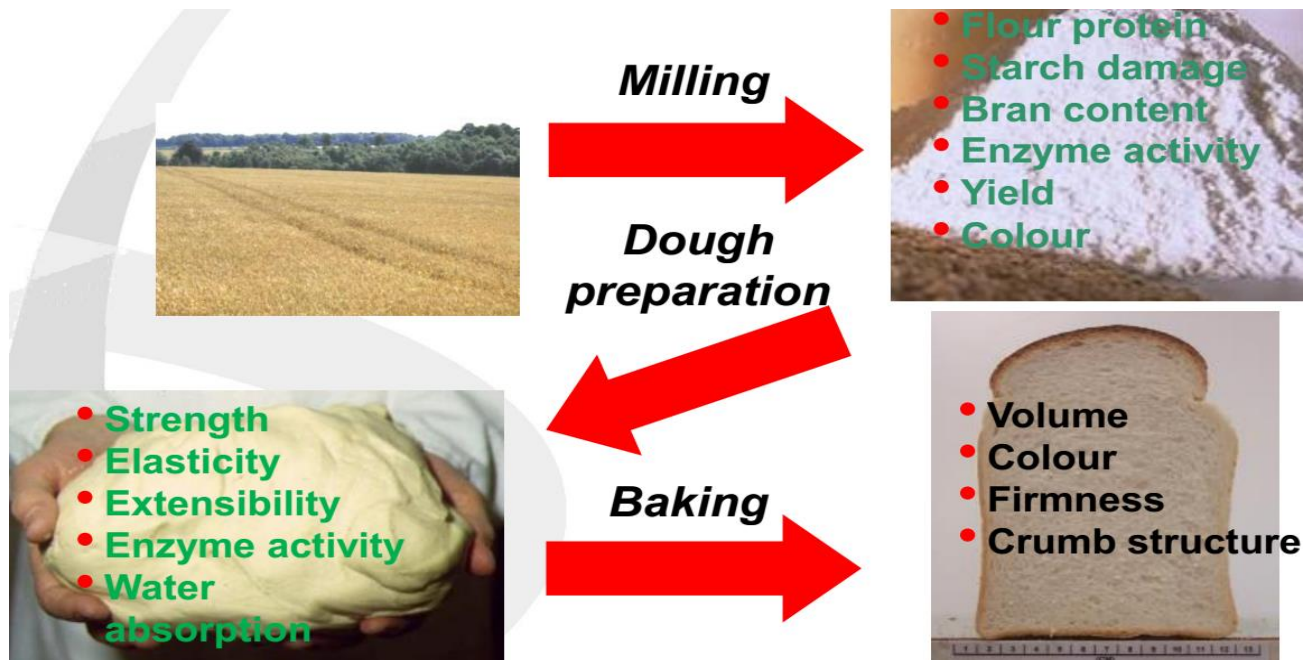


Figure 4: Wheat product qualities

Chapter Three

3. Materials and Methods

3.1. Study design

The experiment was conducted in Ethiopian Institute of Agricultural Research (EIAR), Kulumsa, Melkassa, Debre Zeit, Holeta Agricultural Research Centers, and Agricultural Quality Research Laboratory (AQRL) Central lab of EIAR, Food Science and Nutrition Research laboratories and Center for Food Science and Nutrition laboratory of Addis Ababa University. Milling of the wheat and measurements of some of the physicochemical parameters were undertaken using the facilities of (EIAR), Addis Ababa, and Center for Food Science and Nutrition laboratory of Addis Ababa University.

3.1. The experimental framework of this study

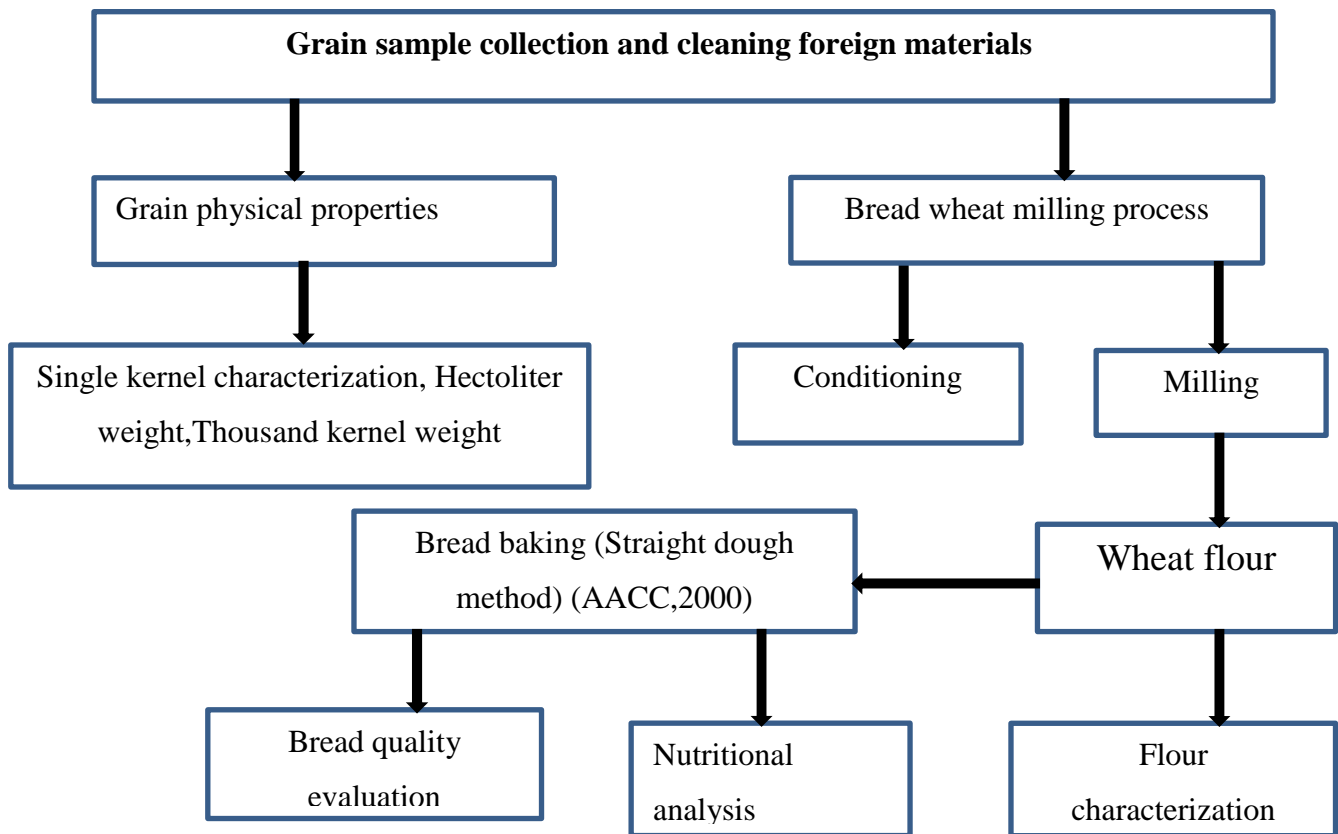


Figure 5: Experimental framework of the study

3.2. Experimental design

The physicochemical, techno-functional properties, sensory quality analysis of samples were conducted in triplicate and Completely Randomized Design (CRD) experimental design was applied for this study.

3.3. Materials collection and preparation

Recently released Ethiopian bread wheat varieties were collected from Kulumsa Agricultural Research Center which has grown under similar agronomic practices and from the same location. Kulumsa Agricultural Research Center (KARC), was selected for the wheat sample collection since it is one of the East African wheat regional centers of excellence (EIAR, 2016). It is located in Oromia Regional State Arsi Zone, 167 km SouthEast of Addis Ababa, and 8 km to the North of Asella town. It is located in the latitude of 8°17' N and longitude of 39°09'35'' E. Its altitude and annual rainfall are 2,200 m.a.s.l and 820 mm respectively. The annual average temperature of the study area is 17°C with a maximum and minimum of 22.8°C and 10.5°C respectively. The soil type is classified as clay loam soil with a pH of 6 (EIAR, 2016). The collected bread wheat samples were manually cleaned by winnowing, sifting, and sorting with hand picking to remove stones, foreign materials (large chaff, dust, and soils) and broken kernels.

Bread Wheat Improvement Program of KARC provided the bread wheat samples. The grain samples were from the producers of the 2018/19 main crop production season, which grew in the premises of KARC using the recommended agronomic practices for optimum production. The collected freshly harvested bread wheat varieties were packed airtight in polyethylene bags and transported to the Food Science and Nutrition Laboratory of KARC for further preparation. The selected varieties in this study were due to their popularity among bread wheat-producing Ethiopian farmers (higher yield potential and disease resistance). The bread wheat varieties used for this study were: Wane and Daka (promising), Hidasse, Lemu, Ogolcho, and Kingbird (recently released) in addition to Pavon76 earlier released (International Maize and Wheat Improvement Center (CIMMYT)) was selected as a local check since breeders have recommended it to be superior and popular variety since 1982 (EIAR, 2016). A total of around 10 kg of wheat samples was collected through purposive, random and homogenous representative sampling method for each wheat variety following the method by the International seed sampling method (2015).

3.4. Methods

3.4.1. Grain physical characteristics

Grain sample divider (Boerner Divider model: S-111, India) was used to prepare the required amount of representative samples for each variety. Foreign matters like other grains dirt, dust, stones, and straw and weed seeds were handpicked. The measured physical grain properties were thousand kernel weight, hectoliter weight, kernel weight, diameter, and hardness index. All the parameters were analyzed using standard procedures as described in AACC, (2000).

3.4.1.1. Thousand kernel weight and hectoliter weight

The wheat sample was taken on the analytical balance after counting 1000 wheat kernels on seed counter (India Mart, VT54, India), whereas, test weight was determined with Schopper Chondrometer (Graintec, QLD4350, Australia) and expressed as kilogram per hectoliter (kg/hl) as described in AACC method 55-31 (AACC, 2000). Hectoliter weight was measured on dockage free samples using a standard laboratory hectoliter apparatus and electronic balance according to AACC method 55-10 (AACC, 2000).

3.4.1.2. Single kernel characterization

Single kernel characteristics are related to milling properties such as tempering, roll gap settings, and flour starch damage content. Single Kernel Characterization System (SKCS 4100 Perten Instruments, USA) measured the moisture, hardness index, diameter, and weight of each kernel.

3.5. Wheat milling process

A standard wheat milling procedure was used for the flour extraction method with a standard laboratory milling instrument. The wheat grain was manually cleaned very carefully by winnowing, sifting, and sorting with hand picking to remove foreign materials. Then the samples were conditioned to 16.5% of moisture level with distilled water in plastic containers based on the initial moisture content of the grain and left for 24 hours to facilitate tempering situation (Donnelly and Ponte, 2000).

$$\text{Water in (\%)} = \frac{100*(F2-F1)}{100-F2} * \text{weight of the wheat sample (g)} \dots\dots\dots(\text{equation 1})$$

Where: F1=Initial wheat moisture F2= Desired wheat moisture. The water was added in the blended container which contained 10 kg wheat grain and mixed well for 15 min by using mixers (Chopin Technology, Type: MR 10L, France) and stored in a plastic container and stored for 24hrs.

After tempering, the samples were milled using a laboratory mill (Chopin Moulin CD1 mill, Chopin technology, France). This mill has a simple flow comprising of three breaks and three reduction passages which are set at right and left side position. The three break passages are built on the first roll pair and the three reduction passages are built on the second roll pair. The breaker part placed at the right side of the mill, it aims to separate the bran from the kernel. Flour, rough flour, and bran were obtained from this breaking operation.

The reduction part also equipped with three corrugated rolls placed on the left side of the mill, their role is to reduce the rough flour produced previously into, fine flour and some rough flour. The separation process was done by a centrifugal sifting, on each part of the mill. Bran finisher was used to optimize the test milling processes and get a higher extraction rate (up to 5% more flour); Retrieve important components from the outer edge of the grain miller(AACC,2000). Then wheat flour obtained was stored at 4°C after packing airtight polyethylene bags until bread baking and further laboratory analysis.

3.5.1. Flour yield

Flour production was achieved by pre-cleaning the samples using sieves and manual cleaning. Samples were tempered to 16.5% water content overnight (based on previous trial work). Moistened samples were milled into flour using a Chopin laboratory mill (Moulin CD1 mill, Chopin technology, France). Five hundred grams of wheat grain were used during the milling test the flour yield was easily calculated multiplying by 0.2 they correspond to flour yield obtained in flour milling because the weight of original grain milled was 500g. Then 100 divided by five hundred simplified to 0.2 multiplied by the weight of extracted flour and flour extraction was expressed on a total product basis (Maghirang *et al.*, 2006).

$$\text{Flour yeild(\%)} = \left(\frac{\text{weight of extracted flour(g)}}{\text{weight of grain milled(g)}} \right) * 100 \dots\dots\dots (\text{equation 2})$$

3.5.2. Flour color

The color of the flour was determined using the Minolta CR-410 colorimeter (Konica Minolta Inc., Japan; illuminant D65, measurement area $\phi=8\text{mm}$, standard observers 2°), and the results were expressed by the CIE Lab color space (AACC, 2000). The analyzed parameters were L^* ($L^* = 0$ (black) to $L^* = 100$ (white)), a^* ($-a^*$ = greenness and $+a^*$ = redness), b^* ($-b^*$ = blueness and $+b^*$ = yellowness). The hue (h) and the chroma (C^*) were calculated with the equations:

$$h = \tan^{-1}\left(\frac{b^*}{a^*}\right), \text{ and } C^* = [(a^*)^2 + (b^*)^2]^{\frac{1}{2}} \dots\dots\dots(\text{equation 3})$$

The hue (h) scale extends from 0° (red), 90° (yellow), 180° (green) to 270° (blue). The chroma (C^*) informs about the purity of the color: a near-zero C^* value corresponds to a color of low purity, near grey. On the opposite high C^* values mean colors of high purity near the pure spectral colors. The difference of color (ΔE) was calculated from

$$\Delta E = [(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta C^*)^2]^{\frac{1}{2}} \dots\dots\dots(\text{equation 4})$$

3.5.3. Starch content

The starch content of flour was determined by using Near-Infrared Spectroscopy (Model 9500 NIRS, Sweden as described in AACC method 44-26B (AACC, 2000) method at Melkassa Agricultural Research Center (MARC), Food Science and Nutrition research laboratory.

3.5.4. Bulk density

Bulk density was done by the method described Oladele and Aina (2007) used for the determination of bulk density. Flour sample (50 g) was weighed into 100 ml measuring cylinder. The measuring cylinder was then tapped continuously until a constant volume was obtained. Bulk density (g/ml) was calculated using the formula

$$\text{Bulk density (g/ml)} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \dots\dots\dots(\text{equation 5})$$

3.5.5. Falling Number

Falling Number was determined by using the instrument (“Falling No.1500”, perten instrument, Sweden) according to AACC (2000) methods 56-81B. A suspension of flour was prepared by adding 25ml distilled water in 7 grams (at 14 % moisture basis) wheat flour in falling number tubes. The suspension was heated in boiling water bath at 100 °C and stirred constantly to gelatinize the starch of wheat flour; time counted in seconds to drop down a plunger having definite weight (37g, automatic plunger fixed in the water bath of falling number machine) into the gelatinized flour paste was recorded as falling number value (FN) was recorded in second.

3.5.6. Gluten extraction, gluten quantity and quality

The gluten quantity and quality were evaluated by using perten glutomatic washing instrument (Perten, Glutomatic 2200, Sweden) according to the standard method 38-12 (AACC, 2000). Where ten grams of flour samples were weighed and placed into the glutomatic washing chamber (GM2020, Perten, Swedeen) on top of the polyester screen then every sample of flour was mixed and washed with a 2% salt (NaCl) solution for 5 minutes. Then the total wet gluten was removed from the washing chamber placed in the centrifuge holder and centrifuged (CF2015, Perten, Sweden) at 6000 rpm for 1 minute. Then the gluten is weighed to obtain the total gluten and the sample was drained by putting on a sieve and weighed to get wet gluten content passed through the sieve.

