Addis Ababa Institute of Technology (AAiT)
School of Graduate Studies
Department of Chemical Engineering

PRODUCTION AND CHARACTERIZATION OF OAT - WHEAT BASED FOOD 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: Shewarega Habtamu

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Addis Ababa, Ethiopia

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List of Acronyms and Abbreviations

AACC	American Association of Cereal Chemist
AAiT	Addis Ababa Institute of Technology
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
BEP	Break Even Point
BU	Brabender Unit
CBP	Chorleywood Bread Process
CHO	Carbohydrate
CSA	Central Statistical Agency
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FN	Falling Number
FQN	Farinograph Quality Number
FU	Farinograph Unit
ICC	International Cereal Chemistry
KFSC	Kaliti Food Share Company
MC	Moisture content
OAA	Overall acceptability
SGF	Straight grade flour
TKW	Thousand Kernels Weight
WHO	World Health Organization

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Abstract

In this study the proximate composition and rheological properties of oat and wheat flour were investigated. The oat flour contained considerable amounts of protein (16.92%), total carbohydrates (64.65%) ash (1.80%), crude fiber (4.92%), moisture (5.61%) and fat (6.10%). The wheat flour also contained protein (13.56%), total carbohydrates (73.51%), ash (0.6%), crude fiber (0.32%), moisture (11.35%) and fat (0.98%). Based on these results, oat flour is nutritious and has a potential for use as composite flour in food formulations. Effects of oat flour supplementation (5%, 10%, and 15% of oat flour) on nutritional properties of the composite bread were investigated. The crude fiber, fat and protein all are increased as the addition of oat flour increased. The farinograph water absorption values of the composite flour (5%, 10%, and 15% of wheat flour) were 58.3%, 59.0% and 64.2% while the dough stability values were 8.5, 5.2 and 3.4 minutes; respectively. The dough development times were also 2.4, 3.0, and 4.3 minutes and that of the farinograph quality number were 99, 65 and 58 Brabender units; respectively. According to the results of wet gluten, falling number, and sedimentation values all decreased with the increase of oat flour supplementation ($p<0.05$) while color grade and oil absorption increased. The loaf volume of the composite flour bread were 340.6(100% wheat flour), 323.5 (5% oat flour), 298.4(10% oat flour), 250.3 (15% oat flour) and 210.9(100% oat flour). Loaf volume was significantly decreased with increase in level of incorporation of oat flour whereas loaf weight at 5%, 10% and 15% level of oat incorporation was significantly lower as compared to 100% oat supplementation ($p<0.05$). Results of this research suggested that supplementation of oat flour up to 10% results in bread with acceptable qualities. Oat flakes were prepared from locally grown varieties. The major parameters (specific weight, flake thickness and moisture content) which mostly affect the quality of oat flakes were measured and compared with the control oat flake. Specific weight, flake thickness and moisture content values were 0.53gm/L, 0.51mm and 9.5; respectively. These results are not significantly different to that of the control one. The sensory evaluation results also suggested that the flakes are acceptable. The economic analysis of the composite bread production plant revealed that it is profitable to produce the product.

Key words: *Composite bread, Farinograph values, Flour supplementation, Oat flake, Wet gluten*

CHAPTER ONE

Introduction

1.1. Background

The genus of oat is *Avena L. (Poaceae)* and belongs to the tribe *Aveneae* of the family *Gramineae*. The primary species cultivated is *Avena sativa*. However, *Avena byzantina* and *Avena strigosa* are also grown in some regions for animal feed and fodder (Colin *et al.,* 2008).

Oats have played a significant role in farming systems from domestication to present due to the versatile uses of the grain and plant. Oats currently rank sixth in world production of cereals after maize, rice, wheat, barley, and sorghum. World oat production was similar to millet and exceeded rye, and triticale (Colin *et al.,* 2008).

Oats are primarily grown in cool temperate climates with 67% of world production occurring in the northern hemisphere. The Russian Federation, Canada, United States of America, Finland, and Poland were ranked as the top five countries for world oat production. Oats are also grown in the southern hemisphere with Australia ranked first in production while Argentina, Chile, and Brazil are also significant producers (Colin *et al.,* 2008).

Oats for human consumption are used to produce traditional, functional, and medicinal products. Oats are differentiated from other cereal grains by using the entire kernel after the hull is removed for many food products. Porridge or oatmeal, hot cereals, bread, biscuits, infant food, and muesli or granola bars are a few examples of food products produced from oats. Non dairy food uses have been developed resulting in oat milk, yoghurt, and ice cream. Oats have been shown to have health benefits for lowering blood cholesterol, normalizing blood glucose levels, and reducing the risk of colorectal cancer. Although pharmacological properties are reported in the literature, no products have been commercialized (Anna *et al.,* 2003).

1.2. Statement of the problem

Developing countries are facing problems of malnutrition due to lack of food resources. High prices of food commodities and policy barriers are the factors aggravating the food crisis in developing countries (Weaver, 1994). Food security is defined as “condition where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 1996).

Cereal grains like wheat, corn, rice, barley, sorghum, etc. provide 68% of the total world food supplies. Wheat is mainly used as a dietary staple, averaging two-thirds of total consumption (Anjum *et al.,* 2005). Owing to shortage of wheat, several developing countries have devised programs to assess the feasibility of alternate sources for substituting or blending with wheat flour (Abdel-Kader, 2000).

Most developing countries including Ethiopia rely on importation to get wheat or wheat flour needed for making bread, rolls, biscuits and other pastry products. For this reason, most developing countries are interested in the possibility of replacing the wheat needed for making baked goods, wholly or partly with flour obtained from home grown products .Africa is becoming increasingly food insecure. In 2011 Africa imported some $7.7 billion worth of cereals and cereal products, equivalent to nearly $10 per person (FAO, 2011). Most of the imports are wheat and flour for bread making. Importation of cereals is having a devastating effect on the economies of many African countries like Ethiopia. It uses valuable foreign exchange, which would be much better applied for economic development. It also inhibits local agricultural development (Stanley *et al.*, 2004). To combat this problem, as long ago as the 1960s, the FAO launched a "Composite Flour Program". The objective was to seek new possibilities for the use of raw materials other than wheat in the production of bread, biscuits (cookies), pastas, and similar flour based foods (De Ruiter, 1978).

Knowledge of functional and rheological properties of un-conventional and/or novel food ingredients is imperative to incorporate successfully in existing food formulations. Blending non wheat flours with wheat might result in technological difficulties and impairment of baking quality. For this purpose, determining potential use of composite flour blends in food formulations, informations regarding functional and rheological properties of blends are essential (Akubor *et al.*, 2003).

Wheat protein is deficient in some essential amino acids, especially lysine which is the first limiting amino acid in wheat. This deficiency results in lowering the protein nutritional quality of products made from wheat flour (Wrigley and Bietz, 1988). The deficiency of lysine leads to the poor utilization of protein and thus results in protein malnutrition. The cereal which attracts much interest in this context on account of its nutritional value is oats. Its grain is rich in protein and dietary fiber and its content of fatty acids is favourable (Liukkonen *et al.*, 1992). Wieser *et al.* (1980) demonstrated that oat flour is much richer in protein than wheat, rye, barley, rice, maize and sorghum flours.

In recent years, there has been an increased demand for high quality oats destined for the milling and food manufacturing industries. Much of this demand is in response to consumer interest in oat products as a source of whole grain, high fiber, and high β glucan foods (Geiger *et al.,* 1996). The majority of milled oats are ground into flour for use in ready-to-eat breakfast cereals but a significant portion are flaked for use in bakery products, granola bars, and hot oatmeal (Caldwell *et al*., 1989). The major disadvantage of oat is it takes a long time to cook, but processing it to oat flake will solve this problem

Studying the possibilities of increasing oat utilization as an important food is the basis of this research which tries to find alternative ways in which oat can be more accepted not only as a traditionally processed food but also as a value added product in Ethiopia. Therefore, this study is initiated to study the possibility of incorporating oat flour in bread formulation and so as to harness its potential in nutritional terms.

1.3. Objectives

1.3.1. General objectives

The general objective of this research work was to develop and characterize bread from oat blended with wheat flour and also, to evaluate the potential of producing oat flake in Ethiopia using the selected cultivars.

1.3.2. The Specific objectives were:

- To Study the proximate composition, physico-chemical and functional properties of oat flour and its composite with wheat flour.
- To evaluate the rheological properties of the oat - wheat flour dough using Brabender Farinograph.
- To study the proximate composition as well as organoleptic property of oat based bread.
- To study some quality parameters for oat flake.
- Suggest a process technology for the processing of oat flake
- To evaluate techno-economic feasibility of producing composite flour bread.

1.4. Significance of the project

- It will maximize oat utilization by diversification of its products to bread and flake.
- Result in cost effective weaning product for low and middle income families that can be produced at industrial level.
- The major disadvantage of oat is it takes a long time to cook, but processing it to oat flake will solve this problem.
- Characterize the locally grown oat variety which can serve as a source for further study.
- Make awareness on the nutritional value of oat.

CHAPTER TWO

Literature Review

2.1. Cereal production in Ethiopia

Ethiopia with its wide range of agro-climatic condition grows a wide variety of cereals. Some of the major cereals are: Teff, maize, sorghum, wheat, barley, oat, finger millet, rice etc… but some of these cereals are not fully exploited by the general population, especially by the urban people. These seem to be dependency on a single crop such as Teff. This dependency may result in shortage of food if there is crop failure affecting this particular cereal.

Table 2.1: Area, Production and Yield of Crops for Private Peasant Holdings for Meher Season 2011/12 (2004 E.C.)

