ADDIS ABABA INSTITUTE OF TECHNOLOGY

ADDIS ABABA UNIVRESITY

SCHOOL OF CHEMICAL and BIO ENGINEERING

EFFECT OF PROCESSING ON QUALTIY CHARACTERISTICS OF PEARL MILLET *(pennisetum glaucum)* BASED VALUE ADDED PRODUCTS

A Thesis Submitted to the School of Graduate Studies of Addis Ababa Institute of Technology, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Chemical Engineering (Food Engineering Stream)

By: Eyoel Legesse

Advisor: Dr.Eng. Shimelis Admassu (Associate Professor)

Addis Ababa, Ethiopia

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Abstract

The effect of processing on characteristics of pearl millet (Pennisetum glaucum) was investigated. The proximate and mineral compositions, physicochemical and functional properties and reduction of antinutrients concentration were determined. In addition, the sensory quality of pearl millet value added products were studied. The value of moisture content of raw, roasted, fermented, blanched and autoclaved pearl millet flours were 8.82, 7.58, 11.55, 10.04 and 7.77%, crude protein 11.72, 12.02, 20.79, 11.26, and 12.25% and total ash 2.75, 3.11, 2.57, 3.08, and 2.69%; respectively. Micronutrient concentration of the seeds showed large variation. Phosphorus was the most abundant (290.04 mg/100g) mineral whereas Ca was low (2.66mg/100g). The ranges for tannins and phytate were 0.80 to 3.66mg/100g and 167 to 294mg/100g, respectively. Significant difference ($p<0.05$) were observed between treated pearl millet flours in their proximate and antinutritional composition. Roasting process was least effective in reducing phytate and tannins as compared with other processing methods due to the less antinutrient loss expected by roast in cereals. A slight significance was observed during autoclave on elimination of phytate as compared to conventional processing methods. In contrast, fermentation (72h) and blanching (110 ^oC) was found to be the relatively best method for reducing the phytate and tannins content (0.83 and 0.80mg/100g for tannin and 167.14 and 208.17mg/100g for phytate), respectively. The sensory evaluation of thin porridge and bread products was generally acceptable by panelists. The thin porridge prepared from 75% of unfermented and 25% of fermented pearl millet flour was more preferred in sensory attribute investigation, while the thin porridge prepared from 100% fermented and blanched pearl millet flour was least preferred. With respect to, the acceptability of control and 5% substituted of fermented pearl millet flour breads were highly acceptable by the panelists and prominently for 5% blanched pearl millet flour bread. Meanwhile, loaf qualities expressed in such a way loaf volume range between (451- 134ml), and specific volume range between (4.1- 1.2ml/g) were significantly decreased ($p<0.05$) at higher substitution level of pearl millet flours. Based on the preliminary techno-economic evaluation, the suggested process technology and product diversification is feasible.

Keywords: *Antinutritional factors, Least gelation concentration, Liquefaction, Pearl millet flour, Staple food, Wheat flour*

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List of Abbreviations

AOAC	Association of Official Analytical Chemistry
APMF	Autoclaved Pearl Millet Flour
BPMF	Bleached Pearl Millet Flour
CFTIR	Central Food Technology Research Institute
EHNRI	Ethiopian Health and Nutrition Research Institute
FAO STAT	Food and Agricultural Organization Statistics
FFA	Free Fatty Acid
FPMF	Fermented Pearl Millet Flour
GI	Glycemic Index
GPMF	Germinated Pearl Millet Flour
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IFAD	International Fund for Agricultural Development
IP3	Inositol TrisPhosphate
LGC	Least Gelation Concentration
OAC	Oil Absorption Capacity
RoPMF	Roasted Pearl Millet Flour
RPMF	Raw Pearl Millet Flour
RTE	Ready to Eat
WAC	Water Absorption Capacity

CHAPTER ONE

Introduction

1.1. Backgrounds

Pearl millet (*Pennisetum glaucum*) is the sixth most important cereals. Descended from a Wild West African grass, it was domesticated more than 4,000 years ago, probably in what is now the heart of the Sahara Desert. Long ago it spread from its homeland to East Africa and thence to India. Both places adopted it eagerly and it became a staple. Today, pearl millet is so important that it is planted on some 14 million hectares in Africa and 14 million hectares in Asia. Global production of its grain probably exceeds 10 million tons a year. At least 500 million people depend on pearl millet for their lives (ARSO, 2012).

Despite its importance, however, pearl millet can be considered a "lost" crop because its untapped potential is still vast. Currently, this grain is an "orphan" among the significant cereals. It is poorly supported by both science and politics. In fact, few people outside of India and parts of Africa have ever heard of it. As a result, it lags behind sorghum and far behind the other major grains in its genetic development. For instance, its average yields are barely 600 kg per hectare and it is almost entirely a subsistence crop; perhaps for this last reason alone pearl millet has attracted little research or industrial support. In Africa, India, China, Korea, Japan, the millets are cultivated abundantly for human and animal food in the arid and semiarid regions under rainfed conditions. Owing to increasing populations and the greater demand of food, it is a great necessity to incorporate the crop species for better adaptation to the stress situations such as high temperature, drought, poor fertile, salinity, and alkalinity of soils.

The height of the pearl millet plant may range from 0.5 to 4 m and the grain can be nearly white, pale yellow, brown, grey, slate blue or purple. The ovoid grains are about 3 to 4 mm long, much larger than those of other millets, and the 1 000-seed weight ranges from 2.5 to 14 g with a mean of 8 g. The size of the pearl millet kernel is about one-third that of sorghum. The relative proportion of germ to endosperm is higher than in sorghum (FAO, 1995).

In different pearl millet genotypes the starch content of the grain varied from 62.8 to 70.5 percent, soluble sugar from 1.2 to 2.6 percent and amylose from 21.9 to 28.8 percent (Jambunathan and Subramanian, 1988). Lower values for starch (56.3 to 63.7 percent) and amylose (18.3 to 24.6 percent) have been found in some high-yielding Indian pearl millet varieties (Singh and Popli, 1973). Subramanian, Jambunathan and Suryaprakash (1981) found that the predominant component of total soluble sugar (2.16 to 2.78 percent) was sucrose (66 percent), followed by raffinose (28 percent). Other sugars detected in measurable amounts were stachyose, glucose and fructose. The proportion of sucrose in total sugar was lower in pearl millet than in sorghum.

Pearl millet, like sorghum, is generally 9 to 13 percent protein, but large variations in protein content, from 6 to 21 percent, have been observed (Serna Saldivar, McDonough and Rooney, 1991). Lysine is the first limiting amino acid of pearl millet protein. A significant inverse correlation has been reported between the level of protein in the grain and the Iysine content of the protein (Deosthale et al., 1971). In high-protein varieties of pearl millet with protein content ranging from 14.4 to 27.1 percent, significant inverse correlations have also been observed between protein and threonine, methionine and tryptophan. The essential amino acid profile shows more Iysine, threonine, methionine and cystine in pearl millet protein than in proteins of sorghum and other millets. Its tryptophan content is also higher.

Wide variation is observed in the lysine content of pearl millet protein, with values ranging from 1.59 to 3.8 g per 100 g protein. From chemical scores calculated in relation to amino acid requirements for different age groups it was apparent that pearl millet has greater potential to meet the lysine requirements of growing children than most other cereals. Pushpamma, Parrish and Deyoe (1972) observed in rat feeding trials a PER of 1.84 for pearl millet as against 1.74 for finger millet, 1.46 for sorghum and 1.36 for maize. This has supported the view that the protein quality of pearl millet ranks quite high in comparison with that of other cereals. On fortification of a pearl millet diet with 0.3 percent lysine hydrochloride, the growth response of rats was enhanced and nearly equalled that of controls fed a casein diet (Howe and Gilfillan, 1970).

Protein quality is associated with the distribution pattern of protein fractions in the grain. Sawhney and Naik (1969) observed large variability in the protein fractions of pearl millet varieties. Albumin ranged from 6.1 to 26.5 percent (mean 15.1 percent), globulin from 3.5 to 14.7 percent (mean 8.7 percent), prolamin from 21.3 to 38.0 percent (mean 30.2 percent) and glutelin from 23.8 to 37.7 percent (mean 30.3 percent). As in other cereals, albumin and globulin are rich in lysine as well as the other basic amino acids arginine and histidine. The globulin fraction appeared to be very rich in sulphur amino acids. The prolamin fraction is characterized by high glutamic acid proline and leucine and was also shown to be rich in tryptophan, whereas glutelin was found to contain more lysine and less tryptophan.

Pearl millet is sown in the arid and semiarid tropical regions with annual temperature ranging from 18 to 35° C, precipitations of 200-600 mm per year under rainfed situations. The poor distribution, frequency and duration of precipitation generates severe drought which affect the grain yield and forage. Pearl millet has capacity to produce under these conditions compared to other traditional crops.

Pearl millet is grown in the west low land of Tigray and Illubabor and in the low land of Harerge; usually interplanted with sorghum. penicillium glaucum, the weedy annuals associated with it and the perennial species pennisetum purpureum from the section pennisetum of the genus, characterized by penicilate anther-tips, a partially indurate shiny upper floret and ciliate bristles. They cross readily to produce hybrids, the sterile triploid hybrid pennisetum purpureum x Penicillium glaucum being sometimes also cultivated for fodder according to Brunken (1977).

Finally, Ethiopia also producing pearl millet in a convincing amount compared with other type of cereals and the distribution of Pearl millet in Ethiopia is cover area in Million ha (0.30), Production in Million tonnes (0.31)and Yield in Kg/ha (1049), FAO STAT (24^{th} April, 2006).

1.2. Statements of the problem

According to the food and agriculture organization (FAO) pearl millet is the sixth most grown cereal in the world (FAO, 2005). Out of the 28 million production globally (1992- 1994 average), 15 million tons are pearl millet. It is considered one of the most important crops in semi-arid areas of the African and Indian because it contributes to food security in these regions (ICRISAT and FAO, 1996).

Accounting for 84% of the country's labor force, agriculture in Ethiopia is the largest contributor to economic growth and the economy's most important sector. Especially among the poverty-stricken rural population, the livelihood of most Ethiopians depends on agriculture. Although it is a country with "significant agricultural potential because of its water resources, its fertile land areas, and its large labor pool," this potential goes largely undeveloped. Ethiopian agriculture is incredibly sensitive to shifts in weather. When rainfall is erratic or insufficient for even a few successive rainy seasons, the entire country is prone to falling into famine. Based on the above information pearl millet is alleviating the problem of the food security by its nature pearl millet is adapted to low fertility soils, drought tolerant, almost it doesn't need fertilizer (fertilizers consumption is low) and good leaf stem ratio and the nutrient values also make it preferable.

Pearl millet composite flour technology initially referred to the process of mixing wheat flour with cereal and legume flours for making bread and biscuits. However, the term can also be used in regard to mixing of non-wheat flours, roots and tubers, legumes or other raw materials (Dendy, 1992). Thus pearl millet flour used in partial replacement of wheat flour can be successfully substituted for malt and sugar in the preparation of bakery products such as bread, biscuits and pasta.

Therefore, this research paper focused on finding the substitution of the processed pearl millet flour with the wheat flour and producing a value added baking product like bread and as a secondary product is thin porridge at different proportions of pearl millet flours, which had increases the nutritional value and quality.

1.3. Objectives of the study

- **General objective of the study**

The general objective of this study was aimed to evaluate the effect of processing on the quality characteristics of pearl millet based value added products of bread and thin porridge.

- **Specific objectives of the study**

  - ❖ Study proximate composition of raw and processed pearl millet flour;
  - ❖ Determine the physico-chemical and functional properties of raw and processed pearl millet flour;
  - ❖ Quantify the levels of phytic acid and tannins, in raw and processed pearl millet flour;
  - ❖ Develop value added products;
  - ❖ Techno-economic evaluation (suggested process technology for value added products).

1.4. Scope of the study

This study aim at examining effect of processing on characteristics of pearl millet (*Pennisetum glaucum)* based value added products. Particularly, the investigation focused on proximate and minerals composition, antinutritional factors, physicochemical and functional property, bioavailability of pearl millet flours and sensory quality of pearl millet based value added products.

CHAPTER TWO

Literature Rreview

2.1. Overview of production and utilization of pearl millet

Pearl millet is a widely grown rain fed cereal crop in the arid and semiarid regions of Africa and southern Asia. Pearl millet (*Pennisetum glaucum*) is the most important crop in the drier parts of semi-arid tropics and accounts for almost half of the global production of the millet species from amongst different species of millets cultivated. As general estimate, global millet production is broken down into pearl millet (50%) and other millets 50%. In other continents it is grown under intensive cultivation as a forage crop. Pearl millet is a crop of hot and dry climates, and can be grown in areas where rainfall is not sufficient (200- 600 mm) for maize and sorghum. Primarily a tropical plant, pearl millet is often referred to as the "Camel", because of its exceptional ability to tolerate drought. Even with minimal rainfall millet will typically still produce reasonable yields. In many areas where millet is the staple food, nothing else will grow. Besides providing food for human, millet stems are used for a wide range of purposes, including: the construction of hut walls, fences and thatches, and the production of brooms, mats, baskets, sunshades, etc (IFAD, 1999).

Pearl millet (Pennisetum glaucum (L) R. Br.) is one of the four most important cereals (rice, maize, sorghum and millets) grown in the tropics (The Syngenta Foundation for Sustainable Agriculture, 2002). It is believed to have descended from a West African wild grass which was domesticated more than 40,000 years ago (National Research Council, 1996). It spread from there to East Africa and then to India. Today millet is a food staple for more than 500 million people. Areas planted with pearl millet are estimated at 15 million hectares annually in Africa and 14 million hectares in Asia. Global production exceeds 10 million tons a year (National Research Council, 1996).

In addition to tolerating hot and dry climates, pearl millet is able to produce reasonable yield on marginal soils, where other crops would fail. Low fertility and high salinity are frequent problems in millet producing areas. At the same time, pearl millet responds very favorably to slight improvements in growing conditions such as irrigation and tillage (Leisinger *et al.*, 1995). For these reasons it has the potential to spread to more areas of the world, namely the semi-arid zones of Central Asia and the Middle East, North and South America, and Australia (National Research Council, 1996).

Pearl millet is grown by millions of resource-poor, subsistence level farmers (IFAD, 1999). The percentage of millet used for domestic consumption is rising steadily in Africa (World Bank, 1996). Pearl Millet is the third major crop in sub-Saharan Africa, with the major producing countries being Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania and Senegal in the west; Sudan and Uganda in the east. In Southern Africa, maize has partially or completely displaced millet because of the predominance of commercial farming.

Pearl millet, which accounts for about two-thirds of India's millet production, is grown in the drier areas of the country, mainly in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana (FAO, 1996).

In Pakistan, pearl millet is an important grain crop, especially in areas where drought is common. Millet is grown primarily south of latitude 34^{o} N. Sixty percent of the area is in Punjab; 37.8 percent in Sindh. Ninety percent of the grain produced is used as food and as seed. The little surplus is sold mainly as seed to producers who grow millet for fodder and do not have seed of their own (Pakistan Agriculture Research Council, 2006).

Outside Africa and India, millets are also grown in China, The Russian Federation, Mexico, Australia, Canada and the United States of America. In most of these other countries, pearl millet is grown primarily as a forage crop for livestock production (National Research Foundation, 1996; The Syngenta Foundation for Sustainable Agriculture, 2003).

Figure 2-1: Pearl millet production and productivity

The four most important millets cultivated in Africa are: Pearl millet- Pennisetum glaucum (L.) R.Br. (accounting for 76% of total production), finger millet – Eleusinecoracana L. Gaertn. (19%), Teff – Eragrostisteff (Zucc.) Trotter (1.8%), and Fonio – Digitariaexilis Stapf (acha) and Digitoriaiburua Stapf. (blackfonio) (0.8%).

Table 2-1: Relative production of pearl millet species cultivated in Africa

Region / country	Total millet (‘000 tonns)	Pearl millet (%)
North African	554	98
Western Africa	8986	95
Central Africa	477	87
Eastern Africa	1547	35
Southern Africa	404	65
Africa	11938	76

Source: Obilana and Manyasa, E. Millets. (2002) pp 177-217.

The ICRISAT pearl millet (*Pennisetum glaucum*) variety ICMV 221 was introduced from India and registered/released in 2007 after adaptation study with the local name Kola-1. The Amharic word 'Kola' stands for lowland. An Open Access Journal published by ICRISAT

2.2. Proximate composition of pearl millet

- **Carbohydrate**

In different pearl millet genotypes the starch content of the grain varied from 62.8 to 70.5 percent, soluble sugar from 1.2 to 2.6 percent and amylose from 21.9 to 28.8 percent (Jambunathan and Subramanian, 1988). Lower values for starch (56.3 to 63.7 percent) and amylose (18.3 to 24.6 percent) have been found in some high-yielding Indian pearl millet varieties (Singh and Popli, 1973). Subramanian, Jambunathan and Suryaprakash (1981) found that the predominant component of total soluble sugar (2.16 to 2.78 percent) was sucrose (66 percent), followed by raffinose (28 percent). Other sugars detected in measurable amounts were stachyose, glucose and fructose. The proportion of sucrose in total sugar was lower in pearl millet than in sorghum.

Pasting properties of pearl millet starch were generally similar to those of sorghum except when it was held for one hour at 95°C (Bad), Hoseney and Finney, 1976). Beleia, Varriano-Marston and Hoseney (1980) considered inherent molecular dissimilarities the primary factor in physico-chemical differences among five pearl millet starches examined. The amylose content of these starches varied within a narrow range (22 to 24 percent). Variation in the water-binding capacity (83.6 to 99.5 percent) was probably due to differences in the proportions of amorphous and crystalline starch in the granule; amorphous starch has greater water absorption capacity than crystalline starch. In the five starches, the initial gelatinization temperature ranged from 59° to 63°C, the mid-point from 65° to 67.5°C and the final gelatinization temperature from 68° to 70°C. The gelatinization of pearl millet starch occurred at a lower temperature than that of sorghum starch. In general it was observed that starches having low solubility and swelling below 75°C showed greater solubility and swelling at and above 80°C. The peak pasting temperature of the five starches was the same, 76.5°C. Differences in paste viscosity were larger in magnitude after one hour's holding at 95°C and during the cooling cycle. This showed that some starches tended to retrograde more than others.

➢ Total fiber

The total dietary fibre in pearl millet (20.4 percent) and finger millet (18.6 percent) was higher than that in sorghum (14.2 percent), wheat (17.2 percent) and rice (8.3 percent). Singh *et al.* (1987), also using the Southgate method, found that the total dietary fibre content of pearl millet was 17 percent. There are not enough data available on the dietary fibre components of the millets. Bailey, Sumrell and Burton (1979) have isolated pentosan containing a mixture of heterogeneous polysaccharides from the cell wall of pearl millet grains Kamath and Belavady (1980).