Finally, the wet gluten was dried in a Glutrok 2020 dryer (GT2020, Perten, Sweden) at 150 °C for 4 minutes and weighed to determine the dry gluten content. In many world markets, wheat flour quality is often based upon protein content. The wheat gluten quality and quantity parameters were: Gluten strength by gluten index, Wet gluten content, Dry gluten content, and gluten water-binding capacity was calculated as follows Gluten Quality and Quantity (ICC Standard No. 155 and 158, AACC Method No. 38-12, ISO 21415).

$$\text{Glutenindex(GI)} = \left(\frac{[(\text{total wet gluten (g)} - \text{wet gluten passed through sieve (g)})]}{\text{Total wet gluten (g)}} \right) \times 100\% \dots (\text{equation 6})$$

$$\text{Wet gluten content (WGC)} = \left(\frac{\text{total wet gluten (g)}}{\text{Weight of sample}} \right) \times 100\% \dots (\text{equation 7})$$

$$\text{Dry gluten content (DGC)} = \left(\frac{\text{dry gluten (g)}}{\text{Weight of sample}} \right) \times 100\% \dots (\text{equation 8})$$

Water-binding in wet gluten (WB) = WGC-DGC.....(equation 9)

3.5.7. Techno-functional properties of recently released bread wheat varieties

1. Flour dispersibility

Dispersibilities of the flours from the studied cultivars were determined in accordance with Kulkarni *et al.*, (1991). The flour samples (10 g) were weighed into a graduated cylinder. Then distilled water was added to make up to 100 ml mark and shaken vigorously. The dispersion was allowed to stand for 3 hours and the volume of the settled particles was recorded. The dispersibility was calculated using the formula depicted below

$$\text{Dispersibility(\%)} = \left(\frac{100 - \text{volume of settled particles}}{100} \right) * 100 \dots\dots\dots \text{(equation 10)}$$

2. The Water holding Capacity (WHC)

The amount of water retained by the sample without being subjected to any stress was determined with a slight modification of the method used by Nelson (2001). One gram of flour sample was mixed with distilled water (10 ml) in 15 ml of the test tube and keep at room temperature for 24 hours. The supernatant was removed and WHC was measured as grams of water retained per gram of solid.

$$\text{Water holding capacity} = \frac{\text{weight of retained water(g)}}{\text{weight of dry sample(g)}} \dots\dots\dots \text{(equation 11)}$$

3. Water Absorption Capacity (WAC)

The WAC of flour samples were determined by the centrifugation method described by Beuchat (1977). One gram of flour was mixed with 10 ml of distilled water in 15 ml centrifuge tubes. The dispersions were occasionally vortexed while held at room temperature for 30 min, followed by centrifugation for 30 min at 3000 rpm (Orto Alresa, M24, Spain). The supernatant was removed and weighed and results were expressed as grams of water retained per gram of flour.

$$\text{water absorption capacity} \left(\frac{g}{g} \right) = \frac{\text{weight of retained water(g)}}{\text{weight of dry sample(g)}} \dots\dots\dots \text{(equation 12)}$$

4. Oil Absorption Capacity (OAC)

The OAC of flour was determined by the centrifugation method described by Beuchat (1977). One gram of flour was mixed with 10 ml of sunflower oil (Tena Zeit) in 15 ml centrifuge tubes. The dispersions were occasionally vortexed while they are held at room temperature for 30 min, followed

by centrifugation for 30 min at 3000 rpm. The supernatant was removed and weighed and results were expressed as grams of water or oil retained per gram of flour.

$$\text{Oil absorption capacity}(\%) = \frac{\text{weight of retained oil}}{\text{weight of dry sample}} \times 100 \dots\dots\dots(\text{equation 13})$$

5. Water Absorption Index (WAI) and Water Solubility Index (WSI)

The wheat flour was measured with the slight modification of the method used by (Kaushal *et al.*, 2012). One gram of flour sample (W_o) was dispersed in 12 ml of distilled water, using a glass rod, in tarred centrifuge tubes; then cooked at 85 °C for 10 min, cooled to room temperature, and centrifuged at 3000 rpm for 10 min. The supernatant was poured into a pre-weighed evaporating dish (Petri plate) to determine its solid content and the sediment was weighed (W_{ss}). The weight of dry solids was recovered by evaporating the supernatant overnight at 110 °C (W_{ds}). WAI, WSI, and swelling power (SP) were calculated from the equations:

$$\text{WAI (g/g)} = \frac{W_{ss}}{W_o} \dots\dots\dots(\text{equation 14})$$

$$\text{WSI (g/100g)} = \left(\frac{W_{ss}}{W_o} \right) * 10 \dots\dots\dots(\text{equation 15})$$

$$\text{SP (g/g)} = \left(\frac{W_{ss}}{W_o - W_{ds}} \right) \dots\dots\dots(\text{equation 16})$$

Where, WAI = Water absorption, WSI = Water solubility index, SP = Swelling power

3.6. Nutritional composition

3.6.1. Crude protein

The nitrogen content was determined by the Kjeldahl method as stated in the AACC method 46-11(AACC, 2000). About 1 g flour sample was weighed into Kjeldahl digestion flasks and 1g of catalyst mixture (K₂SO₄ mixed with anhydrous CuSO₄ in the ratio of 1:10) was added in each. Then 5ml concentrated H₂SO₄ was added and the sample was digested at 380 °C for about 3 hours until the solution was clear white and allowed to cool.

Then 30ml of distilled water was added into each digestion flask followed by 25 ml 40% NaOH. Immediately the content was distilled by inserting the digestion tube line into the receiver flasks that contain 25 ml of 4% boric acid solution. The collected ammonia distillate was then titrated against a standardized 0.1N HCl until the endpoint of the titration was attained (where the titration color

changed from green to blue). Then the volume of HCl consumed to reach the titration endpoint was read from the burette and the nitrogen content % was calculated as follows:

$$\% N = \left(\frac{(V_{HCl \text{ sample}} - V_{HCl \text{ blank}}) \times N_{HCl} \times 14.0}{\text{Wight of sample (g)}} \right) \times 100 \dots \dots \dots (\text{equation 17})$$

Where V HCl = the volume of HCl in liter consumed to the endpoint of the titration, N HCl = the normality of the HCl used and 14.00 is the molecular weight of nitrogen. A conversion factor of 6.25 was used to convert the percent of nitrogen to percent protein of wheat flour. The protein content of foodstuff is obtained by estimating the nitrogen content of the material and multiplying the nitrogen value by 6.25 (according to the fact that nitrogen constitutes on average 16% of a protein molecule).

3.6.2. Moisture

Moisture content was determined by the oven-dry method using (AACC, 2000) method 44-15A. Five gram of sample was weighed and placed in a moisture dish. The crucible was heated 105 °C in an air oven for 1 hour then cooled to room temperature in a desiccator.

The sample Flour was evenly dispersed on the bottom of the crucible plate, and the weight of the crucible and the sample was measured and recorded. Following this, the sample was dried by the drying oven for 3 hours at the prescribed temperature, 105 °C After 3 hrs. The sample was allowed to cool to room temperature in a desiccator. The weight of the metallic and dried sample was, finally, measured and recorded. The drying process was, further, repeated for 30 min, until a constant weight was recorded without any change in weight to ensure that all the moistures of the sample had been evaporated during the drying period. The moisture content of wheat flour can be calculated in the following formula:

$$\text{Moisture content}(\%) = \left(\frac{W_2 - W_3}{W_2 - W_1} \right) \times 100 \dots \dots \dots (\text{equation 18})$$

Where, W₁ = Weight of the empty container & cover

W₂ = Weight of the container, it is cover & the sample before drying and

W₃ = Weight of the container, its cover, and sample after drying or 1 hour and then cooled to room temperature.

3.6.3. Crude fat

The fat content of the samples was measured by AOAC (2010) method by using the Soxtec Extraction system (Foss Soxtec TM 8000 Extraction unit, Sweden). Three gram of the sample was weighed (W1) into each of the thimbles and then the mass of cooled cups was weighed (W2). The thimbles with their sample were placed into the Soxtec TM 8000 Extraction system. 50 ml of petroleum ether was added as a solvent into each cup by using a dispenser. The extraction process was carried out for 20 min boiling, 30 min rinsing, and 10 min recovery. Then the cups with their residue were removed from the Soxtec system and placed in the drying oven at 105 °C for 30 min. The cups were then cooled in desiccators for an hour. The mass of each cooled cup together with its fat contents were weighed (W3). The crude fat was calculated by using the formula below equation

$$\text{Crude fat (\%)} = \frac{(W3-W2)}{(W1)} \times 100 \dots\dots\dots(\text{equation 19})$$

Where, W1 = weight of the sample (g), W2 = the weight of extraction cup and W3= Weight of fat residue and extraction cup (g)

3.6.4. Crude fiber

The crude fiber was determined according to AOAC (2010) method. Two gram of sample was weighed in each of crucible (W1) and inserted with 600 ml beaker. A 200 ml of 1.25% sulfuric acid solution was added to each beaker and allowed to boil on the crude fiber apparatus for 30 min by stirring periodically. After 30 min, 20 ml of 28% potassium hydroxide solution was added into each beaker and again allowed to boil for another 30 min. During boiling the level was kept constant by the addition of hot distilled water. The solution in each crucible was then filtered through a funnel fitted with a rubber stopper. During filtration, the sample residue was washed with hot distilled water; with 1% sulphuric acid solution, hot distilled water, 1% sodium hydroxide solution, and finally with acetone. Each of the crucibles with their contents was dried at 130 °C for 2 hours and cooled in desiccators and weighed (W2). Then again they were ashed for 30 min at 550 °C in the furnace and were cooled in desiccators. Finally, the mass of each crucible was weighed (W3). The crude fiber was calculated from Equation

$$\text{Crude fiber (\%)} = \left(\frac{W2-W3}{W1} \right) * 100 \dots\dots\dots(\text{equation 20})$$

Where, W1= Weight of the sample (g)

W2 = Weight of crucible and sample after drying (g)

W3= Weight of crucible and sample after ashing (g)

3.6.5. Ash

Ash content was determined according to the AACC (2000) method 08-01. 4 g of flour sample was weighed on pre-weighed crucible using a four-digit analytical balance., the sample was burned at 550°C for 5 hours. After allowing, the temperature of the furnace to drop to 250°C the sample was quickly transferred to a desiccator and cooled at ambient temperature. Finally, the ash content of the sample was calculated as follows:

$$\text{Total ash\%} = \frac{(M3-M1)}{M2-M1} \times 100 \dots\dots\dots(\text{equation 21})$$

Where: M2= mass of the flour sample, M1= mass of the crucible before putting the flour sample in it, M3= samples mass in gram on a dry basis, and M3-M1 is mass of ash in gram.

3.6.6. Available carbohydrates

Carbohydrate content was determined by subtracting the sum of the percentages of moisture, ash, protein, and lipid content from 100 (Pearson, 1976).

$$\text{Available carbohydrate (\%)} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ crude protein} + \% \text{ crude fat} + \text{crude fiber}) \dots\dots\dots (\text{equation 22})$$

3.6.7. Available energy

The energy was obtained based on the values of crude protein, crude fat, and available carbohydrate which were multiplied with factors of 4, 9, and 4 respectively, i.e., was calculated in kilocaloriesper100g of the sample as reported by (Tull,1996) and shown below.

$$\text{Energy (kcal/100 g)} = (4* \% \text{Protein}) + (4*\% \text{ Available carbohdrate}) + (9*\% \text{Fat}) \dots\dots\dots(\text{equation 23})$$

3.6.8. Minerals

Iron and zinc contents were analyzed as described in AOAC (2010) using (AAS) Atomic absorption spectrometry (Agilent, AAS 240, USA). The iron content was determined by adding 10 ml of concentrated HNO₃ to 1 g of flour sample and left overnight. The sample was carefully heated until the production of red nitrogen dioxide fumes cease. The sample was cooled and then 4ml of 70% HClO₄ was added and evaporated to a smaller volume (7ml) by carefully heating. The results solution was transferred into a 50 ml volumetric flask and makeup with distilled water. The solution sprays into the atomic absorption spectrophotometer at 248.3 nm to determine the concentration of iron. The intermediate iron standards were prepared to use with the concentration of 0 ppm, 1ppm, 2ppm, 3ppm, and 4ppm respectively.

The zinc content of wheat flour was determined by weighing 1 g of sample and treating with 7 ml of 6 N HCl to wet it completely. After the sample was ashed by dry ashing at 525 °C, then 15 ml of 3 N HCl was added and heated the dish on the hot plate until the solution just boils. The solution was then cooled and filtered into a graduated flask. The solution was sprayed into Atomic absorption spectrophotometer at 213.857 nm to determine the concentration of zinc. The zinc standards used were 0 ppm, 0.5 ppm, 1 ppm, 1.5 ppm, 2 ppm, and 2.5 ppm respectively. Using the atomic absorption spectrophotometer, the calibration curve was prepared by plotting the absorption or emission values against the metal concentration in mg/100g of the sample minerals.

$$\text{Metal content (mg/100g)} = \frac{A-B}{10W} * V \dots\dots\dots(\text{equation 24})$$

Where: W= Weight of sample in (g)

V = Volume of extract (ml)

A = Concentration of sample solution (µg/ml)

Phosphorus amount was determined according to the method by AOAC (2010), protocol 968.08 using UV-Vis Spectrophotometer (Agilent Technologies, Cary 60 UV-Vis, Malaysia) Phosphorus stock solution (50ppm) was prepared by dissolving 0.2197 g dried KH₂PO₄ into 1 liter distilled water. The standards of concentrations 1, 2, 3, 4, 5, and 6 mg/ml as phosphorus were used. Ammonium molybdate (23 g) and 1.25 g ammonium metavanadate were dissolved into 400 ml and hot 300 ml of distilled water in two beakers, respectively. Concentrated HNO₃ (250 ml) were added into the above-

mixed solution and bring to 1 l with distilled water. Then, 5 ml of aliquot was taken from the sample digested by dry ashing into 100ml volumetric flask, and 10ml of ammonium molybdate and metavanadate solution was added to the sample and standards and make up with distilled water. The resulting solution was shaken for uniform mixing and waited for 30 minutes to develop color. The absorbance of each sample and standard was determined with a UV-Vis Spectrophotometer at 460nm.

$$P \text{ (ppm)} = \frac{C*V1*V2*mcf}{S*A} \dots\dots\dots(\text{equation 25})$$

Where: C = P concentration in sample digest read from the curve, ppm

V1 = Volume of the digest (100ml)

V2 = Volume of the dilution

S= Weight of the plant material calcinated in g.

A= Aliquot (5 ml)

mcf= moisture correction factor

3.7. Anti-nutritional factors

Phytate content was estimated by undertaking phytic acid analysis using the Latta and Eskin method as modified by Vaintraub and Lapteva (1988). UV-Vis spectrophotometer, Labda,9500) was used and the series standard solution was prepared to contain 0, 5, 9, 27, and 36 µg/g of phytic acid (sodium phytate) weighed 0.1814g in 100 ml of distilled water) in 0.2N HCl. Three ml of each standard was added into 15 ml of centrifuge tubes and 3 ml of 0.2 N HCl was used as a blank. Two ml of Wade reagent was added to each test tube and the solution was mixed on a Vortex mixer for 15 seconds. The phytate concentration was calculated from the difference between the absorbance of the blank and that of the assayed sample.

About 1 g of dried sample was extracted with 10 ml 0.2 N HCl for 1 hour at ambient temperature and centrifuged at 3000 rpm for 30 min. The clear supernatant was used for phytate estimation. One ml of wade reagent was added to 3 ml of the supernatant sample solution and homogenizes and centrifuged at 3000 rpm for 10 min. The absorbance at 500 nm was measured using a UV-Vis spectrophotometer, Lambda 9500, Malaysia). The phytate concentration was calculated from the difference between the absorbance of the blank (3 ml of 0.2N HCl + 2 ml of wade reagent) and that of the assayed sample. The amount of phytic acid was calculated using a phytic acid standard curve and the result was expressed as phytic acid in µg/g fresh weight.

$$\text{Phytic acid } (\mu\text{g/g}) = \frac{[(As-Ab)-intercept]}{slope*W*3} * 10 \dots\dots\dots(\text{equation 26})$$

Where; As=Absorbance of sample Ab= Absorbance of blank, W= weight of the sample.