Crop	Number of holders	Area in hectare	Production in quintal	Yield(qt/ha)
Teff	6,300,048	2,731,111.67	34,976,894.64	12.81
Barley	4,085,236	948,107.43	15,852,869.21	16.72
Wheat	4,324,679	1,437,484.73	29,163,336.88	20.29
Maize	9,154,883	2,054,723.69	60,694,130.14	29.54
Sorghum	5,166,690	1,923,717.49	39,512,942.36	20.54
Finger millet	1,556,134	432,561.00	6,518,509.00	15.07
Oats/'Aja'	253,195	30,568.39	494,749.24	16.18
Rice	93,286	30,649.30	886,185.47	28.91

(Source: CSA, 2004)

In order to avoid this kind of occurrences, it is probably high time for most Ethiopian to modify their eating habits. Wrong beliefs and taboos have to be gradually replaced by more scientific ones. Table 2.2 shows the major cereal crops and producing regions in Ethiopia. (Asrat Wondimu *et al.,* 1994)

Table 2.2: Major cereal crops and producing regions in Ethiopia

REGION	*CROP*
Shoa, Arsi	Teff, barley, wheat, maize, sorghum
Gojam, Wellega, Gamogofa, Tigray	Teff, sorghum, barley, maize, wheat, oat
Gonder	Teff, barley, wheat, sorghum
Wollo	Teff, barley, sorghum, oat
Sidamo	Teff, barley, maize,
Keffa, Illubabour	Teff, maize, sorghum
Hararghe	Maize, sorghum
Bale	Barley, wheat, oat

(Source: Asrat Wondimu *et al.,* 1994)

2.2. Over view of world oat production and composition

Oats have played a significant role in farming systems from domestication to present due to the versatile uses of the grain and plant. Oats currently rank sixth in world production of cereals after maize, rice, wheat, barley, and sorghum. World oat production was similar to millet and exceeded rye, and triticale. Oats are primarily grown in cool temperate climates with ~67% of world production occurring in the northern hemisphere. The Russian Federation, Canada, United States of America, Finland, and Poland were ranked as the top five countries for world oat production. Oats are also grown in the southern hemisphere with Australia ranked first in production while Argentina, Chile, and Brazil are also significant producers (Colin *et al.,* 2008).

Oats were introduced to North America with other grains by Scottish settlers in 1602. It gradually became a major crop until about 1920, when machines began to replace horsepower. Acreage previously devoted to feed oats has now been replaced by soybeans, a more marketable crop. With the advance of knowledge about nutrition, oats were recognized as a healthy food in the mid 1980's and therefore may become more popular once again for human nutrition.

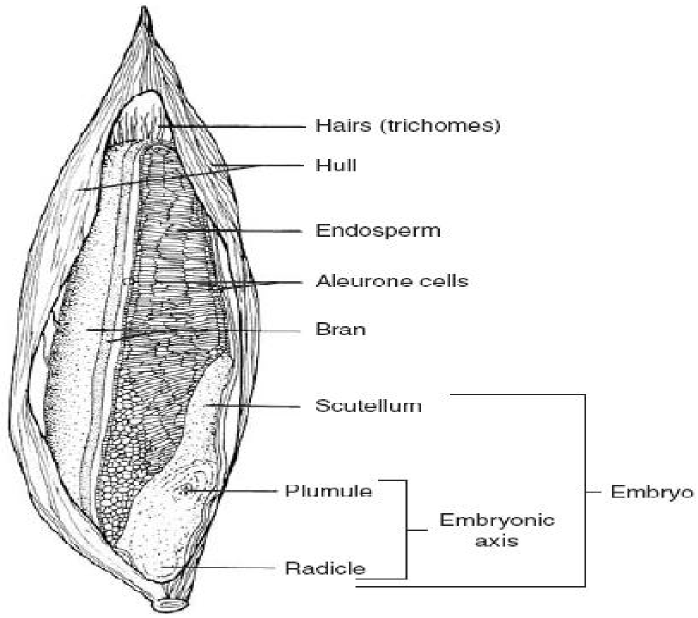


Figure 2.1 Composition of an oat kernel. *(Oats: Chemistry and Technology. St. Paul, MN: The American Association of Cereal Chemists, 2000)*

Worldwide, about 50% of oats are fed to cattle and it is especially used as feed for horses, dairy cattle, breeding animals, poultry and young livestock. It is estimated that 25% of oats are used for food, seed and industrial products (Bruce *et al.,* 2008). There are two types of oats; husked oats, with hulls surrounding the kernel or groat after harvest and naked oats, where the hull is removed when the crop is harvested. Naked oats have the free threshing character similar to wheat. Husked oats represent the majority of oat production, but naked oats are gaining prominence for specialist markets as improved varieties are being developed (Colin *et al.,* 2008).

Table 2.3. The general composition of whole grain oat flour and oat bran

Components	**Whole grain oat flour (%)**	**Oat bran (%)**
protein	15-17%	15-18%
Starch and sugars	59-70%	10-50%
Fat	4-9%	5-10%
Total dietary fiber	5-13%	10-40%
β - Glucan	2-6%	5-20%

(Source Bruce *et al.,* 2008)

2.3. Health benefits of oat

Oats for human consumption are used to produce traditional, functional, and medicinal products. Oats are differentiated from other cereal grains by using the entire kernel after the hull is removed for many food products. Porridge or oatmeal, hot cereals, bread, biscuits, infant food, and muesli or granola bars are a few examples of food products produced from oats. Non dairy food uses have been developed resulting in oat milk, yoghurt, and ice cream. Oats have been shown to have health benefits for lowering blood cholesterol, normalizing blood glucose levels, and reducing the risk of colorectal cancer. Although pharmacological properties are reported in the literature, no products have been commercialized (Colin *et al.,* 2008).

2.3.1. β- glucans

Food industry aims at the development of new products towards functional foods and ingredients With regard to the consumer's demands on healthy nutrition. Functional foods are eatables which besides their initial function (satiation and nutrition of the organism) provide also a health benefit to the consumer (Havrlentova *et al*., 2011).

Cereals are generally known to have a positive influence on the general state of the human organism. The attention of the nutritional experts is paid especially to oats and barley. Besides their accessibility, these cereals are interesting due to their relatively high contents of soluble non-starch polysaccharides (fibrous material), out of which β-glucans have a dominant position from the aspect of health benefit (Havrlentova *et al*., 2011).

Structure, occurrence, and sources

β- glucans are indigestible polysaccharides occurring naturally in various organic sources such as corn grains, yeasts, bacteria, algae. They are important components of the fibers containing unbranched polysaccharides consisting of β-d-glucopyranose units linked through (1→4) and (1→3) glycosidic bonds in cereals (Figure 2.2) and (1→6) glycosidic bonds in fungal sources (Figure 2.3) ; respectively. The structure has an impact on the water solubility of β-glucans. Extensive research has been done into the structure and properties of water soluble β-glucans in contrast to water-insoluble β-glucans (Johansson *et al*., 2000; Ren *et al*., 2003). Generally, no sharp distinction exists between the soluble and insoluble fractions and the ratio is highly dependent on the extraction conditions of the soluble fiber (Virkki *et al*., 2005). Glucans are usually concentrated in the internal aleurone and subaleurone endosperm cells walls (Charalampopoulos *et al*., 2002; Demirbas , 2005; Holtekjølen *et al*., 2006). Out of cereals, the highest amounts of β-glucans are found in barley and oat grains (Havrlentová *et al*., 2006). Literature data indicating the yields of β-glucans in different cereal-based food sources are listed in Table 2.4.

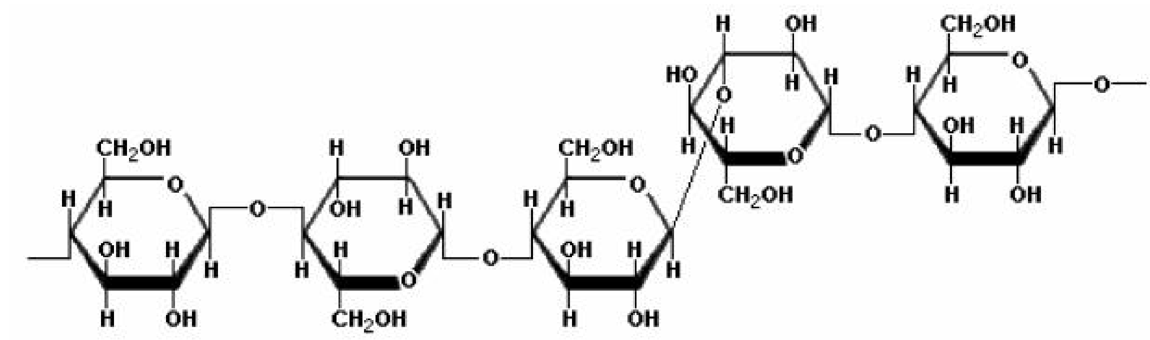


Figure 2.2: Basic structure of β-glucans in cereals with combined bonds β-(1→3) and b-(1→4)

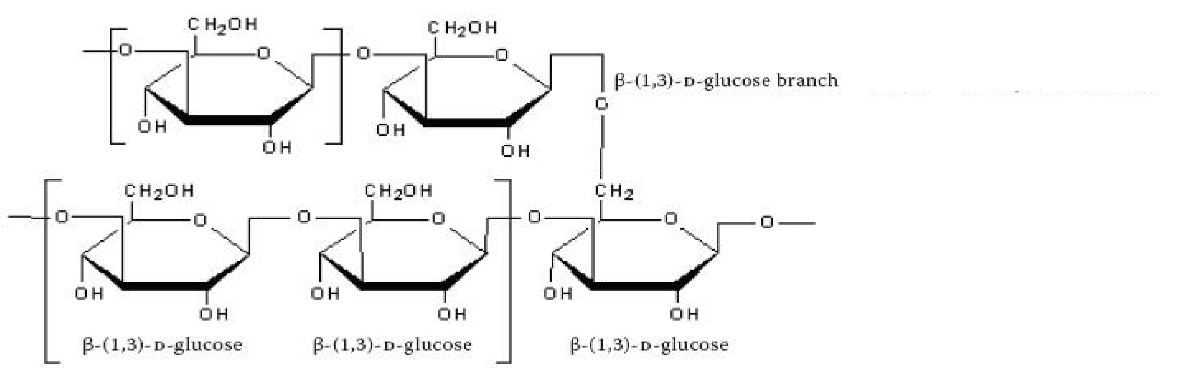


Figure 2.3: Basic structure of β-glucans combined bonds (1→3) and (1→6) in yeast sources

The potential use of oats in the production of functional foods is bound to the nutritional value of the grain, in particular to the content and composition of dietary fibre, proteins, and lipids; respectively (Demirbas, 2005). Thanks to dietary fibre, especially soluble β-glucan, a health claim was published about the beneficial effects of oats. Higher amounts of β-glucans are observed in naked oats compared to hulled ones, their content being affected by the genotype and environment (Havrlentová, 2009).

Table 2.4: β-glucan contents in different cereal based food products

Cereal	Cereal food source	Soluble β- glucans (g/100g dry wt)
Wheat	Whole meal	0.39
	bran	1.38
	groat	0.42
Barley	Whole meal	3.95
	groat	3.35-3.74
	bran	4.14
Oat	Whole meal	2.66
	groat	3.16
	Bran concentrate	11.5-17.0
	flakes	2.64-4.6

(Source Havrlentová, 2009)

2.4. Production Process of oat flour and flake

The processing steps for the production of oat flour and flakes are receiving, cleaning and drying, hulling, groat processing, steaming, flaking and finally packing. They are described in detail as follows:

Receiving: Oats arrive at the mill via bulk truck and are sampled to ensure suitable quality for milling. Suitable milling oats should be relatively undamaged by weather, insects, disease, or mold; be of suitable width (not too thin); and free from insect infestation. Grain that is infested with insects must undergo treatment utilizing approved fumigants before it can be milled. Once the grain is deemed acceptable, it is passed over a receiving separator to remove coarse material, such as field trash, and fine material, such as chaff dust. The oats are binned according to milling criteria, such as weight, and are maintained so that grains sent to the mill are uniform.