➢ Protein

Pearl millet, like sorghum, is generally 9 to 13 percent protein, but large variations in protein content, from 6 to 21 percent, have been observed (SernaSaldivar, McDonough and Rooney, 1991). Lysine is the first limiting amino acid of pearl millet protein. A significant inverse correlation has been reported between the level of protein in the grain and the Iysine content of the protein (Deosthale *et al.*, 1971). In high-protein varieties of pearl millet with protein content ranging from 14.4 to 27.1 percent, significant inverse correlations have also been observed between protein and threonine, methionine and tryptophan. The essential amino acid profile shows more Iysine, threonine, methionine and cystine in pearl millet protein than in proteins of sorghum and other millets. Its tryptophan content is also higher.

Wide variation is observed in the lysine content of pearl millet protein, with values ranging from 1.59 to 3.8 g per 100 g protein. This has supported the view that the protein quality of pearl millet ranks quite high in comparison with that of other cereals. On fortification of a pearl millet diet with 0.3 percent lysine hydrochloride, the growth response of rats was enhanced and nearly equaled that of controls fed a casein diet (Howe and Gilfillan, 1970).

➢ Lipid

The lipid content is generally high (3 to 6%) for pearl millet, higher than for sorghum and most other common cereals. For this reason the energy of millet is greater than that for sorghum and nearly equal to that of brown rice. About 75% of the fatty acids in pearl millet are unsaturated, and linoleic acid is particularly high (46.3%). After hulling or milling, the high lipid content, higher amounts of unsaturated fatty acids and high enzymatic-hydrolytic activity in millet products leads to rapid development of odors and flavors. The flour of millet becomes rancid rather

- **Mineral**

Wide variations have been reported in the mineral and trace-element composition of pearl millet and as with sorghum the composition and nature of the soil was considered the main environmental factor determining the mineral content of the grain (Hoseney, Andrews and Clark, 1987; Jambunathan and Subramanian, 1988). Milling of pearl millet to flour with an extraction rate of 75 percent reduced the calcium and iron content by about 66 percent. Dassenko (1980) observed significant losses of calcium, magnesium and sodium but not of iron and potassium on milling pearl millet to flour with 67 percent extraction rate.

Malting enhanced severalfold the ionizable iron content of pearl millet and finger millet grains and also significantly increased their soluble zinc content, indicating an improvement in in vitro availability of these two elements (Sankara Rao and Deosthale, 1983).

2.3. Antinutritional factors

Beside its nutritional qualities, the bioavailability of various minerals like Ca and P and trace elements such as Zn, Fe, Cu and Mn is low because of presence of some inherent anti-nutritional factors such as protease inhibitors, phytate, tannin and other phenolic compounds, oxalic acid and saponins) are plant constituents which play an important role in biological functions of plants. These compounds, in human, reduce the digestibility of nutrients and the absorption of minerals, which are undesirable Dicko *et al.*, (2005).

However, several processing techniques have been developed to enhance food value and shelf-life of pearl millet products and to improve the availability of starch, protein and minerals. Decreasing or degrading of phytic acid is very advantageous, due to its influence on nutrition.

2.3.1. Phytic acid

Phytate represents a complex class of naturally occurring phosphorus compounds that can significantly influence the functional and nutritional properties of foods. Although the presence of these compounds has been known for over a century, their biological role is not completely understood. Phytic acid, myo-inositol 1, 2, 3, 4, 5, 6-hexakis (dihydrogen phosphate), is the main phosphorus store in mature seeds. Phytic acid has a strong binding capacity, readily forming complexes with multivalent cations and proteins. Most of the phytate-metal complexes are insoluble at physiological pH. Hence phytate binding renders several minerals biologically unavailable to animals and humans.

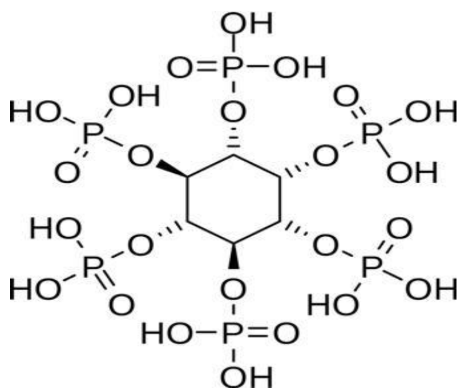


Figure 2-2: Structure of phytate

2.3.2. Tannins

Other inhibitors of the absorption of divalent minerals and proteins are phenolic compounds. Phenolics cover a range of compounds including flavonoids, phenolic acid, polyphenols and condensed tannins. Phenolics affect the biological availability or activity of metal ions by chelating the metal. Phenolic compounds can affect color, flavor and nutritional quality of the grain and products prepared from it. The two types of tannins found in plants are classified as hydrolysable and condensed tannins.

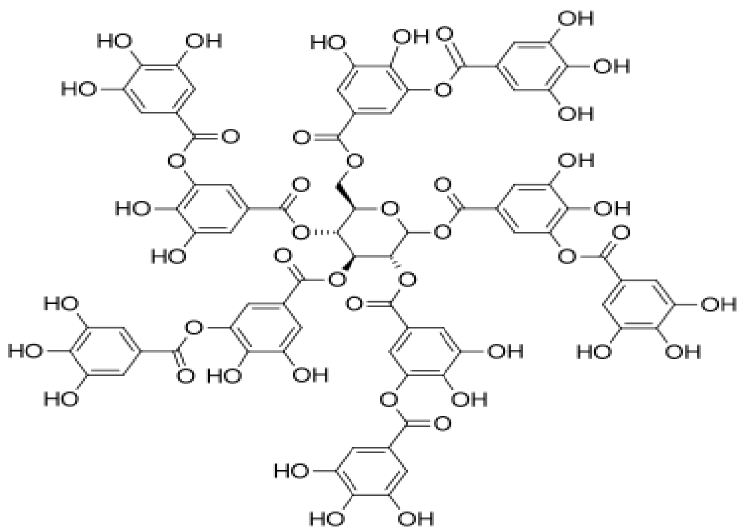


Figure 2-3: Structure of tannin

2.3.3. Oxalic acid

Oxalic acid in pearl millet reduces the bioavailability of calcium and hence has a negative impact on milk production and fat content. Pearl millet, along with other grains, contains oxalic acid, which forms an insoluble complex with calcium, thereby reducing biological availability of this mineral. Calcium concentration in pearl millet is quite low, and the presence of oxalate can exacerbate the deficiency.

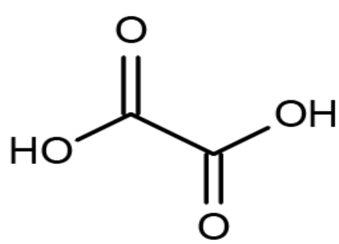


Figure 2-4: Structure of oxalic acid

2.4. Reduction or degradation of antinutritional elements

Technologies for various processing treatments, such as milling, malting, blanching, acid treatment, dry heating, and fermentation, which reduce antinutritional factors and increase the digestibility and shelf life of various alternative food products made from pearl millets such as unleavened flat bread (roti/ chapati), porridges, noodles, bakery products, and extruded and weaning food products have been developed and tested at the laboratory scale. Some of the techniques are Fermentation, Dehulling, Milling, Malting, and Dry heat treatment. These are described below in brief:

- **Fermentation**

Fermented foods are those foods which have been subjected to the action of micro-organisms or enzymes so that desirable biochemical changes cause significant modification to the food Campbell-Platt (1987). However, to the microbiologist, the term "fermentation" describes a form of energy-yielding microbial metabolism in which an organic substrate, usually a carbohydrate, is incompletely oxidised, and an organic carbohydrate acts as the electron acceptor (Adams, 1990).

Generally, a significant increase in the soluble fraction of a food is observed during fermentation. The quantity as well as quality of the food proteins as expressed by biological value, and often the content of watersoluble vitamins is generally increased, while the antinutritional factors show a decline during fermentation (Paredes-López & Harry, 1988). Fermentation results in a lower proportion of dry matter in the food and the concentrations of vitamins, minerals and protein appear to increase when measured on a dry weight basis (Adams, 1990). Single as well as mixed culture fermentation of pearl millet flour with yeast and lactobacilli significantly increased the total amount of soluble sugars, reducing and non-reducing sugar content, with a simultaneous decrease in its starch content (Khetarpaul & Chauhan, 1990). Combination of cooking and fermentation improved the nutrient quality of all tested sorghum seeds and reduced the content of antinutritional factors to a safe level in comparison with other methods of processing (Obizoba & Atii, 1991). Mixed culture fermentation of pearl millet flour with Saccharomyces diastaticus, Saccharomyces cerevisiae, Lactobacillus brevis and Lactobacillus fermentum was found to improve its biological utilisation in rats (Khetarpaul & Chauhan, 1991). Fermentation induced a significant decrease in lipid and lignin contents of okara, which is an insoluble residue obtained as a by-product in the manufacture of soybean milk. The fermented okara on the other hand neither increased PER nor the14 weight gain in rats (Guermani et al., 1992) compared to non-fermented samples.

The digestibility of starch in bengal gram, cowpea and green gram was increased by fermentation. Cooking of these fermented legumes further increased the starch digestibility (Urooj & Puttaraj, 1994).

- **Dehulling**

Both whole grains and dehulled (decorticated) grains of pearl millet are used for preparing various types of food products. Decortication is generally to the extent of removing 12-30% of the outer grain surface. Increased decortication leads to greater loss of fiber, ash and fat. It also reduces protein, lysine, histidine and arginine. Decorticated grains improve the nutritional quality and sensory properties of various food products, but these also have cost considerations in terms of the time and investments and grain weight losses. Further, these also lead to micronutrient losses, which are more concentrated in the outer layers of the grain. Pearl millet grains can be decorticated in rice mills or other modified mills. In some villages and urban areas, pearl millet grains are decorticated with abrasive disks in mechanical dehullers.

- **Milling**

Grains can be milled either by using a hammer mill or a roller mill. The flour produced using a hammer mill has large particle size and is not uniform; hence it is suitable for preparing thin and stiff porridge of rough texture and not suitable for preparing baked and steamed food products of smooth texture. Shelf life of grains is almost 18 months whereas that of flour is about 2 weeks due to its high fat contents and ranicificaton after grinding.

This is a limitation as well as opportunity for preparing fermented products. A new method for improving the shelf life of pearl millet has been developed at the Central Food Technological Research Institute (CFTRI), Mysore. It involves moist heating of the grains followed by drying to about 10-12% moisture and decortication to the desired degree or pulverization. This process improves the milling characteristics of pearl millet varieties which have high proportions of floury endosperm. Flour from treated and decorticated pearl millet could be stored for about 3-4 months, during which the free fatty acid (FFA) content remained below 10%, which is the limit of perceptible deteriorative condition. The oxidative rancidity also remains low, as the flours are refined. Another advantage of this process is that the microbial load on the grain surface is drastically reduced.

- **Malting**

This process involves limited germination of cereal in moist air under controlled conditions. Malting reduces protein, but improves the quality of protein compared to that in the bran, so a small loss in protein in milling of the malted pearl millet is compensated for by protein quality. The process results in a higher protein efficiency ratio and bioavailability of malting of pearl millet grains with 48-h germination reduced polyphenols and phytic acid by more than 40%. Malting also increases vitamins such as riboflavin, thiamin, ascorbic acid, and vitamin A.

- **Dry heat treatment**

Lipase activity is the major cause of spoilage of pearl millet meal, so its inactivation before milling improves the meal quality. The application of dry heat effectively retards lipase activity and minimizes lipid decomposition during storage. It has been observed that when pearl millet grains were given a dry heat treatment in a hot air oven at 100±2°C for different time periods ranging between 30 and 120 min, and then cooled to room temperature, there was about 50% increase in fat acidity, free fatty acids, and lipase activity during the 28 days of the storage of flour produced from the acid-treated grains, while there was a 4-fold increase in these parameters in the flour produced from untreated grains. Heating grains for 120 min has been found to be most effective for maximum retardation of the lipolytic decomposition of lipids during storage (Kadlag *et al.*, 1995). Fat acidity, free fatty acid presence, and lipase activity decrease significantly during storage of 28 days in pearl millet flour given an 18h acid treatment and a 120 minutes heat treatment. Results also showed that heat treatment increased the shelf life of pearl millet flour as compared to raw flour (Poonam, 2002).

2.5. Diversified value added health food products of pearl millet

Processed pearl millet grains and meals from them are used to prepare various types of traditional and nontraditional food products. Murty and Kumar (1995) summarized and classified these into major food categories (thick porridge, thin porridge, steam-cooked products, fermented breads, unfermented breads, boiled rice-like products, alcoholic beverages, nonalcoholic beverages, and snacks); and they provided the details of their preparations and the various common names in many countries. These products are described under seven different categories below.

2.5.1. Traditional food products

The simplest and the most common traditional food made from pearl millet are thin porridge (gruel); thick porridge (fermented and unfermented) and flat and unfermented bread such as chapati. Flat, unleavened bread prepared from pearl millet flour enriched with soy flour has been reported to have high protein efficiency ratio, minimal thickness, puffing, and uniform color and texture. Chapati prepared from pearl millet flour produced after the grains had been bleached or acid-treated or heat-treated has been reported to have enhanced overall acceptability as compared to the chapati prepared from the raw untreated grains (Poonam, 2002). Use of processed flour, in comparison to raw flour, in the product development has been found to reduce anti-nutritional factors and increase the digestibility (Singh, 2003).

Various types of snacks are also made from pearl millet in India. Products like laddoo, namkeen sev, and matari have been made using blanched and malted pearl millet flour. These products were highly acceptable and have shown to have longer shelf life and stored well up to 3 months. Rekha (1997) incorporated blanched and malted pearl millet flour in various products like bhakri, suhali, khichri, churma, shakkarpala, mathari and the products werefound to be organoleptically acceptable. An earlier study (Chaudhary, 1993) also indicated that the traditional food products including chapati, khichri, bhakrii, popped grain, dalia, and shakkarpala prepared from pearl millet were not only acceptable but their protein and starch digestibilities were also better.

2.5.2. Baked products

Pearl millet flour is not a good raw material for the baking industry, since it does not contain gluten and this forms dough of poor consistency. For instance, cookies made from pearl millet flour do not spread during baking, have a poor top grain character, and are dense and compact (Badi *et al.,* 1976). However, pearl millet flour hydrated with water, dried, and supplemented with 0.6% unrefined soy lectin can produce cookies with spread characteristics equal to those made from soft wheat flour. Various types of biscuits and cakes produced using blanched pearl millet have been found to be organoleptically acceptable. Various types of biscuits developed by incorporating different levels of blanched as well as malted pearl millet flour have been found to be acceptable and store well up to 3 months (Singh, 2003).

2.5.3. Extruded products

Extrusion is being used increasingly for making ready-to-eat foods. In extrusion processes, cereals are cooked at high temperature for a short time. Starch is gelatinized and protein is denatured, which improves their digestibility. Anti-nutritional factors that are present may be inactivated. Pearl millet grit and flour can be used to prepare ready-to-eat (RTE) products. Such products have crunchy texture and can be coated with traditional ingredients to prepare sweet or savory snacks. Alternatively, the grits could be mixed with spices and condiments prior to extrusion to obtain RTE snacks of desirable taste. The acid-treated pearl millet yields products of better acceptability as compared to that from just decorticated pearl millet. Pearl millet, blended with soy or protein-rich ingredients, such as legumes or groundnut (peanut) cake, on extrusion gives nutritionally balanced supplementary foods (Sumathi *et al.,* 2007). Noodles, macaroni and pasta-like extruded products could be prepared from pearl millet flour (Desikachar, 1975). Extruded snacks prepared with mixed millet flour containing rice flour and/or corn flour and/or tapioca starch in various proportions have been shown to have acceptable appearance, color, texture, and flavor (Siwawij and Trangwacharakul, 1995). Extrusion-cooking also enhances the in vitro protein digestibility of foods (Malleshi *et al.,* 1996).

Utilization of pearl millet for producing soft-cooked products such as vermicelli noodles is very rare, although these grains are unique with respect to taste and aroma, and provide dietary fiber. Research at the CFTRI, has led to a process to prepare noodles (Sowbhaghya and Ali, 2001a). The noodles on cooking in water retained the texture of their strands and firmness without disintegration, and the solid loss is less than 6% (Sowbhaghya and Ali, 2001b). The noodles from pearl millet were readily acceptable in the savory and sweet formulations.

2.5.4. Flakes and pops

Extensive work has been carried out on sorghum flaking at CFTRI, Mysore, and various process parameters, such as soaking time, temperature, wet-heat or dry-heat treatment conditions, have been standardized. The grain soaked to its equilibrium moisture content is steamed or roasted to fully gelatinize the starch, dried to about 18% moisture content, conditioned, decorticated, and then flaked immediately by passing through a pair of heavy-duty rollers.

The flakes can also be used for the preparation of traditional snacks like 'uppitu' after boiling and seasoning. The thicker flakes could be deep-fried or dry-roasted to prepare expanded and crunchy snack products. Results of exploratory studies on flaking of pearl millet following the method adopted for sorghum have been promising. Pearl millet flaking would be a new avenue for its widespread utilization. Popping of pearl millet is not very popular, but the popped pearl millet is a good source of energy, fiber and carbohydrates. Varieties with hard endosperm and medium-thick pericarp exhibit superior popping quality (Hadimani *et al.,* 2001). The lipolytic enzymes are denatured during the process of popping. The nutritional advantage of the popped millet is utilized in developing formulations for supplementary foods or weaning foods for children and mothers (Bhaskaran *et al.*, 1999).

2.5.5. Weaning foods

Pearl millet can be successfully utilized for the development of weaning foods, as it can satisfy the nutritional requirement of infants during the crucial transitional phase of life from breast milk to other type of food, at reasonable cost. Keeping in view the delicate digestive system and nutritional requirement of the infants, malting seems to be an effective process as it provides an opportunity to develop easily digestible and nutritious weaning foods of low viscosity, low dietary bulk and of high calorie density. In addition malting also improves the availability of protein, minerals, free sugars, vitamin B and ascorbic acid by reducing the level of anti-nutritional factors. It also imparts desirable flavour and taste to the product. Blanched pearl millet can also be used for weaning foods. Blanching improves the storage stability by retarding the lipolytic spoilage of meal without much altering its nutrients.

Nutritive value of pearl millet-based weaning foods can further be enhanced when mixed with legumes like cowpea or green gram because these pulses complement the profile of essential amino acids which is beneficial for infants' optimum growth.