Tannin content was determined by the modified vanillin with HCl assay (Price *et al.*, 1978) method. 0.2 grams of flour sample was weighed and then extracted with 10 ml of 1% HCl in methanol screw cap test tube and put on the mechanical shaker (Model: IKA AS130.1, USA) for 24 hours at room temperature. The mixture was centrifuged for 5 min at 3000 rpm and then 1 ml of supernatant was taken and mixed with 5 ml of vanillin-HCl reagent. About 0.03 g of D-Catechin standard was weighed and dissolved in 100 ml of 1 % HCl in methanol (99% concentration).

The standard stock solution 0.0, 0.2, 0.4, 0.6, 0.8, and 1 ml of D-Catechin was taken and adjusted the volume to 1 ml with 1 % HCl in methanol and then 5 ml of vanillin - HCl analytical grade reagent was added. After 20 min to complete the reaction, the absorbance of the sample solution and the standard solution was measured at 500 nm by using UV-Vis Spectrophotometer, Labda,9500). A standard curve was constructed (Absorbance vs Catechin) and the linear portion of the curve was extrapolated to produce the standard curve. The tannin content was calculated using Equation below;

$$\text{Tannin (mg/g)} = \frac{(As-Ab)-intercept}{slope*d*3*W} * 10 \dots\dots\dots(\text{equation 27})$$

Where, As= Sample absorbance Ab = Blank absorbance d = Density of solution (0.791 g/ml), and W = Weight of sample.

3.8. Bread baking

A straight dough process for a bread type was applied to make bread in this study as demonstrated in figure 6. The ingredient proportion was wheat flour basis: water, dry yeast, sugar, and salt. The dough was made by mixing wheat flour 200 g, 4 g salt, 6 g yeast, and 12 g sugar in 104 - 120 ml of water (based on water absorption capacity done before) followed by kneading for 30 min using a standard kitchen Aid mixer at different mixing speed low, medium and high (Kneader, Model A 5K5SS). The dough was allowed to ferment in a bowl covered with a wet clean plastic cover for 60 min at temperature 30 °C and 85% relative humidity using standard dough fermenter until the dough doubles in the original size. Later, the dough was punched and weighed to 100 g dough pieces and shaped. The

dough pieces were proofed in a proofing cabinet for 60 min at 30°C in 85% relative humidity and baked at 190 °C for 20 min in preheating the baking oven at 200 °C (Model MS2535GISW, France).

The bread was cooled on a cooling tray to room temperature made ready for subsequent measurements. Bread physical characteristics evaluated were loaf weight, loaf volume, and specific loaf volume. Loaf weight was measured 30 minutes after the loaves were removed from the oven using a weighing balance. The loaf volume was measured using the rapeseed displacement method as stated in Greene, *et.al* (2004). Rapeseed grain was poured into a container of known volume until the bottom was covered.

The loaf was placed inside the container which was then filled to the top with more seeds. Then the extra rapeseed grain which had equal volume with the loaf was measured in a graduated cylinder and recorded as loaf volume. The specific volume of the loaf was calculated using the following equation:

$$\text{Specific volume (ml/g)} = \frac{\text{Loaf volume}}{\text{Loaf weight}} \dots\dots(\text{equation 28})$$

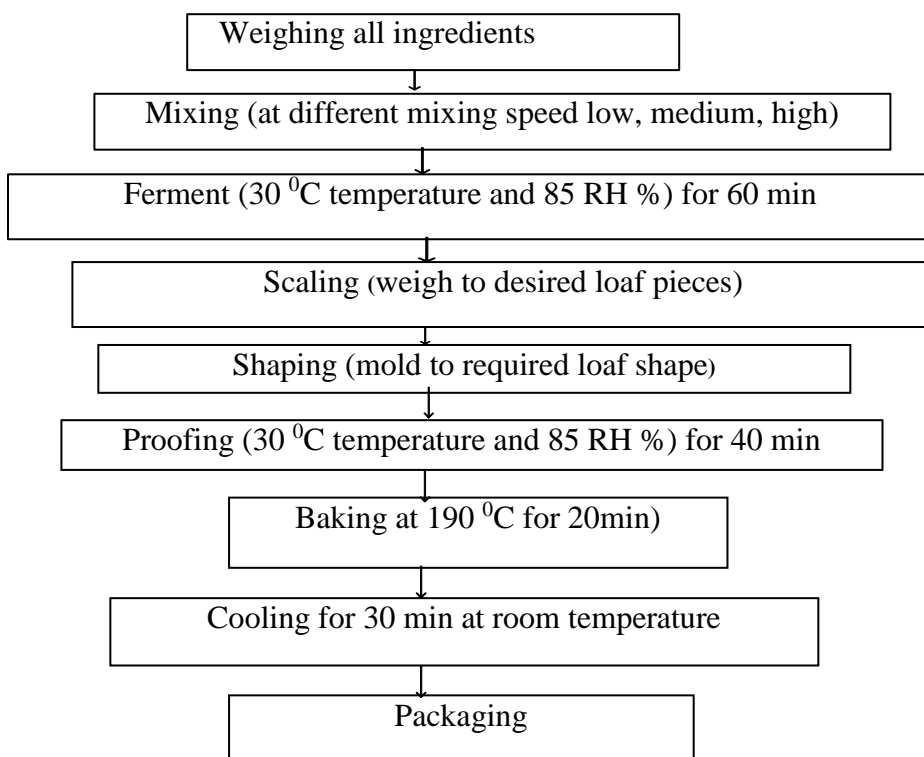


Figure 6: Bread baking flow chart

Modified from AACC, (2000)

3.9. Sensory evaluation

Rating acceptance sensory test was carried out by twenty semi-trained panelists of Food Science and Nutrition laboratory staff members from Debre Zeit Agricultural Research Center (DZARC). The bread samples were coded with three-digit numbers and randomly presented to the 20 panelists in random order with a white color container.

Nine-point Hedonic rating scale ranging (1=extremely dislike, 2 = dislike very much, 3 = dislike slightly 4 = dislike, 5 = neither like nor dislike, 6 = slightly like, 7= like, 8 = like very much and 9 = Extremely like) was used for the sensory study. The panelists were asked to score for sensory attributes that were used to evaluate the samples in terms of color, appearance, flavor, taste, texture and overall acceptability and instructed to rinse their mouth by water before and after testing each sample. The samples were served randomly from right to left or left to right to each panelist in triplicates and average scores were reported.

3.10. Statistical analysis

Statistical comparisons of the mean values were performed by analysis of variance (ANOVA), followed by Duncan's multiple range test using SPSS software (SPSS version 20.0 for Windows, SPSS Inc. Illinois, USA). All analyses were conducted in triplicate and the results were expressed as mean \pm standard error and significant differences were defined at $p < 0.05$.

Chapter Four

4. Results and Discussion

In this study, six bread wheat varieties (Wane, Daka-promising), (Kingbird, Ogolcho, Lemu, and Hidasse - recently released) by the National Bread Wheat Breeding Program of the EIAR grown under the similar agronomic condition and the same location were compared. Also, one variety (Pavon - released earlier) was included as a check. The evaluated parameters include grain physical properties, hardness classification together with flour physicochemical properties, techno-functional properties, nutritional composition, mineral composition, and anti-nutritional factors. Furthermore, the quality of bread baked from these varieties were evaluated for physical characteristics, sensorial quality, and nutritional composition. The detailed results are presented in consecutive Tables and discussed below.

4.1. Grain physical properties

4.1.1. Thousand Kernels Weight (TKW)

TKWs of the tested bread wheat varieties were significantly different ($p < 0.05$) and most of the wheat varieties scored between 30 to 40 g. Hidasse (45g) scored the highest TKWs followed by Pavon (41g) and Ogolcho (41g) in (Table 1). The lowest TKW was obtained for variety Wane. As reported in previous studies, this significant variation might be due to the dependence of TKW on genotypes. Estifanos, (2007) and Solomon *et al.* (2007) reported that the TKWs values of 20 advanced bread wheat lines grown at Haromaya and ten Ethiopian bread wheat cultivars grown at Kulumsa fall in the range of 33 to 45 g and 32 to 46 g, respectively, which are in the same range to the results of the present study. Similar findings were reported by Australian wheat quality standard, TKW of wheat grain ranges between 31g to 43g(understanding Australian wheat quality,2009).

Solomon *et al.* 2007 reported that bread wheat varieties that possessing relatively higher(greater than 30) TKWs can be explored by different stakeholders for improvement in grain yield and better flour extraction during milling and Ethiopian standards wheat grain quality standard,(2017). Therefore, all bread wheat varieties used in this study had TKWs greater than 35 g, which indicates the soundness of the wheat grains for bread making. Also, the HLWs and TKWs were correlated positively to flour yield ($r = 0.83$) in this study.

4.1.2. Hectoliter Weight (HLW)

Hectoliter Weight (HLW) which is dependent on both grain size and shape and used in all wheat grading systems because it highly influences wheat products (Brennan, *et al.*,2012). In this study, the highest and lowest HLWs were reported in Hidasse (86g) and Kingbird (78g) varieties respectively (Table 1). There was a significant difference in the HLW between Hidasse, (Ogolcho, Daka, Payon), (Lemu, Wane) and Kingbird varieties ($p < 0.05$). The variation might be associated with the genotypic variation as the agronomic conditions in this study were uniform. Seyoume (2006) reported HLW values between (80 to 82) kg/hl in 20 bread wheat cultivars of Ethiopia. Also, closer HLW values were reported on Ethiopian improved bread wheat varieties between (77.69 to 82.50) Kg/hl by Soboka *et al.*, (2017). Similarly, Cornish *et al.*(2001) reported HLWs for 130 hard red spring bread wheat varieties grown in different locations of USA (66 to 80) kg /hl, Australian wheat quality standard indicates that HLW greater than 74kg/hl is sound grain. High values of HLW indicate a good variety of having plump kernels undamaged by disease or environmental stress. Also ethiopian standard of wheat grain quality state HLW greater than 70kg/hl (Ethiopian standards,665:2017)which is comparable with the present study. Therefore, in the present study, all the varieties can be considered as sound grains in terms of high HLW values.

4.1.3. Single kernel characterization

SKCS rapidly measures important physical characteristics of wheat grain and provides a forecast for milling quality. Characteristics of the wheat kernel are decisive factors in both the milling quality and end-use food products. The SKCS of the wheat varieties in the present study are shown inTable1.

4.1.3.1. Grain kernel size

There was a significant difference ($p < 0.05$) in single kernel diameter among wheat varieties (Wane, Hidasse), (Daka, Kingbird), (Lemu, Ogolcho) and Payon in this study (Table 1). All the wheat varieties in this study had a standard grain diameter which was greater than 2 mm sieve size (Australia wheat quality standard,2006).

Martin *et al.* (2007) reported a lower kernel diameter (2.41-2.45mm) transgenic isolines of bread wheat than in the present study. This might be due to different genetic make-up of wheat varieties and agronomic practice as well as grown location. Knowing the grain size is very important for choosing a

cleaning sieve, that eliminates impurities larger than the largest wheat kernel and impurities smaller than the smallest kernel. During the milling process of wheat, the cylinder gap of the first grinding break roll can be diminished or enlarged depending on the lots, grain size and the adjustment of the rate of grain feed at the beginning of the milling stage can be changed accordingly (Australia wheat quality standard,2006).

4.1.3.2. Grain kernel weight

In this study, there was a significant difference in kernel weight between bread wheat varieties (Wane, Hidasse), (Daka, Lemu, Ogolcho), and Pavon ($p < 0.05$). The mean value for kernel weight was significantly different by wheat variety. Among all the varieties, Hidasse (37.42 mg/kernel) had the highest kernel weight as compared to the rest varieties (Table 1). Wane (36.34), Lemu (32.11), Ogolcho (32.93), Daka (32.96), Pavon (28.75) and Kingbird (33.42) mg/kernel) respectively. Other Previous studies reported that kernel weight ranged between 33.6 -35.4mg/kernel for Hard red spring wheat and (Martin *et al.*, 2008). Similarly, Martin *et al.* (2007) reported that the kernel weight of transgenic isolines wheat ranged between 34.9-35.3mg/kernel.

High kernel weight values indicate a good variety of having plump kernels undamaged by disease or environmental stress (Abebe *et al.*, 2013). Kernel weights are associated with flour yield, in which wheat can be classified according to grain weight as 15-25 mg (very small), 26-35 mg (small), 36-45 mg (medium), 46-55 mg (large) and over 55 mg (very large) (Williams *et al.*, 1986). Accordingly, in the present study, the wheat cultivars (Hidasse, Ogolcho, Lemu, and Daka) fall under large grain category; while the rest of the cultivars (Wane, Pavon, and Kingbird) fall in slightly small-sized kernels.

Table 1: Grain physical properties and single kernel characterization of six recently released Ethiopian bread wheat varieties

Varieties	Parameters					
	Single kernel characterization					Flour yield(%)
	TKW(g)	HLW(Kg/hl)	Single kernel weight (mg)	Single kernel hardness index (%)	Single kernel diameter (mm)	
Wane	34.99 ± 0.11 ^e	80.19 ± 0.07 ^c	36.34 ± 0.13 ^a	70.68 ± 0.29 ^d	2.75 ± 0.04 ^a	69.05 ± 0.03 ^e
Lemu	39.70 ± 0.26 ^e	80.59 ± 0.16 ^c	32.11 ± 0.78 ^c	72.93 ± 1.27 ^c	2.65 ± 0.04 ^{bc}	71.47 ± 0.01 ^d
Ogolcho	40.92 ± 0.10 ^c	81.57 ± 0.59 ^b	32.93 ± 0.93 ^{bc}	77.47 ± 1.14 ^b	2.62 ± 0.02 ^c	63.18 ± 0.02 ^f
Hidasse	44.45 ± 0.43 ^a	86.04 ± 0.09 ^a	37.42 ± 0.52 ^a	32.02 ± 0.80 ^f	2.76 ± 0.02 ^a	74.78 ± 0.01 ^a
Daka	39.00 ± 1.00 ^d	81.69 ± 0.27 ^b	32.96 ± 0.74 ^{bc}	70.42 ± 1.20 ^d	2.67 ± 0.02 ^b	73.34 ± 0.01 ^b
Pavon	41.12 ± 0.10 ^b	81.30 ± 0.07 ^b	28.75 ± 0.59 ^d	86.72 ± 0.33 ^a	2.49 ± 0.03 ^d	61.73 ± 0.01 ^g
Kingbird	35.20 ± 0.20 ^e	78.43 ± 0.25 ^d	33.47 ± 0.49 ^b	58.80 ± 0.41 ^e	2.70 ± 0.03 ^b	73.32 ± 0.01 ^c

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test (p < 0.05). TKW- Thousand Kernel Weight, HLW- Hectoliter Weight.