Cleaning and drying: Cleaning removes foreign material, such as dust, stems, and weed seeds, and oats that are unsuitable for milling, such as doubled oats, pin oats, light oats, and hulled oats. Doubled oats contain two groats, neither of which are well developed, and have a high percentage of hulls. The groat is the portion of the oat that remains after the hull has been removed and is the part processed for human consumption. Pin oats contain very thin groats. Light oats may be of acceptable milling size, but contain a high percentage of hulls. Hulled oats lack the protective hull cover and are subject to shattering during the hulling process. The cleaning process utilizes several devices to take advantage of particular physical properties of the grain. For example, screens utilize the overall size of the grain, aspirators and gravity tables utilize grain density, and discs with indent pockets and/or indent cylinders utilize the grain length or shape. After completing the cleaning process, the grain is called clean milling oats or green oats.

Hulling: the oats are fed through a rotating disc and flung out to strike the wall of the cylindrical housing tangentially, which separates the hull from the groat. The cylinder wall is designed so that the friction between it and the hull approaches or exceeds that between the hull and the groat. The mixed material then falls to the bottom of the huller and is subjected to aspiration to separate the hulls and the groats. Any oats that are not hulled are separated using an indent cylinder, a table separator, or a disc separator and are returned for another pass through the huller.

Groat processing: it involves polishing, sizing, and cutting (for quick oats production). After the groats are hulled, the groats are sized to separate the largest groats from the average-sized groats. The large groats are used to make the so-called old-fashioned oats and the other groats are cut using steel cutters to make quick oats, which cook considerably faster than old fashioned oats. The cutting process utilizes revolving drums with countersunk holes through which the groats fall to be cut by stationary knives positioned on the outer surface of the drum. The groat can usually be cut into three to five pieces, depending on its size.

Steaming: After groat processing, the groats (either whole or cut pieces, depending on the end product) typically pass through an atmospheric steamer located above the rollers. The groats must remain in contact with the live steam long enough to achieve a moisture content increase from 8 to 10 percent up to 10 to 12 percent, which is sufficient to provide satisfactory flakes when the whole or steel-cut groats are rolled. Contact with the steam also increases the temperature of the groats, which has a plasticizing effect and ensures that lipolytic enzymes are inactivated for product stability. To increase the taste one can add the soup of sugar, salt or any other ingredient like malt, syrup to make it more congenial to health.

Flaking: The production of old-fashioned oat and quick oat flakes is the same, except for the starting material (old-fashioned oats start with whole groats and quick oats start with 2-4 steel-cut groats). Both products are rolled between two cast iron equal-speed rolls in rigid end frames. Feeder rolls uniformly distribute the groats across the roll gap to ensure uniform thickness. The rolls are carefully adjusted to give the flake thickness required by the particular product. Quick-oat products are rolled thinner than old-fashioned oats. Following rolling, the flakes are typically cooled by drawing ambient air through the mass of flakes, although other cooling devices may also be used.

The flakes after flaking machine are baked in rotary oven, which is heated by gas. There is a cone type revolving cylinder fitted in this oven. The outer surface of this cylinder is insulated, while the interior one contains a perforated metallic screen. The flakes after being perfectly baked fall on the conveyor belt to the holding tank for packing

The milling process of an oat kernel is summarized in the following figure.

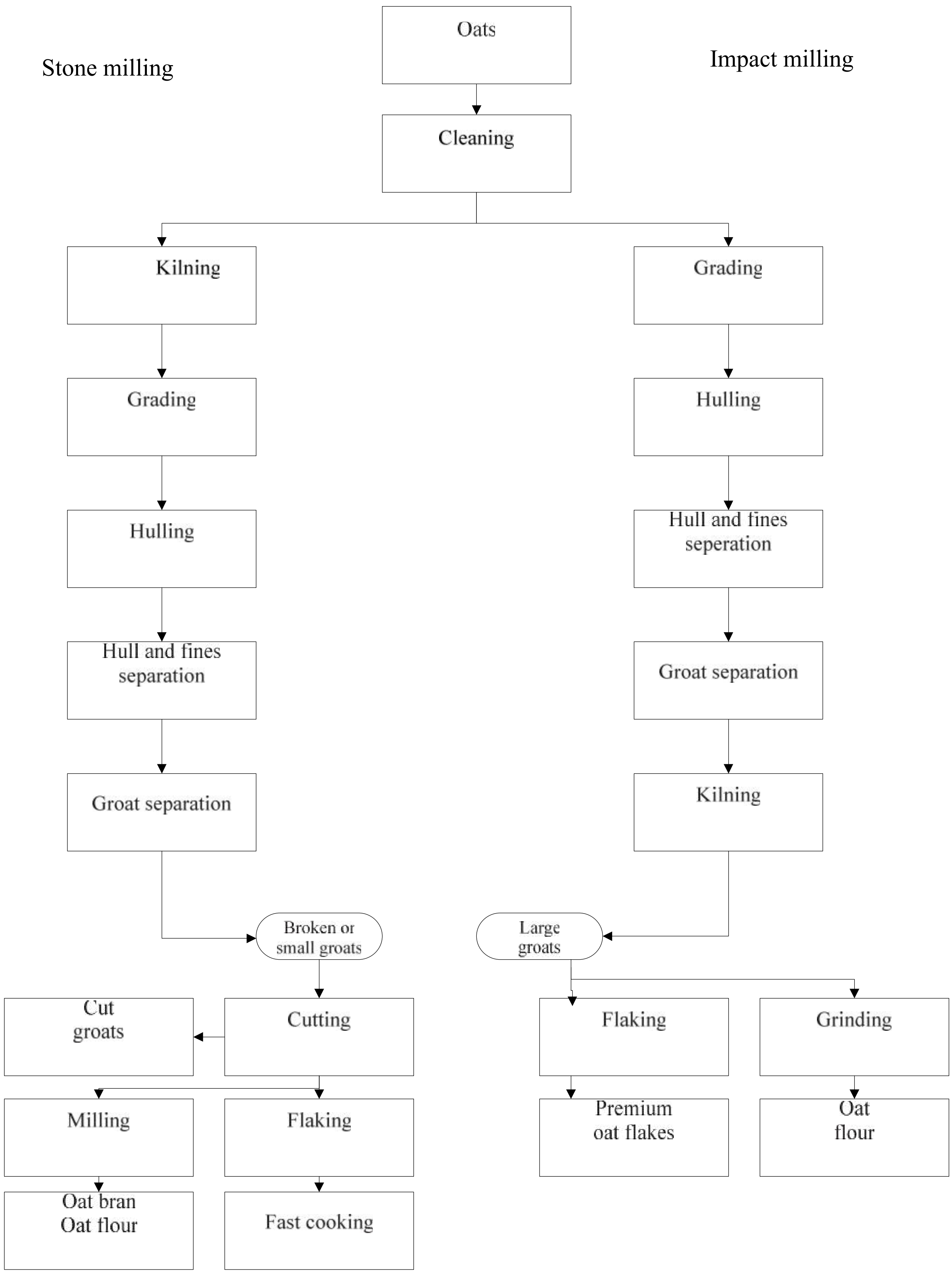


Figure 2.4: The milling process of an oat kernel

Hulls and fines are separated from whole groats, broken groats, and unhulled oats. Further refinement occurs when groats are separated based on physical characters, such as groat size and weight. Because oat groats have a high oil content, a heat treatment is required to inactivate enzymes that cause rancidity and bitterness in the final product. Kilning is a process that heats the groat at a certain temperature and moisture content to inactivate the enzymes. Kilning can occur before grading or after groat separation.

Commercial processors generally can produce 100 kg of product from 175 kg of oats. Milling efficiency varies according to the variety and the mill operating efficiency. Products produced include steel-cut groats, rolled oats, quick oats, baby oats, instant oat flakes, oat flour, and oat bran (Harold *et al.,* 2007).

2.5. Composite flour

Composite flours may be considered firstly as blends of wheat and other flours for production of 1) leavened breads, 2) unleavened baked products, 3) porridges, 4) pastas and 5) snack food; or, secondly, wholly non-wheat blends of flours or meals, for the same purposes. Sometimes, only one flour is used as a replacement – for example, tortillas and wheat less bread from sorghum, pasta from sorghum or maize, lager beer from sorghum (David and Dandy, 1993). 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).

Also, the addition of wheat flour to locally available cereals and root crops was found to be desirable to encourage the agricultural sector and reduce wheat imports in many developing countries. Although actual consumer trials have been rare, products made with composite flour have been well accepted in Colombia, Kenya, Nigeria, Senegal, Sri Lanka and the Sudan (Dendy, 1992). Consumer acceptance trials in Nigeria indicated that bread made with 30% sorghum flour was comparable to that from 100% wheat bread (Aluko and Olugbemi, 1989; Olatunji *et al.,* 1989). Bread with 30% sorghum and 70% wheat are also prepared in Senegal (Thiam and Ndoye, 1977). In recent times, the use of composite flour has become more popular in bread making (Shittu *et al.,* 2008).

When a fiber ingredient is used in a bakery product, its sensory compatibility with the product should be considered; for example, wheat fibers may be more appropriate for bread. Oat fibers, which are rich in β-glucans, have drawn attention during the last decade due to cholesterol-lowering properties. In a diet including several fat-reduced foods with oat fiber (Oat rim), baked goods had the highest rating and were acceptable by the middle-aged population. These results indicate that oat fiber-based ingredients are good candidates for fat replacement in bakery goods.

The protein fraction (gluten) is the main contributor to dough structure formation and viscoelasticity. The viscoelastic character can be found in a lesser extent in rye and barley (which contain a smaller amount of gluten proteins), and is entirely absent from oat, maize, and sorghum (which are cereals completely lacking in gluten proteins (Pavinee and Yael, 2001).

2.6. Oat wheat based product development

2.6.1. Bread ingredients and bread types

Advances in bread making technology facilitated new ingredients to enhance the physicochemical attributes of breads. Bread quality is determined by the complex interactions of the raw materials, their qualities and quantities used in the bread formulation and the processing method employed (Cauvain, 2003).

A. Flour

Wheat flour is the most important ingredient in bread formulation, as it is responsible for formation of viscoelastic dough when hydrated with water, is capable of supporting gas cells and retaining gas (Maforimbo *et al.*, 2008; He and Hoseney, 1991). Strong (hard-wheat) flour in which the high protein content ranged from 9% to 15% of dry weight is the basic ingredient for most baked products (Wilde, 2003).