2.5.6. Health foods

Pearl millet can find uses in preparing various types of health foods and food ingredients as it contains a relatively higher proportion of insoluble dietary fiber. This causes slow release of sugar, thus making the food products based on them especially suitable for those suffering from or prone to diabetes. For instance, various pearl millet-based food products were found to have a lower glycemic index (GI) than those based on wheat, with the extent of reduction in the GI trait ranging from 20% for biscuits to 45% for dhokla. Gluten intolerance, leading to protein allergy (specifically gliadin allergy), is a physiological disorder from which about 500,000 people suffer in the USA alone (Dahlberg *et al.*, 2004). Pearl millet is gluten-free and, hence, has a good chance of being commercialized for the food-based management of this problem.

Various value added products were developed and standardized using pearl millet, finger millet, barnyard millet and sorghum. Some health foods were also developed for diabetics utilizing pearl millet. The details of food products developed are summarized below from pearl millet.

CHAPTER THREE

Materials and Methods

3.1. Sample collection, transportation, preparation and storage

Pearl millet (*Pennisetum glaucum*) variety 'ICMV 221' was collected from Gondar (specifically Omera) local market and the sample of pearl millet was screened to remove broken and cracked grains, weed seeds and other extraneous matter. Then flours were prepared in the laboratory for immediate use and processing.

3.2. Processing methods and their combination

The processing methods used for antinutrients reduction were blanching, autoclaving, roasting soaking, germination, fermentation and their combinations

3.2.1. Blanching

About 500 grams of pearl millet sample was blanched by distilled water which was brought to boiling at 110 ºC in an oil bath. The grains were subjected to blanching [1:5 ratio of seeds to boiling water] for 30 seconds and dried at 50 ºC for 60 minutes using Yorko hot air oven (YSI-431, 1990). The blanched seeds were milled to obtain the blanched millet flour.

3.2.2. Autoclaving

About 500 grams of pearl millet sample (particle size 0.4 - 1.0 mm) were placed in a 1 l capacity glass jar. Distilled, deionized water (800 ml) was added and the mixture stirred for 1 min. Samples were placed in an autoclave and heat treated at 110°C at 1 Kgf/ cm^2 pressure for 15 min. then was cooled and dried in an oven at 60ºc. The autoclaved seeds were milled to obtain the autoclaved pearl millet flour.

3.2.3. Roasting

About 500 grams of pearl millet grains was cleaned and roasted in acid washed sand for 10 min. at 80 ^{o}C. and the roasted pearl millet grain was separated from the sand by sieving. The roasted seeds were milled to obtain the roasted pearl millet flour.

3.2.4. Soaking

About 500 grams of pearl millet grains were washed three times using deionized water. Then, the cleaned and washed grains were soaked in a volume of water 3 times the weight of seeds (3:1) for 8h in a plastic plate at room temperature (Ali *et al*., 2009). The unabsorbed liquid was drained off, and the seeds were rinsed twice in distilled water. Dried seeds were ground to obtain the soaked pearl millet flour.

3.2.5. Fermenting

About 500 grams of pearl millet grains was steeped in water for 72 h after which they were rinsed with clean water and dried in an oven at 45 – 50 ^{o}C for 10h. The dried seeds were milled to obtain the fermented pearl millet flour.

3.2.6. Germinating

About 500 grams of pearl millet grains was washed three times using deionized water. Then, the cleaned and washed grains was soaked in a volume of water 3 times the weight of seeds (3:1) for 16h at 30 ^{o}C in BOD incubator (Einrichtungen, Germany) in plastic containers (Egli*et al*., 2002). Then, the steeping water was drained off and the soaked pearl millet was washed twice using formaldehyde to protect the growth of microorganisms during germination. The soaked and washed grains were germinated for 72h. The soaked seeds were covered with wet clean cloth and placed in a plastic sieve. The content was left at 30 ^{o}C in an incubator and watered 2-3 times a day to enhance the germination process. The dried seeds were milled to obtain the germinated pearl millet flour.

The whole resultant milled flour samples were then packed in airtight polythene plastic bags. The bags were stored at room temperature until laboratory analysis.

Figure 3-1: Processed pearl millet flours

3.3. Analysis methods

3.3.1. Physical characterizations of pearl millet grain

Physical appearance of grain is an important characteristic which determines consumer acceptability, and hence the study of physical characteristics of the grains becomes a basic step in any research. The characteristics of the pearl millet like color and shape were visually observed. Seed sizes, hundred grain weight, volume, bulk density, hydration, and swelling characteristics were studied by following the procedures as described below. All the estimations were done in duplicates. The size of the seed was measured using calipers to the nearest of 0.01 mm. Seed tests are based on the standards recommended by International Seed Testing Association (ISTA).

- ❖ **Hundred seed weight**

Weight of randomly selected hundred grains was recorded in grams using electronic balance with a sensitivity of 0.01 mg.

- **Hundred seed volume**

Hundred randomly selected grains were dropped in a measuring cylinder containing known volume of distilled water. The difference in volume was recorded in ml.

- **Seed bulk density**

Seed bulk density was determined according to the method of Alfonso *et al*. (1998). One hundred seeds were weighed and transferred into 100 ml measuring cylinder containing 50 ml of distilled water. The seeds were allowed to soak for 10 minutes for equilibration and the volume of water displaced should be recorded at room temperature. The mass and volume were used to calculate the seed density as g/ml.

- **Hydration capacity and index**

Hydration capacity was calculated as the difference in weight of seeds after soaking for 24 hours. It was expressed as weight per gram (Dhingra*et al.*, 1992).

Hydration index was calculated by using the formula given by Kantha*et al.* (1986).

$$Hydration\ index = \frac{hydration\ capacity\ per\ 100\ seeds \times 100}{original\ dry\ weight\ of\ 100\ grains} \qquad Eq. (3.1)$$

- **Swelling capacity and index**

Swelling capacity was calculated as the difference in volume of seeds after soaking for 24 hours. It was expressed as weight per gram (Dhingra*et al.*, 1992).Swelling index of pearl millet was calculated as described by Kantha*et al.* (1986) using the formula.

$$Swelling\ index = \frac{swelling\ capcity\ per\ 100\ seeds \times 100}{seed\ volume\ per\ 100\ seeds} \qquad Eq. (3.2)$$

3.3.2. Proximate and mineral composition of pearl millet flours

The crude protein (Kjeldahl, Nx6.25), crude fat (solvent extraction), crude fiber, total ash and moisture were determined according to AOAC (2000) methods.

- **Determination of crude protein**

Protein content was determined according to AOAC (2000) using the official method 979.09. A digestion flask containing an accurately weighed 1g sample, to which some amount of acid mixture (concentrated sulphuric acid and concentrated Orthophosphoric acid) and catalyst mixture (K_2SO_4 and Selenium) were added, and then it was exposed to a temperature of about 370 ^oC in order to allow digestion. Then distillation took place by adding 40% NaOH to the compartment and using boric acid solution as indicator. Finally the distillate was titrated with 0.1N Sulphuric acid to a reddish color. The protein content was estimated using the formula given below.

$$Total\ nitrogen\ content(\%\ weight) = \frac{(T - B) \times N \times 14.007 \times 100}{W} \qquad Eq. (3.3)$$

Where:

T= Volume in ml the standard Sulphuric acid of used in the titration for the test material

B= Volume in ml the standard Sulphuric acid used in the titration for the blank determination
N= Normality of standard Sulphuric acid

W= Weight in g of the test material

Therefore, Crude Protein Content (% / Weight) = % Total Nitrogen Content × 6.25

- **Determination of crude fat**

A clean and dried thimble containing about 5 g of dried sample and covered with fat free cotton at the bottom and top was placed in the extraction chamber. The extraction was take place for at least 4h AOAC (2000) official method 4.5.01. Then, the crude fat content was determined as follows:

$$Crude\ fat = \frac{100(W2 - W1)}{W} \qquad Eq. (3.4)$$

Where:

W = Weight in g of the dried test material

W_1 = Weight of extraction flask

W_2 = Weight in g of the extraction flask and dried crude fat

❖ Crude fiber determination

Crude fiber analysis was conducted using the method of AOAC (2000) official method 962.09. About 1.5g weighed sample was transferred into a 600 ml beaker and about 200 ml 1.25% sulfuric acid was added and boiled for 30 minutes. Recording was taken place by placing a watch glass over the mouth of the beaker. After 30 minutes heating by gently keeping the level constant with distilled water, 20 ml 28% KOH was added and again boiled gently for further 30 minutes. Subsequently, washing was conducted with 1% sulfuric acid and NaOH solution. Then, it was filtered and dried in the electric oven at 130 ^{o}C for 2h. Furthermore, it was cooled at room temperature for 30 minutes in a desiccator and weighed, and then it was ashed in a muffle furnace at 550 ^{o}C. Finally, it was cooled again in desiccators and re-weighed. The crude fiber content was determined by using the formula.

$$Crude\ fiber\ content = \frac{[(w_1 - w_2)(100 - m)]}{w_3} \qquad Eq.(3.5)$$

Where:

w_1=Crusible weigth after drying, g

w_2= Crucible weight after ashing, g

w_3= Dry weight, g

m= % moisture of the sample

❖ Total ash determination

The porcelain dish which was used for the analysis was cleaned by drying at 120^{0}C and igniting at 550^{0}C in furnace for three hour. Then the dish was removed from the furnace and cooled in desiccators .The mass of the dish was measured by analytical balance (M_1). About 3gram of the sample was weighed in to porcelain dish (M_2). The sample was dried at 120^{0}C for one hour in drying oven (memmert, 854 schwabach, Germany). The sample was removed from the drying oven and carbonized by blue flame of Bunsen burner by placing the sample dish on wire gauze. The sample was then placed in furnace (Carbolite, astonlane Hope, Sheffield S302RR, England) at about 550^{0}C until free from carbon and the residues appear grayish white (about 8 hours).The sample was removed from the furnace and if the ashing was incomplete it was moistened by the few drops of water and placed in an oven at 120^0C for one hour and re-ashed at 550^0C until white ash color was obtained. It was removed from the furnace and placed in the desiccator. Finally the mass was weighed (M_3).

$$Ash(\%) = \frac{(M_3 - M_1) \times 100\%}{M_2 - M_1} \qquad Eq. (3.6)$$

Where:

M_1=Weight of the dish

M_2=Weight of fresh sample and dish

M_3=Weight of ash and dish

- **Determination of moister content**

Moisture of the sorghum grain flour was determined according to AOAC (2000) using the official method 925.09. A clean dried and covered, flat aluminum dish containing 5-10g the sample was transferred to an oven at 100-105 ^oC for 4-6 h under a pressure of 25mm and it was cooled in a desiccator and weighed. Then the moisture content was estimated as follows:

$$Moisture\ content\ (\%) = \frac{Weight\ of\ fresh\ sample - Weight\ of\ dry\ sample \times 100}{Weight\ of\ fresh\ sample} \qquad Eq. (3.7)$$

- **Carbohydrate determination**

The carbohydrate content of each sample was determined by difference

$$\%Carbohydrate = 100 - (\%Moisture + \%Protein + \%Crude\ fiber + \%Fat + \%Ash) \quad Eq. (3.8)$$

Total energy was calculated using Atwater factors:

$$Energy\ value = \%Protein \times 4 + \%Carbohydrate \times 4 + \%Fat \times 9 \qquad Eq. (3.8)$$

- **Determination of mineral composition**

Mg content of the processed flour samples flour were determined using flame photometry methods (AOAC official method 923.03, 1990). The concentrations of Ca, Fe and Zn were determined after wet digestion with a mixture of perchloric and nitric acid using atomic absorption spectro-photometry**.** While, P was estimated colorimetrically by the ammonium molybdate method (AOAC official method965.17, 1990).

3.3.3. Determination of antinutritional factors of pearl millet flours

- **Determination of tannin acid**

About 2.0000 g of fresh sample was weighed in screw cap test tubes (in triplicate). The samples were extracted with 10 ml of 1% HCl in methanol for 24 hours at room temperature with a mechanical shaking. After 24 hours shaking, the solution was centrifuged at 1000 rpm for 5 minutes. One ml of supernatant was taken and mixed with 5 ml of Vanillin-HCl reagent (prepared by combining equal volume of 8% concentrated HCl in methanol and 4% Vanillin in methanol). D-catechin was used as standard for condensed tannin determination. Forty mg of D-catechin was weighed and dissolved in 1000 ml of 1% HCl in methanol, which was used as stock solution.

Exactly 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of stock solution was taken in test tubes and the volume of each test tube was adjusted to 1.0 ml with 1% HCl in methanol. Five ml of Vanillin-HCl reagent was added into each test tube.

After 20 minutes, the absorbance of the solutions and the standard solution were measured at 500 nm by using deionized water as blank, and the calibration curve was constructed from a series of standard solution using SPSS Version 15. Concentration of tannin was read in mg of D-catechin per gm of sample.

$$Tannin\ \left(\frac{\mu g}{g}\right) = \left[\frac{(absorbation - intercept)}{slope \times density \times weight\ of\ sample}\right] \times 10 \qquad Eq. (3.9)$$

- **Determination of phytate content**

About 0.1500 g of fresh samples was extracted with 10 ml 2.4% HCl in a mechanical shaker for 1hour at a room temperature. The extract was centrifuged at 3000 rpm for 30 minute (Dynac II centrifuge, Clay Adams, Bacton, Dickinson and c0mpany, USA). The clear supernatant was used for phytate estimation. One ml of Wade reagent (containing 0.03% solution of $FeCl_3.6H_2O$ and

0.3% of sulfosalicilic acid in water) was added to 3 ml of the sample solution (supernatant) and the mixture was mixed on a Vortex for 5 seconds. The absorbance of the sample solutions were measured at 500 nm using UV-VIS spectrophotometer.

A series of standard solutions were prepared containing 0, 5, 10, 20 and 40 μg/ml of phytic acid (analytical grade sodium phytate) in 2.4% HCl. Three ml of the standard solution was added into 15ml of centrifuge tubes. Three ml of water was prepared to serve as standard blank. One ml of the Wade reagent was added to each test tube and the solution was mixed on a Vortex mixer for 5 seconds. The mixture was centrifuged for 10 minutes and the absorbance of the solutions (both the sample and standard) was measured at 500 nm by using deionized water as sample blank.

$$Phytic\ acid\ (\frac{\mu g}{g}) = \left\{\left[\frac{absorbance - intercept}{slope \times density \times weight\ of\ sample}\right] \times 10\right\} \div 3 \quad Eq.(3.10)$$

- **Determination of molar ratio of phytate/ mineral**

The mole of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight (phytate: 660g/mol; Fe: 56g/mol; Zn: 65g/ mol; Ca: 40 g/mol). The molar ratio between phytate and mineral was obtained after dividing the mole of phytate with the mole of minerals.

- **Determination of phytate and non-phytate phosphorus**

Phytate and phosphorous were determined by the above methods. Phytate phosphours was calculated with the following formula (Duhan*et al*., 2002).

$$Phytate\ phosphorous(mg/100g) = \frac{A \times 28.18}{100} \qquad Eq.(3.11)$$

Where: *A* = phytate content (mg/100g)

Non-phytate phosphorus was calculated as a difference between the total phosphourus and phytate phosphorus.

3.3.4. Determination of physicochemical and functional properties of pearl millet flours

❖ Determination of pH

This was done by the method of Ofori and Hahn (1994). Before measurements of pH were taken, the sample slurries were thoroughly stirred to homogenize the mixture and achieve uniformity. The pH electrode was dipped in each of the slurries and measurements were taken when the readings on the pH meter were stable using a TOA pH meter HM 7B.

❖ Determination of Total Titratable Acidity (TTA)

The TTA analysis was done using AOAC (1996) method. Approximately 10 ml of sample was pipetted into a conical flask and two drops of phenolphthalein indicator added. Titration was done using 0.1N NaOH to a faint pink colour for at least 1 min compared against a white background. The titre volume was noted and used to calculate TTA which was expressed as percentage lactic acid. TTA was determined and expressed as follows:

$$\%Lactic\ acid = A \times 0.009 \times 100 \div V \qquad Eq. (3.12)$$

Where:

A = ml of 0.1 NaOH required for the titration

V = ml of sample taken for the test

❖ Bulk density of the flours

Bulk densities were determined by the method of Narayana and Narasinga-Rao (1984). An empty calibrated centrifuge tube was weighed, and then tubes filled with a sample to 5 ml by constant tapping until no further change in volume. The weight of the tube and its contents were taken and recorded. The weights of the sample alone were then determined by difference. Bulk density was calculated as weight per unit volume of the sample.

❖ Dispersibility of flours

Dispersibility in water was determined by the method of Kulkarni *et al*. (1991). About 10g of each flour sample was weighed into a 100 ml measuring cylinder. Distilled water was added up to 100 ml volume. The sample was vigorously stirred and mixed and allowed to settle for 3 hr.

The volume of settled particles was recorded and subtracted from 100 to give a difference that is taken as percentage dispersibilty.

❖ Water and oil absorption capacity of flours

The water and oil absorption capacity (WAC and OAC) were determined by the method of Roario and Flores (1981). One gram sample was mixed with 10ml distilled water or 10 ml oil (refined oil) for 30 sec. in a mixer. The sample was then allowed to stand for 30min at 30ºC in water bath and centrifuged at 3000 rpm for 20 min. the volume of supernatant were recorded to calculate the amount of hydration or oil absorption capacity.

❖ Least gelation concentration of flours

Least gelation concentration (LGC) of the sample was determined by the method of Iyen and Singh (1997) with slight modification. Sample suspension containing 2-10% (w⁄v) sample was prepared in 10ml of distilled water. The test tubes were heated for 1h in boiling water, rapidly cooled under running tap water and refrigerated for 3h at5˚C. The least gelation concentration were determined as that concentration at which the sample did not fall down or slip from inverted test tube.

❖ Color grade of flours

The color grade value of the flour samples was measured to make sure the brightness of the flours using satake color grader series IV. 30g of flour sample was placed in a beaker containing 50 ml distilled water and made in to a paste by continuously stirring it with a glass rod for 45 seconds. The paste was then poured in to the sample cell and the sample cell containing the paste was inserted in to the carriage of the instrument. The result was displayed within 90 seconds.

❖ Falling number and liquefaction of flours

♣ Falling number of flours

Wheat flour and blended of wheat flour with processed pearl millet was evaluated for falling number using the Hagberg falling number apparatus (model 1500, Sweden) according to the ICC standards No 107/1 for the determination of the amylase activity of cereal and flour.

- ♣ **Liquefaction number of flours**

Correlation coefficients were determined for the falling number (FN) ground wheat and milled flours, the falling number were also converted into liquefaction number (LN) using the expression.

$$LN = \frac{6000}{(FN - 50)} \qquad Eq.(3.13)$$

Where: LN=Liquefaction number of flour

FN=Falling number of flour

This was done to study the interrelation in view of the reported linear relation of liquefaction number with α- amylase content of the flours.