4.1.3.3. Kernel hardness index

The kernel hardness index significantly differs (p<0.05) for varieties Ogolcho, Lemu, (Wane, Daka), Kingbird, Hidasse, in this study. There was a large difference in the hardness index between the highest value in Ogolcho (77.5%) and the lowest value (32%) in the Hidasse variety. Hard and soft wheat types have hardness scores greater and less than 50 respectively (Edwards, 2010). Hardness index which describes endosperm texture is regarded as the most important single kernel characteristic that is used in wheat classification. Also, it influences the functionality of common wheat and associated quality factors (Pomeranz. and Williams, 1990). Accordingly, in the present study, Wane, Daka, Pavon, Kingbird, Lemu, and Ogolcho varieties can be considered as hard wheat varieties that suitable for leavened products like bread. However, Hidasse fell into a soft wheat type which is not suitable for the production of bread rather recommended for the production of biscuit. Therefore, breeders can identify/recommend the categories of wheat varieties for farmers corresponding to the concept of its end-use products. However, an increase in kernel hardness results in an increase in

energy input during milling, flour granularity, damaged starch, water absorption, gas production, and technological properties (Pomeranz and Williams, 1990). Ma *et al.* (2009) reported the hardness index of (67.9 - 75.5) % in seven near-isogenic lines of wheat. Meanwhile, 64.0 to 73.7% index was reported in Hi-line hard red spring wheat and transgenic isolines by Martin *et al.*, (2008). These values are slightly different from the results in the present study, which might be due to different genetic make-up, agronomic practices, growing location, etc. From the current study, hardness could not provide a valuable prediction of break flour yield). Hard wheat flour, characterized by high levels of protein (gluten) is used for bread and fine cakes, while durum wheat flour is used for macaroni, spaghetti, and other pasta products. Soft wheat flour is lower in protein content and is primarily used for biscuits, cookies, crackers, and breakfast foods (Punia *et al.*,2017).

Hard wheat has SKCS hardness scores greater than 50 (HI) while soft wheat has scored less than 50 (Edwards, 2010). Wheat variety Hidasse had a significantly lower hardness index than the rest of the varieties. Hardness index which describes endosperm texture is regarded as the most important single kernel characteristic that is used in wheat classification and influences the functionality of common wheat and its associated quality factors (Pomeranz and Williams .1990). Hard wheat flour, characterized by high levels of protein (gluten) is used for bread and fine cakes, while durum wheat flour is used for macaroni, spaghetti, and other pasta products. Soft wheat flour is lower in protein content and is primarily used for biscuits, cookies, crackers, and breakfast foods (Punia *et al.*,2017).

4.1.4. Flour Yield

The flour yield of six recently released bread wheat varieties and one local check variety ranged from Ogolcho (63%) to Hidasse (74.78 %). Hidasse had significantly highest break flour yield than the rest of the varieties. This may be due to the highest hectoliter weight and lowest hardness index of varieties. There was a significant difference in flour yield between all the newly released wheat varieties ($p < 0.05$) (Table 1). Comparable flour yield(72%) with the present study was reported by Abboud Al-Saleh and Charles (2012) on six Syrian bread wheat genotypes.

4.4. Nutritional composition

4.4.1. Moisture

Wheat grain deterioration increases when the moisture content is high. The permeable moisture content of different cereals is 10-12% at storage conditions. It is an important factor for other nutrients as they vary with it. The moisture content of the newly released wheat varieties varied from 11.40 % - 12.27%, the highest and lowest determined from Daka and Wane varieties respectively (Table 2). The moisture content of all varieties in this study was in the standard range.

4.4.2. Crude protein

In this study, the protein contents of the bread wheat varieties varied from Ogolcho (9.74 %) to Wane (14.14 %). There was a significant difference in protein content among the varieties (Pavon, Wane), Daka, Lemu, Kingbird, (Ogolcho, Hidasse) from the highest to lowest respectively ($p < 0.05$) (Table 2). This variation might be linked with the different genotypes. The results were consistent with the report by (Soboka *et al.* (2017). Protein is one of the primary quality components that influence most of wheat grain baking quality characteristics. The protein content is a key factor for many processing properties such as water absorption capacity and gluten strength. Also, it contributes significantly to texture and flour mixing tolerance of baked food. With this regard, in this study, the protein content was positively correlated to gluten content ($r = 0.75$). In hard wheat, variation in the loaf volume of bread can be attributed directly to differences in protein concentration and quality (Fowler, 2002).

Similar to the present study, (Solomon *et al.* (2000) reported a significant difference in protein content of ten Ethiopian bread wheat cultivars grown under Arsi condition (highlands) varying from 7.7% to 13.2%. In fact, a significant difference in protein content due to genotype variation was reported by other previous studies too. Anjum *et al.* (2008) reported (9.68 -13.45) %, variation in protein content. Among Pakistan wheat varieties; (Wilson *et al.* (2001) also reported protein content of six bread wheat cultivars grown over three years varied from (8.7 -12.9) %.

Except for Hidasse and Ogolcho varieties, the protein contents of all the varieties were in the expected range of bread wheat. This further put them under the hard bread wheat category that is suitable for leavened bread preparation. In general, higher protein content ($>12\%$) is the property of hard bread wheat which is suitable for leavened bread preparation (Punia *et al.*, 2017). However, (Qarooni *et al.*

(1988) described that flour with protein content ranging from (10 -12) % is more suitable for the production of Arabic bread. On the other hand, wheat varieties with lower protein content (<10) % suitable for the production of soft wheat products like biscuits, cookies, and cakes. From this study, the wheat cultivars Wane, Pavon, Daka, and Lemu, Kingbird are suitable for leavened bread production. Meanwhile, Hidasse and Ogolcho variety with low protein content are suitable for biscuits production.

4.4.3. Ash

In this study, the ash content of the wheat varieties ranged from 0.52 % (Hidasse) to 0.84 % (Pavon). The ash content of the newly released wheat varieties had similar ash content with refined wheat flour Mepba *et al.* (2007) reported ash content value as 0.46%. and Similar finding were reported by USDA National nutrient data base (2016)) reported ash content of wheat flour (0.45 to 1) %. Abboud and Charles (2012), reported similar ash content with the present study in Syrian and English wheat varieties. There was a significant difference ($p < 0.05$) in ash content among varieties Payon, (Wane, Lemu, Ogolcho), (Daka, Kingbird), Hidasse, from highest to lowest, respectively (Table 2). This difference might be described as differences in wheat genotypes since the wheat grains were grown under similar conditions and processed in the same way

The presence of higher ash content indirectly reflects the availability of more amounts of minerals and lower starch. Also, higher ash content in wheat flour indirectly reveals the presence of a higher amount of bran and minerals (NAEGA, 2004). High ash in flour can affect color, imparting a darker color to products. Similarly, ash content is also one of the best indicators of flour yield. Hence, the wheat variety with lower content of ash may have more endosperm and ultimately yield good flour extraction (Williams, 1986). Other factors affecting ash content include environmental conditions and stages of wheat grain maturation.

4.4.4. Crude fiber

In this study, there was a significant difference in crude fiber content among the wheat varieties (Daka, Wane), Ogolcho, Hidasse, Pavon, Kingbird), (Lemu, Ogolcho, Pavon) (Table2). Lemu and Wane had the highest and lowest crude fiber content respectively. Similar to the previously discussed nutrients, this variation might be due to genotypes variation. In fact, wheat flour is among cereals containing the lowest fiber content (0.3 - 0.65) % (Okafor *et al.*,2012). Crude fiber helps in the prevention of heart

diseases, colon cancer, and diabetes however, refined wheat flour would not be a better source of fiber content since it had significantly lower crude fiber content. on the other, high fiber containing wheat flour affects bread specific volume and crumb hardness of bread loaf and these characteristics were also dependent on both bread-making process and specific volume is an indication of the gluten content of the bread. In conventional bread making, fiber replacement of flour disrupts the starch-gluten matrix and restrict and force gas cells to expand in a particular dimension (Collar *et al.*, 2006).

Table 2: Proximate composition of flour six recently released Ethiopian bread wheat varieties

Varieties	Composition (g/100g flour)							
	Moisture	Crude Protein	Ash	Crude Fiber	Crude Fat	Available carbohydrate	Available energy (Kcal/100g)	
Wane	11.40 ± 0.11 ^f	14.14 ± 0.18 ^a	0.72 ± 0.03 ^b	0.62 ± 0.02 ^a	1.45 ± 0.011 ^a	71.05 ± 0.18 ^e	356.27 ± 0.55 ^a	
Lemu	12.20 ± 0.05 ^{ab}	12.64 ± 0.23 ^c	0.74 ± 0.02 ^b	0.22 ± 0.01 ^c	1.21 ± 0.03 ^{bc}	72.77 ± 0.30 ^c	353.37 ± 0.16 ^c	
Ogolcho	12.07 ± 0.03 ^{bc}	9.74 ± 0.11 ^e	0.74 ± 0.01 ^b	0.32 ± 0.01 ^{bc}	1.4833 ± 0.10 ^a	75.33 ± 0.15 ^{ab}	354.87 ± 0.20 ^b	
Hidasse	11.60 ± 0.14 ^e	9.99 ± 0.15 ^e	0.52 ± 0.05 ^e	0.45 ± 0.02 ^b	1.0900 ± 0.12 ^{cd}	75.88 ± 0.10 ^a	355.12 ± 0.03 ^b	
Daka	12.27 ± 0.17 ^a	13.17 ± 0.65 ^b	0.62 ± 0.03 ^c	0.60 ± 0.01 ^a	1.3167 ± 0.08 ^b	71.42 ± 0.42 ^{de}	352.61 ± 0.50 ^c	
Pavon	11.79 ± 0.04 ^d	13.79 ± 0.26 ^a	0.84 ± 0.01 ^a	0.34 ± 0.19 ^{bc}	1.0400 ± 0.02 ^d	71.85 ± 0.37 ^d	353.32 ± 0.37 ^c	
Kingbird	11.93 ± 0.05 ^{cd}	10.72 ± 0.05 ^d	0.64 ± 0.01 ^c	0.37 ± 0.03 ^b	1.0167 ± 0.01 ^d	74.95 ± 0.03 ^b	353.32 ± 0.05 ^c	

Values are expressed as mean ± SE(n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test (p < 0.05).

4.4.5. Crude fat

In this study, the crude fat content of the newly released bread wheat varieties was determined by soxhlet extraction method. Among the varieties, there was a significant difference in crude fat content (Wane, Ogolcho), (Lemu, Daka), (Lemu, Hidasse) (p<0.05) (Table 2). The lower fat content the wheat varieties might be due to the complete removal of germ and bran during the milling process of wheat. The wheat germ contains more fat content while, endosperm contain lowest fat content. Similarly, low-fat content of less than 1.5% was reported for wheat flour by Akubor and Yusif, (2013). Crude fat content is genetically controlled and cereal grain contains the lowest amount. The most probable reason for the low level may be the presence of lipase, which is responsible for the hydrolysis of lipids in dormant wheat during storage (Rose and Pike, 2006). Low-fat content affects the mouthfeel of bread and the appearance of loaf bread.

4.4.6. Available carbohydrates

Carbohydrate is the major nutrient component of the wheat kernel. Generally, starch, reducing sugar, and crude fiber are considered as the main components of carbohydrate. Carbohydrate is the main component in wheat grain (54-72) % of grain dry weight) and it affects the structure of baked products and it consists of 20-25% of the linear molecule, amylose, and 75-80% of complex and highly branched molecule amylopectin (Stone *et al.*,2009). At maturity, the wheat grain consists of 85% (w/w) carbohydrate, 80% of which is starch (present only in the starchy endosperm (Stone and Morell ,2009).

In this study, there was significant difference in the total carbohydrate contents of the wheat varieties Hidasse, (Ogolcho, Kingbird) Lemu, (Wane, Pavon) ($p < 0.05$) (Table 2). Generally, all wheat varieties in this study had a good source of carbohydrate for baked product formulation. This could be due to bread wheat flour extraction that removed the germ in the wheat and lower the fiber content by removing the bran Hidasse variety had the highest amount of carbohydrate (74.34%) among all the varieties. This variation might be due to different genotypes. The present results were more or less similar with the report by Singh *et al.*, (2006). Nitika *et al.*,2008) and Rahman and Kader, (2011).

4.4.7. Available energy

Bread wheat varieties used in this study had a significantly different ($p < 0.05$) in the gross energy content of the flour (Table 2 and bread (Table 5). The energy of the wheat flour and bread ranged between (352 .61 to 356.28) and 352.58 to 356.26 kcal respectively. The lowest energy value was obtained in the Daka variety while, the highest energy value was obtained in Wane. All the bread wheat varieties had higher energy value. This is due to the fiber, the protein, and the fat content of the bread wheat varieties and the highest carbohydrate content. The trend of the energy level of bread was significantly ($p < 0.05$) influenced by varieties.

4.4.8. Mineral

In this study, three minerals iron, zinc, and phosphorus were determined in the seven newly released Ethiopian bread wheat varieties as shown in Table 3. Because there was a strong genetic component to iron and zinc accumulation in the grain (Welch and Graham,2002) and bran has been shown to have a detrimental effect on the quality of bakery products. Gamal *et al.* (2012) reported that higher amounts

of iron, phosphorus, zinc in wheat bran, and lower in wheat flour respectively, and deficiency of micronutrients, such as iron and zinc, are a critical and major problem. Also, wheat is one of the cereals which is classified as rich sources of phosphorous (Heshe *et al.*,2015).

Accordingly, there was a significant difference ($p < 0.05$) in iron concentration among the wheat varieties Hidasse, Daka, (Ogolcho, Kingbird), (Lemu, Payon), Wane. Hidasse variety had the highest iron concentration and variation among the varieties might be influenced by the iron concentration. In this study, the iron concentration in the wheat flour ranged between (0.30-1.94) mg/100g, while the previous study, reported in the whole wheat flour was (2.51-3.35) mg/100gm (Heshe *et al.*,2015). Another study reported by Gamal *et al.*2012) indicated that iron concentration in refined wheat flour (1.3) mg/100g which is similar with the finding of present study. The bran and the germ of wheat grain are relatively rich in minerals and the milled products contain lesser content of minerals (Abebe *et al.*, 2015). According to Lopez *et al.*, (2003), 80% of the total amounts of minerals are concentrated in the aleurone layer of the pericarp (bran), which was removed during the milling process while only 20% minerals are present in the endosperm. As a result of milling, minerals bioavailability, the palatability of the baked products will increase, but the nutritional value of the products will decrease (Hoseney,1992).

In the present study, zinc concentration varied significantly among the varieties Kingbird, Lemu, (Ogolcho, Payon), Wane, Daka, Hidasse ($p < 0.05$) (Table 3).in the current study, zinc content varied from (0.43 to 0.69) mg/100(Wane, Kingbird) respectively. in a previous study, the white wheat flour contained zinc content in the range of 0.58 to 1.39 mg/100g (Hashe *et al.*,2015). As reported in the previous discussion iron part, 80% of the total amounts of minerals are concentrated in the (bran), which was removed during the milling process while only 20% minerals are present in the endosperm.

Therefore, such issues would need further evaluation, and the optimum bran content needed for enhancement of nutritional quality of bread, so, it would be critical to compromise all the product qualities in terms of nutritional, minerals bioavailable, sensorial, and processing made from wheat varieties.

Table 3: Mineral composition of six newly released Ethiopian bread wheat varieties

Varieties	Minerals (mg/100g flour)		
	Iron	Zinc	Phosphorous
Wane	0.3 ± 0.06 ^c	0.43 ± 0.01 ^d	137 ± .0.6 ^c
Lemu	0.68 ± 0.02 ^d	0.51 ± 0.02 ^b	172 ± 0.5 ^c
Ogolcho	0.85 ± 0.01 ^c	0.47 ± 0.01 ^c	208.5 ± 0.6 ^b
Hidase	1.93 ± 0.02 ^a	0.18 ± 0.01 ^f	279 ± 0.15 ^a
Daka	1.25 ± 0.02 ^b	0.28 ± 0.02 ^e	305.44 ± 0.7 ^a
Pavon	0.63 ± 0.01 ^d	0.47 ± 0.01 ^c	196.56 ± 0.6 ^{bc}
Kingbird	0.89 ± 0.04 ^c	0.69 ± 0.01 ^a	211 ± 0.42 ^b

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test ($p < 0.05$).

The phosphorous content in the present study of recently released bread wheat varieties was ranged between (137 and 305) mg/100g (Wane, Daka) respectively. There was a significant difference in phosphorous concentration ($p < 0.05$) among wheat varieties due to genotypes variations. In the previous study reported by Gamal *et al.* 2012), refined white wheat flour which contained 101mg/100 g phosphorous concentration. The result of the wheat newly released wheat varieties was in line with the finding of (Heshe *et al.* (2015), which reported the presence of 145 mg/100 g phosphorous in wheat flour.