Wheat flour consists of starch, gluten, non-starch poysaccharides, lipids and trace amounts of minerals. Starch, a major component of wheat flour, making up to 80% of wheat flour dry weight, significantly affects the dough rheological properties, particularly the starch gelatinization upon heating in the presence of water. Available water content has been suggested to modify the structural properties of the dough (Giannou *et al.*, 2003).

Martínez-Anaya (1996) stated that wheat flour contains considerably low amounts of sugar, about 1.55-1.84% (0.19-0.26% sucrose, 0.07-0.10% maltose, 0.01-0.09% glucose, 0.02- 0.08% fructose and 1.26-1.31% oligosaccharides (fructosans and maltooligosaccharides)).

Typically, wheat flour contains two types of amylases i.e. α-amylase and β-amylase. Both amylases degrade the wheat starch producing dextrins and maltose sugars. Almost 85% of starch is converted to sugars, ready for transformation by yeast into carbon dioxide (CO_2) and alcohol during dough fermentation (Belderok, 2000).

B. Yeast

Yeast's roles in bread making are crucial by acting as a leavening agent, strengthen and developing gluten in dough and contributing to the flavor generation in the bread. *Saccharomyces cerevisiae* is the most common yeast species used in bread making. The suggested amount of yeast for optimum dough rheology and crumb texture is 2% w/w of flour (Mondal and Datta, 2007; Giannou *et al.*, 2003).

Yeast cells metabolize the fermentable sugars (glucose, fructose, sucrose and maltose) under anaerobic conditions producing carbon dioxide, which acts as a leavening agent and enhances dough volume (Giannou *et al.*, 2003). Sugar and warm water were added to the yeast for initiation of fermentation (Mondal and Datta, 2007).

C. Salt

The presence of salt (sodium chloride) primarily contributes to the improvement of bread flavor. According to Mondal and Datta (2007), addition of salt at optimum level helps in conditioning the dough by improving its tolerance to mixing process, subsequently producing a more stable and stiff dough by affecting the dough rheological properties.

D. Sugar (sucrose)

Sugar, particularly sucrose provides the characteristics of sweetness of the bread. The common practice of sugar level added in the bread is up to 4% of total flour. Sugar normally is used as the fermentable carbohydrate for the yeast during initiation of fermentation (Belderok, 2000).

Later, additional sugar is released for further gas production by the action of enzymes in the flour (Giannou *et al.*, 2003). However, higher levels of sugar may inhibit the yeast activity although it is fermentable (Cauvain, 2003).

E. Shortening

Shortening is often added to the dough to obtain a softer crumb, improvement in loaf volume and to act as anti-staling effect, which may extend the shelf life of loaf. Shortening is a term used in the baking industries to describe fats, oils and their derivatives to improve the bread quality (Stampfli and Nersten, 1995).

Addition of shortening allows the weaker flour to be used in the formulation by aiding the increment of the dough strength and stability, and gas retention (Stampfli and Nersten, 1995). Hence, by adding shortening in high-fibre breads increased the loaf volume (Autio and Laurikainen, 1997). Conversely, Lai *et al.*, (1989a) reported the elevated amount of shortening stimulated little effect on augmentation of loaf volume with the addition of bran in the bread formulation.

F. Improvers

The use of improvers in bread making has been practiced to improve dough handling properties, increase the quality of fresh breads and extend the shelf life of stored bread (Rosell *et al.*, 2007). Improvers are added to improve dough strength which results in higher loaf volume and better crumb texture. Improvers in the bread formulation may contain one or combination with other ingredients, depending on the functionality of the additive in the bread making (Cauvain, 2003). Oxidative flour improvers such as ascorbic acid and potassium bromate are widely used in the bakery industry.

Many different bread types have been evolved with the passage of time and all require their own individual bubble structures, processing techniques, processing equipment and process control mechanisms. The main bread types can be divided into four broad categories (Gavin, 2000)

1. Pan breads – that is, products based on placing a piece of dough in a metal pan for the proving and baking stages. Commonly the pan will be rectangular, though round pan shapes are known. Sometimes the pan may have a separate lid fitted to more tightly control product shape. Examples are the sandwich loaf (lidded), open-top pan breads, pan

coburgs (round, unlidded), milk rolls (round, lidded) and malt loaves (baked under inverted pans).

2. Free-standing breads – that is where the dough product is proved and baked without the aid of a pan to constrain and support the sides of the dough. This approach leads to a crustier product. Examples of this type of product include, bloomers, cottage loaves and coburgs.
3. Baguettes, pain Parisien and other products made as long, stick-shaped loaves. Sometimes placed on indented trays for proving and baking. Typically these products will have a high degree of crust formation and characteristic surface markings.
4. Rolls and other small fermented breads baked on trays or indented pans. These products will have higher levels of sugar and fat in the recipe and so typically will have a sweeter flavour and softer eating character.

The process by which bread quality is determined still relies heavily on subjective assessment (Cauvain, 1998b). Broadly there are groups of attributes which will be taken into account:

- External character which encompasses product dimensions, volume, appearance, colour and crust formation.
- Internal character which considers the sizes, numbers and distribution of cells in the crumb (crumb grain), the crumb colour and any major quality defects, such as unwanted holes or dense patches, visible in a cross section of the product. Each bread type has its own special cell structure requirements and therefore there is no single standard which can be applied to all products.
- Texture, eating quality and flavour. In assessing texture we are concerned with its mechanical properties such as firmness and resiliency.

2.6.2. Bread making processes

Bread represents a substantial part of the daily food around the world. Continuous improvement in baking technology and introduction of new materials and ingredients to the bread composition resulted in better quality product which enhance its' nutritional value (Mondal and Datta, 2007).

The value-added products in the health food sector are significantly expanding and gaining popularity in the world due to the increase consciousness in health. Various types of high fiber food products are found in the market. High dietary fiber content of bread and baked products are well accepted by the consumers for its health claim.

However, bread and baked products with high dietary fiber content required new technology to satisfy the quality and palatability of the products. In recent years, baking technology has advanced drastically to meet the preference of consumers needs. In the modern baking industries, bread making technology evolved significantly to suit the large scale production and increased demand of consumers on high qualities, yet maintaining the cost efficiency for the industry itself (Mondal and Datta, 2007; Giannou *et al.*, 2003).

A. Major bread making process methodologies

Generally, the process of bread making can be divided into three basic operations i.e. mixing, fermentation (resting and proving) and baking (Sahlström and Bråthen, 1997). Mixing entrains gas cells into the dough; proving inflates these gas cells with CO_2 generated by yeast during fermentation; and baking transforms the foam structure containing discrete bubbles into a sponge of interconnected gas cells, and sets the structure (Campbell, 2003). However, different processing methods vary in the aforementioned operations and responded differently to diverse ingredient qualities and formulations (Cauvain, 1998b).

The simplest bread making procedure is the straight-dough method whereby all the ingredients in bread formulation are mixed to form developed homogenous dough in one-step (Sahlström and Bråthen, 1997). Dough formation for straight-dough method require low amount of energy during mixing process to produce a suitable bread quality (Cauvain, 1998b). Subsequently, the resting periods of the dough in this method varied depending on the flour quality, yeast level, dough temperature and the specificity in types of bread produced (Mondal and Datta, 2007). A typical white wheat flour protein content used in this bread making procedure is 12% or higher to obtained an optimum dough development. However, addition of non-wheat flour resulted in lower bread quality due to lower flour quality and strength (Cauvain, 1998b).

Sponge and dough method is another type of bread making processes which includes two-stages of mixing process. Leavening agent consists of yeast and certain amount of water and flour are mixed to form homogenous soft dough i.e. the sponge (Mondal and Datta, 2007). The leavening agent is left to develop, depending on flavour requirements and later mixed with the remainder of the ingredients to form homogenous dough (Cauvain, 1998b).

In typical sponge-dough methods, combinations of high-protein and low-protein flours were used to obtain a satisfactory loaf. Stronger gluten bread flours are commonly used in the sponge state, as the sponge is subjected to double mixing and extended fermentation. Meanwhile, in the dough stage, the remainder weaker gluten flour is added to preferment and mixed to obtain optimum dough development (Hareland and Puhr, 1998).

Hareland and Puhr (1998) hypothesized that the adjustment of weaker gluten flour (non-bread flour) used in the dough stage will be made by stronger gluten bread flour used in the sponge stage. However, the differences of crumb firmness were observed attributed by the water binding capacity of different flour blends.

The invention of mechanical dough development or Chorleywood Bread Process (CBP) from 'no-time dough' method was to achieve optimum dough qualities in an ultrahigh mixer for a few minutes (Mondal and Datta, 2007). The energy expenditures are capable in breaking the disulphide bonds, which modified the protein structure in the dough and thus improved its ability to stretch and retained gas from yeast fermentation in the prover (Cauvain, 2003; Cauvain, 1998b). In the CBP, mixing process carried out under partial vacuum condition gives fewer bubbles in the loaf, resulting in a finer gas cell structure (Campbell, 2003). However, in the CBP method, bakery fat or shortening is an obligatory ingredient in the formulation for production of acceptable final product (Campbell, 2003; Gan *et al.*, 1995).

The CBP method was adopted in modern baking industries to produce similar dough consistency and bread qualities even with lower protein content flour due to mechanical mixing actions (Cauvain, 2003).

B. Mixing

Mechanical and enzymatic degradation involved during bread making are necessary to eliminate the starchy residual taste of flour (Martínez-Anaya, 1996). Mixing is considered as the critical control point in bread making, which in turn determined the quality of the final product (Campbell, 2003). Mixing is the homogenization of ingredients for uniform dispersion, development of the gluten structure in the dough and incorporation of air bubbles within the dough (Cauvain, 2003; Autio and Laurikainen, 1997). Mixing is a comprehensive series of compressing and stretching (kneading) process of the ingredients (Cauvain, 2003) to impart the necessary work for formation of extensibility and cohesive strength of the dough for subsequent processing (Gan *et al.*, 1995).

During dough mixing, wheat flour is hydrated and starch from flour absorbs almost 46% of total water (Goesaert *et al.*, 2005). As a consequence of the mechanical energy input, distinct masses of gluten proteins were disrupted and transformed into a continuous cohesive viscoelastic gluten protein network (Keetles *et al.*, 1996). Other ingredient interactions such as lipid, salt, non-starch polysaccharides and starch itself contributes significantly to the formation of gluten matrix for optimum dough development (Giannou *et al.*, 2003).