3.4. Product formulation of pearl millet

3.4.1. Blend formation and baking process of bread

Bread was produced according to a commercial formulation and baking practice of bakery Company with some modifications (Pedersen *et al.*, 2004). The dough was prepared by blending wheat flour and raw or fermented pearl millet flours at the ratio of 100% of wheat, 95:5%, 90:10%, 85:15% and 100% fermented or blanched pearl millet flours respectively with other ingredients such as sugar, shortening, salt, active dry yeast, and water. Produced bread samples were stored at room temperature for further analysis.

Table 3-1: Blending proportion for making breads

Sample type	Blend proportion of bread	
	Ratio of WF to FPMF	Ratios of WF to BPMF
100%	100% wheat flour (Control)	100% wheat flour (Control)
5%	95% wheat flour to 5% fermented PM flour	95% wheat flour to 5% blanched PM flour
10%	90% wheat flour to 10% fermented PM flour	90% wheat flour to 10% blanched PM flour
15%	85% wheat flour to 15% fermented PM flour	85% wheat flour to 15% blanched PM flour
100%	100% fermented PM flour	100% blanched PM flour

WF= wheat flour, RPMF = Raw pearl millet flour, FPMF= Fermented pearl millet flour, BPMF=blanched pearl millet flour

The ten blend formulations were baked using the straight dough method (Chuahan *et al.,* 1992). The baking formula was 56% wheat flour or the blend, 36% water, 3.4% sugar, 1.6% shortening, 1% skim milk powder, 1% salt and 1% active dry yeast (Ihekoronye, 1999). All ingredients were mixed in a Kenwood mixer (Model A907 D) for 5 min. The dough was fermented in bowls, covered with wet clean muslin cloth for 55 min at room temperature (29°C), punched, scaled to 250 g dough pieces, were proofed in a proofing cabinet for 90 min at 30°C, 85% relative humidity and were baked at 250°C for 30 min. (Giami *et al.,* 2004)

3.4.2. Blend formation and cooking process of thin porridge

Thin porridge was produced in the traditional way with some own modifications. The thin porridge ingredients was prepared by blending raw pearl millet flour with fermented and blanched pearl millet flours at the ratio of raw pearl millet flour 100%, 75:25%, 50:50%, 25:75% and 100% fermented, or blanched pearl millet flours respectively with other ingredients such as milk, sugar, salt and water. Produced thin porridge samples were stored at room temperature for further study.

Table 3-2: Blending proportion for making thin porridge

Sample type	Blend proportion of thin porridge	
	Ratio Unfermented PM flour to Fermented PM flour for 72h	Ratio Unbleached PM flour to Blanched PM flour at 110°c
100%	100% Unfermented PM flour (Control)	100% Unbleached PM flour (Control)
75%	75% Unfermented PM flour to 25% Fermented PM flour	75% Unbleached PM flour to 25% Blanched FM flour
50%	50% Unfermented PM flour to 50% Fermented PM flour	50% Unbleached PM flour to 50% Blanched PM flour
25%	25% Unfermented PM flour to 75% Fermented PM flour	25% Unbleached PM flour to 75% Blanched PM flour
100%	100% Fermented PM flour	100% Blanched PM flour

The ten samples of blend were cooked using traditional preparation method with some modifications. The cooking of thin porridge formula was 5% or 15% raw or blend pearl millet flours, 53% or 43% water was mixed respectively, 40% milk, 1% sugar and 1% salt. All the ingredients were mixed step wisely and cooked for 10min at 50^{0}C and further at the temperature of 92^{0}C for 25 minutes.

3.5. Characteristic of value added products of pearl millet

3.5.1. Viscosity of thin porridge

The thin porridge samples were prepared in a glass beaker by mixing 15 g and 5 g of pearl millet flours and 100 ml of water. The mixture of water and flour were cooked at 92^{0}C for 25 minutes. The thin porridge was placed in water bath maintained at 50°C (heating temperature) and its viscosity was measured by the Sv10 sine wave vibro viscometer at this temperature. Modified traditional methods of porridge preparation were used after adapting to laboratory conditions. The ratio of flour: water and the heat treatment were controlled to avoid the contribution of these parameters in viscosity measurement by the method of Ikujenlola (2005).

3.5.2. Loaf volume and specific volume of bread

The weight of the bread was determined and the respective volume by rape seed displacement method (AACC, 2000). A rectangular box made from wood was used. The box was fixed with cleaned millet grain, leveled and poured out. The bread was placed in the same bowel and filled with the measured millet grain and leveled. The volume of the remaining grains from the same measured grains was taken as the volume of the loaf.

3.6. Sensory quantity analysis of value added products

The sensory attributes, including color, flavor, aroma, texture and general acceptability, was evaluated by a semi trained 10-member panel, using a 9-point Hedonic scale with 1 representing the least score (dislike extremely) and 9 the highest score (like extremely). Analysis of variance (ANOVA) was performed on the data gathered to determine differences, while the least significant test was used to detect significant differences among the mean (Ihekoronye and Ngoddy, 1985).

3.7. Framework of the research experiment

The research was conducted to see the effect of processing on quality characteristics of pearl millet based value added product by doing all the experiments shown in Figure 3-9.

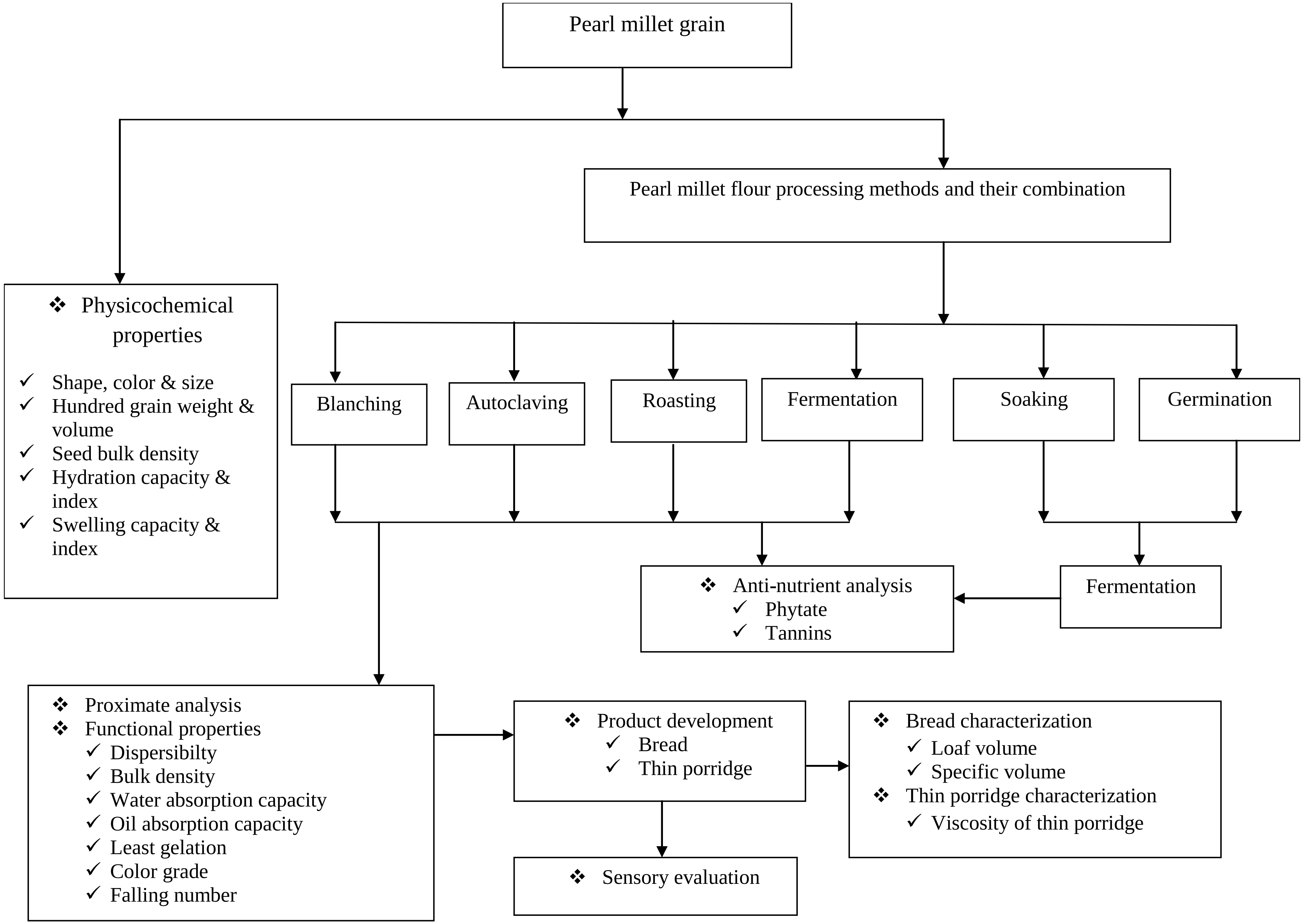


Figure 3-2: Structure of the thesis

3.8. Experimental design and statistical data analysis

The data obtained from the chemical and functional determination were statistically analyzed using (JMP5) (pronounced "jump") is a computer program for statistics developed by the JMP business unit of SAS Institute. Comparisons between sample treatments and the indices were done using analysis of variance (ANOVA) with a probability $p < 0.05$. Student's t -test was used to identify significant differences among mean main effects for processing methods. All physical and chemical measurements were performed in duplicate.

CHAPTER FOUR

Results and Discussion

4.1. Physical characterizations of pearl millet grain

Physical characteristics: Physical characteristics of pearl millet grain are presented in Table 4.1. The whole pearl millet is yellow in color. The pearl millet grain is pearl drop in shape. The size of the pearl millet grain ranged from 1.70 to 1.73mm with a mean value of 1.71mm. The morphology of the seed such as size, uniformity of seed size and seed shape are varietals character that are key factors affecting the process of pulses Tizazu and Shimelis *et al.*,(2010). These properties thus play a vital role in the selection of sieves and milling machines. The mean hundred grain weight was 0.84g, with a range between 0.82 to 0.86g. The hundred grain volume of pearl millet ranged from 0.42 to 0.50ml with a mean of 0.46ml. The value of the volume obtained for 1000 sorghum grain 0.091± 0.04 cm^3 was higher obtained by Simonyan *et al.*, (2000). The seed bulk density of the pearl millet grain ranged from 1.77 to 1.87g/ml with a mean value of 1.82g/ml. The mean hydration capacity of the grains was 0.27g/100 seeds, with an index of 32.14 per cent. Swelling capacity of the grain was 0.32ml/100 seeds, with an index of 69.56.

Table 4-1: Physical characterizations of pearl millet grain

Parameter	Characteristics
Shape	Pearl drop
Whole grain color	Yellow
Size (mm)	1.71 ± 0.03
Hundred grain weight (g)	0.84 ± 0.02
Hundred grain volume (ml)	0.46 ± 0.04
Seed bulk density	1.82 ± 0.05
Hydration capacity (g/100 seeds)	0.27 ± 0.03
Hydration index (%)	32.14 ± 0.01
Swelling capacity (ml/100 seeds)	0.32 ± 0.02
Swelling index (%)	69.56 ± 0.05

4.2. Proximate and mineral composition of pearl millet flours

4.2.1. Proximate compositions of pearl millet flours

Chemical Composition: The chemical composition of raw, roasted, fermented, blanched, and autoclaved pearl millet flours were shown in Table 4.2. And in this table were computed each treated sample based on their percentage compositions of moisture, protein, fiber, fat, ash, carbohydrate and also total energy in kilo calories.

Moisture Content: Results showed that the three layers of pearl millet flour (raw, roasted and autoclaved) treated in different ways contained significantly ($P<0.05$) lower moisture content compared to the whole pearl millet flours. The low moisture content could probably be due to the roasting during preparation of sample. Natural fermentation for 72 hour at 37 ^{o}C as well as blanched pearl millet flours was the highest moister content 11.55% and 10.04% respectively. The significantly ($P< 0.05$) higher moisture content of fermented and blanched can be attributed to the hydroscopic properties of the flour.

Ash Content: The treatment methods of pearl millet no significant difference. The results were oscillating from 1.22% to1.35%. The ash content of raw, roasted, fermented, blanched and autoclaved obtained from pearl millet flour ranged from 1.35% to 1.34, 1.22, 1.22 and 1.30% respectively. This reduction may be due to the leaching of the soluble inorganic salts during fermentation and blanching. The Statistical ash content indicates the rough estimations of mineral content of the products. Fasasi *et al.,* (2009)

Protein Content: Protein content of the four layers of pearl millet flours was 12.02, 11.75, 11.22, and 12.36 for raw, roasted, blanched, and autoclaved respectively. This result found to range from 12.38 to 11.22% without significant difference ($P< 0.05$) among the four layers. Raw, roasted, blanched, and autoclaved isolated from fermented pearl millet contained the highest protein (20.79%). The result shows that in a fermentation process may be decomposition of carbohydrate by enzymatic activity had its own contribution. This result agreed with findings of Fasasi *et al.,* (2009), who reported 17.50% protein content for fermented pearl millet flour.

Fat content: raw and roasted pearl millet flour found to contain relatively highest fat content (3.86% and 3.82%, respectively) compared to other treatments fermented, blanched and autoclaved pearl millet flours without significant ($P<0.05$) difference between the first two and the other types of pearl millet flours. Also fermented and autoclaved flours prepared from pearl millet showed the same trend and the two layers found to contain 3.65% and 3.67%. However, a slightly lower value of fat content was 3.48%. The low fat level in the blanched pearl millet flour could be due to the separation of subsequent loss into the decanted water during the course of blanched pearl millet flour preparation. In addition losses of fat can be partially attributed to fermentation. Present values were fairly compatible with results of Fasasi *et al.,* (2009) who reported 2.68% fat for fermented pearl millet flour.

Fiber Content: without significant (P<0.05) reduction were observed in fiber content of the pearl millet flours obtained for the whole. But the two roasted and blanched pearl millet flours were 3.11% and 3.08% respectively compared to the starting materials (raw pearl millet flour). Fermented pearl millet flour contained significantly (P<0.05) lower fiber (2.57% compared to 2.75%, 3.11%, 3.08% and 2.67% fiber content of raw, roasted, blanched, and autoclaved were respectively). Earlier natural fermentation was claimed to reduce fiber content of pearl millet. Ahmed *et al.,* (2004)

Table 4-2: Proximate composition of pearl millet flours

Treatment	Moisture (%)	Protein (%)	Fiber (%)	Fat (%)	Ash (%)	CHO* (%)	Energy (kcal/100g)
RPMF	8.82 ± 0.50^{bc}	11.72 ± 0.32^{b}	2.75 ± 0.61^{a}	3.86 ± 0.10^{a}	1.35 ± 0.13^{a}	71.50	367.62
RoPMF	7.58 ± 0.41^{c}	12.02 ± 0.04^{b}	3.11 ± 0.36^{a}	3.82 ± 0.02^{a}	1.34 ± 0.23^{a}	72.13	370.98
FPMF	11.55 ± 1.23^{a}	20.79 ± 0.76^{a}	2.57 ± 0.16^{a}	3.65 ± 0.18^{a}	1.22 ± 0.19^{a}	60.22	356.62
BPMF	10.04 ± 0.79^{ab}	11.26 ± 0.32^{b}	3.08 ± 0.37^{a}	3.48 ± 0.38^{a}	1.22 ± 0.19^{a}	70.92	360.32
APMF	7.77 ± 0.79^{c}	12.25 ± 0.31^{b}	2.69 ± 0.20^{a}	3.67 ± 0.14^{a}	1.30 ± 0.21^{a}	72.30	371.23

All values are means of duplicate ± standard deviation
$^{a-c}$ Means with the same superscript letters within a column are not significantly different (p>0.05)
RPMF - Raw pearl millet flour, RoPMF – Roasted pearl millet flour, FPMF – Fermented pearl millet flour, BMPF – Blanched pearl millet flour, APMF – Autoclaved pearl millet flour; CHO*=carbohydrate

4.2.2. Mineral composition of pearl millet flours

Table 4.3 showed that the mineral content of the raw, roasted, fermented, blanched, and autoclaved pearl millet flour sample.

The value of calcium showed on the Table 4.3 range from (4.35mg/100g to 2.66mg/100g) significantly reduced ($p<0.05$) the value of the calcium in the roasted pearl millet flour was (2.66mg/100g). Raw and autoclaved pearl millet flours were relatively containing the larger calcium content 4.35 and 4.01mg/100g respectively. The amount of magnesium in raw, roasted, fermented, blanched, and autoclaved pearl millet flours were range from (52.23mg/100g to 67.35mg/100g). A significantly reduced ($p<0.05$) the value of roasted pearl millet flour was (52.23 mg/100g).

Table 4-3: Minerals composition of pearl millet flours (mg/100g)

Treatment	Ca(mg/100g)	Mg(mg/100g)	Fe(mg/100g)	Zn(mg/100g)	P(mg/100g)
RPMF	$4.35±0.42^{a}$	$67.35±0.42^{a}$	$22.38±0.52^{a}$	$4.55±0.28^{a}$	$290.04±0.04^{a}$
RoPMF	$2.66±0.24^{c}$	$52.23±0.26^{d}$	$9.04±0.19^{c}$	$3.55±0.14^{b}$	$223.49±0.65^{e}$
FPMF	$2.70±0.35^{b}$	$54.18±0.24^{c}$	$9.93±1.15^{c}$	$3.52±0.57^{b}$	$250.88±0.18^{b}$
BMPF	$2.80±0.57^{b}$	$60.23±0.31^{b}$	$10.35±0.45^{bc}$	$3.94±0.09^{ab}$	$230.29±0.39^{c}$
APMF	$4.01±0.50^{a}$	$66.45±0.54^{a}$	$11.74±0.57^{b}$	$4.21±0.21^{ab}$	$228.39±0.54^{d}$

All values are means of duplicate ± standard deviation
[a-e] Means with the same superscript letters within a column are not significantly different ($p>0.05$)
RPMF - Raw pearl millet flour, RoPMF – Roasted pearl millet flour, FPMF – Fermented pearl millet flour, BMPF – Blanched pearl millet flour, APMF – Autoclaved pearl millet flour.

In the case of the iron raw pearl millet flour was highest compared to the other (22.38mg/100g). And the lowest amounts of iron were (9.09mg/100g and 9.93mg/100g) of autoclaved and fermented pearl millet flour. A significant reduction ($p<0.05$) in total zinc were obtained in the entire processed pearl millet flours sample when compared with the raw flour sample. Expect Autoclaved pearl millet flour (APMF) is the highest zinc content (4.21mg/100g). The values of phosphorus in raw, roasted, fermented, blanched, and autoclaved pearl millet flours were range from (290.04mg/100g to 223.49mg/100g) from it fermented pearl millet flour was significantly increased 250mg/100g may be due to the synthesis of phosphorus phytate enzyme in the fermented pearl millet flour.