4.5. Physicochemical properties of six recently released Ethiopian bread wheat varieties

4.5.1. Flour color

In this study, the color values of the newly released bread wheat varieties were given in Table 4. Accordingly, there was a significant difference in L* values among the varieties Daka, Hidasse, Ogolcho, Lemu,(Wane, Kingbird). In fact, the L* values in all the wheat varieties were exceeded 92) which is an indication of white color and accepted color by consumers (AACC, 2000).

Flour color often affects the color of the finished product and is therefore one of many flour specifications required by end-users. Generally speaking, a bright white color flour is more desirable for many products. The color values of a typical white flour, for example, L* values greater than 92.5, indicate flour whiteness. The a*color value was significantly different between the varieties

(Wane, Hidasse), Daka, Payon. Meanwhile, the b^* were significantly different between the varieties - Payon, Lemu, Ogolcho, Kingbird, Wane, Hidasse, Daka ($p < 0.05$) (Table 4). This could be due to the difference in pigment concentration and ash content among the varieties (Canadian, USAID, 2010). Flour color A Minolta spectrophotometer CN-508i (Minolta, Co., Ltd., Japan) was used for flour color measurements. Results were obtained in the CIE L^*a^*b coordinates using the D65 standard illuminant, and the 2° standard observer. The hue (h) and the chroma (C^*) were calculated from the Eqs. (1) and (2) respectively. The spectrophotometer was programmed to report an average of 5 measurements. $h = \tan^{-1} (b^*/ a^*)$ (1) $C = ((a^*)^2 + (b^*)^2)^{1/2}$. The hue angle (h) of the flours varied among varieties. The wheat flours were lighter which could be due to being refined or with very little amount of bran components. However, although significant, the flour color differences attributed to the mill was hardly be detected by eye.

4.5.2. Bulk density

In this study, there was a significant difference in bulk density among the varieties (Ogolcho, Wane, Lemu, Daka, Payon, Kingbird) and Hidasse ($p < 0.05$) (Table 4). The highest bulk density was obtained in the wheat flour Wane and Ogolcho (0.83 g/ml), while the lowest was for wheat flour Hidasse (0.52 g/ml). These values are comparable with previous studies for other wheat flour; Eltayeb *et al.* (2011) (0.77 g/ml) and (Abebe *et al.* (2013) (0.76 g/ml) respectively. In some previous literature, the bulk density of wheat flour ranged between (0.5 to 1) g/ml. Bulk density is generally affected by the particle size and density of the flour.

According to (Lakshmi., 2015), BD of standard wheat flour reported as values (0.93 g/ml). Bulk density is very important in determining packaging requirements and material handling. Higher bulk density is desirable in that it offers greater packaging advantage as a greater amount of flour may be packed within a constant volume (Akubor, 2007). The high bulk density of flour suggests their suitability for use in food preparations. In contrast, low bulk density would be an advantage in the formulation of complementary foods (Akapata and Akubor, 1999).

In the present study, the highest bulk density was found in varieties (Wane) and Ogolcho). Whereas, Hidasse had the lowest BD of wheat varieties which is suitable for weaning food since weaning food should have low bulk density and low water absorption capacity to produce a more nutritious and suitable weaning food (Appiah, 2011). Similar findings were reported by Eltayeb *et al.*, (2011).

Therefore, the present study suggests that the high bulk density of wheat varieties (Wane, Ogolcho, Kingbird, Daka, and Pavon) also suggests its suitability be used as a thickener in food products. While, high BD also helps to reduce paste thickness, which is an important factor in convalescent and child feeding. Hence, Hidasse can be an ingredient for the development of complementary food development since it had low BD among varieties.

Table 4: Color, bulk density, starch, and falling number of six recently released Ethiopian bread wheat varieties

Varieties	Parameters								
	L*	a*	b*	H	C	ΔE	BD(g/ml)	Starch (g/100 flour)	Falling number(sec)
Wane	93.82 ± 0.07 ^e	0.97 ± 0.01 ^a	1.70 ± 0.01 ^e	60.28 ± 0.39 ^e	1.95 ± 0.05 ^c	2.76 ± 0.05 ^c	0.83 ± 0.01 ^a	74.99 ± 0.25 ^c	421.00 ± 20.22 ^b
Lemu	94.19 ± 0.02 ^d	0.32 ± 0.01 ^d	0.61 ± 0.01 ^b	62.12 ± 0.94 ^b	0.68 ± 0.01 ^e	0.97 ± 0.01 ^e	0.77 ± 0.02 ^a	76.35 ± 0.93 ^b	438.67 ± 54.90 ^b
Ogolcho	94.36 ± 0.02 ^c	0.31 ± 0.01 ^d	0.48 ± 0.01 ^c	57.23 ± 0.08 ^c	0.56 ± 0.05 ^f	0.80 ± 0.01 ^f	0.83 ± 0.01 ^a	77.65 ± 0.05 ^a	335.00 ± 17.00 ^c
Hidasse	95.01 ± 0.01 ^b	0.97 ± 0.01 ^a	2.54 ± 0.01 ^f	68.35 ± 1.39 ^f	2.71 ± 0.05 ^b	3.84 ± 0.01 ^b	0.56 ± 0.29 ^d	78.02 ± 0.06 ^a	507.33 ± 16.65 ^a
Daka	98.47 ± 0.02 ^a	0.83 ± 0.01 ^b	3.15 ± 0.05 ^g	75.22 ± 0.39 ^a	3.25 ± 0.45 ^a	4.60 ± 0.06 ^a	0.81 ± 0.01 ^a	75.14 ± 0.48 ^c	437.00 ± 42.58 ^b
Pavon	92.82 ± 0.01 ^f	0.71 ± 0.01 ^c	1.29 ± 0.01 ^a	61.24 ± 0.70 ^b	1.46 ± 0.05 ^d	2.07 ± 0.01 ^d	0.78 ± 0.03 ^a	74.78 ± 0.07 ^c	300.33 ± 56.59 ^c
Kingbird	93.83 ± 0.01 ^e	0.42 ± 0.01 ^d	0.41 ± 0.01 ^d	44.30 ± 0.70 ^d	0.58 ± 0.01 ^f	0.82 ± 0.01 ^f	0.82 ± 0.02 ^a	76.91 ± 0.13 ^c	401.67 ± 11.68 ^b

Values followed by different letters within a column indicate a significant difference ($p < 0.05$). All values are means ± SE(n=3). Where: BD = Bulk density, L*, a*, and b* are CIE coordinates, h = hue and C* = Chroma (C*), ΔE = Color difference; FN = Falling number.

4.5.3. Starch content

The starch content of the wheat varieties for this study ranged between (74-78) % for Pavon and Hidasse respectively (Table 4). Cereal grains store energy in the form of starch and all the varieties had high amount of starch. The inner endosperm contains most of the starch and protein in the wheat grain. The amount of starch contained in a wheat grain may vary between 60% and 75% of the total dry weight of the grain (Belderok *et al.*, 2000).

There was a significant difference in starch content among the varieties (Hidasse, Ogolcho), Lemu, (Wane, Daka, Payon) ($p < .05$) (Table 4). Apparently, this might be linked with the genotype variation. Many of the properties of cereal starches that determine their suitability for end-use are dependent upon the starches contents. The starch composition is important when considering the dietary impact of bread. These properties include gelatinization and gelation characteristics, solubility, the formation

of resistant starch, and textural characteristics of wheat flour for baking quality of bread (Cornel, 1998).

4.5.4. Falling number

The falling number of the newly released Ethiopian bread wheat varieties in this study varied between 300-507 seconds for Pavon and Hidasse respectively. All the varieties had a higher falling number than previous common reports. There was a significant difference in the falling number among the varieties Hidasse, (Wane, Lemu, Daka, Kingbird), (Ogolcho, Payon) ($p < 0.05$) (Table 4). FN indicates the amount of sprout damage that has occurred within a wheat variety. Generally, a falling number of 350 seconds and higher indicates a low enzyme activity and very sound wheat quality. In contrast, values below 200 seconds indicate high levels of enzyme activity (AACC, 2000) which is not suitable for the baking quality of bread. Therefore, bread wheat varieties investigated in this study had a high falling number, which indicates their soundness for end-product use. This further might be due to the wheat varieties being harvested freshly, in optimum time and no rain-damaged at the field.

4.6. Gluten content and quality

4.6.1. Gluten

In many world markets, wheat flour quality is often based on protein content. While total protein content is very important, it is only part of the information required to determine suitable wheat flour usage. Many situations require additional information about the functional properties and quality of protein to predict dough and baking properties. Thus, in this study, the gluten content and quality in the newly released Ethiopian bread wheat varieties were determined and discussed below. The wet gluten content, gluten index, dry gluten content, and water absorption capacity of gluten are presented in Table 5.

The wet gluten content was significantly different ($p < 0.05$) among the varieties Daka, Wane, (Lemu, Hidasse, Pavon), Kingbird, Ogolcho. the WGC in the varieties ranged between (22-32) %, the highest and lowest values were in Daka and Ogolcho varieties respectively. Daka and Wane varieties had wet gluten content higher than 30% and Pavon, Hidasse, Lemu, Kingbird, and Ogolcho had between 20 and 30%. According to Sadowska *et al.* (2001), wet gluten contents of bread wheat varied from 17.1% to 33.60% for different winter and spring wheat varieties. The present study results are incomparable with this report. The results are also in close relation with the findings of Miralbes, (1988) who

reported a variation between 15.6% to 39,3% in wet gluten content in wheat varieties. The variation in wet gluten content among wheat cultivars in this study might be attributed to the difference in genotypes.

4.6.2. Gluten index and gluten strength

The gluten index provides information on both the quantity and quality of wet gluten. It is also a criterion in defining whether gluten quality is weak, strong, or normal. Furthermore, it is a standard quality indicator of high or low molecular weight proteins. In this study, Daka, (Lemu, Pavon), (Wane, Kingbird), Ogolcho, Hidasse had significant different($p<0.05$) GI values. The highest and lowest values were obtained in varieties Daka (95%) and Hidasse (59%) respectively.

Based on GI, Cubadda *et al.* (2007) proposed seven gluten quality classes in wheat. Gluten index values between 65% and 80% are good while values above 80 are excellent. Based on this, in the current study all the wheat cultivars had high ($>80\%$) gluten index values(excellent), except, Hidasse, which fall under poor quality range indicating of higher low molecular weight gluten subunit that is not suitable for leavened food products. But, for biscuits preparation this variety is suitable. an indicator of higher low molecular weight gluten subunit which is not suitable for leavened baked products but for biscuits preparation this variety was suitable.

4.6.3. Dry gluten

In this study, the dry gluten contents of the test cultivars varied from (8-13) % Wane, and Ogolcho varieties with the highest and lowest values, respectively. There was a significant difference in DGC among the varieties Wane, (Ogolcho, Daka), (Lemu, Pavon), (Hidasse, Pavon), Kingbird ($p<0.05$) in (Table 5). The values in the present study were comparable with the findings of (Seleiman *et al.* 2011); who reported significant variation in dry gluten contents among different Egypt wheat cultivars that ranged from 10.4% to 13.5%. The gluten protein content determines the flour quality and has a significant impact on bread-making quality.

4.6.4. Gluten water binding capacity

In this study, gluten water-binding capacity ranged between (Ogolcho (13.45 %) to Daka (20.20 %). the varieties Daka (Wane, Pavon), Lemu, (Hidasse, Kingbird), Ogolcho, showed a significant

difference in the GWBC($p < 0.05$). The results of the current study were similar to the results of improved bread wheat varieties reported by (Soboka, *et al.* 2017), which was ranged from 16.27 % to 17.88% of the water-binding capacity of gluten of wheat varieties in general, important of gluten in bread baking test provides information on the quantity and estimates the quality of gluten in wheat flour. Gluten is responsible for the elasticity and extensibility characteristics of dough. Wet gluten reflects protein content and is a common flour specification required by end-users in the bakery industries. Therefore, the present study clearly indicated that; the importance of gluten characterization. Based on the current study, bread wheat varieties (Wane, Daka, Pavon) had the highest gluten qualities suitable for bread baking qualities. While, Kingbird, and Ogolcho) varieties had the lowest gluten qualities for bread baking from these varieties.

Table 5: Gluten quantity and quality of six recently released Ethiopian wheat varieties

Varieties	Parameters			
	GI(%)	WGC(%)	DGC(%)	GWBC(%)
Wane	89.23 ± 1.09 ^c	31.60 ± 0.40 ^a	12.55 ± 0.35 ^a	19.05 ± 0.75 ^b
Lemu	91.72 ± 0.09 ^b	29.00 ± 0.30 ^c	11.15 ± 0.25 ^c	17.85 ± 0.05 ^c
Ogolcho	79.63 ± 0.46 ^d	21.60 ± 0.01 ^e	8.15 ± 0.15 ^f	13.45 ± 0.15 ^e
Hidasse	59.12 ± 1.19 ^e	29.15 ± 0.15 ^c	10.60 ± 0.40 ^d	16.55 ± 0.25 ^d
Daka	94.57 ± 1.42 ^a	32.25 ± 0.15 ^a	12.05 ± 0.05 ^b	20.20 ± 0.10 ^a
Pavon	91.51 ± 0.82 ^b	29.50 ± 0.50 ^c	10.80 ± 0.40 ^{cd}	18.70 ± 0.10 ^b
Kingbird	89.57 ± 0.43 ^c	26.40 ± 0.60 ^d	9.60 ± 0.10 ^e	16.80 ± 0.50 ^d

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test ($p < 0.05$). Where; GI- Gluten Index, WGC- Wet Gluten Content, DGC- Dry Gluten Content, GWBC-Gluten Water Binding Capacity.

4.7. Techno-functional properties of wheat flour

Techno-functional properties are the intrinsic physicochemical properties that reflect the complex interaction between the composition, structure, confirmation, and physicochemical properties of protein and other food components and the nature of the environment in which these are associated and measured (Kinsella, 1976). In food processing applications, techno-functional properties determine how flours behave during preparation and cooking, and how it affects the finished food product in terms of appearance, tastes, and mouth feels (Dasa and Binh, (2019). While Functional

foods are defined as any component or substance of food that displays health benefits, including the prevention and treatment of diseases. The techno-functional properties of the six newly released Ethiopian wheat varieties are presented and discussed in Table 6.

4.7.1. Water Absorption Capacity (WAC)

Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield and consistency and give shape to the food (Osundahunsi,2003). In this study, the WAC between bread wheat varieties (Wane, Lemu, Ogolcho, Payon) (Daka, Kingbird),(Hidasse, Kingbird) was significantly different ($p<0.05$) (Table 6). Variation in WAC of wheat flours may be due to differences in concentration of protein, their degree of interaction with water, and possibly their conformational characteristics. Overall, higher WAC results in swelling along with the concentration of protein and starch (Abebe *et al.*,2015).

Accordingly, the highest WAC was obtained for varieties protein content high (Daka, Wane, Pavon) while, least WAC was found in low protein content(Hidasse, Ogolcho, Kingbird) in (Table6). High WAC might lead to the production of moister and soft textured bread as well as an increase in loaf weight, as observed in this study (Table 6). Therefore, the determination of WAC is important because it affects bread-baking quality. High water absorption is desirable in bread baking because the rate of staling will slow down due to the added moisture. In the present study, the low WAC in the varieties (Hidasse and Kingbird) was observed. This might be due to the loose association of amylose and amylopectin in the native granules of starch and low protein content. Also, weaker associative forces maintaining the structure of the granules might lead to low WAC (Lorenz and Collins, 1990). Thus, among all the bread wheat varieties, (Wane, Daka, and Pavon) had high WAC, which makes them good for bread making. These varieties had good water absorption values; this suggests that their flour would be useful functional ingredients in bakery products.