During mixing, the dough resistance began to increase gradually until optimum level is reached and further mixing decreased the dough resistance, a condition of 'over-mixing' (Goesaert *et al.*, 2005). Over-mixing affects the gluten protein network, which certain disulphide bonds disrupted to form thiol radicals and gluten proteins are partially depolimerized (Giannou *et al.*, 2003), thus increased solubility of proteins and decreased extractability of lipids, which resulted in sticky dough (Autio and Laurikainen, 1997).

Mixing conditions is highly dependent on the rapid processing, homogeneity and temperature (Giannou *et al.*, 2003), as well as atmospheric conditions (Cauvain, 2003) to form dough with good rheological properties and bread characteristics (Autio and Laurikainen, 1997). Types of mixers are crucial in determining the structure of the final bread product. High-speed mixers with blades shear the dough effectively and produce small bubbles, which results in fine structured bread, while low-speed mixers, such as spiral-type mixer occlude more air but result in uneven pore size distribution (Autio and Laurikainen, 1997).

C. Proofing

Proofing is stipulation for dough resting period allows time under favourable conditions to activate the yeast and enzymes in the flour. The purpose of proofing is to produce dough that are sufficiently soft, extensible and relaxed for optimum rheological properties (Giannou *et al.*, 2003). Proofing link the bubbles size distribution created in the mixer to the bubble distribution apparent in the baked loaf, through the dynamics of CO_2 generation by yeast and its mass transfer into gas cells and further coalescence (Campbell, 2003).

Flander *et al.*, (2007) reported that the proofing time is more pronounced in determination of specific volume and firmness of bread than the proofing temperature. Relaxation time of the dough is one of the important rheological properties which is related to disappearance of free liquid water at certain temperature (Mondal and Datta, 2007).

Proofing mainly attributed to the yeast action regarded as dough maturing or ripening (Giannou *et al.*, 2003). During proofing, starch from the flour progressively converted into dextrins and sugars by enzyme actions (Cauvain, 2003). Proofing process further changes the gluten protein network by becoming less extractable. Gluten protein network of fermenting dough is essential in retaining the CO_2 production during fermentation period as CO_2 production contributes to dough expansion and the initial stages of baking (Goesaert *et al.*, 2005).

The gas phase of a proofing dough exists as a dispersion of discrete gas cells comprising of starch, gluten and other minor constituents (Gan *et al.*, 1995). The proportion of gas retention depends on the development of a suitable gluten matrix within the dough which the expanding gas can be held (Cauvain, 1998b). Hence, gas stabilization and gas retention stimulates the crumb structure and volume of bread (Giannou *et al.*, 2003).

During proofing, the dough expands by a factor of three or four to its almost final volume. However, the dough expansion is restricted by the walls of the tin, which determine the shape and orientation of the cells in the final product (Wiggins, 1998). The growth of gas cells during proofing depends partly on the size of the cells. Greater pressure is needed to expand a small gas cell than the larger cells, while the smallest gas cell presumably will not undergo gas expansion at all (Autio and Laurikainen, 1997).

D. Baking

During all processing steps of bread making, various complex chemical, biochemical and physical transformation occurs, which affect and are affected by the diverse flour constituents (Goesaert *et al.*, 2005). Baking is the last but the most important stage in bread making procedure. Time and temperature of the baking process determine the quality and shelf life of the bread products. Temperature affects various physicochemical changes, which increase in baking temperature promotes the formation of protein cross-links to set the loaf during baking (Mondal and Datta, 2007).

Meanwhile, Campbell (2003) stated that baking contributed to additional leavening action and bread dough, which experienced a structural transformation from foam into an open sponge structure, containing a porous interconnected network of fine gas cells separated by thin walls through rupture of starch-protein matrix and gas diffusion (Keetles *et al.*, 1996; Gan *et al.*, 1995). In addition, protein denaturation and starch gelatinization both affect the water diffusion by releasing and absorbing water, hence contributing to transformation from dough to crumb (Mondal and Datta, 2007). Breadcrumb has a porous structure, mainly consisting of open polyhedral cells with very small cells enclosed together thus forming solid elastic sponge material (Keetles *et al.*, 1996).

Simultaneously, several conversion activities take place during baking such as evaporation of water, formation of porous structure, starch gelatinization, protein denaturation, melting of fat crystals, volume expansion, crust formation and browning reaction. In addition, incorporation into the surface of air cells, rupture of gas cells and sometimes fragmentation of cell walls occur during baking process (Mondal and Datta, 2007; Giannou *et al.*, 2003; Autio and Laurikainen, 1997). Baking process alters the physical properties of wheat flour through a series of changing procedure, known as gelatinization (Mondal and Datta, 2007; Primo-Martín *et al.*, 2006) and the flour properties are continuously modified until the structure of final product is achieved (Giannou *et al.*, 2003). Thermal reactions during baking, including caramelization and non-enzymatic browning promote crust flavor and color (Martínez-Anaya, 1996).

The role of baking is purposely to alter sensory properties of food products, to improve palatability and to extend the range of tastes, aromas and textures in food products from its raw material (Giannou *et al.*, 2003). According to Campbell (2003), baking resulted in structure having a solid outer crust and a soft, delicate crumb comprising of cell walls, which surround the gas cells and determine the mechanical properties of the loaf. The internal and external appearance, compressibility and fracture mechanics of the loaf are the main indicators in determining its aesthetic appeal, apparent freshness and performance.

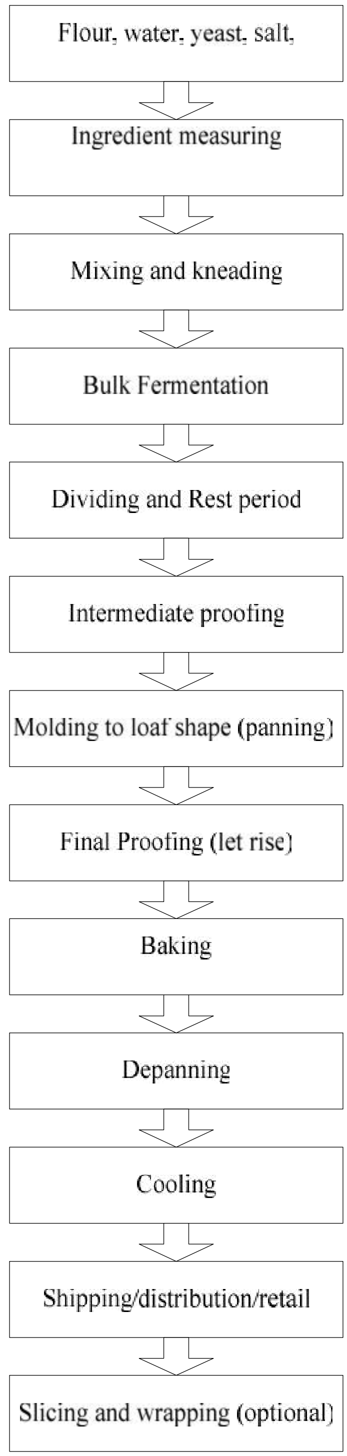


Figure 2.5. The basic procedures carried out in the bakery.

2.6.3. Farinograph parameters

The farinograph determines dough and gluten properties of a flour sample by measuring the resistance of dough against the mixing action of paddles (blades). Farinograph results include absorption, arrival time, stability time, peak time, departure time, and mixing tolerance index.

The farinograph test is one of the most commonly used flour quality tests in the world. The results are used as parameters in formulation to estimate the amount of water required to make dough, to evaluate the effects of ingredients on mixing properties, to evaluate flour blending requirements, and to check flour uniformity for the detailed extension of the parameters see Figure-2.6. The results are also used to predict processing effects, including mixing requirements for dough development, tolerance to over mixing, and dough consistency during production. Farinograph results are also useful for predicting finished product texture characteristics. For example, strong dough mixing properties are related to firm product texture.

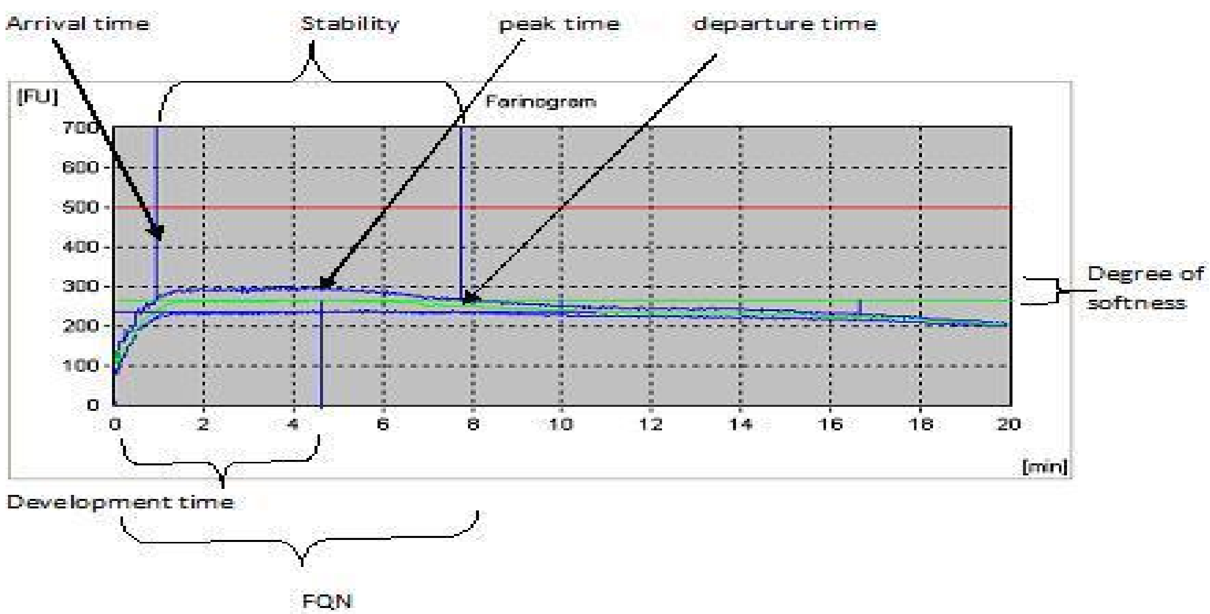


Figure 2.6: The graphical representation of the farinograph

The farinograph test measures and records the resistance of dough to mixing with paddles.