4.3. Antinutrational factors reduction of pearl millet flours

Levels of phytate and tannin of the processed and unprocessed pearl millet flours were given in Table 4.4 below:

Table 4-4: Antinutrational compositions of raw and processed pearl millet flours

Treatment	Tannin (mg/100g)	Phytate (mg/100g)
RPMF	3.64±0.18[a]	288.69±0.16[b]
RoPMF	2.93±0.21[b]	294.29±1.17[a]
FPMF	0.83±0.07[c]	167.14±0.13[e]
BPMF	0.80±0.04[c]	208.17±0.13[d]
ADMF	2.93±0.14[b]	246.29±0.33[c]

All values are means of duplicate ± standard deviation
[a-e] Means with the same superscript letters within a column are not significantly different ($p>0.05$)
RPMF - Raw pearl millet flour, RoPMF – Roasted pearl millet flour, FPMF – Fermented pearl millet flour, BMPF – Blanched pearl millet flour, APMF – Autoclaved pearl millet flour

Tannin content: the tannin content of raw, roasted, fermented, blanched, and autoclaved pearl millet flours were (3.64, 2.93, 0.83, 0.80, and 2.93mg/100g) respectively and of these the tannin significantly reduced in the fermented and blanched pearl millet flours 0.80mg/100g and 0.83mg/100g respectively but still higher than reported by Fasasi *et al.*, (2009). The values for roasted and autoclaved pearl millet flour were 2.93mg/100g and 2.93mg/100g respectively and the result were almost similar.

Phytate content: the phytate content of pearl millet flours range from 167mg/100g to 294.29mg/100g The value of the fermented pearl millet flour decreased during fermentation treatment (167mg/100g) significantly reduced (<0.05) the phyate content. The phyate content of roasted pearl millet flour was the highest value from all others pearl millet flours (294.29mg/100g).

4.4. Effect of combined processing of pearl millet flours on the reduction of antinutritions

Tannin in combination effect: The tannin content of processed pearl millet flours were found to decrease during this study. Tannin content in raw pearl millet flour (control) was 3.64 mg/100g. The treatment 72 hours fermentation and germination decreased steadily the content of tannin values to 0.83 and 0.89 mg/100g, respectively. Similarly, the values of combination process effect were 1.98 and 1.78 mg/100g, for soaking 48 hours followed by 24 hours fermentation and germinating 48 hours followed by 24 hours fermentation, respectively. According to Shimelis and Rakshit *et al.,* (2008), decreased in tannin content during germination may be due to the leaching of tannins in the sprouting medium and decreased activity of polyphenol oxidase and other catabolic enzymes.

Table 4-5: Effect of combined pearl millet flours on reduction of antinutritional factors

Treatment	Tannin (mg/100g)	Phytate (mg/100g)
RPMF	3.64±0.18[a]	288.69±0.16[a]
$FMPF_{72}$	0.83±0.07[d]	167.14±0.13[e]
$GPMF_{72}$	0.89±0.01[d]	212.46±0.09[d]
$SPMF_{48}$+$FPMF_{24}$	1.98±0.02[b]	246.86±0.10[b]
$GPMF_{48}$+$FPMF_{24}$	1.78±0.03[c]	236.66±0.18[c]

All values are means of duplicate ± standard deviation
[a-e] Means with the same superscript letters within a column are not significantly different (p>0.05)
RPMF= Raw pearl millet flour, $GMPF_{72}$=Germinated pearl millet flour for72h,
$FPMF_{72}$=fermented pearl millet flour for 72h, $SPMF_{48}$+$FPMF_{24}$ = Soaking for 48h + fermenting for 24h, $GPMF_{48}$+$FPMF_{24}$ = Germinating for 48h+ fermenting for 24h.

Phytate in combination effect: Phytate level (mg/100 g) of raw pearl millet flour was found to be 288.69, while values 167.14 and 212.46 mg/100g were recorded for pearl millet flour samples fermented and germinated both for 72 hours, respectively. In addition, the values of combination process effect were 246.86 and 236.66 mg/100g, for soaking 48 hours followed by 24 hours fermentation and germinating 48 hours followed by 24 hours fermentation, respectively.

4.5. Bioavailability of minerals in pearl millet flours

4.5.1. The molar ratio between phytate and minerals of pearl millet flours

From Table 4.6 the molar ratio for phytate with calcium, magnesium, iron, and zinc content were analysed. Phytate contents ranged from 167mg/100g to 300mg/100g.

For calcium content, the highest value obtained was 4.35mg/100g and the lowest was 2.66mg/100g for raw and roasted pearl millet flour respectively. The molar ratios of phytate/calcium of all pearl millet flours were > 3.72. The molar ratio of phytate/calcium the lowest was 3.72 and the highest value obtained was 6.66 for autoclaved and roasted pearl millet flour respectively.

The range of magnesium content in pearl millet flours was between 52.23mg/100g to 67.35 mg/100g, the molar ratios of phytate/magnesium of all pearl millet flours were < 1.00. The molar ratio of phytate/magnesium the lowest was 0.11 and the highest value obtained was 0.20 for fermented and roasted pearl millet flour; respectively.

Table 4-6: The molar ratio between phytate and mineral of pearl millet flours

Treatment	Phytate/Ca	Phytate/Mg	Phytate/Fe	Phytate/Zn
RPMF	4.02^{c}	0.15^{ab}	1.09^{d}	6.24^{b}
RoPMF	6.66^{a}	0.20^{a}	2.84^{a}	8.33^{a}
FPMF	3.75^{d}	0.11^{b}	1.43^{c}	4.67^{e}
BMPF	4.50^{b}	0.12^{b}	1.71^{b}	5.20^{d}
APMF	3.72^{d}	0.13^{b}	1.78^{b}	5.76^{c}

All values are means of duplicate ± standard deviation
$^{a-e}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

While the content of iron range from 9.04mg/100g to 22.38mg/100g for pearl millet flours. Phytate:iron molar ratios >0.15 is indicator of low iron bioavailability Shimelis Tizazu *et al.*,(2009).The molar ratios of phytate/iron of all pearl millet flours were > 1.00 and the highest was for roasted pearl millet flour that was 2.84.

Phytate:zinc molar ratio is used to estimate the likely absorption of zinc from a diet. Diets with a phytate:zinc molar ratio greater than 15 have relatively low zinc bioavailability, those with phytate:zinc molar ratios between 5 and 15 have medium zinc bioavailability and those with a phytate:zinc molar ratio less than 5 have relatively good zinc bioavailability Shimelis Tizazu *et al.*,(2009).

A similar molar ratio for phytate/zinc of > 4.67 was obtained for fermented pearl millet flour was good bioavailability. The rest of the pearl millet flours were medium zinc bioavailability were between 5 and 15. These ratios predict that all the flour samples from pearl millet flours had good bioavailability of zinc.

This could be due to the high content of phytate in the flours which affects the mineral bioavailability of these flours. For zinc content, all pearl millet flour samples had medium bioavailability except for fermented pearl millet flours, which had a good bioavailability < 5 molar ratios of phytate/zinc.

A study by Shamsuddin *et al.,* (1999) had shown that only phytate in the form of inositol trisphosphate (IP3) could inhibit the absorption of minerals. In this paper, however, covered at the total phytate content and did not differentiate between the different classes of phytate. It is probable that the phytate present in the flours analysed was not in the form of IP3 that would inhibit the absorption of minerals.

4.5.2. Phytate phosphorus and non phytate phosphorous contents of pearl millet flour

Table 4-7: Phytate phosphorus and non phytate phosphorous contents of pearl millet flour

Treatment	Phytate (mg/100g)	Phosphorus (mg/100g)	Phytate Phosphorus (mg/100g)	Non-Phytate Phosphorus (mg/100g)	Proportion of phosphorus as phytate (%)
RPMF	288.69^{b}	290.04^{a}	81.35^{b}	208.69^{a}	28.05^{c}
RoPMF	294.29^{a}	223.49^{e}	82.93^{a}	140.56^{e}	37.10^{a}
FPMF	167.14^{e}	250.88^{b}	47.10^{e}	203.78^{b}	18.77^{e}
BMPF	208.17^{d}	230.29^{c}	58.66^{d}	171.63^{c}	25.47^{d}
APMF	246.29^{c}	228.39^{d}	69.40^{c}	158.99^{d}	30.38^{b}

All values are means of duplicate ± standard deviation
$^{a-e}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

Fermented, blanched, and autoclaved pearl millet flours were lowered the levels of phytate phosphorus in the sample with a parallel increase in non phytate phosphorus significantly ($p<0.05$) in the above Table 4.7. Thus, the hydrolytic reduction of phytic acid during processing may have contributed the bioavailability of phosphorous.

Generally, diets with phosphorus as phytate (%) ≤ 60% are regarded as being adequate in bioavailable phosphate (Melaku *et al.,* 2005). The whole processed and unprocessed pearl millet flours were the effect of phytate in bioavailability of phosphate.

Hence, this study showed that germination and fermentation made to have a significant proportion of phosphorus as phytate to diets. Malleshi and Desikachar (1986) conclude that, increase in lysine, tryptophan and ascorbic acid, and the decrease in phytate phosphorous form the important nutritional benefits of germination of millets.

4.6. Physicochemical and functional properties of pearl millet flours

4.6.1. Least gelation concentration of pearl millet flours at different concentrations

Gelation Concentration: The least gelation concentration of raw, roasted, fermented, blanched, and autoclaved pearl millet flours were shown in Table 4.8. The four types of raw, roasted, blanched, and autoclaved pearl millet flours were given no gel at concentration of 2%. Fermented pearl millet flour was shown that very strong gel at concentration of 8%.

At concentration of 10% (w/v) whole sample of pearl millet flours were showed that very strong gel. However, a least gelation concentration of 12% (w/v) for roasted pearl millet flour reported. Fasasi, *et al.*, (2009)

Table 4-8: Least gelation concentration of pearl millet flours at different concentrations

	Concentration (g PMF/100 ml water)				
Treatment	2%	4%	6%	8%	10%
RPMF	-	±	++	++	+++
RoPMF	-	±	++	++	+++
FPMF	±	±	++	+++	+++
BMPF	-	±	++	++	+++
APMF	-	-	+	++	+++

-No get, ± very weak gel, + weak gel, ++ strong gel, +++ very strong gel

Variations among the pearl millet samples were linked to the relative ratio of various constituents' protein, carbohydrates and lipids. Sathe *et al.*, (1982) Relevant to raw, roasted, blanched and autoclaved pearl millet flours the lower least gelation concentration may be because of their higher starch content, which induced gelation due to starch and/or starch protein interactions. Singh and Singh *et al.*, (1991)

4.6.2. Effect of blending on falling number and color of pearl millet flours

Falling number: The falling number of wheat and blend flours at different blending proportion was presented in Table 4.9. The falling number method indicates alpha amylase activity using the starch in the sample as substrate.

Table 4.9 indicated that for wheat flour as a control, and at different blending proportions with pearl millet including that a significant ($p<0.05$) effect on the reduction falling number by increased enzymatic activity of the flour, however, not significant ($p>0.05$) in the case of blended pearl millet fermentation at 10% and 15% proportions. The hundred percentage of blanched and fermented flours as well very significantly ($p<0.05$) decreased a falling number to 189 and 179 respectively. Normally, bakery type wheat flour has a falling number between 200 and 300. When the falling number lies below 150, there is great danger that the bread crumb will be sticky, when the falling number is greater than 350, bread volume is diminished and a dry crumb results, unless the defect is balanced by the addition of malt (Herald *et al.*, 1964). Value below 200 seconds indicates that high levels of enzyme activity (Bekele *et al*., 2009). From these results might be concluded that bread quality was significantly affected when blended of blanched and fermented pearl millet flour to wheat flour.

Table 4-9: Effect of blending on falling number and color of pearl millet flours

Sample code	Moisture content	Falling number	Liquefaction number	Color of flours
100% WF (control)	9.55±0.02[e]	264.85±0.70[a]	28.0[g]	0.65
95%WF+5% FPMF	9.68±0.00[d]	255.74±0.69[b]	29.3[f]	1.08
90%WF+10% FPMF	9.77±0.03[c]	249.70±0.63[c]	30.2[e]	1.13
85%WF+15% FPMF	10.31±0.00[a]	248.94±0.77[c]	30.3[e]	1.24
100% (FPMF)	10.32±0.01[a]	189.70±0.63[g]	43.2[b]	16.5
95%WF+5% BPMF	9.67±0.02[d]	244.70±2.12[d]	30.9[d]	1.23
90%WF+10% BPMF	9.79±0.03[c]	241.07±1.59[e]	31.4[cd]	1.45
85%WF+15% BPMF	10.08±0.00[b]	238.11±1.49[f]	31.9[c]	2.05
100% (BPMF)	10.32±0.00[a]	179.31±0.20[h]	46.5[a]	17.6

All values are means of duplicate ± standard deviation
[a-h] Means with the same superscript letters within a column are not significantly different ($p>0.05$)
FPMF= Fermented pearl millet flour, BPMF= Blanched pearl millet flour and WF= Wheat flour

Liquefaction number: The value of the liquefaction for blend fermented pearl millet flour is range from 28.0 to 43.2, and 43.2 indicates that the value for 100% of fermented pearl millet flour was significantly ($p<0.05$) increased. While, the liquefaction number value of control to blend blanched pearl millet flours were range from 28.0 to 46.5 and the highest liquefaction number values 46.5 also belongs to the 100% blanched pearl millet flour.

Generally, when compared the fermented pearl millet flours with the blanched pearl millet flours the values of liquefaction number were greater for the blanched pearl millet flours. The linear relation between "liquefaction number" and "percentage compositions of wheat flour (WF)" as is evident from figure 4.1 also indicted that the values of the blended blanched pearl millet four were greater than the values of the blended fermented pearl millet flours.

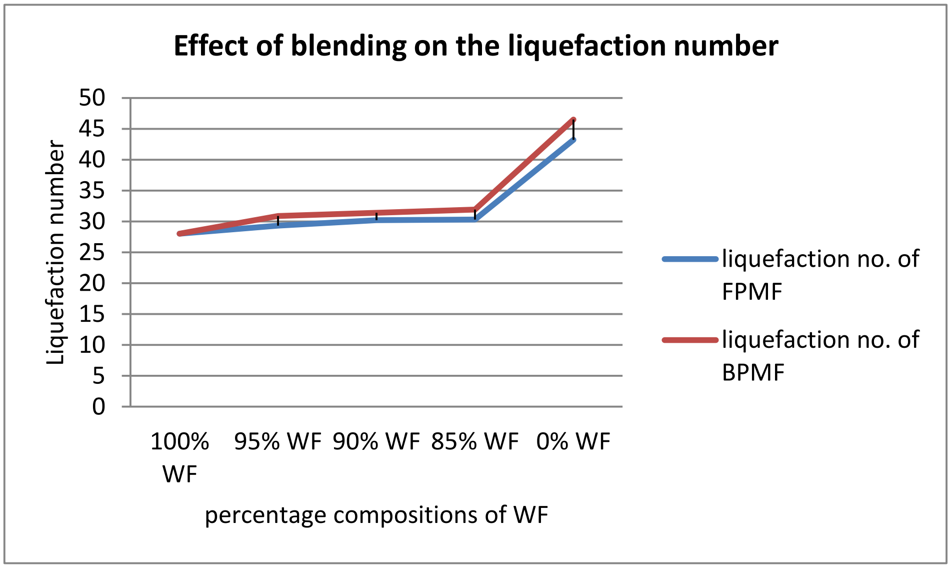


Figure 4-1: Linear relation of liquefaction number with percentage compositions of wheat flour (WF)

Color of flours: The color grade value of the flour sample was measured to see the effect of processing methods on color change. The color grade of flours with 100% wheat flour and 100% of fermented pearl millet flours were 0.65 and 16.5 having the highest and lowest values respectively. In addition to these the substituted fermented pearl millet flours value of color increase also increase the fermented flour proportions in the wheat flour. Blanched pearl millet flours the color ranged from 0.65 to 17.6 that indicated the color of the flours increase with increased the blended proportions. In a case of blanched pearl millet flours the partial non-enzymatic browning which might have occurred during processing blanched of pearl millet grains. The mean reasons for higher the color value of 100% FPMF and 100% BPMF is due to the presence of the outer coating of the grains.

4.6.3. Effect of blending on pH and Total Titratable Acidity (TTA) of pearl millet flours

Table 4.10 shows the effect of blending on by pH and Total Titratable Acidity (TTA) of fermented and blanched pearl millet flours.

The pH: The pH drop of 100%, wheat flour (control) was found to be 5.28 and for 5%, 10%, 15%, and 100% fermented pearl millet flour substitutions the values were 4.32, 4.25, 4.06 and 3.36, respectively. These results also agree with those obtained by (Giese *et al.,* 1994) who reported that, as a result of fermentation, acidity increased and pH falls down and this enhanced the keeping quality of pearl millet foods, by inhibiting microbial growth and also contributing to the flavour of processed pearl millet. Similarly, the pH drop of 100%, wheat flour (control) was found to be 5.28 and for 5%, 10%, 15%, and 100% blanched pearl millet flour substitutions the values were 5.02, 4.36, 4.17 and 3.80, respectively.

Table 4-10: Effect of blending on pH and Total Titratable Acidity (TTA) of pearl millet flours

Sample code	pH	Reduction $^{\Psi}$ (%)	TTA (as % of lactic acid)	Reduction $^{\Phi}$ (%)
100% WF (control)	5.28±0.01^{a}	_	1.09±0.02^{f}	_
95%WF+5% FPMF	4.32±0.01^{c}	18.18	1.20±0.01^{e}	9.17
90%WF+10% FPMF	4.25±0.02^{d}	19.50	1.63±0.02^{d}	33.12
85%WF+15% FPMF	4.06±0.01^{f}	23.10	2.35±0.08^{b}	46.38
100% (FPMF)	3.36±0.07^{h}	36.36	3.14±0.03^{a}	65.28
95%WF+5% BPMF	5.02±0.03^{b}	0.05	1.10±0.03^{f}	0.91
90%WF+10% BPMF	4.36±0.01^{c}	17.42	1.21±0.02^{e}	9.92
85%WF+15% BPMF	4.17±0.02^{e}	21.02	1.27±0.03^{e}	14.17
100% (BPMF)	3.80±0.03^{g}	28.03	2.05±0.02^{c}	46.83

All values are means of duplicate ± standard deviation
$^{a\text{-}h}$ Means with the same superscript letters within a column are not significantly different ($p>0.05$)
FPMF= Fermented pearl millet flour, BPMF= Blanched pearl millet flour and WF= Wheat flour
Reduction $^{\Psi}$= indicates% decreased over wheat flour (control) value
Reduction $^{\Phi}$ = indicates% increased over wheat flour (control) value

Total Titratable Acidity (TTA): TTA also increased from 1.09 to 3.14, that 1.09, 1.20, 1.63, 2.35 and 3.14 g lactic acid/100 g for 100%,wheat flour to 5%, 10%, 15%, 100% fermented pearl millet flour substitutions, respectively. TTA was associated with the drop in pH there was a rise in TTA of cereal flours throughout the fermentation process (Singh and Yadav *et al.,* 2012). Likewise, TTA for blanched pearl millet flour were also increased from 1.09 to 2.05, that 1.09, 1.10, 1.21, 1.27 and 2.05 g lactic acid/100 g for 100% wheat flour to 5%, 10%, 15%, 100% blanched pearl millet flour substitutions, respectively.