4.7.2. Oil Absorption Capacity (OAC)

Oil Absorption Capacity can predict the palatability of a flour-based product since oil increases mouthful and retains flavor (Aremu *et al.*, 2007). The hydrophobic property of fats reduces the ability of the flour to absorb water. In this study, the OAC of the bread wheat flour varieties ranged between (1.00 - 1.34) g/g. The Wane variety has OAC of 1.34g/g, which was significantly different from the other varieties ($p<0.05$) (Table 6). But there was no significant difference in OAC between the

remaining varieties. The mechanism of oil absorption is attributed mainly to the physical entrapment of oil and the binding of oil to a non-polar chain of protein (Wang and Kinsella, 1976). The higher oil absorption capacity suggests the lipophilic nature of flour constituents (Ubbor and Akobundu, 2009). The increase in oil absorption may also be attributed to the presence of more hydrophobic proteins that shows superior binding of lipids (Wang and Kinsella, 1976).

4.7.3. Water Solubility Index(WSI)

Swelling power and solubility properties of wheat flour can influence the characteristics of bakery products. Flour with lower swelling power, apparently will produce less swell in the bakery product (Dhingra and Jood ,2001). In the present study, WSI of the wheat varieties ranged from Hidasse (3.59g/g) to Pavon (6.75 g/g). There was a significant difference in WSI between the varieties Payon, (Lemu, Ogolcho, Daka), (Wane, Kingbird), (Hidasse, Kingbird) ($p < 0.05$) (Table 6). Compare with the previous standard values WSI (5 to 7) g/g in different literature (Abebe .*et al*, 2013) which is similar with the current study except Hidasse (4 g/g) variety

4.7.4. Swelling Power (SP)

In the present study, the SP of the bread wheat varieties ranged from 4.25 g/g to 5.98 g/g. There was significant difference in SP among the varieties (Payon, Daka), (Lemu, Ogolcho, Daka), (Wane, Lemu, Ogolcho), (Wane, Lemu, Kingbird) ($p < 0.05$) (Table 6). Standard SP values for wheat flour is (4.00-5.30) g/g (AACC, 2000), which is comparable with the results of the present study. Swelling power of wheat flour granules is an indication of the extent of associative forces within the granule(Ruales *et al.*, 1993). According to Shimelis *et al.* 2006), amylose and lipids form insoluble complexes that decrease swelling power. Similarly, proteins lower the swelling power by forming a stiff matrix when they are being embedded in the starch granules, thus limiting the access of water (Apranita *et al.*, 2014). Hence commonly swelling power is inversely proportional to protein, fat, and amylose contents (Sasaki and Matsuki 1998; Phattanakulkaewmorie *et al.*, 2011). In generally, compare with standard values reported by(Lakshami.*et al*, (2015) of SP of wheat flour indicated that greater than (4g/g) which is similar with the present findings.

Table 6: Techno-functional properties flour of recently released Ethiopian bread wheat varieties

Varieties	Functional properties						
	WAC(g/g)	OAC(g/g)	SP(g/g)	WSI(g/g)	WHC(g/g)	DSP (%)	WAI(g/g)
Wane	1.72 ± 0.04 ^a	1.34 ± 0.21 ^a	4.46 ± 0.14 ^{cd}	4.43 ± 0.24 ^c	1.76 ± 0.14 ^c	78.75 ± 0.25 ^{bc}	4.26 ± 0.12 ^{cd}
Lemu	1.71 ± 0.06 ^a	1.03 ± 0.05 ^b	4.79 ± 0.22 ^{bcd}	5.06 ± 0.37 ^b	1.95 ± 0.04 ^{bc}	76.50 ± 0.50 ^e	4.54 ± 0.19 ^{bc}
Ogolcho	1.71 ± 0.03 ^a	1.01 ± 0.10 ^b	5.02 ± 0.64 ^{bc}	5.12 ± 0.34 ^b	2.17 ± 0.04 ^b	77.25 ± 0.25 ^d	4.77 ± 0.59 ^{bc}
Hidasse	1.55 ± 0.02 ^c	1.00 ± 0.04 ^b	4.25 ± 0.22 ^d	3.59 ± 0.19 ^d	2.74 ± 0.13 ^a	78.25 ± 0.75 ^c	4.32 ± 0.26 ^{bc}
Daka	1.73 ± 0.04 ^a	1.06 ± 0.04 ^b	5.35 ± 0.09 ^{ab}	5.19 ± 0.36 ^b	2.22 ± 0.13 ^b	79.50 ± 0.01 ^a	5.07 ± 0.09 ^b
Pavon	1.71 ± 0.06 ^a	1.17 ± 0.02 ^b	5.98 ± 0.50 ^a	6.75 ± 0.35 ^a	2.14 ± 0.18 ^b	74.17 ± 0.29 ^f	5.67 ± 0.41 ^a
Kingbird	1.58 ± 0.03 ^{bc}	1.11 ± 0.05 ^b	4.13 ± 0.34 ^d	3.99 ± 0.21 ^{cd}	2.09 ± 0.43 ^{bc}	79.00 ± 0.01 ^{ab}	3.78 ± 0.05 ^d

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test (p < 0.05). Where; WAC-Water Absorption Capacity; OAC-Oil Absorption Capacity; SP -Swelling Power; WSI -Water Solubility Index; WHC-Water Holding Capacity; DSP-Dispersibility, WAI-Water Absorption Index.

4.7.5. Water Absorption Index (WAI)

The results of the water absorption index of this study ranged between 3.78 (g/g) for Kingbird and 5.67(g/g) for Pavon varieties and Kingbird had lowest WAI whereas Pavon had the highest WAI. There was significant difference in WAI among the bread wheat varieties Payon, (Lemu, Ogolcho, Hidasse, Daka), (Wane, Lemu, Ogolcho, Hidasse), (Wane, Kingbird) (p<0.05) (Table 6). The water absorption index (WAI) measures the volume occupied by the gelatinized starch, and denatured protein and other components after swelling in excess water maintaining the integrity of starch in aqueous dispersion (Hoseney, 1986). Compared with other cereals, wheat flours, the mean values of the WAI of the flours from seven bread wheat varieties were apparently higher. Water Absorption Index (WAI) measures the amount of water absorbed by starch and can be used as an index of gelatinization (Anderson *et al.*, 1969). WAI depends on the availability of hydrophilic groups that bind water molecules.

4.7.6. Water Holding Capacity (WHC)

In the present study, the water holding capacity WHC of the bread wheat varieties varied ranged between from (1.76 - 2.74) g/g, the lowest and highest values obtained in (Wane) and to 2.74 g/g (Hidasse varieties, respectively). There was significant difference in the WHC among the varieties Hidasse, (Lemu, Ogolcho, Daka, Payon, Kingbird), (Lemu, Kingbird) (p<0.05) (Table 6). Water

holding capacity describes the quantity of water bounded in fiber without the application of external force. The WHC was lowest in standard refined wheat flour, i.e. 1.01g/g.

Thus, according to the results obtained, it can be stated that the increase in water holding capacity for experimental variations were directly proportional to the content of high starch wheat kernel flour. The ability of flour to bind and hold more water was reported to have a significant correlation with its starch content (Mbofung *et al.*,2006). According to (Hodge and Osman (1976), flours with high WHC contain more hydrophilic constituents, such as polysaccharides. Water holding capacity describes the quantity of water that can be bound in fiber without the application of external force. The difference in WHC this study, might be due to genotypes variation in case of hardness index as well as high starch content of wheat flour.

4.7.7. Dispersibility

In this study, the dispersibility of the bread wheat varieties ranged between (74.17-79.50) % The dispersibility of Kingbird variety was the highest followed by Lemu. There was significant difference in dispersibility among the varieties (Daka, Kingbird), (Wane, Kingbird), Hidasse, Ogolcho, Lemu, Payon ($p < 0.05$) (Table 6). Dispersibility determines the tendency of flour to move apart from the water molecules and reveals its hydrophobic action. Adebowale *et al.* (2008) reported that flours of higher dispersibility easily reconstitute to give fine consistent dough during mixing. In the present study, varieties Kingbird and Daka had highest dispersibility values among the rest of the varieties. In fact, the dispersibility values of all the varieties in the present study are relatively high. Hence, the flour from the wheat varieties can easily reconstitute to give fine consistency dough during mixing (Adebowale *et al.*, 2008a). Generally, functional properties are the intrinsic physicochemical properties which may affect the behavior of food systems during processing and storage. Adequate knowledge of these properties indicate the usefulness and acceptability of a product. Bulk density, Water holding capacity, Water absorption capacity, Oil holding capacity, and swelling index.

4.8. Bread physical characteristics

The physical properties of the bread samples are presented in Table 7. The loaf volume, loaf weight, and specific volume of the bread samples were analyzed and are significantly different from 299.67 to 180 ml and 86g to 82.33 g, 2.12 to 3.64 ml/g respectively. This could be attributed to the variation in

gluten content as a result of the bread wheat varieties. Other researchers have also reported that wheat varieties of wheat flour with low gluten content flour results in lower bread volumes. It could, therefore, be postulated that the increase in the quantity of yeast used and/or longer proofing time could improve the physical characteristics. The bread loaf volume is one of the important physical characteristics of consumers' preferences. The loaf volume of the bread in the current study ranged from 180.00 ml to 299.33ml. The bread baked from (Wane, Daka) and Hidasse had the highest and lowest loaf volume, respectively. There was a significant difference in loaf volume among the bread baked from the varieties (Wane, Daka), (Payon, (Ogolcho, (Lemu, Kingbird), Hidasse ($p < 0.05$) (Table 7). In this study, protein content was positively correlated ($r = 0.80$) to bread loaf volume. This might be attributed to the variation in the gluten network among the varieties which in turn reduced gas retention. In this study, bread wheat varieties (Wane, Daka, Pavon) had the highest bread loaf volume and accepted by consumers while (Hidasse, Kingbird) had the lowest bread loaf volume.

Loaf weight was determined by the quantity of dough baked and the amount of moisture and carbon dioxide diffused out of the loaf during baking. The loaf weight of the bread samples ranged from Wane (82.33g) to Kingbird (86.00g). There was significant difference in the loaf weight among the varieties (Kingbird, Daka, Hidasse), (Hidasse, Daka, Lemu), (Wane, Ogolcho, Payon) ($p < 0.05$) (Table 7).

The specific volume of bread, which is the ratio of the two properties, namely, loaf volume to loaf weight, has been generally adopted in the literature as a more reliable measure of loaf size (Shittu *et al.*, 2007). The specific loaf volume of the bread samples ranged from 2.12 to 3.64 ml/g. There was significant difference in the specific volume values among the bread baked from wheat varieties (Wane, Daka, Pavon), Ogolcho, Kingbird, Lemu, Hidasse ($p < 0.05$) (Table 7). The results revealed that as the level of protein in the flour increased, the specific loaf volume increased. This effect is might be due to the decreasing of visco-elasticity and connected with the weak properties of the gluten network in dough and reduced gas retention of dough. This observation might be due to variation in gluten content in the higher bread samples which consequently prevented an increase in bread loaf volume (Berton *et al.* (2002).

The loss of moisture content on baking is called baking loss. This could be due to the compactness of crumb and increased damaged starch content of the wheat flour leading to greater water holding capacity. Therefore, that water can removed during baking process of bread at greater than 180°C baking temperature of bread. Previous study by Berton *et al.* (2002) reported that flour hydration

depended on starch damage during the milling process. The increased amount of damaged starch could result in a higher water holding capacity. The baking loss of the bread in this study was between (14-17) %. There was a significant difference in baking loss among the bread baked from the varieties (Wane, Ogolcho, Payon), (Lemu, Hidasse, Daka), (Hidasse, Daka, Kingbird) ($p < 0.05$) (Table 7).

Table 7: Physical quality characteristics of bread baked from six recently released Ethiopia wheat varieties

Varieties	Parameters			
	Loaf weight(g)	Loaf volume(ml)	Specific volume(ml/g)	Baking loss (%)
Wane	82.33 ± 0.58 ^c	299.67 ± 0.58 ^a	3.64 ± 0.02 ^a	17.67 ± 0.57 ^a
Lemu	84.67 ± 0.58 ^b	250.33 ± 0.58 ^d	2.96 ± 0.0 ^e	15.33 ± 0.57 ^b
Ogolcho	83.00 ± 1.00 ^c	260.00 ± 1.00 ^c	3.13 ± 0.01 ^d	17.00 ± 1.00 ^a
Hidasse	85.00 ± 1.00 ^{ab}	180.33 ± 1.53 ^e	2.12 ± 0.02 ^f	15.00 ± 1.00 ^{bc}
Daka	85.33 ± 1.10 ^{ab}	299.67 ± 0.58 ^a	3.51 ± 0.28 ^b	14.67 ± 1.10 ^{bc}
Pavon	83.00 ± 1.00 ^c	280.33 ± 0.58 ^b	3.38 ± 0.02 ^c	17.00 ± 1.00 ^a
Kingbird	86.00 ± 0.33 ^a	250.33 ± 0.58 ^d	2.90 ± 0.02 ^e	13.76 ± 0.57 ^c

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test ($p < 0.05$).

4.9. Bread nutritional composition

4.9.1. Nutritional composition of baked bread from recently released Ethiopian bread wheat varieties

The results of the proximate composition of the bread samples are presented in Table 8. A straight dough baking process was applied to make bread in this study as demonstrated in (figure 6). The ingredient proportion was wheat flour basis: water, dry yeast, sugar, and salt. The dough was made by followed weighing, mixing, fermenting, proofing molding, and baking steps which were briefly explained in materials and methods (3.8).

There was a significant difference in protein content in the bread baked from (Wane, Daka, Pavon), Kingbird, (Lemu, Ogolcho, Hidasse) ($p < 0.05$). For ash content between the baked bread from (Pavon) (Wane, Lemu, Ogolcho, Daka), Kingbird, Hidasse ($p < 0.05$). Crude fat and crude fiber contents were significantly different among the bread types baked from wheat varieties (Wane, Daka), Hidasse,

(Pavon, Kingbird), (Ogolcho, Pavon),(Wane, Ogolcho),(Lemu, Daka),(Pavon, Kingbird), Hidasse)($p < 0.05$), respectively. Energy values varied significantly in the bread types baked from varieties (Ogolcho, Hidasse), (Lemu, Ogolcho, Kingbird), Wane, Daka, Pavon($p < 0.05$).

The composition of wheat flour is largely determined by the varieties of wheat, which are included in the grist and by the proportion of the grain that becomes flour. Meanwhile, the composition of bread is determined by the flour and by the amounts of other ingredients added during the baking process.

Bread-making involves the addition of water and a small loss of carbohydrate as a result of fermentation by added yeast. Differences between the composition of flours and the corresponding bread are chiefly due to the larger moisture content of bread (Report of the Panel on Bread, 1981).

Table 8: Nutritional composition of bread baked from six recently released Ethiopian bread wheat varieties

Varieties	Composition(g/100g bread)						
	Moisture	Crude Protein	Ash	Crude Fiber	Crude fat	Available carbohydrate	Available energy (Kcal/100g)
Wane	29.49 ± 0.45 ^c	12.39 ± 0.14 ^a	0.83 ± 0.01 ^b	0.52 ± 0.01 ^{ab}	1.55 ± 0.06 ^a	55.22 ± 0.53 ^c	284.42 ± 1.53 ^d
Lemu	28.32 ± 0.48 ^d	10.09 ± 0.18 ^c	0.84 ± 0.01 ^b	0.22 ± 0.01 ^d	1.33 ± 0.07 ^b	59.20 ± 0.61 ^c	289.00 ± 2.08 ^c
Ogolcho	26.83 ± 0.06 ^e	10.24 ± 0.28 ^c	0.88 ± 0.03 ^b	0.31 ± 0.01 ^d	1.56 ± 0.07 ^a	60.19 ± 0.34 ^b	295.75 ± 0.60 ^{ab}
Hidasse	25.75 ± 0.18 ^f	9.56 ± 0.50 ^c	0.62 ± 0.005 ^d	0.43 ± 0.01 ^b	1.03 ± 0.03 ^d	62.61 ± 0.55 ^a	297.95 ± 0.9 ^a
Daka	30.18 ± 0.23 ^b	12.25 ± 0.28 ^a	0.83 ± 0.02 ^b	0.57 ± 0.04 ^a	1.38 ± 0.04 ^b	54.79 ± 0.19 ^d	280.62 ± 0.96 ^e
Pavon	31.04 ± 0.44 ^a	11.95 ± 0.27 ^a	0.95 ± 0.04 ^a	0.34 ± 0.08 ^{cd}	1.23 ± 0.02 ^c	54.49 ± 0.64 ^d	276.84 ± 1.36 ^f
Kingbird	26.60 ± 0.17 ^e	10.17 ± 0.16 ^b	0.78 ± 0.01 ^c	0.35 ± 0.02 ^c	1.22 ± 0.01 ^c	60.88 ± 0.08 ^b	295.12 ± 0.64 ^b

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test ($p < 0.05$).