- Absorption is the amount of water required to center the farinograph curve on the 500-Brabender unit (BU) line. This relates to the amount of water needed for a flour to be optimally processed into end products. Absorption is expressed as a percentage.
- Peak Time indicates dough development time, beginning at the moment water is added until the dough reaches maximum consistency. This gives an indication of optimum mixing time under standardized conditions. Peak time is expressed in minutes.
- Arrival Time is the time when the top of the curve touches the 500-BU line. This indicates the rate of flour hydration (the rate at which the water is taken up by the flour). Arrival time is expressed in minutes.
- Departure Time is the time when the top of the curve leaves the 500-BU line. This indicates the time when the dough is beginning to break down and is an indication of dough consistency during processing. Departure time is expressed in minutes.
- Stability Time is the difference in time between arrival time and departure time. This indicates the time the dough maintains maximum consistency and is a good indication of dough strength. Stability time is expressed in minutes.
- Mixing Tolerance Index (MTI) is the difference in BU value at the top of the curve at peak time and the value at the top of the curve 5 minutes after the peak. This indicates the degree of softening during mixing. Mixing tolerance index is expressed in Brabender units (BU). Weak gluten flour has a lower water absorption and shorter stability time than strong gluten flour adapted from AACC, 2000.
- Farinograph quality number (FQN) is the point of the curve in which the curve has decreased by 30 FU after the maximum (based on the line of the diagram). Thus weak flour weakens early and quickly giving low quality number. Strong flour weakens late and slowly indicting a high quality number.
- Degree of softening is the difference between consistence line and medium line of the torque curve.

Interpretation of Farinograph Curve

1. Farinograph water absorption value: The amount of water added to balance the curve on the 500-BU line, expressed as a percentage of the flour (14% mb), is known as Farinograph absorption. Water absorption value varies from about 50% for cookie and biscuit flour and around 60% for bread flour.

2. Dough development time or mixing time or peak time: This is the time between the origin of the curve and its maximum. The maximum of the Farinogram curve, or any mixing curve, is commonly considered the point at which the dough is optimally developed and best able to retain gas.

3. Mixing tolerance index: It is measured as the difference (in Brabender units) between the top of the curve at the maximum and the point on the curve 5 minute later.

4. Stability: It is defined as the difference in minutes between the arrival time and the time the top of the curve falls below the time 500 BU line (i.e. the departure time).

2.6.4. Falling number

The falling number is defined as the time in seconds required to stir and to allow a viscometer stirrer to fall a measured distance through a hot aqueous meal, flour, or starch jell undergoing liquefaction due to alpha amylase activity (ICC,2000). The falling number method indicates alpha amylase activity using the starch in the sample as substrate. The method is based upon the rapid measurement of the liquefaction of the starch paste by the alpha-amylase in the sample

The falling number indicates the amount of sprout damage that has occurred in wheat grain. According to Sologuk and Sorenson (2005), a falling number value of 300 seconds or longer indicates a low enzyme activity and very sound wheat quality. As the amount of enzyme activity increases the falling number decreases. Values below 200 seconds (Sologuk and Sorenson, 2005; German, 2006; ICC, 2000) indicates high levels of enzyme activity.

In bread, the falling number affects the product in several ways. It can reduce mixing strength, cause stickiness of dough, affect loaf volume and shelf life (German, 2006; ICC, 2000). Generally when the alpha amylase activity is right, high volume bread with firm and soft texture as well as brown colored bread is achieved. On the contrary, when the activity is too high, a sticky bread crumb and low volume is obtained. The diagram (Perten instruments, 2005), below shows this condition.

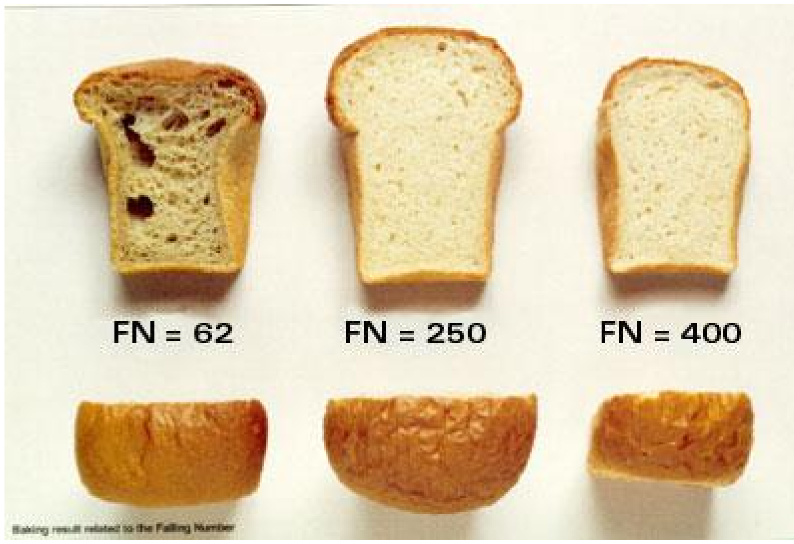


Figure 2.7: Effect of falling number on bread quality (Perten instruments, 2005)

2.6.5. Oat flake

Oat flakes are oats which have been specially treated so that they will cook quickly. This food is extremely versatile, and it can be found in a range of recipes and an assortment of places as a result. Most markets carry oat flakes along with a variety of other oat products, often in bulk form with other grains and near the breakfast cereals, and they can be a very healthy and useful addition to the human diet, thanks to their high nutritional value. Oat flakes can make the addition of fiber to the diet very easy, thanks to their quick cooking time.

When oat flakes are made, whole oats are steamed to soften them and then they are rolled out to flatten them. The flattened oats are then flaked into small pieces of material which will cook very quickly while retaining the nutritional value of whole oats. One of the big disadvantages to whole oats is that they can take a long time to cook; oat flakes cut down on the cooking time, turning the healthy oat into a convenience food.

By adjusting the flake thickness and by pregelatination of flakes, the cooking time of the product can be adjusted. In addition, instant types of the porridge are available.

CHAPTER THREE

Materials and Methods

3.1. Procurement of raw materials and primary treatment

Two types of food grains (wheat and oat) were used in the study. The wheat variety SH 2002 was purchased from KFSC and oat grain was purchased from local market. Whereas yeast, sugar, salt, shortening, etc were obtained from the KFSC. The wheat flour was used as a base material for the preparation of composite flours with oat flour. The cleaning of oat and wheat grains was performed manually to remove damaged seeds, dust particles, seeds of other grains/crops and other impurities such as metals and weeds. The samples were then packed in polypropylene bags and stored at room temperature for further analysis.

3.2. Thousand Kernels Weight

The Thousand Kernels Weight of the wheat samples was determined by counting thousand kernels from the sound and cleaned wheat. The counted thousand kernels were weighed on the precision balance to better describe wheat kernel composition and potential flour extraction. Generally speaking, wheat with a higher TKW can be expected to have a greater potential flour extraction.

3.3. Milling of grains

The wheat grains were tempered to 15.5% moisture level and allowed to stand for 24 hours at room temperature in a closed container in order to equilibrate moisture content in grains. The water required to temper the wheat grains was computed according to the expression given below (AACC, 2000).

$$\text{Wt. of water to be added} = \frac{100 - \text{original moisture}}{100 - \text{desired moisture}} - 1 * \text{Wt. of wheat sample} \qquad 3.1$$

The tempered wheat grains were milled in a poly mix Mill to get straight grade flour. The milling of wheat grain samples was carried out by the instructions provided in AACC (2000). The milling of oat grain was carried out by the method mentioned in figure 2.4.

Figure 3.1: a) Oat flour b) Wheat flour

3.4. Preparation and storage of composite flours

The composite flour was blended using laboratory beating (mixing) machine (Model: R100C, CAT). The straight grade wheat flour was blended with varying levels of oat flour as per detail given in Table 3.1. The ratios were selected based on previous works and trial experiments. The composite flour samples and the control were prepared and packed in plastic buckets. The plastic buckets then kept well in a cool, dry, and dark location to prevent the flour from absorbing moisture as well as odors and flavors from other substances.

Table 3.1: Percentage composition of composite flour

Sample	WF%	OF%
S_1	100	-
S_2	95	5
S_3	90	10
S_4	85	15

WF: wheat flour
OF: oat flour
S_x : $sample_{no}$

3.5. Analysis of flour samples and composite flour breads

3.5.1. Proximate composition

The two flour samples (oat and wheat flour) and breads made from composite flour were analyzed for their chemical composition such as moisture, ash, crude fat and crude fiber contents according to their respective methods described in AACC (2000).

3.5.1.1. Moisture content

The moisture content in the two flour samples (oat and wheat flour) and composite bread samples were determined according to AACC (2000) method No. 44-15A by taking 5 gram sample and drying it in an air forced draft oven at a temperature of 105±5°C till a constant weight of the dried material is attained. The moisture content was calculated according to the following formula:

$$\text{Moisture}(\%) = \frac{\text{Wt. of original flour sample} - \text{Wt. of dried flour sample}}{\text{Wt. of original flour sample}} * 100 \qquad 3.2$$

3.5.1.2. Crude protein

The protein content of wheat and oat grain samples were measured by grain analyzer (Minifra-2000T, made in Slovakia) where clean samples were placed in a sample cell (cuvette) and inserted in to the machine for one minute, as shown in the figure below. The protein content of the samples was read from the instrument and recorded.

Figure 3.2: Mininfra -2000T Grain analyser (Infracont Kft , Slovakia, 2005)

The crude protein content in the two flour samples (oat and wheat flour) and composite flour breads were estimated according to the Kjeldahl's method as described in AACC (2000) method No. 46- 10. Two grams sample was weighed and put into the digestion tube. Twenty milliliters of concentrated sulphuric acid (98%) and 2 tablets of digestion mixture as catalyst were added into the digestion tube. The digestion was carried out for 3-4 hours (till the digested contents attained transparent color). The digested material was allowed to cool at room temperature and diluted to a final volume of 50 mL. The ammonia trapped in H_2SO_4 was liberated by adding 40% NaOH solution through distillation and collected in a flask containing 4% boric acid solution, possessing methyl indicator and titrated against standard 0.1N H_2SO_4 solution. The factors 5.70 and 6.25 were used for the conversion of percent nitrogen into crude protein contents of composite flours and wheat flours; respectively.

$$\text{Total Nitrogen percent by weight} = \frac{14.007 \times (T - B) \times N \times 100}{W} \tag{3.3}$$

Where: T: volume in mL of the standard sulphuric acid solution used in the titration for the test material.

B: volume in mL of the standard sulphuric acid solution used in the titration for the blank determination.

N: Normality of standard sulphuric acid.

W: Weight in grams of the test material.

Percent nitrogen was multiplied by factor 6.25 (for wheat flour and composite bread) and 5.70 (for oat flour) were to calculate percent protein. The calculated protein be on a total nitrogen basis.