4.6.4. Functional properties of pearl millet flours

The functional properties of pearl millet flours were the combination of properties which determine products quality and process effectiveness. These properties differ greatly for different raw materials and processes, and may be measured by chemical analysis or process testing Brennan *et al.,* (2006). Hence some of the functional properties of the flours such as water absorption capacity, oil absorption capacity, bulk density and Dispersibility of the flours were analyzed and the result is presented in the Table 4.11 given below.

Table 4-11: Functional properties of pearl millet flours

Treatment	WAC(ml/100g)	OAC(ml/100g)	BD(g/ml)	Dispersibility (%)
Raw PMF (control)	120.15 ± 0.96^{b}	119.02 ± 0.63^{b}	3.48 ± 0.22^{a}	62.3 ± 0.05^{b}
Roasted PMF	169.62 ± 0.11^{a}	157.42 ± 0.52^{a}	2.80 ± 0.76^{b}	74.2 ± 0.23^{ab}
Fermented PMF	107.65 ± 1.10^{c}	112.77 ± 0.21^{b}	3.49 ± 0.24^{a}	84.3 ± 0.45^{a}
Bleached PMF	116.18 ± 0.24^{bc}	115.55 ± 0.34^{b}	2.54 ± 0.05^{b}	82.1 ± 0.02^{a}
Autoclaved PMF	165.21 ± 0.67^{a}	150.77 ± 0.36^{a}	2.24 ± 0.22^{c}	76.3 ± 0.12^{a}

All values are means of duplicate ± standard deviation
a-c Means with the same superscript letters within a column are not significantly different (p>0.05)
WAC- water absorption capacity, OAC- oil absorption capacity and BD- bulk density.

Water Absorption Capacity (WAC): In respect to WAC, values obtained were 120.15, 169.62, 107.65, 116.18 and 165.21 ml/100g for raw, roasted, fermented, blanched and autoclaved pearl millet flours, respectively. No significant difference (P<0.05) was observed between the roasted and autoclaved pearl millet flours. For fermented pearl millet flour, was the lowest WAC compared to the others. Raw and blanched pearl millet flours were 120.15 and 116.18 ml/100g, respactivly had medium WAC with respect to the others.

Oil Absorption Capacity (OAC): The three layers of raw, fermented, and blanched pearl millet flours were found to have OAC of 119.02, 112.77 and 115.55ml/100g, respectively. Lower with respect to the others, which could probably be due to elimination of fiber and reduction of protein during isolation of the laboratory starch.

The two layers obtained from roasted and autoclaved pearl millet flours showed 157.42 and 150.77ml/100g OAC, respectively were no significant difference (P<0.05) observed.

Oil absorption capacities varying from 0.55 to 2.7 g oil/g were formerly reported for pearl millet flour and products Oshodi *et al.,* (1999). The two layers roasted and autoclaved pearl millet flours were highest oil absorption capacities (OAC). It seems that the high protein and fiber content the greater its OAC.

Bulk Density (BD): The bulk density of raw, roasted, fermented, blanched and autoclaved pearl millet flour layers obtained from processed and unprocessed pearl millet flours were found to be 3.48, 2.80, 3.49, 2.54 and 2.24 g/ml, respectively. For pearl millet flour, 1 g/ml bulk density was reported Akubor and Obiegbuna *et al.,* (1999) The mean separation showed that there were without significant difference (P<0.05) in bulk density for roasted and blanched pearl millet flours, while raw and fermented pearl millet flours sample treatment method showed a bit significantly (P<0.05) highest bulk density compared to the others.

This may be due to the higher moisture content, resulting in dense packing of the starch particles Venktesh and Prakash *et al.,* (1993) in addition to the higher and greater regulatory in shape of the starch granules. Autoclaved pearl millet flour showed that the least bulk density compared to the others 2.24g/ml.

Dispersibility: For the last layer autoclaved pearl millet flour showed the least dispersibility (68.4%), which is significantly (P<0.05) lower compared to that of raw pearl millet flour(71.3%) and roasted pearl millet flour (79.9%). No significant (P<0.05) difference were found between fermented and blanched pearl millet flours (85.5%) and (82.7%) respectively.

4.7. Characteristics of some value added products of pearl millet

The viscosities of thin porridges prepared from fermented and blanched pearl millet flour determined at 50^0C at 15% and 5% dry matter concentration (DMC) were presented in Tables 4.12 and 4.13.

4.7.1. Viscosity of fermented thin porridge at 15% and 5% dry matter concentration

Fermented thin porridge viscosity: At 15% and 5% dry matter concentrations, viscosity in milli Pascal second (mpa-s) was highest for thin porridge prepared from unfermented pearl millet flour 7389.74m Pa-s and 3983.73m Pa-s respectively, At 15% dry matter concentration, the viscosity values of thin porridge prepared from substituted fermented pearl millet flour ranged from 5433.57m Pa-s to 4993.76m Pa-s, while at 5% dry matter concentration viscosity of thin porridge prepared from substituted fermented pearl millet flour ranged from 1837.51m Pa-s to 1537.38m Pa-s. These results indicated that the concentrations of the flours were affecting the viscosity food material. The viscosity can be used to test the thickening potentiality of food materials to be used in fluid foods and beverages (Kinsella *et al.*, 1979).

Table 4-12: Effect of blending on viscosity of thin porridge prepared from fermented pearl millet flours

Sample code	Viscosity (mPa-s) at 15% DMC*	Viscosity (mPa-s) at 5% DMC*
100% control	7389.74[a]	3983.73[a]
75% plain	5433.57[b]	1837.51[b]
50% plain	5313.09[b]	1598.32[b]
25% plain	5272.83[b]	1573.21[b]
100% fermented	4993.76[c]	1537.38[b]

Values within the same column with different superscript letters are significantly different from each other ($p < 0.05$). *DMC=dry matter concentration

4.7.2. Viscosity of blanched thin porridge at 15 and 5% dry matter concentration

Blanched thin porridge viscosity: At 15% and 5% dry matter concentrations was highest for thin porridge prepared from unbalanced pearl millet flour 7384.43m Pa-s and 3980.30m Pa-s respectively, At 15% dry matter concentration, the viscosity values of thin porridge prepared from blended balanced pearl millet flour ranged from 5914.72m Pa-s to 5435.56mPa-s, while at 5% dry matter concentration viscosity of thin porridge prepared from blended balanced pearl millet flour ranged from 1946.23m Pa-s to 1556.49m Pa-s. In addition, the values may indicated that as a concentration of blanched pearl millet flours increases in unfermented pearl millet flour the viscosity of thin porridge were decreases.

Table 4-13: Effect of blending on viscosity of thin porridge prepared from blanched pearl millet flours

Sample code	Viscosity (mPa-s) at 15% DMC*	Viscosity (mPa-s) at 5% DMC*
100% control	7384.43[a]	3980.30[a]
75% plain	5914.72[b]	1946.23[b]
50% plain	5744.30[b]	1877.77[b]
25% plain	5612.91[b]	1747.47[b]
100% blanched	5435.56[b]	1556.49[b]

Values within the same column with different superscript letters are significantly different from each other ($p < 0.05$). *DMC=dry matter concentration

4.7.3. Loaf volume and specific volume of bread

The loaf weight of the sample breads were taken as an average 110g weight. In Table 4.14 discussed loaf volume and specific volume of bread.

As the level of pearl millet flour in the blend was increased, loaf volume of bread decreased subsequently. A significant reduction in loaf volume was recorded in blend at a substitution level of 5%, 10%, and 15%. Highest loaf volume was given by control bread prepared from wheat flour while the lowest loaf volume 134 ml was given by bread prepared from flour containing 100% blanched pearl millet flour. Partial substitution of composite flour into bread formulation in amounts that are of health benefits can be expected to exert detrimental effects on the physical characteristics in term of loaf yield, loaf volume, texture and flavor (Katina *et al.*, 2003).

Specific volume of bread: Results of specific volume indicate a decrease in specific volume on increasing the level of substitution of pearl millet flour of any type. Maximum specific volume (4.1ml/g) was given by wheat flour while the minimum specific volume (1.2 ml/g) was obtained at 100% of blanched pearl millet flour based bread. The results of the specific volume of bread found in this study indicated that there was a substantial decrease in the specific volume of bread when it was supplemented with any type of pearl millet flour irrespective of level of supplementation. This result was similar to the report of Harinder and Sharma, 1999; Mubarak, 2001; Badifu *et al.,* 2005; Mepba *et al.,* 2009, for pigeon pea, lupin seed. Mango and cowpea flour supplemented bread.

Table 4-14: Effect of blending on loaf volume and specific volume of bread

Sample code	Loaf volume of bread (ml)	Specific volume of bread (ml/g)
100% WF (control)	451^{a}	4.1
95% WF + 5% FPMF	437^{b}	3.9
90% WF + 10% FPMF	407^{d}	3.7
85% WF + 15% FPMF	396^{e}	3.6
100% FPMF	148^{h}	1.3
95% WF + 5% BPMF	429^{c}	3.9
90% WF + 10% BPMF	392^{f}	3.7
85% WF + 15% BPMF	380^{g}	3.4
100% BPMF	134^{i}	1.2

All values are means of duplicate ± standard deviation
$^{a-i}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

4.8. Sensory quality analysis of value added products

4.8.1. Sensory quality of thin porridge

- **Fermented pearl millet thin porridge**

The color of the thin porridge made from 100% and 75% unfermented pearl millet flours were most preferred (liked very much) by the panelists. In addition, the thin porridge prepared from 50% and 25% unfermented pearl millet flours were preferred (liked moderately) for color. While, a thin porridge from 100% fermented pearl millet flour was preferred (neither liked nor disliked).

For flavor, highest values were obtained for thin porridge prepared from unfermented pearl millet flour were preferred 100%,75% and 50% (liked very much) by the panelists. Panelists liked moderately the flavor of thin porridge prepared from 25% unfermented pearl millet flours. While a thin porridge prepared from the 100% fermented pearl millet flour was preferred (neither liked nor disliked).

The odor of thin porridge prepared from 100%, 75%, and 50% unfermented pearl millet flour were most preferred (liked very much). Thin porridge prepared from 25% unfermented and 100% fermented pearl millet flour were least preferred for the odor (liked slightly and neither liked nor disliked, respectively).

Texture for the unfermented pearl millet flour thin porridge prepared from 100% and 75% were most preferred (both liked very much). While, a texture of thin porridge prepared from 50% unfermented pearl millet flour was liked moderately by panelists. The texture of 25% unfermented pearl millet flour thin porridge was preferred (neither liked nor disliked). In addition, for 100% pearl millet flour fermented thin porridge was least acceptable (disliked slightly).

Overall acceptability of thin porridge prepared from 100%, 75% and 50% unfermented pearl millet flours were most accepted (moderately accepted). For acceptability, thin porridge prepared from 25% fermented pearl millet flour was (slightly accepted). While the thin porridge prepared from the 100% fermented pearl millet flour was preferred (neither accepted nor unaccepted).

Table 4-15: Effect of blending on mean scores of sensory evaluation and overall acceptability of fermented pearl millet based thin porridge

Sample code	Color	Flavor	Aroma	Texture	Acceptability
100% (control)	7.89^a	7.45^a	7.14^a	8.01^a	7.56^a
75% plain	7.21^a	7.60^a	7.63^a	7.72^a	7.63^a
50% plain	6.94^b	7.39^a	7.36^a	6.93^b	7.45^a
25% plain	6.64^b	6.88^b	6.82^b	6.56^b	6.95^b
100% (fermented)	4.43^c	5.08^c	5.07^c	4.17^c	5.12^c

Values within the same column with different superscript letters are significantly different from each other (at $p< 0.05$)

- **Blanched pearl millet thin porridge**

The color of the thin porridge made from 100% fermented pearl millet flour was least preferred (disliked moderately) by the panelists, while the thin porridge prepared from 25% unfermented pearl millet flour was preferred for color (liked slightly) and for the thin porridge prepared from 50%,75% and 100% unfermented pearl millet flour was most preferred (liked moderately).

The highest values were obtained for thin porridge prepared from 100% and 75% unfermented pearl millet flour (both liked moderately). Panelists liked slightly the flavor of thin porridge prepared from 50% and 25% unfermented pearl millet flours. While the thin porridge prepared from 100% fermented pearl millet flour was the least preferred (neither liked nor disliked).

The aroma of thin porridge prepared from 100% and 75% unfermented pearl millet flour were most preferred (both liked slightly). While the thin porridge prepared from 50% and 25% unfermented pearl millet flours were preferred (neither liked nor disliked). Thin porridge prepared from 100% fermented pearl millet flour was least preferred for the aroma (disliked slightly).

Table 4-16: Effect of blending on mean scores of sensory evaluation and overall acceptability of blanched pearl millet based thin porridge

Sample code	Color	Flavor	Aroma	Texture	Acceptability
100% (control)	6.85^{a}	7.47^{a}	6.32^{a}	7.59^{a}	7.28^{a}
75% plain	6.65^{a}	7.68^{a}	6.02^{a}	7.28^{a}	7.09^{a}
50% plain	6.20^{a}	6.32^{b}	5.78^{b}	6.75^{b}	6.85^{b}
25% plain	5.62^{b}	6.17^{b}	5.47^{b}	6.30^{b}	6.46^{b}
100% (blanched)	3.90^{c}	5.30^{c}	4.90^{c}	3.87^{c}	4.35^{c}

Values within the same column with different superscript letters are significantly different from each other (at $p < 0.05$)

Texture for the 100% and 75% unfermented pearl millet flours thin porridge were the most preferred (both liked moderately). The texture of thin porridge prepared from 50% and 25% unfermented pearl millet flours were preferred (both liked slightly). In addition, the value of thin porridge prepared from 100% fermented pearl millet flour was least preferred (disliked moderately).

Overall acceptability of thin porridge prepared from 100% and 75% unfermented pearl millet flours were most accepted (moderately accepted). For acceptability, thin porridge prepared from 50% and 25% fermented pearl millet flours were (both slightly accepted). While, the value for 100% fermented pearl millet flour thin porridge was least acceptable, which was called disliked moderately.

4.8.2. Sensory quality of bread

Sensory evaluation is an important criterion for quality assessment in new product development and to meet the consumer requirements. Any new product must give satisfaction and pleasure to the consumers if it has to be a part of their eating habits. For this reason, bread prepared from blends of wheat flour with pearl millet flours are evaluated for various sensory attributes.

- **Fermented pearl millet bread**

Table 4-17: Effect of blending on mean scores of sensory evaluation and overall acceptability of fermented pearl millet based bread

Sample code	Color	Flavor	Aroma	Texture	Acceptability
100% WF(control)	8.52^{a}	8.73^{a}	8.34^{a}	8.06^{a}	8.76^{a}
95% WF to 5% FPMF	8.46^{a}	8.60^{b}	8.25^{b}	7.43^{b}	8.13^{b}
90% WF to 10% FPMF	6.53^{b}	7.19^{c}	7.56^{c}	7.04^{c}	7.65^{c}
85% WF to 15% FPMF	5.64^{c}	6.59^{d}	7.35^{d}	6.78^{d}	7.25^{d}
100% FPMF	1.02^{d}	2.02^{e}	3.03^{e}	1.02^{e}	4.06^{e}

WF = wheat flour, FPMF = fermented pearl millet flour
Values within the same column with different superscript letters are significantly different from each other (at $p < 0.05$)

Color of the bread changed from creamy white to brown as the blended level of pearl millet flour was increased. Significant decrease in color value was observed with increase in the level of replacement of fermented pearl millet flours. The effect of blending, on the color of bread was more noticeable when 100% of fermented pearl millet flour were used and its color was dark brown. However, for the 100% wheat flour and 5% of substitution of fermented pearl millet flour no significant differences were observed 8.52 and 8.46, respectively in the bread color. It was observed that at substitution level of 10% and 15%, the color become brown and the value were 6.53 and 5.64, respectively. The brown color may be attributed due to the greater amount of maillard reaction between reducing sugars and proteins.

Value for flavor of bread samples at a substitution level of 10% and 15% decreased significantly ($p<0.05$). However, wheat blend with fermented pearl millet show a satisfactory taste score up to 15% level of substitution. Highest taste value 8.73 was gained by control while the bread containing 100% fermented pearl millet flour was assigned the lowest taste score 2.02. It is obvious from the results that the flavor values for bread decreased proportionally with increasing levels of fermented pearl millet flour in wheat flours.

The aroma value decreased on increasing the level of blending of fermented pearl millet flour. The highest value for aroma 8.34 was gained by bread prepared from 100% wheat flour. The higher values of 10% and 15% blended fermented pearl millet flour bread were 7.56 and 7.35, respectively. While the lowest aroma value 3.03 was obtained by bread prepared from flour containing 100% fermented pearl millet flour. The effect of blending, on the aroma of bread was more pronounced when higher proportions of fermented pearl millet flour were used. This was primarily due to the aroma difference of wheat flour as compared to fermented pearl millet flour.

Texture values also decreased with increase in the substitution of fermented pearl millet flour as compared to control bread. Among the blended bread the higher score was obtained by bread at 5% substitution level. Texture score was decreased significantly at a substitution level of 10% and 15% and the values were optioned 7.04 and 6.78 respectively. It is revealed from the results that the highest texture score 8.06 was assigned to control while lowest texture score 1.02 was obtained by bread prepared from flour containing 100% fermented pearl millet flour.

Acceptability of the bread for the control bread and 5% substitution of fermented pearl millet flours were highly acceptable by the panelists. However, wheat blend with pearl millet show a moderately acceptable values 10% and 15% level of substitution. While the slightly unacceptable bread prepared from flour containing 100% fermented pearl millet flour.

- ♦ **Blanched pearl millet bread**

Color value of substituted blanched pearl millet breads were range between 8.52 and 1.02, which indicated the value of control 8.52 was the highest and the value of 100% blanched pearl millet flour bread was 1.02. However, for the 5%, 10% and 15% of substituted blanched pearl millet flour breads the values were significant decreased 6.61, 6.45 and 5.74 respectively.

The reason can be explained by Maillard reaction. The Maillard reaction is quite universal in the food industry, and this reaction occurs, when most foods are heated and results in reactions that promote browning of cookies, bread, and other baked goods (Trierum *et al.,* 2004).