4.9.2. The mineral content of bread baked from six recently released Ethiopian bread wheat varieties

The mineral concentration of the bread baked from the newly released bread wheat varieties is reported in Table 9. Accordingly, the iron concentration was significantly different among all the bread types baked from the varieties Hidasse, Daka, Kingbird, Ogolcho, Lemu, Pavon, Wane, the amount being in the given order from highest to lowest content. Similarly, the bread baked from the

wheat varieties Kingbird, (Lemu, Pavon), (Wane, Lemu), Daka, Hidasse had significantly different zinc concentrations ($p < 0.05$). Bread baked from these wheat varieties (Daka, Hidasse, (Ogolcho, Kingbird), Pavon, Lemu, Wane had a significant phosphorus content difference ($p < 0.05$) (Table 9).

Table 9: Mineral content of bread baked from six recently released Ethiopian wheat varieties

Varieties	Parameters (mg/100g bread)		
	Iron)	Zinc	Phosphorous
Wane	0.31 ± 0.01^g	0.41 ± 0.01^c	116 ± 0.66^f
Lemu	0.61 ± 0.01^e	0.44 ± 0.04^{bc}	149.33 ± 0.32^e
Ogolcho	0.75 ± 0.01^d	0.45 ± 0.01^b	185.10 ± 0.15^c
Hidasse	1.83 ± 0.02^a	0.17 ± 0.01^e	233.3 ± 0.19^b
Daka	1.25 ± 0.02^b	0.27 ± 0.01^d	302.75 ± 0.24^a
Pavon	0.53 ± 0.01^f	0.45 ± 0.01^b	174.16 ± 0.33^d
Kingbird	0.85 ± 0.03^c	0.66 ± 0.02^a	185.5 ± 0.22^c

All values are expressed means \pm SE (n=3). Values followed by different letters within a column indicate a significantly different based on Duncan's multiple range test ($p < 0.05$).

4.10. Anti-nutritional factors

In the present study, tannin and phytate concentrations of wheat flour were below the detection limit (BDL). This might be due to the complete tannin and phytate reduction during the milling process. Also, the below detection limit of the anti-nutritional factors might be linked with the formation of insoluble complexes due to thermal degradation and denaturation during the bread baking process (Kataria *et al.*, 1998).

The bioavailability of minerals in wheat bran is under debate because of the presence of the anti-nutrient phytic acid. Phytic acid is a naturally occurring organic compound present in cereals, usually as myoinositol hexaphosphate. It is concentrated in the external covers in the pericarp and aleurone layer of the grain at lower levels, in the germ as well (Cheryan, 1980); 90% of the phytic acid in the grain is in the aleurone layer with 10% in the embryo (Dost and Tokul 2005). Consequently, the amount of phytic acid is greatly determined by the fractions removed during milling: white flour has almost no phytate (Anon, 1979). Phytate can bind minerals such as iron, calcium, and zinc, and there is some evidence showing decreased absorption of these minerals in the presence of

phytate(Harris,1955). The results of the present study were similar to previous studies since refined wheat flour was used in this study.

4.11. Sensory evaluation of bread baked from six recently released wheat varieties

The sensory evaluation of the quality characteristics of bread is an important step in product development. Rating acceptance of sensory test was carried out by 20 semi-trained panelists. Nine-point Hedonic scale (1= extremely dislike and 9 = extremely like) was used for the sensory study.

There was a significant difference in the rating of the appearance among the bread types baked from the wheat varieties (Wane, Ogolcho, Daka, Payon, Kingbird), Lemu, Hidasse (least score) ($p < 0.05$). The appearance of a baked product is a function of the properties of flour. The bread baked from varieties, Hidasse and (Wane, Daka) had the lowest and highest color scores, respectively. All the varieties gave a bread with comparable aroma score except Hidasse, in which the bread from it scored the least. The bread baked from wheat varieties Hidasse and Daka scored the lowest and highest values respectively, for both taste and texture sensory attributes (Table 10). The texture of the bread may be linked with starch damages during milling and the degree of fineness of the flour.

In general, the differences in color, taste, and flavor of all the bread might be attributed to the differences in hardness/softness of wheat grains and other factors like wheat varieties and milling characteristics of wheat (Farooq *et al.*, 2001). The bread obtained from the new cultivars were acceptable to the panelists with some attribute differences except Hidasse. Bread baked from Hidasse variety had the lowest (4.65) overall acceptability.

This might be due to the physical, physicochemical, hardness index, proximate composition, and gluten quality of the genotype. For instance, the presence of fiber in flour could puncture expanding gas cells during fermentation, thus giving a reduced loaf volume. As stated by Brown (2000), the gluten contained in wheat serves to solidify the dough giving characteristic dome-shaped top. The results of the present study indicated that recently released bread wheat varieties (Wane, Daka, Ogolcho, Lemu, Kingbird) were acceptable for leavened products like bread. However, the bread baked using the Hidasse variety bread wheat was not accepted by consumers.

Table 10: Sensory evaluation of bread baked from six recently released wheat varieties

Varieties	Tested sensory attributes					
	Appearance	Color	Aroma	Taste	Texture	Overall acceptability
Wane	8.15 ± 0.67 ^a	8.30 ± 0.06 ^a	7.85 ± 0.67 ^a	7.95 ± 0.15 ^{ab}	7.90 ± 0.12 ^{ab}	8.25 ± 0.44 ^{ab}
Lemu	6.55 ± 0.37 ^b	6.80 ± 0.51 ^{ab}	6.50 ± 0.33 ^b	6.55 ± 0.25 ^c	6.15 ± 0.28 ^b	6.50 ± 0.21 ^d
Ogolcho	7.80 ± 0.89 ^a	7.65 ± 0.99 ^{ab}	7.30 ± 0.23 ^a	7.75 ± 0.19 ^b	7.30 ± 0.25 ^c	7.55 ± 0.16 ^c
Hidase	4.65 ± 0.90 ^c	4.15 ± 0.45 ^c	4.70 ± 0.32 ^c	5.10 ± 0.28 ^c	5.00 ± 0.28 ^e	4.65 ± 0.27 ^e
Daka	8.05 ± 0.82 ^a	8.30 ± 0.57 ^a	7.7 ± 0.24 ^a	8.1 ± 0.21 ^a	8.15 ± 0.13 ^a	8.40 ± 0.11 ^a
Pavon	7.90 ± 0.91 ^a	7.20 ± 0.77 ^{ab}	7.25 ± 0.17 ^a	7.80 ± 0.23 ^{ab}	7.90 ± 0.16 ^{abc}	7.95 ± 0.16 ^{abc}
Kingbird	8.10 ± 0.65 ^a	7.90 ± 0.72 ^{ab}	7.4 ± 0.22 ^a	7.65 ± 0.24 ^{ab}	7.60 ± 0.23 ^{bc}	7.75 ± 0.19 ^{bc}

Values are expressed as mean ± SE (n=3). Means in the same column with different letters are significantly different based on Duncan's multiple range test (p < 0.05).

Chapter Five

5. Conclusions and Recommendations

5.1. CONCLUSIONS

This study was conducted due to the presence of limited information on the physicochemical characteristics and technological properties of the Ethiopian improved bread wheat varieties (released and promising) by the national bread wheat improvement program of the Ethiopian Institute of Agricultural Research. Six varieties (Wane and Daka- promising; Hidasse, Ogolcho, Kingbird, and Lemu-recently released and one variety (Pavon-released earlier and check) were included in the study. The presence of inherent unique variation on bread-making potential among the varieties was also assessed.

The results obtained indicated the presence of significant variations in the grain physical properties, nutritional composition, flour techno-functional properties of the bread wheat varieties evaluated which in turn dictated their respective bread-making quality.

Accordingly, the varieties, Wane, Daka, and Pavon had better performance in most physicochemical properties required for bread making. Also, these varieties were superior in both protein and gluten quantity and quality which made them distinct excellence for producing leavened bread products. While, Lemu, Kingbird, and Ogolcho had medium baking quality whereas Hidasse had poor baking quality.

The weak gluten strength and the lowest hardness index of Hidasse grouped it in the soft wheat category which is suitable for products like biscuits, and cakes. Bread baked from the wheat varieties Wane, Daka, and Pavon had the highest loaf volume while Hidasse, Ogolcho, Lemu, and Kingbird had the lowest value. On the other hand, Kingbird, Daka, and Lemu had the highest loaf weight while, Ogolcho, Pavon, and Wane had the lowest bread loaf weight. Consumer judgment is the most valuable tool in food quality assessment; therefore, a sensory analysis for bread quality evaluation was performed using a panel of assessors who regularly consume the product.

The sensory analysis done also clearly demonstrated the effect of the kernel physical characteristics, flour chemical traits, and flour functional properties on bread quality. Color, appearance, and texture were the major factor in bread quality evaluation. In this study, variety Wane and Daka was the most appreciated among all varieties for bread baking quality, while Hidasse was the least appreciated by the assessors which may suggest their suitability for biscuit preparation rather than bread making.

5.2. RECOMMENDATIONS

- ✚ Single kernel characterization system is a very important tool for breeders at the early stages of the varieties screening process.
- ✚ Considering most grain quality characters, bread wheat cultivars Wane, Daka, Pavon, can be considered as having superior bread-making quality while Ogolcho, Kingbird, and Lemu having medium bread baking quality whereas Hidasse had poor baking quality.
- ✚ Hidasse, is suitable for making soft wheat products. According to this research finding, bread wheat varieties: Daka, Wane, and Pavon should be maintained and multiplied for farmers by the Ethiopian seed multiplication sector.
- ✚ Ogolcho, Kingbird, and Lemu need some improvement in quality traits to get superior bread production and Hidasse was not suitable for leavened production, however, it can be suggested for use in making unleavened products like biscuits, cakes and use for blending with other bread wheat variety since it was observed higher flour yield extraction during the milling process.
- ✚ The nutritional composition of wheat depends on the processing method, therefore, process optimization(milling) should also be needed to get the required nutrients from wheat products.
- ✚ To get a clear cut for physicochemical and techno-functional properties and baking qualities of the potential genotypes, further researches should be conducted on these varieties at multi-locations, seasonal variation, and processing methods(milling) for better recommendations.

6. REFERENCES

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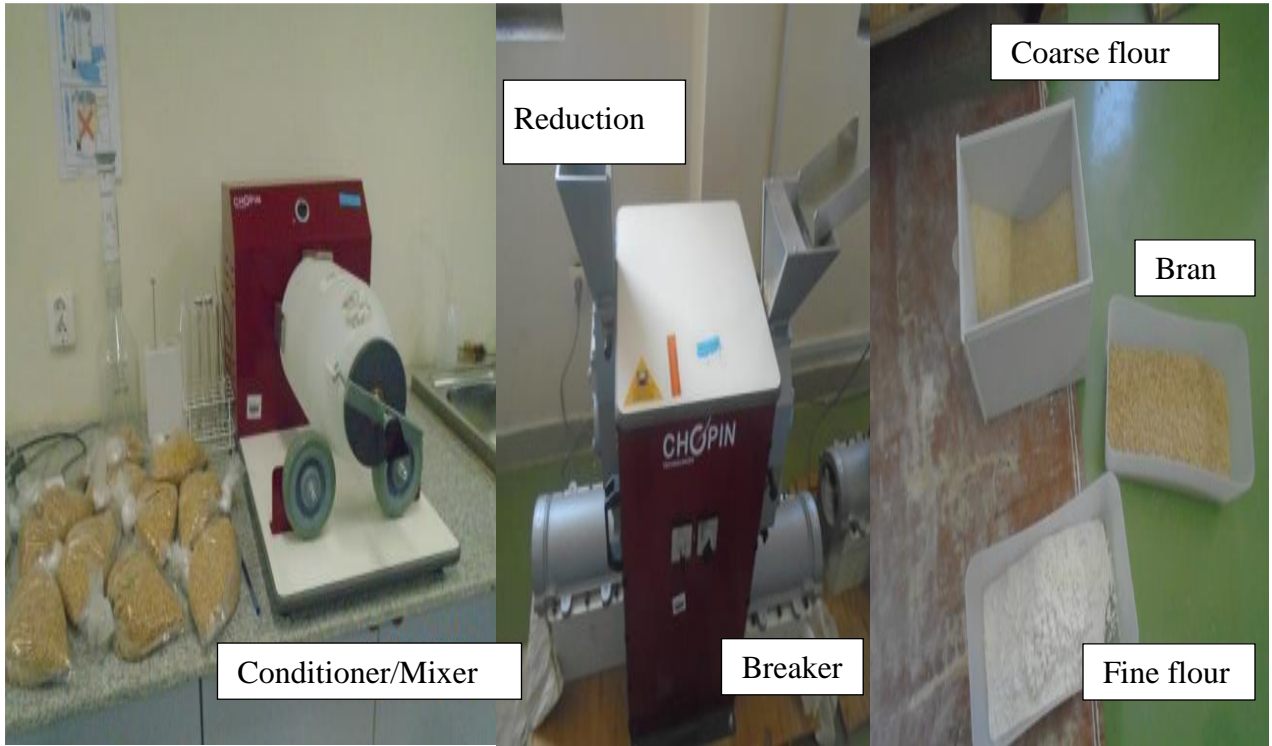
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7. APPENDIXES

Appendix 1: Bread wheat milling and flour extraction process



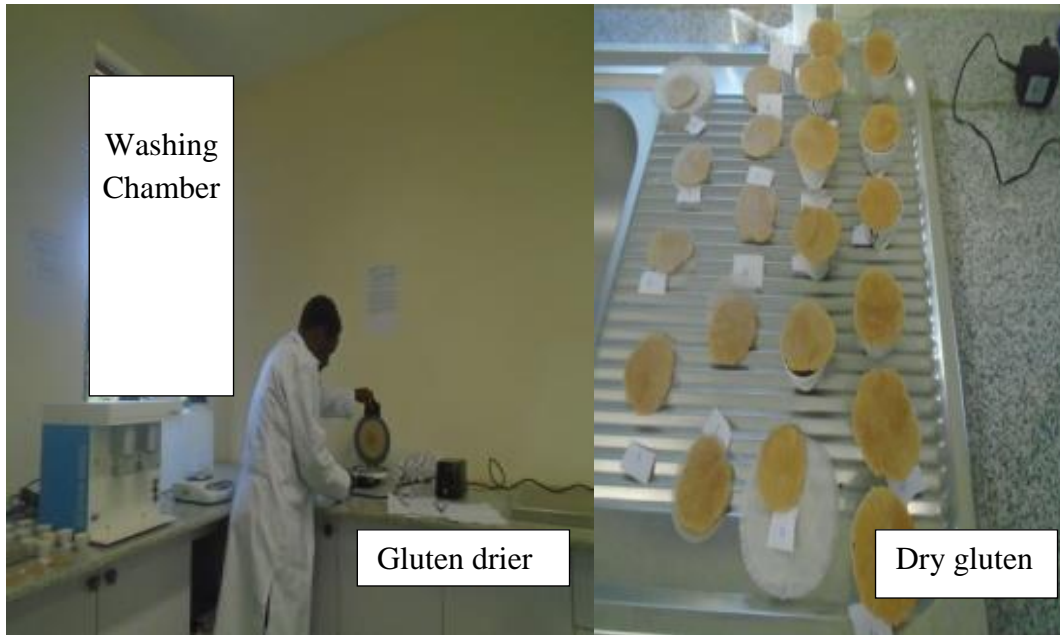
Appendix 2: Bran finishing /removal of bran process/