3.5.1.3. Total ash

The two flour samples (oat and wheat flour) and composite flours bread were tested for total ash content by taking 3g sample in tarred crucibles and charred on a flame until it turned black and put into a muffle furnace maintained at a temperature of 550 °C for 5 hours or till a grey color of ash was obtained. The details described in AACC (2000) method No.08-01 were followed for the estimation of total ash contents. The ash content was calculated according to the formula given below:

$$\text{Ash}(\%) = \frac{\text{Wt. of ash}}{\text{Wt. of flour sample}} * 100 \quad 3.4$$

3.5.1.4. Crude fat

The crude fat content in the two flour samples (oat and wheat flour) and composite flours bread samples were determined by taking 3g dried sample and running through Soxhlet apparatus for 2-3 hours using petroleum ether as a solvent by following the procedure described in AACC (2000) method No.30-10.

$$\text{Crude fat}(\%) = \frac{\text{Wt. of fat}}{\text{Wt. of flour sample}} * 100 \quad 3.5$$

3.5.1.5. Crude fiber

The crude fiber was estimated according to the procedure as outlined in AACC (2000) method No. 32-10. It was carried out by taking 3g of each fat free sample and digested first with 1.25% H_2SO_4, washed with distilled water and filtered, then again digested with 1.25% NaOH solution, washed with distilled water and filtered. Then ignited the sample residue by placing the digested samples in a muffle furnace maintained for 3-5 hours at temperature of 550-650 °C till grey or white ash was obtained. The percentage of crude fiber was calculated after igniting the samples according to the expression given below.

$$\text{Crude fiber}(\%) = \frac{\text{Wt. loss in ignition}}{\text{Wt. of flour sample}} * 100 \quad 3.6$$

3.5.2. Mineral contents

The mineral contents like K, Ca and Mg in the two flour samples (oat and wheat flour) and composite breads were determined by the method described in AOAC (1990). One gram of sample was digested with 10 ml of nitric acid: Percholric acid (7:3) mixtures at temperature up to 180-200°C till transparent contents were obtained. The contents were diluted to a volume of 100 ml with double distilled water. Concentration of mineral contents was determined by running the diluted samples through Atomic Absorption Spectrophotometer (Model: Varian, AA-240, Victoria, Australia) using air Acetylene flame.

3.5.3. Wet gluten determination

The wet gluten test provides information on the quantity and estimates the quality of gluten in wheat or flour samples. Gluten is responsible for the elasticity and extensibility characteristics of flour dough.

Wet gluten content was determined by washing the composite flour samples with a 2% salt solution to remove the starch and other solubles from the sample. The residue remaining after washing is the wet gluten. Wet gluten content results are expressed as a percentage.

$$\text{wet gluten}(\%) = \frac{\text{weight of finally washed gluten}}{\text{amount of flour used}(10\text{gm})} * 100 \qquad 3.7$$

3.5.4. Rheological characteristics

Rheological characteristics of composite flour samples such as water absorption, stability, dough development, degree of softening and farinograph quality number of the composite flours were measured using the Brabender Farinograph (C. W. Brabender, Duisburg, Germany) according to the standard method of ICC No 115/1 for the determination of the quality characteristics of composite flour samples. The instrument automatically determines the amount of flour to be poured into the mixer of the farinograph based on the moisture content of the flour. The farinograph is equipped with a 300 g capacity mixer. Mixing was carried out for 20 minutes. Immediately when the mixing starts, the computer automatically starts to plot the graph. The speed of the torque was adjusted to be 63 min^{-1}

Figure 3.3: Farinograph measuring instrument (Brabender, Germany)

3.5.5. Color grade

Flour color often affects the color of the finished product and is therefore one of many flour specifications required by end-users. The color analyzer (model Satake Color Grader Series IV, Germany year) uses ultra violet light to determine the absorbance of emitted lights. The color grade value of the flour samples was measured to make sure the brightness of the flours. 30 g 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 with in 90 seconds.

Figure 3.4: Stake color grade series (series IV, Germany)

3.5.6. Falling Number

The level of enzyme activity measured by the Falling Number Test affects product quality. Both the wheat and oat flour samples were evaluated for falling number using the Hagberg falling number apparatus (model 1500, Sweden , 2005) according to the ICC standard No 107/1 for the determination of the amylase activity of cereal and flour.

Figure 3.5: Falling Number measuring instrument (Perten Instruments, Sweden , 2005)

3.6. Functional properties

3.6.1. Oil absorption capacity

Oil absorption was determined by the method of Rosario and Flores (1981). One gram sample was mixed with 10mL oil (refined groundnut oil) for 30 sec in a mixer. The samples were then allowed to stand for 30 min at 30 ^{0}C in a water bath and centrifuged at 3000rpm for 20 min. the volume of supernatant was recorded to calculate the amount of oil absorption capacity.

3.6.2. Sedimentation value

Sedimentation value were determined by AACC method 56-60.01 which follows the following procedure

- ✓ A small sample of flour or ground wheat (3.2 grams) was weighed and placed in 100-milliliter glass-stopper graduated cylinder.
- ✓ Water (50 milliliter) was added to the cylinder and mixed for 5 minutes.
- ✓ Lactic acid solution was added to the cylinder and mixed for 5 minutes.
- ✓ The cylinder was removed from the mixer and kept in upright position for 5 minutes.
- ✓ The sedimentation volume is recorded.

3.7. Development of oat based products

3.7.1. Bread preparation

Bread was prepared by straight dough method bread production process (mixing and kneading, bulk fermentation, molding, rounding, intermediate proofing, molding, final proofing, baking, cooling and packaging). The control flour (100% wheat flour (wf)), blended flours at ratios of 5 of : 95 wf, 10 of : 90 wf and 15 of : 85 wf were employed in the production of bread.

The baking formula was 62% wheat flour or the blend, 0.3 % yeast, 0.3% bread improver, 0.6 % salt and 37.0 % water. All ingredients were mixed in a dough mixer (model: B15mixer) for 15 minutes. The dough was fermented in a bowl covered with polyethylene plastic for 30 minutes at room temperature. It was then knocked back and molded. The dough pieces were then allowed to ferment for 60 minutes in a proofing room of temperature 35 ^{0}C and relative humidity of 80 %. The fermented dough was baked at 250 ^{0}C for 20 minutes (Toufeili *et al.,* 1999; the federation of baking, 2002; Edema *et al.,* 2005; Olaoye *et al.,* 2006).

3.7.2. Oat flake processing

Groats were steamed in a laboratory steamer and tempered in an oven at 110°C for 30 min. The maximum force required to compress the steamed groats were applied. Tempering conditions also affected water absorption.

Flakes were prepared from the tempered groats using a laboratory flaking machine(roller mill). Different properties (specific weight, thickness and moisture content), were studied and compared with the control sample. Sensory analysis using trained panelists were conducted.

3.8. Bread quality

The loaves were packed in polyethylene bags and analyzed for volume (cm^3), weight (g) and specific volume (g/cm^3). Bread volume was measured by rapeseed displacement method (AACC, 2000) and the volume was divided by bread weight to calculate the specific volume.

$$\text{Specific volume} = \frac{\text{Loaf volume}}{\text{Loaf weight}} \qquad 3.8$$

3.9. Sensory evaluation of bread and flake products

The subjective evaluation of bread and flake products were carried out for the external sensory characteristics. Bread and flake products were evaluated for color, appearance, flavor, taste, mouth feel, and overall acceptability by taste panel using 5-Point Hedonic Score System (Meilgaard *et al.,* 2007) with following individual scores: 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1 = Poor, to find out the most suitable product for commercialization.

3.10. Experimental design and data Analysis

Data were reported as mean values and standard deviation. Comparisons among means were performed by one-way ANOVA. The Student's t was used to test for comparison of the means among different products. Significance was accepted at probabilities of less than 0.05. All statistical analyses performed used JMP version 5 (SAS Institute Inc., USA, 2002). All measurements were performed in duplicate.

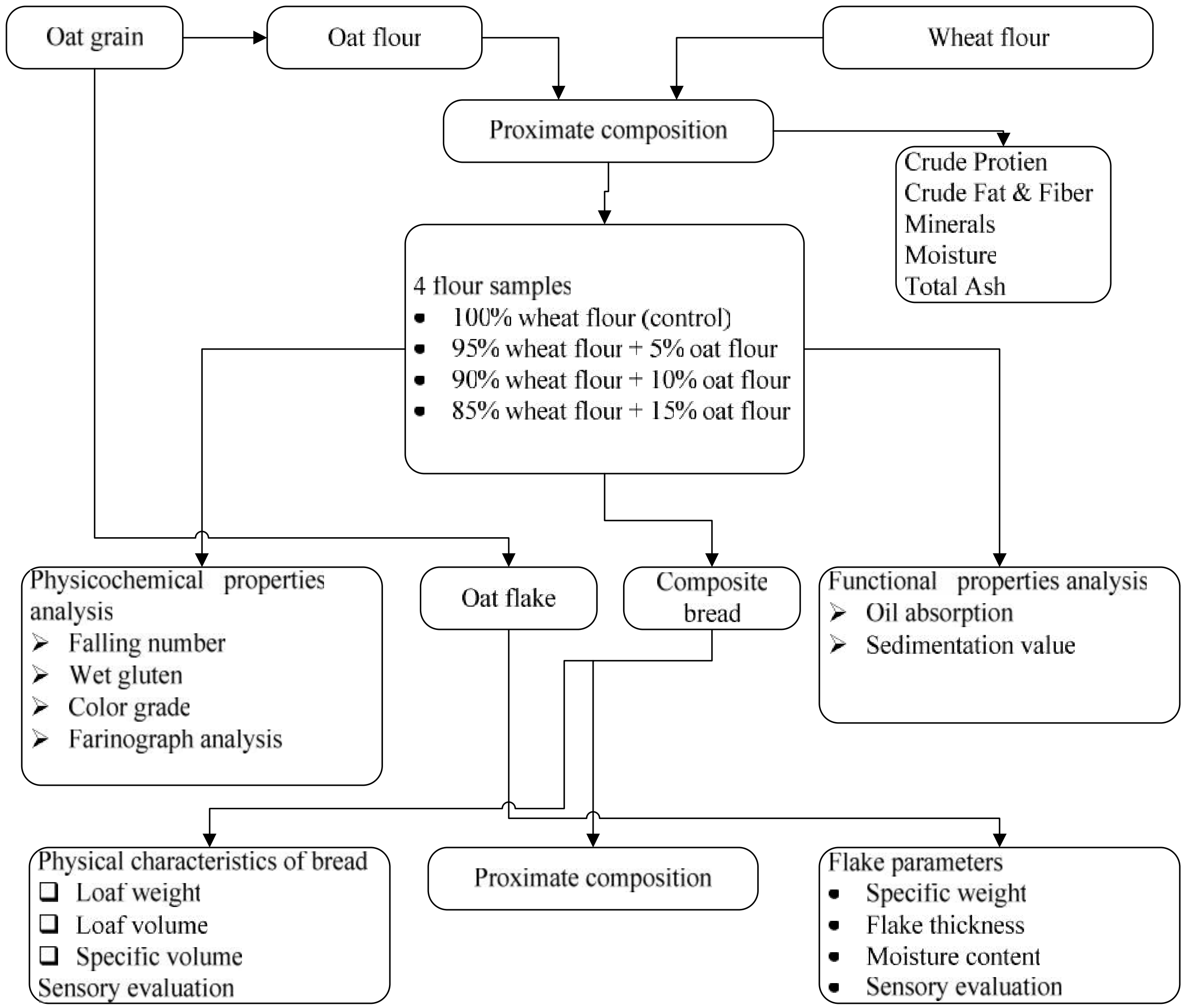


Figure 3.6: Framework of experiment carried out to evaluate baking and flaking quality of local oat grain variety

CHAPTER FOUR

Results and Discussion

The wheat and oat grains were used as basic research materials in this study. Two types of flours (wheat and oat flour) were analyzed for their chemical composition before blending to get different composite flours. Composite flours were analyzed for their rheological properties. The composite flour breads were also analyzed for proximate composition. The oat flake and breads prepared from different composite flours were subjected to sensory evaluation to assess their quality. The results of all the investigated parameters are discussed in the following sections.