Table 4-18: Effect of blending on mean scores of sensory evaluation and overall acceptability of blanched pearl millet based bread

Sample code	Color	Flavor	Aroma	Texture	Acceptability
100% WF(control)	8.52^{a}	8.73^{a}	8.34^{a}	8.06^{a}	8.76^{a}
95% WF to 5% BPMF	6.61^{b}	7.65^{b}	6.53^{b}	7.88^{b}	8.13^{b}
90% WF to 10% BPMF	6.45^{c}	6.13^{c}	6.26^{c}	7.58^{c}	7.75^{c}
85% WF to 15% BPMF	5.74^{d}	5.09^{d}	5.98^{d}	6.78^{d}	7.65^{d}
100% BPMF	1.02^{e}	1.04^{e}	2.02^{e}	1.03^{e}	3.00^{e}

WF = wheat flour, BPMF = blanched pearl millet flour
Values within the same column with different superscript letters are significantly different from each other (at $p< 0.05$)

Value for flavor of bread samples at different substitution level of 5%, 10% and 15% decreased significantly ($p<0.05$) were 7.65, 6.13, 5.09, respectively. However, wheat blend with blanched pearl millet show a satisfactory flavor score up to 10% level of substitution. Highest taste value 8.73 was gained by control while the bread containing 100% blanched pearl millet flour was assigned the lowest flavor value 2.02. It is obvious from the results that the flavor values for bread decreased proportionally with increasing levels of blanched pearl millet flour in wheat flours.

The aroma of bread samples value decreased when increased the level of substituted blanched pearl millet flour used in preparation of bread. The values for 5%, 10% and 15% substituted blanched pearl millet flour bread were 6.53, 6.26 and 5.98, respectively. While the lowest aroma value 2.02 was obtained by bread prepared from flour containing 100% blanched pearl millet flour. The effect of blending, on the aroma of bread was more pronounced when higher proportions of blanched pearl millet flour were used. This was primarily due to the aroma difference of wheat flour as compared to blanched pearl millet flour. .

The texture of samples ranged from 8.06 to 1.03 with the highest obtained in the control and lowest in the 100% substituted composite blanched pearl millet flour bread. The texture value of breads for 5%, 10%, and 15% substitution were 7.88, 7.58, and 6.78 respectively. This suggests that the quality of bread that can be produced from wheat pearl millet flours mixtures depends on the level of substitution.

Acceptability of the bread for the control and 5% substitution of blanched pearl millet flour breads were highly acceptable by the panelists. However, wheat composed with 10% and 15% blanched pearl millet flour breads was moderately acceptable. While the moderately unacceptable bread prepared from 100% blanched pearl millet flour.

CHAPTER FIVE

Suggested Process Technology for Production of Pearl Millet Based Bread

5.1. Bread processing

Bakery is a traditional activity and occupies an important place in food processing industry. Despite the advent of fully automatic and semi-automatic bread as well as biscuit making plants, a sizeable number of people still prefer fresh bread and other products from bakery. With growing population and preference for fresh and ready-to-eat convenient food items, demand for bakery products is steadily increasing.

There are many bakery products like bread and its different variants, biscuits, cakes & pastries, cookies, puffs etc. having ready market round the year. Each product enjoys a very wide range in terms of size or weight, flavors, end-use and so on.

Breads were prepared using pearl millet and wheat flours and other ingredients like sugar, milk powder, active dry yeast, baking powder and salt. The flour particle size of the ingredients was less than 250µm and obtained by using sieving screen. Individual mixing and baking of twenty experimental run samples of bread was done and finally its quality evaluation and sensory characteristics were evaluated. The breads prepared were circular in shape with variable thickness. The bread were baked in an oven at 250 ^{0}C for 30min, cooled and packaged in LDPE bags of thickness 0.1016 mm and stored in airtight containers for further studies.

5.2. Material and energy balance on major unit operations

Material quantities, as they pass through processing operations, can be described by material balances. Such balances are statements on the conservation of mass. Similarly, energy quantities can be described by energy balances, which are statements on the conservation of energy. If there is no accumulation, what goes into a process must come out. This is true for batch operation. It is equally true for continuous operation over any chosen time interval.

Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products. The first material balances are determined in the exploratory stages of a new process, improved during pilot plant experiments when the process is being planned and tested, checked out when the plant is commissioned and then refined and maintained as a control instrument as production continues. When any changes occur in the process, then the material balances need to be determined again.

The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product.

Material and energy balances can be simple, at times they can be very complicated, but the basic approach is general. Experience in working with the simpler systems such as individual unit operations will develop the facility to extend the methods to the more complicated situations, which do arise. The increasing availability of computers has meant that very complex mass and energy balances can be set up and manipulated quite readily and therefore used in everyday process management to maximise product yields and minimise costs.

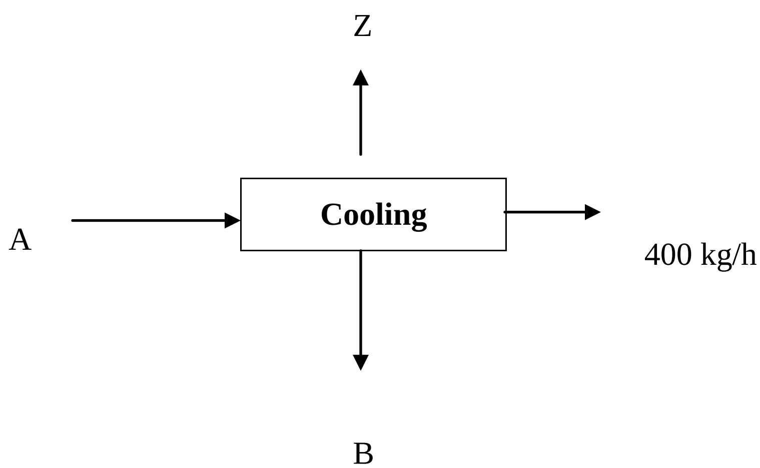
5.2.1. Material balance

- Bread moisture content before cooling = 40%
- Final bread moisture content = 36.6%
- Dry matter content of bread = 63.4%
- Bread dough moisture content = 63.71%

It is recommended to install bread making capacity of machine is 6,400kg/ day considering 300 working days and 16h per day. So in order to calculate in an hourly basis, divided its production capacity by 16h:

$$\frac{6{,}400\text{kg/day}}{16\text{h/day}} = 400 \text{ kg/h}$$

- **Material balance during cooling and packaging of bread**



Moisture = 40% | Moisture = 36.6%

Dry matter content = y | Dry matter content = 63.4%

Where: - A = Bread leaving from oven

B = Moisture content out from bread

Z= Total baking loss = 4% of 400 kg/h = 16kg/h

General A = B + 16kg/h + 400kg/h

A – B = 416kg/h- (1)

Moisture (A* 0.4) – B = (400* 0.366) + (16* 0.366)

(A* 0.25) – B = 152.256- (2)

Substituting equation 1 into equation 2

(416+B)*0.4 – B = 152.256

166.4 + 0.4B – B =152.256

0.6B = 14.144

B = 23.57 kg/h - (3)

Substituting equation 3 in to equation 1

A = 416 + 23.57

A = 439.57 kg/h - (4)

Dry matter

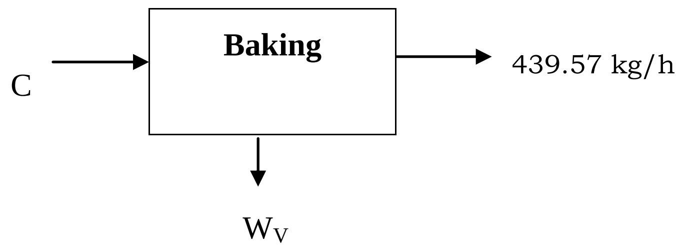
A*Y = (400* 0.634) + (Z* 0.634)

A*Y = (400*0.634) + (16*0.634)

A*Y= 253.6 + 10.14 = 263.74

Y = 59.99% - (5)

- **Material balance during baking (oven drying) of bread**



Moisture = 63.71%   Moisture = 40%

Dry matter = K   Dry matter content = 59.99%

Where: - C= Divided and rounded dough

W_V = water vapor

<u>General</u>   C = Wv + A - (1)

<u>Moisture</u> C* 0.6371 = Wv +A*0.4

C* 0.6371 = Wv + 175.82 - (2)

<u>Dry matter</u>   C* K = A* 0.5999 - (3)

Substituting the value A into equation 1

C = Wv + 439.57 - (4)

In equations (2 & 4) having two unknowns Wv and C then solve this two equation simultaneously.

Substituting equation 4 into equation 2

(Wv + 439.57)*0.6371 = Wv + 175.82

0.6371 Wv + 280.05 = Wv + 175.82

0.3629Wv = 104.23

Wv = 287.11 kg/h - (5)

Substituting equation 5 into equation 4

C = Wv + 432.13

C = 287.11 + 439.57

C = 726.68 kg/h - (6)

Substituting equation 6 into equation 3

C*K = A * 0.5999

726.68*K = 439.57 * 0.5999

726.68*K = 263.69

K = 36.28% - (7)

- **Material balance during Dividing and Rounding**

Moisture content = N — Moisture content = 63.71 %

Dry matter content = M — Dry matter content (K) = 36.28%

Where D = Dough mass

General D = C

D = 726.68 kg/h

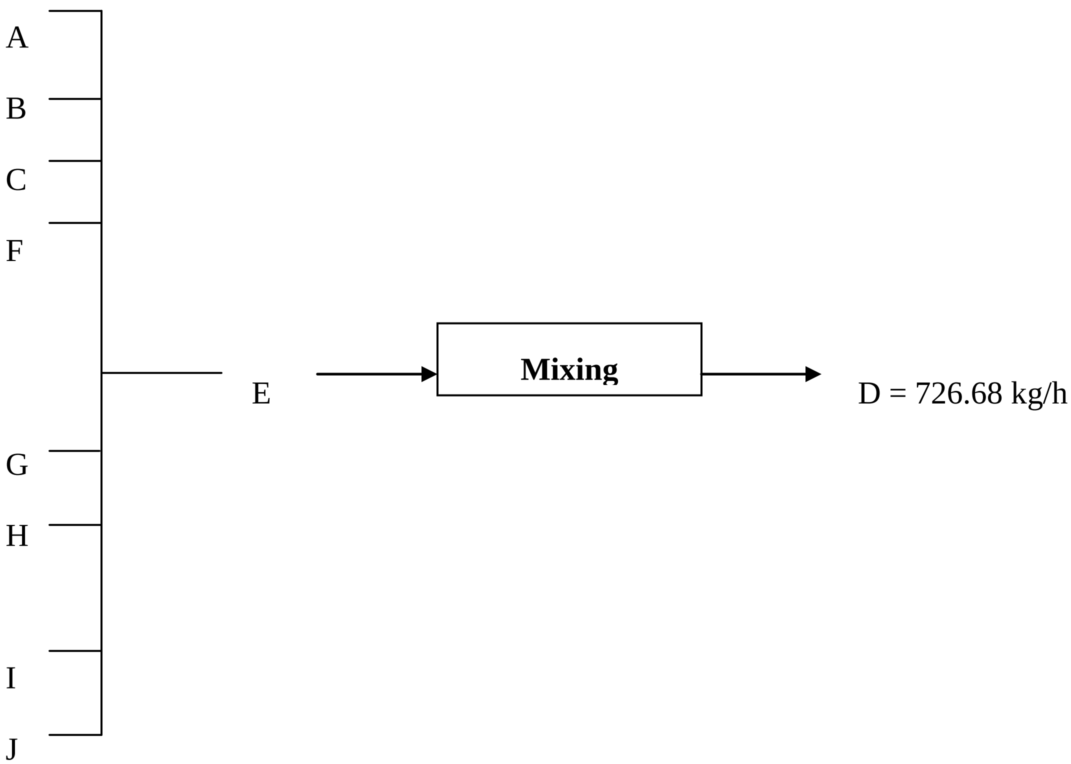
Moisture D* N= C* 0.6371

N = 63.71%

Dry matter D *M = C* K

M = K = 46.28%

- **Material balance during mixing of ingredients**



This material balance was done for wheat to pearl millet flour proportion of 95%:5%

Where A = Wheat flour = $\frac{95}{100} * 56$ =53.20 % * E -(1)

B = Pearl millet flour = $\frac{5}{100} * 56$ = 2.80% * E -(2)

C= Salt= 1.0% * E -(3)

F= Shortening = 1.6%*E -(4)

G =Active dry yeast =1.0%* E - (5)

H= Water = 36%*E - (6)

I = Sugar = 3.4% *E - (7)

J = Skim milk powder =1% *E - (8)

General $E - D = 0$

$E = D$

$E = 726.68$ kg/h - (9)

Substituting equation (9) into equation 1

$A = \frac{53.2}{100} * 726.68$ kg/h $= 386.59$ kg/h - (10)

Substituting equation (9) into equation 2

$B = \frac{2.80}{100} * 726.68$ kg/h $= 20.347$ kg/h - (12)

Substituting equation (9) into equation 3

$C = \frac{1.0}{100} * 726.68$ kg/h $= 7.2668$ kg/h - (13)

Substituting equation (9) into equation 4

$F = \frac{1.6}{100} * 726.68$ kg/h $= 11.62$ kg/h - (14)

Substituting equation (9) into equation 5

$G = \frac{1.0}{100} * 726.68$ kg/h $= 7.2668$ kg/h - (15)

Substituting equation (9) into equation 6

$H = \frac{36}{100} * 726.68$ kg/h $= 261.6$ kg/h - (16)

Substituting equation (9) into equation 7

$I = \frac{3.4}{100} * 726.68$ kg/h $= 24.71$ kg/h - (17)

Substituting equation (9) into equation 8

$J = \frac{1.0}{100} * 726.68$ kg/h $= 7.2668$ kg/h - (18)

5.2.2. Energy balance

The dough could be heated by electricity, gas, fuel, oil or steam but for this project electric heating was chosen by its economic advantage and ease of maintenance.

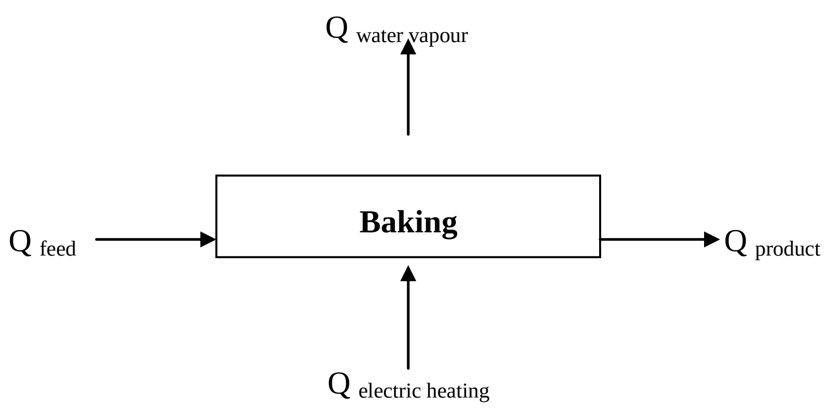
Cp of dough = 2880 J/kg.k

Cp of bread = 1880 J/kg.k

$m_{feed/dough}$ = 726.68 kg/h

$m_{product\ /bread}$ = 439.57 kg/h

$m_{water\ vapor}$ (Wv) = 287.11 kg/h



General

$Q_{feed} + Q_{electric} = Q_{water\ vapor} + Q_{product}$ - (1)

$Q_{feed} = m_{feed} C_{P feed} (T_{feed} - T_{ref})$

726.68 kg/h x 2880 J/kg.K (25-0^0C)

= 5.23×10^7 J/ h - (2)

$Q_{product} = m_{product} C_{p\ product} (T_p - T_{ref})$

= 439.57 kg/hx 1880 J/kg.k (250-0 ^oC)

= 2.06×10^8 J/h - (3)

$Q_{water\ vapour} = m_{water\ vopour} * \lambda_{watervapour}(100\ ^oC)$

= 287.11 kg/h x 2257 kJ/kg (100 ^oC)

= 6.48×10^7 J/h -(4)

Substituting equation 2, 3, & 4 into equation 1

$Q_{feed} + Q_{electric} = Q_{water\ vapour} + Q_{product}$

$Q_{electric} = Q_{water\ vapour} + Q_{product} - Q_{feed}$

= 6.48×10^7 J/h +20.6×10^7 J/h –5.23×10^7 J/h

= 21.85×10^7 J/h - - -- (5)

Water consumption for bread making process

- **Water consumption during bread baking**

It was found that 265L of water is required to make 400 kg of bread per hour.

1 hr ________ 400 kg of bread

16hr ________ X, where x = weight of bread production per day

X = 6,400kg of bread per day

1 day _____ 6,400 kg of bread

300 day _____ Y, where Y weight of bread production per year

Y = 300 x 6,400= 1,920,000 kg of bread per year

From the above material balance of water required during bread production

265 L of water ———————— 400 kg

Z ———————— 1,920,000 kg

Where Z = the amount of water required for production of bread per year.

Z = 1,272,000 L of water per annum - (1)

- **Water required for workers**

According to the studies conducted on sanitary comfort condition in working sites of bread manufacturing, 60 L is established as a minimal water value per day for day each worker however, this figure can be reduced when we consider the situation in developing countries it would not be far from the actual situation if we assumed 40 L per day/ person.

$$40\ L * 25\ person = \frac{1000\ L}{Day} = 300{,}000\ L\ /annum \qquad (2)$$

- **Processing plant hygiene**

Water consumption was estimated according to the specification of high pressure water model HD 585 capacity 500 L/hr. The water volume is designed for the processing plant washing and sanitization hence for 300 working days of the plant assuming one hour of cleaning per day so the quantity of water required for plant hygiene

300 hr per year *500L /hr = 150,000L /year - (3)

Total plant water requirement is the sum of equation 1, 2 and 3

= 1,272,000 L + 300,000 L + 150,000 L/year

= 1,722,000 L/year - (4)

5.3. Techno-economic evaluation

5.3.1. Building, equipment and manpower requirements

- **Plant parameters**

✷ Capacity, tons per year	1920
✷ Number of shifts /day	2
✷ Working days/year	300
✷ Land area/ covered, m^2	1200

- **Machinery and equipment**

If the cost of a piece of equipment or plant of size or capacity q_1 is C_1, then the cost of a similar piece of equipment or plant of size or capacity q_2 can be calculated from

$$C_2 = C_1(q_2/q_1)^n$$

Where, the value of the exponent n depends on the type of equipment or plant.