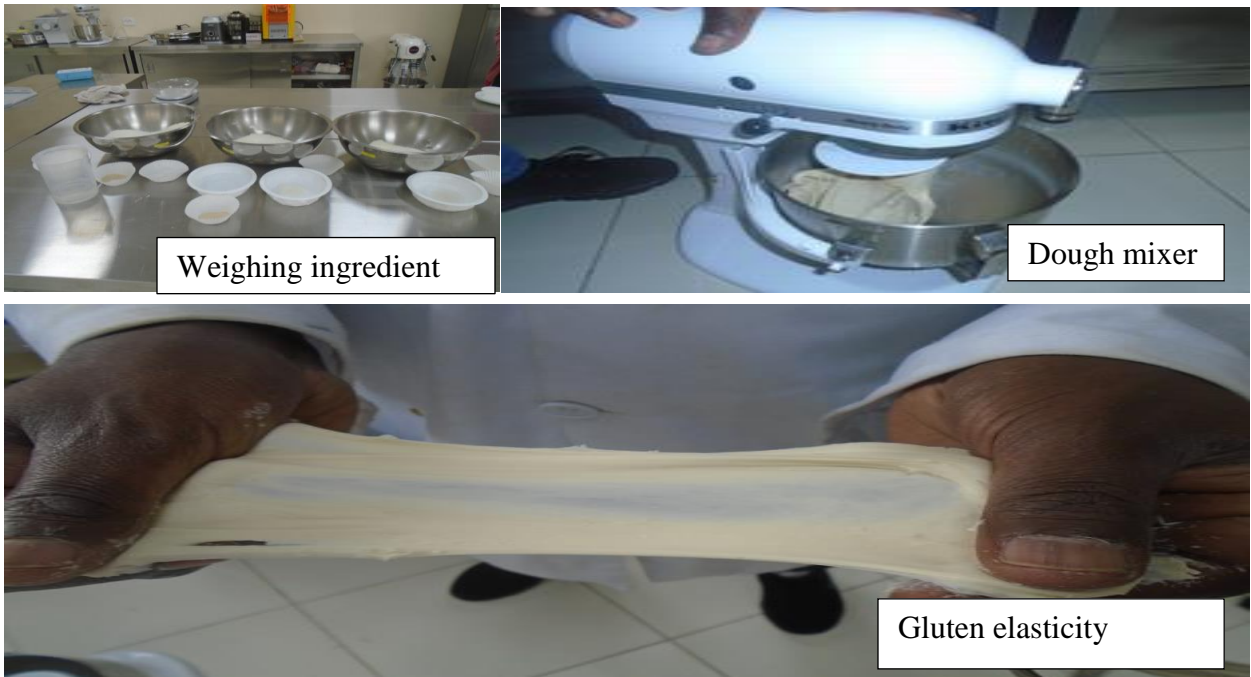
Appendix 3: Falling number and single kernel characterization



Appendix 4: Extraction of gluten and Gluten quantity and quality determination



Appendix 5: Dough preparation



Appendix 6: Dough proofing



Appendix 7: Bread baking process by standard baking oven



Appendix 8: Sensory evaluation ballot forms

Sensory Evaluation Ballot for Bread

Panelist: - _____

Date: - _____

Sensory evaluation form

Instructions: Please look at and test each sample of bread order from left to right or right to left as shown on the ballot. Indicate how much you like or dislike each sample by checking the appropriate phrase of category which is listed below and mark your choice with the number that corresponds to your preference on each parameter. Please rinse your mouth before and after testing each sample.

Appendix 8: Sensory evaluation ballot forms

Code	Appearance/ቅረቦ	Color /ቀለም/	/Aroma/ መዓዛ	/Taste/ ጣዕም	/Texture/ የአካል ቅንጣቶች ኅብር	/Overall Acceptability/ አጠቃላይ ሁኔታ

Nine-point hedonic scale: - **9**-like extremely, **8**-like very much, **7**-like moderately, **6**-like slightly, **5**-neither like nor dislike, **4**-dislike slightly, **3**-dislike moderately, **2**-dislike very much and **1**-dislike extremely

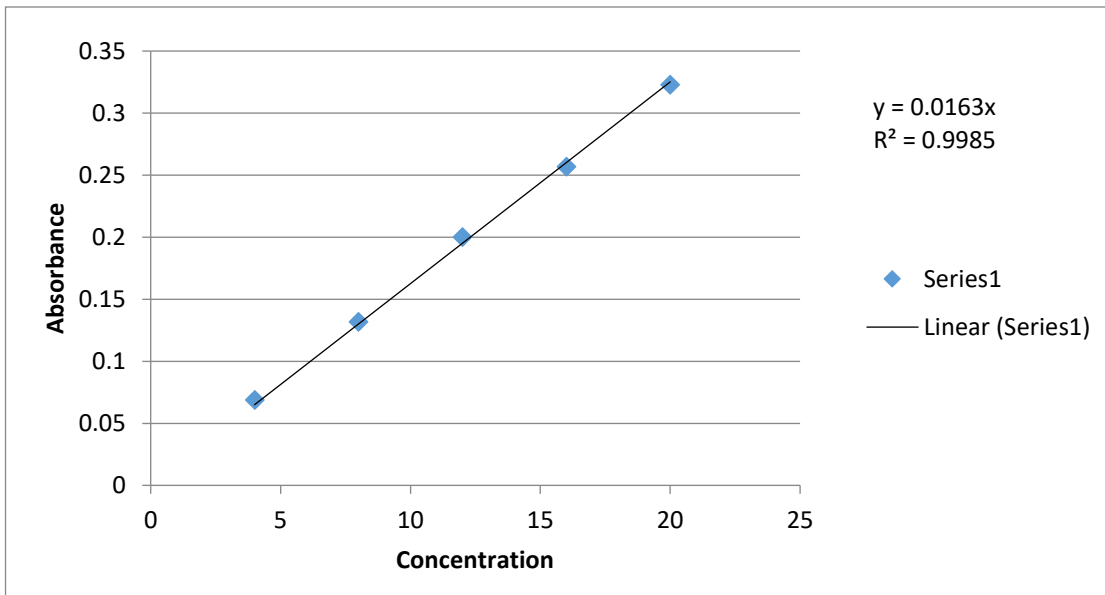
3. Comment/አስተያየት/: _____

4. Signature /ፈርማ/: _____

Thank you in advance for your valuable contribution!

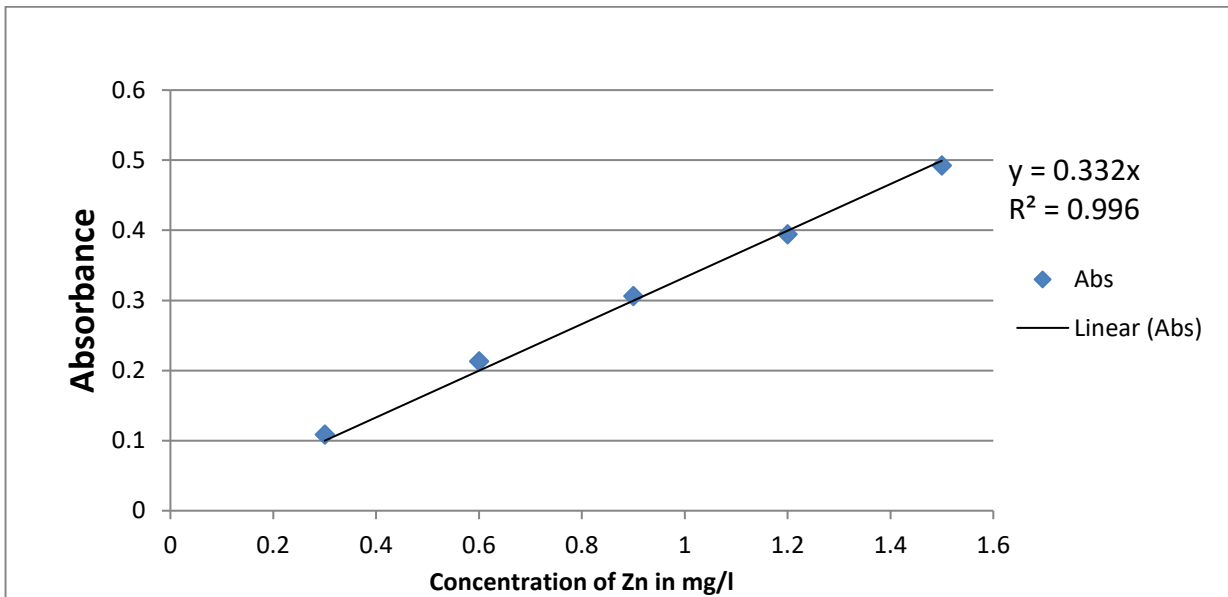
Standard calibration curve for Fe (mg/l)

Appendix 9: Calibration curve for mineral (Iron)

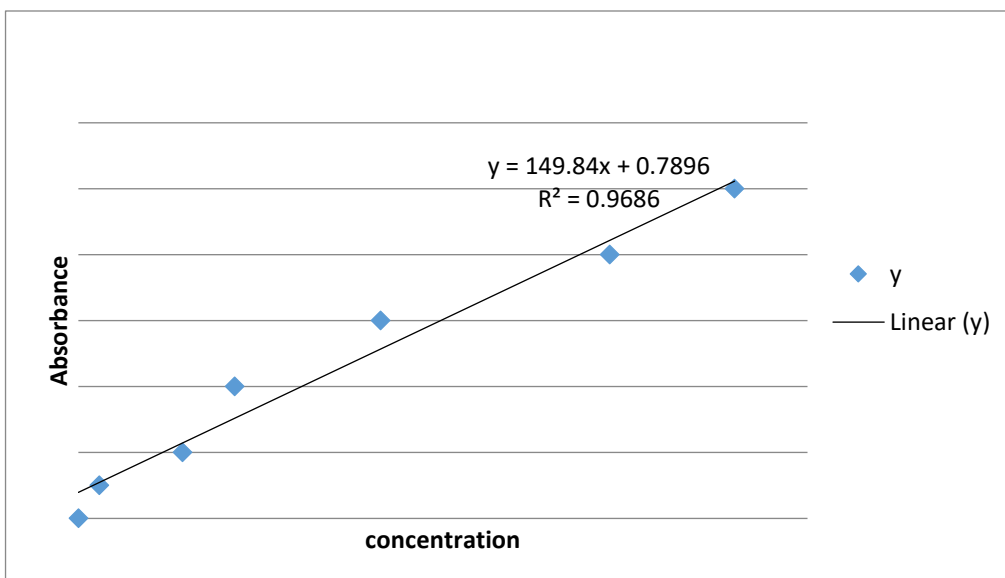


Concentration

Appendix 10: Standard calibration curve for Zinc (mg/l)

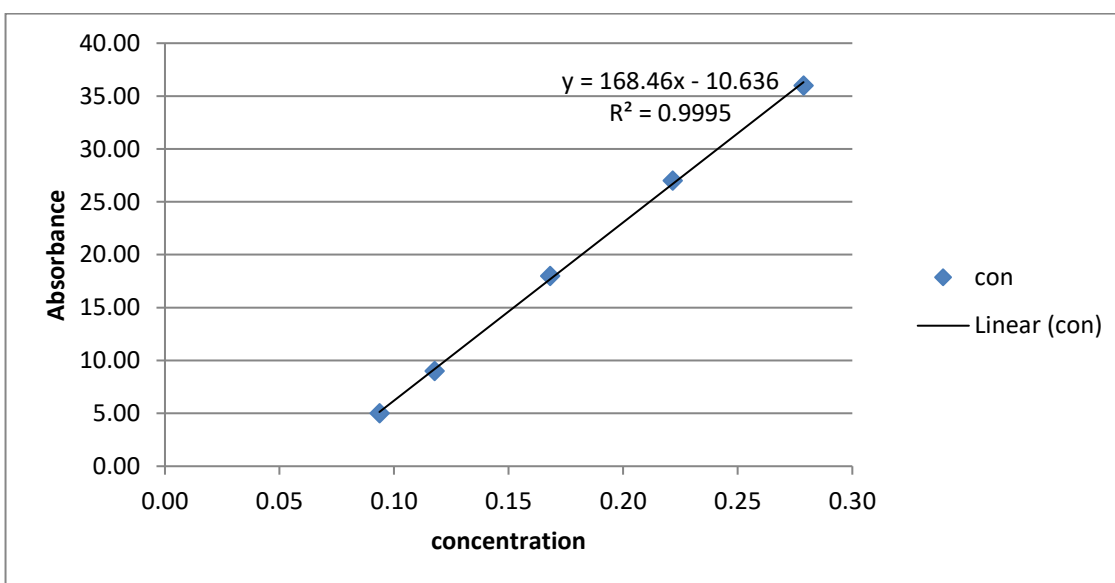


Appendix 11: Standard calibration curve of phosphorous (mg/l)

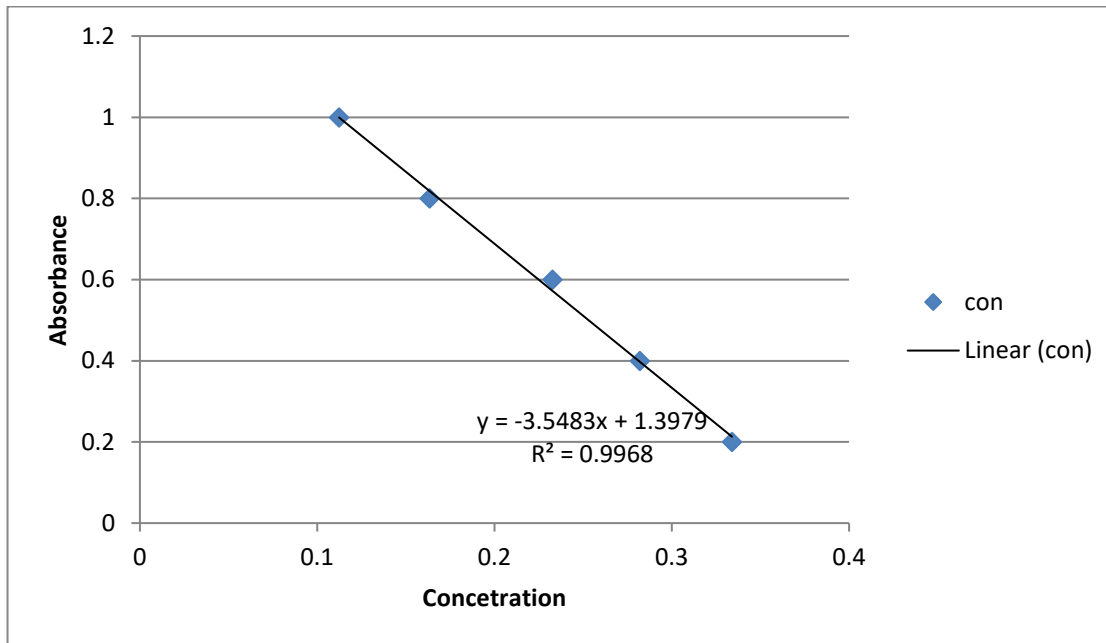


Appendix 12: Calibration curve for anti-nutritional factors (phytate and tannin)

Phytate standard calibration curve (mg/l)



Tannin standard calibration curve (mg/l)



Appendix 13: Correlation coefficient of some parameters for recently released wheat varieties

Parameters	TKW	HLW	Protein	Gluten	Bread loaf volume
TKW	1.00				
HLW	0.83*	1.00			
Protein	-0.28	-0.34	1.00		
Gluten	-0.13**	0.09**	0.75*	1.00	
Bread loaf volume	-0.54**	-0.65	0.74*	0.80*	1.00

*,** Correlation is significant at the 0.05,0.01 p value respectively.