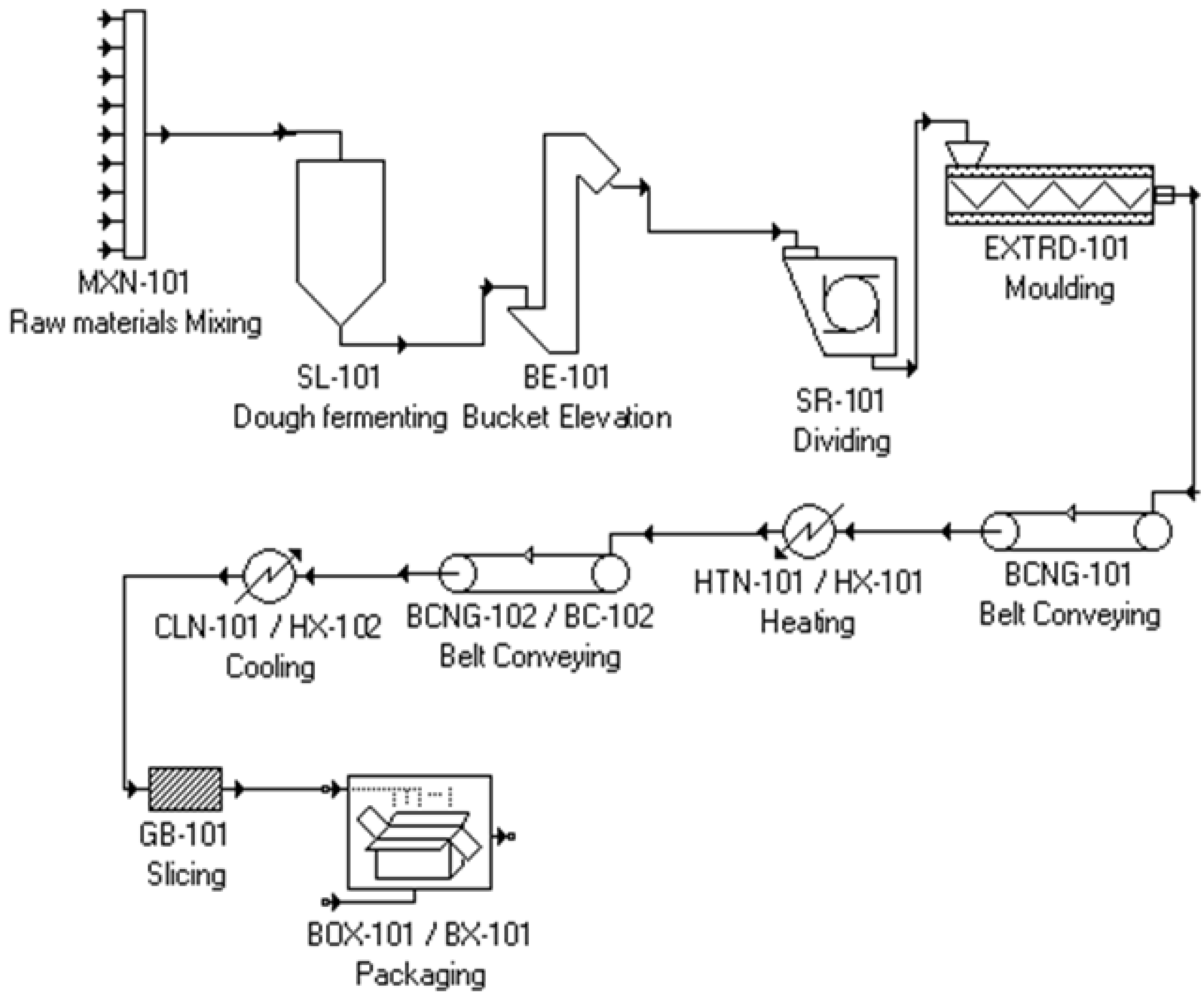


Figure 5-1: Bread making process flow sheet

Table 5-1: Total plant and machinery cost

SN	Item	Quantity	Unit price (birr)	Total price (birr)
1	Flour sifter	1	51,899.11	51,899.11
2	Universal mixer-135.6 kg capacity	1	66,700.00	66,700.00
3	Electric band oven-size 25m	1	163,696.00	163,696.00
4	Cooling conveyor-size 10m	1	6,947.58	6,947.58
5	Work conveyor-size 30m	1	12,033.00	12,033.00
6	Divider and Moulds	1	25,000.00	25,000.00
7	Water tank (10000 liter)	1	6,000.00	6,000.00
8	Weighing scale	1	27,589.49	27,589.49
9	Delivery vehicle	1	750,000.00	750,000.00
10	Contingency	10%		110,986.52
	Total	**10**		**1,220,851.70**

- **Building requirement**

Several structures are required for different purposes like production area, packaging area, laboratories, stores, etc. The total area required for these structures is 1200sqm and from the current construction costs in Addis Ababa city administration the average lease price for the plots was 4,690 Birr a square meter and this research took the average value as land requirement price for the buildings. Whilst the highest offer of 12,307 Birr was for a 162.5sqm plot. The least lease price, 250 Birr, was offered for 337sqm.

Table 5-2: Building requirement

SN	Building	Total area (m^2)	Unit price Birr/m^2	Total Price(Birr)
1	Raw material storage (25*5)	125	4,690.00	586,250.00
2	Working space(20*25)	500	4,690.00	2,345,000.00
3	Office(10*20)	200	4,690.00	938,000.00
4	Laboratory(15*5)	75	4,690.00	351,750.00
5	Final product storage (10*25)	250	4,690.00	1,172,500.00
6	Other common facilities like cafeteria, bath etc (10*5)	50	4,690.00	234,500.00
7	Contingencies on Building	10%		510.040.00
	Total	**1200**		**5,610,440.00**

- **Manpower requirement**

Table 5-3: Human resource requirement

SN	Particulars	Required No	Gross monthly salary (birr)	Total monthly salary (birr)	Gross yearly salary (Birr)
1	Manager	1	4,000	4,000	48,000.00
2	Skilled workers	2	2,000	4,000	48,000.00
3	Weighing of ingredients workers	2	500	1000	12,000.00
4	Mixing operator	1	500	500	6,000.00
5	Baking operator	2	500	1000	12,000.00
6	Cooling (cooling conveyor) operator	1	500	500	6,000.00
7	Packing operators	10	500	5000	60,000.00
8	Sealing operators	3	500	1500	18,000.00
9	Semi – skilled worker	1	1000	1000	12000.00
10	Driver	1	950	950	11,400.00
11	Production supervisor	1	2500	2500	30,000.00
	Total	**25**			**263,400.00**

5.3.2. Cost estimation

- **Cost of raw materials**

Table 5-4: Cost of raw material

Particulars	Quantity per annum	Unit price	Total cost(birr)
Wheat flour (386.59*300*16)	1,855,632	6.09 birr/kg	11,300,798.00
Pearl millet flour (20.347*300*16)	97,665.6	7 birr/kg	683,659.20
Salt (7.268*300*16)	34,886.4	1.00 birr/kg	34,886.4
Shortening (11.62*300*16)	55,776	10 birr/pkt	557,760.00
Active dry yeast (7.268*300*16)	34,886.4	18 birr/pkt	627,955.20
Water (261.6*300*16)	1,255,680	0.00315 birr/liter	3,892.60
Sugar (24.71*300*16)	118,608	14 birr/kg	1,660,512.00
Skim milk powder (7.268*300*16)	34,886.4	45 birr/kg	1,569,888.00
Total			**16,439,351.46**

Source: www.ecx.com.et/commodities.aspx

- **Cost of utility**

Table 5-5: Cost of utilities

Particulars	**Quantity per annum**	**Unit price**	**Total cost (Birr)**
Electricity (kWh)	810,640	0.4993	404752.55
Water	1,722,000	0.00315birr/liter	5,424.3
Packing material (400*300*16)*10pack/Kg	1,920,000	4.00 Birr/250gm beard	30,720
Total			**440,896.85**

- **Fixed capital cost estimation**

Table 5-6: Fixed capital cost estimation

	Item	Description/factor	Total cost, birr
I. Direct cost	A. Material + labor	estimated	31,761,014.00
	a. Equipment	,, ,,	4,542,280.30
	b. Installation	0.35*4,542,280.30	1,589,798.10
	c. Instrumentation	0.10*4,542,280.30	454,228.00
	d. Piping	0.30*4,542,280.30	1,362,684.09
	e. Electrical	0.25*4,542,280.30	1,135,570.00
	B. Building + auxiliary	Direct estimated	5,610,440.00
	C. Service facilities	0.4*4,542,280.30	1,816,912.12
	Total direct cost	**A + B + C**	**48,272,926.49**
II. Indirect cost	A. Engineering + supervision	0.1*48,272,926.49	4,827,292.65
	B. Construction + Contractor fee	0.1*48,272,926.49	4,827,292.65
	C. Contingency	0.06*48,272,926.49	2,896,375.59
	Total indirect cost	**A + B + C**	**12,550,960.89**
III. Fixed capital investment		**Direct + Indirect cost**	**60,823,887.38**
IV. Working capital		**0.15*60,555,229.56**	**9,123,583.10**
V. Total capital investment		**III + IV**	**69,947,470.48**

- **Estimation of total product cost**

Table 5-7: Estimation of total product cost

Item		Description/factor	Total cost, birr
I.Manufacturing cost	A. Fixed Charges		
	a. Depreciation	0.1*mach + 0.02 *buil.	234,293.97
	b. Local taxes	0.02*FCI	1,216,4777.74
	c. Insurance	0.006*FCI	364,943.32
	Total of A		**1,815,715.03**
	B. Direct production cost		
	Total product cost (tpc)	Total fixed charge/0.15	12,104,766.87
	a. Raw material	Already estimated	16,439,351.46
	b. Utilities	,, ,,	440,896.85
	c. Operating labor (ol)	0.1*tpc	1,210,476.69
	d. Supervisory	0.1*ol	121,047.67
	e. Maintenance	0.05*FCI	3,041,194.37
	f. Lab charges	0.1*ol	121,047.67
	Total of B		**33,478,781.58**
	C. Plant over heads	0.1*tpc	**1,210,476.69**
	Total manufacturing cost	**A + B + C**	**36,504,973.30**
Π.General Expenses	a. Administrative cost	0.05*tpc	3,840,780.35
	b. Distribution	0.1*tpc	3,054,695.79
	c. R & D	0.05*tpc	3,840,780.35
	d. Interest	0.05*tpc	3,840,780.35
	Total general expenses		**14,577,036.86**
Total product cost		**I + Π**	**84,560,791.72**
Total product cost/kg of bread		**84,560,791.72÷1,920,000=44.04 Birr/kg**	

- **Gross earnings**

Whole selling price of 1kg of bread = 60 birr

Expecting all produced bread will be sold

Total income = 1,920,000 x 60

Gross income = Total income – Total product cost

= 115,200,000.00 – 84,560,791.72= **30,639,208.28 birr**

Let the tax rate be 35% (Income tax of Ethiopia)

Taxes = 0.35*30,639,208.28 birr = **10,723,722.89 birr**

Net profit = Gross income - Tax

= 30,639,208.28 birr – 10,723,722.89 birr

= 19,915,485.38 birr

- **Rate of return**

$$ROI = \frac{net\ \ profit}{total\ \ capital\ \ investment} x100 = \frac{19{,}915{,}485.38}{69{,}947{,}470.48} x100 = 28.47\ \%$$

$$payback\ \ period = \frac{FCI}{NP + Depre} = \frac{60{,}823{,}887.38}{19{,}915{,}485.38 + 234{,}293.97} = 3.01\ year$$

5.4. Summary on cost benefit analysis

The profile indicates that the establishment of a plant for the production of bakery product with a capacity 1920 tonns per year. The plant will create employment opportunities for 25 persons. In addition to supply of the domestic needs, the project will generate 10,723,722.89 birr in terms of tax revenue. The total investment requirement is estimated at Birr 69,947,470.48. The project is financially viable with a return on investment (ROI) of 28.47% and a payback period of 3.01 years.

Since no chemicals are used during the production steps and the operating conditions are mild, production of these products are environmental friendly processes. And ready-to-eat bakery produced from pearl millet serves as a good source of nutrition for the human body. As it is clearly shown from the above cost estimation break down, production of this value added product was profitable. Therefore, the projects can fully be implemented after detailed feasibility studies carried out.

CHAPTER SIX

Conclusions and Recommendation

6.1. Conclusions

The study was aimed at investigating the characterizations of the effect of processing on pearl millet based value added products. The physicochemical property of the pearl millet grain was investigated. The flours were passed different processing methods roasting, blanching, autoclaving, fermentation, germination and their combination soaking and germination followed by fermentation. The reduction of antinutritional processing, functional properties of pearl millet flours, and sensory quality attributes of value added pearl millet products were studied.

Fermentation and blanching were much better than other treatments with respect to the antinutrational reduction plus bioavailability of minerals. In addition, the proximate analysis of indicated that pearl millet flours good grain qualities of unique nutritive values of minerals (especially micronutrients including calcium, magnesium, zinc, iron and phosphorus) the quantities, qualities and bioavailability of which need more improvement.

The composition of wheat flour with fermented and blanched pearl millet flours in the production of breads as well as thin porridge resulted in product of high nutritional status with an enhanced flavor and color. Therefore, from the study can conclude that substitution of pearl millet flours with wheat flour in the processing of bread at the substitution level of 95%:05% for both fermented and blanched pearl millet flour breads were acceptable to the consumers.

The sensory evaluation result of the fermented pearl millet flour thin porridge was accepted by the consumers for the blending of 75%:25% and 50%:50% (moderately acceptable). In addition, the blending of the 75%:25% of blanched pearl millet flour also moderately acceptable by consumers.

As a final point, In order to enhance and extend demand of pearl millet production and productivity as well as consumption of pearl millet based value added products, there is need for strategic shift to commercial production and promotion of pearl millet in Ethiopia.

6.2. Recommendation

There are important researchable and development issues that confound or influence the importance and status of pearl millets, and their potential in commercialization and trade. Generally research has focused on the most important species, pearl millet. Adaptation local variety 'ICMV 221' derived materials have been the forms of research. Pearl millet (next most important species) research has focused on processing and end-use in bakery products (bread) and porridges (thin porridges) as composite flour.

Recommendation would also include:

i. Increasing production and productivity: to improve competitiveness and close up deficit gaps; and ensuring food and nutrition security.

ii. Promoting pearl millet for commercialization and markets through:

- ❖ Consider other pearl millet processing and utilization methods and technologies, including malting, steaming, micro milling, compositing, brewing and product development.
- ❖ Evaluating, developing and emphasizing grain and food product qualities and standards for industry and end uses.
- ❖ Using unique qualities of pearl millet use in novel food products, novel traits, and bio fortified food products.
- ❖ Levels of Copper, Iron, Zinc, Magnesium and Manganese nutritional convenience, need further research on minerals constituent and development products of health snack foods.
- ❖ Further *in vivo* and *in vitro* studies need to be carried out in order to get a clearer picture of the effect of phytate on bioavailability of minerals.
- ❖ Developing sustainable regional trade in pearl millet raw and finished products through improving market channels and trading volume with maintenance of quality and standards.

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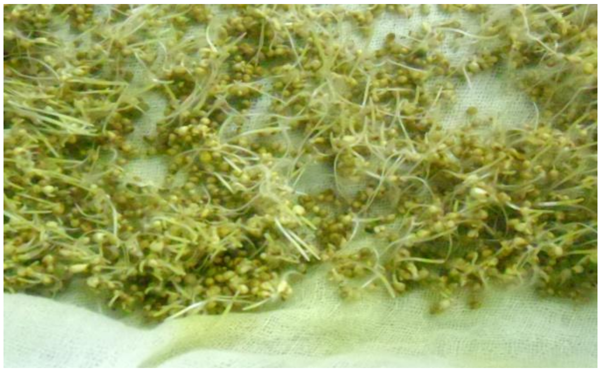
Appendices

Appendix - I: Sensory evaluation score card using nine point Hedonic scale

Panelist code/name: ______________ sample code: ______________ date: _____________

Sensory perception (score)	Sensory quality attributes				Overall acceptability
	Appearance (Color)	Flavor	Aroma	Mouth feel (Texture)	hedonic scale
1=dislike extremely					1=Extremely unacceptable
2=dislike very much					2=very much unacceptable
3=dislike moderately					3=moderately unacceptable
4=dislike slightly					4=Slightly unacceptable
5=neither like nor dislike					5=neither acceptable nor Unacceptable
6=like slightly					6=Slightly acceptable
7=like moderately					7=moderately acceptable
8=like very much					8=highly acceptable
9=like extremely					9=Extremely acceptable

Appendix – II: Photos of pearl millet processing and pearl millet based bread and thin porridge

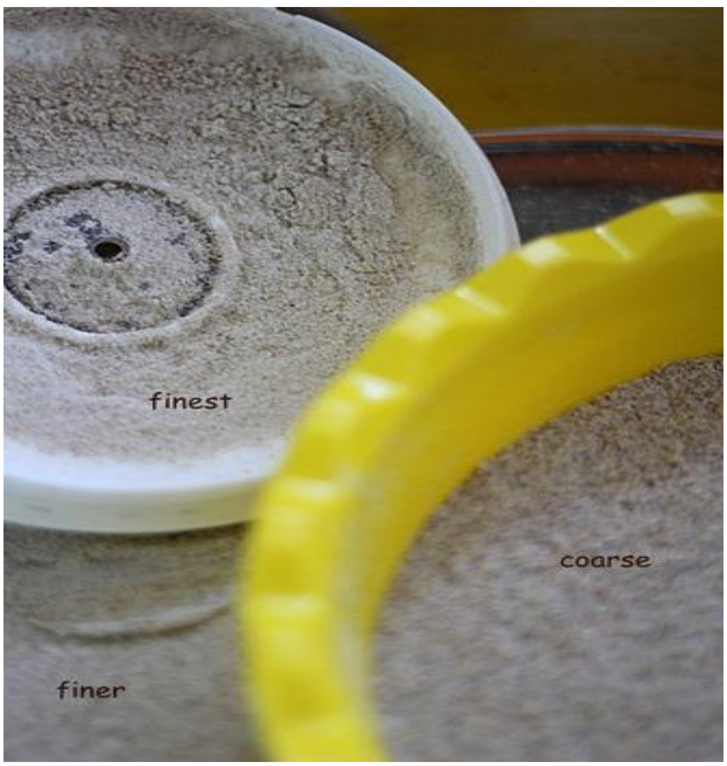


(a) Pearl millet grains germinated for 72hrs.

(b) Pearl millet grains

(c) Bread samples prepared from blended pearl millet flours

(d) Thick porridge of pearl millet (e) Thin porridge of pearl millet



(f) After milling coarse powder, finer, and finest pearl millet flour

100% wheat flour bread

95% wheat + 5%pearl millet flour bread

90% wheat + 10%pearl millet flour bread

85% wheat + 15% pearl millet flour bread

(g) Bread samples

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other University, and that all sources of materials used for the thesis have been duly acknowledged.

Name: **Eyoel Legesse Arega**

Signature: ______________________

Place: **Addis Ababa, Ethiopia**

Date of submission: ______________________

This thesis has been submitted for examination with my approval as University advisor.

Name: **Dr. Eng. Shimelis Admassu (Associate Professor)**

Signature: ______________________