4.1. Quality characteristics of oat and wheat flours

4.1.1. Proximate composition and total kernel weight

The results regarding total kernel weight (TKW), Table 4.2, shows that the wheat grain is non significantly higher than to that of the oat grain. This shows generally speaking, wheat with a higher TKW can be expected to have a greater potential of flour extraction.

The results regarding chemical analyses of oat and wheat flours are presented in Table 4.1. The oat flours possessed minimum moisture (5.61%) content as compared to wheat flours. The highest moisture content (11.35 %) was recorded in straight grade wheat flour. Flour moisture is influenced by weather and environmental or storage conditions such as humidity and storage temperature. Such conditions affect the keeping quality of flour. Higher moisture may lead to spoilage and lump formation during storage.

The oat flour yielded higher contents of protein, fat, ash and crude fiber as compared to wheat flour sample. The wheat flour yielded higher moisture content. These results of proximate composition are comparable with the results found by Salehifar (2007).

The chemical composition of the whole wheat flour for moisture, ash, crude protein, crude fat, crude fibres ranges from 9.38 to 10.43%, 1.32 to 1.85%, 10.13 to 14.74%, 1.96 to 2.52% and 2.31 to 2.99% ;respectively (Ahmad, 2001). It has been reported that chemical composition is dependent upon genetics, the growing environment, the processing of the seed, and the method employed for analysis (Daun *et al*., 2003).

Higher levels of crude fiber and ash are associated with whole oat flour and presence of oat bran particles. The results of chemical composition of oat flour are comparable with the results found by Asif (2009) who reported 5.86 % fat, 15.83 % protein, 4.00 % total dietary fiber, 5.00% moisture and 0.98% ash content.

The analysis results for major minerals for both the oat and wheat flour is shown on table 4.2 and the result indicates that there is a significant difference for their composition, except for that of Calcium composition. The mineral content of flour as such is not related to quality of a final product, but it does affect the appearance of flour and the product. The minerals are concentrated on the outer part of wheat grain, which is removed during milling. However, some contamination does occur in flour due to incomplete removal. Flour that contains higher proportion of minerals will have more ash content and it will be darker in color and it may also contain more fine bran particles. Bran has been shown to have detrimental effect on the quality of bakery products.

Table 4.1: Proximate composition of oat and wheat flours (per 100 gram)

Flour	Moisture	Crude Protein	Crude Fat	Ash	Crude Fiber	Total Carbohydrates
Wheat	11.35 ± 0.49^a	13.56 ± 0.79^a	0.98 ± 0.03^a	0.6 ± 0.14^a	0.32 ± 0.17^a	73.51 ± 0.72^a
Oat	5.61 ± 0.86^b	16.92 ± 1.30^a	6.10 ± 0.14^b	1.80 ± 1.13^a	4.92 ± 1.30^b	64.65 ± 2.33^b

All values are means of triplicate ± standard deviation

$^{a-b}$ Means with the same superscript letters within a column are not significantly different ($p>0.05$)
Values except moisture are expressed in dry weight basis (DWB).
of = oat flour wf = wheat flour
*% Carbohydrates is by difference, i.e. 100 – (crude protein + crude fat + ash + moisture)

Table 4.2: Mineral composition of oat and wheat flours (mg/100 g) and TKW

Flour (Grain for TKW)	K	Ca	Mg	TKW*
Oat	143.02 ± 7.35[b]	21.99 ± 6.93[a]	258.67 ± 9.47[a]	29.83 ± 1.16[a]
Wheat	420.04 ± 4.79[a]	23.10 ± 1.41[a]	20.00 ± 7.07 [b]	32.85 ± 1.13[a]

All values are means of triplicate ± standard deviation

[a-b] Means with the same superscript letters within a column are not significantly different (p>0.05)
TKW* Total kernel weight

4.1.2. Wet gluten determination

The wet gluten test provides information on the quantity and estimates the quality of gluten in wheat or flour samples. Gluten is responsible for the elasticity and extensibility characteristics of flour dough.

Wet gluten content results are expressed as a percentage on a 14 percent moisture basis; for example, 35 percent for high protein, strong gluten wheat or 23 percent for low protein, weak gluten wheat. The statistical result shows that there is a significant decrease of wet gluten from 30.3% (for control) to 22.9% (for 15% oat flour supplementation).

Baking standards require the wheat flour used for bread making to contain at least 25% of wet gluten (Anna *et al.,* 2005).In the experiments, an average of 26.1% of gluten was washed from the mixes containing 10% of oat flour. It may thus be concluded that an appreciable amount of gluten in the flour enriched with as much as 10% of oat flour may be sufficient to obtain good-quality baking products. The results for wet gluten of the composite flour is shown in the table below

Table 4.3: Wet gluten values

Composite flour	Wet gluten (%)
Control (100% wheat flour)	30.3 ± 0.28^{a}
5% oat flour + 95% wheat flour	28.3 ± 0.14^{b}
10% oat flour + 90% wheat flour	26.1 ± 0.14^{c}
15% oat flour + 85% wheat flour	22.9 ± 0.14^{d}

All values are means of triplicate ± standard deviation

$^{a\text{-}d}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

As we see in the above table the wet gluten decreases as the amount of supplementation increases. This phenomenon has been seen on the loaf volume (extensibility of the dough).

4.1.3. Farinograph Measurement

The characteristics of flour, such as how much water it absorbs to achieve optimum dough consistency, mixing time requirement and dough stability, are important measures of its quality. This information is of great importance to millers and bakers. The most common instrument used to determine flour mixing characteristics is the Brabender Farinograph.

Studies on the physical dough properties (Table 4.7) showed increased farinograph water absorption due to addition of oat flour. Dough stability decreased with the increase of supplementation.

The results for water absorption indicated variations among the treatments due to different level of supplementation; ranged from 58.2% to 64.2%. Highest value for water absorption (64.2%) was noted in bread with 15% oat flour followed by 10% oat flour supplementation (59.0%) and 5% oat flour supplementation (58.3%) while lowest water absorption (58.2%) was recorded for control wheat flour. Oat flour had pronounced effects on dough rheology properties. Farinograph characteristics and absorption increased with increasing the oat flour proportion in the formula (Appolonia, 1990). Oat β-glucan played an important role in increasing water absorption and bread moisture. In general, dietary fibre increases water absorption and mixing tolerance. Rossel *et al*., (2001) expected such a result due to the hydroxyl groups of the fibre structure which allows more water interaction through hydrogen bonding. Oat starch has higher water absorption than other cereals (Rossel, 2001). This moisture retention property of oats keeps breads fresher for longer periods of time (Gomez, 1995; Ozboy, 1997).

Dough development time significantly increased with the substitution of wheat flour with oat flour. The results in Table 4.4 indicate that the dough development time in composite flours ranged from 2.2 to 4.3 min among different treatments. The highest dough development time (4.3 min) was observed in bread with 15% oat flour followed by 10% (2.0 min) and 5% (2.4 min) while the lowest dough development time (2.2 min) was noted in control wheat flour. This is consistent with Bhatty (1986), who reported little to no difference in mixograph peak time with the substitution of wheat by 5 to 20% hull-less barley flour and Jacobs *et al.* (2008), who showed that a fiber rich barley fraction increased farinograph dough development time compared to the wheat control. For pure wheat flour, dough development time reflects the total energy amount that is needed to develop the gluten network. In the presence of fibre rich flours, the gluten network formation will be influenced by water availability and mechanical disturbance due to insoluble fibre.

The increase in development time of composite flours found in the present study may be due to decrease in their gluten contents, coarser nature of oat flours added to wheat flours and weakening of protein network due to proteolytic activity during the storage of composite flours.

Dough stability, which indicates the dough strength was also decreased. It is obvious from the results (Table 4.7) that dough stability time in oat supplemented flours ranged from 3.4 to 8.5 min among different treatments. The highest value (8.5min) was observed in bread with 100% wheat flour followed by 5% oat flour supplementation (8.5min) and 10% oat flour supplementation (5.2min) and lowest dough stability (3.4min) was noted in 15% oat supplemented wheat flour. This is probably due to the formation of hydrogen bonds, also gelatinized starch has been shown to be capable of forming a three dimensional network that retains gases and expands during the fermentation and baking of composite bread.

The flour blend (15:85) showed also the lowest farinograph quality number (58) indicating that the flour do not exhibit strong flour characteristics followed by 10 %(65) and 5% (99) and highest farinograph quality number (100) was noted in control wheat flour. The highest values of stability, dough development and farinograph quality number of the flour indicate that this flour blend is strong flour and is suitable for bread production (Toufeili *et al.*, 1999). The degree of softening increased with the increasing oat flour level (Table 4.4). The same result was obtained by Zhang (1998).

Table 4.4: Farinograph values of blended flours for bread

Parameters	**Blended flours ratio (OF:WF)**			
	Control wheat flour	**5:95**	**10:90**	**15:85**
Consistency, FU	451	461	531	739
Water absorption (corrected for 500 FU)	58.8	59.0	60.8	66.0
Water absorption (corrected to 14.0%)	58.2	58.3	59.0	64.2
Stability (min.)	8.5	8.5	5.2	3.4
Development time (min)	2.2	2.4	3.0	4.3
Degree of softening (FU)	30	31	63	124
Degree of softening (ICC),FU	60	69	104	211
Farinograph Quality Number	100	99	65	58

OF – oat flour, WF - wheat flour

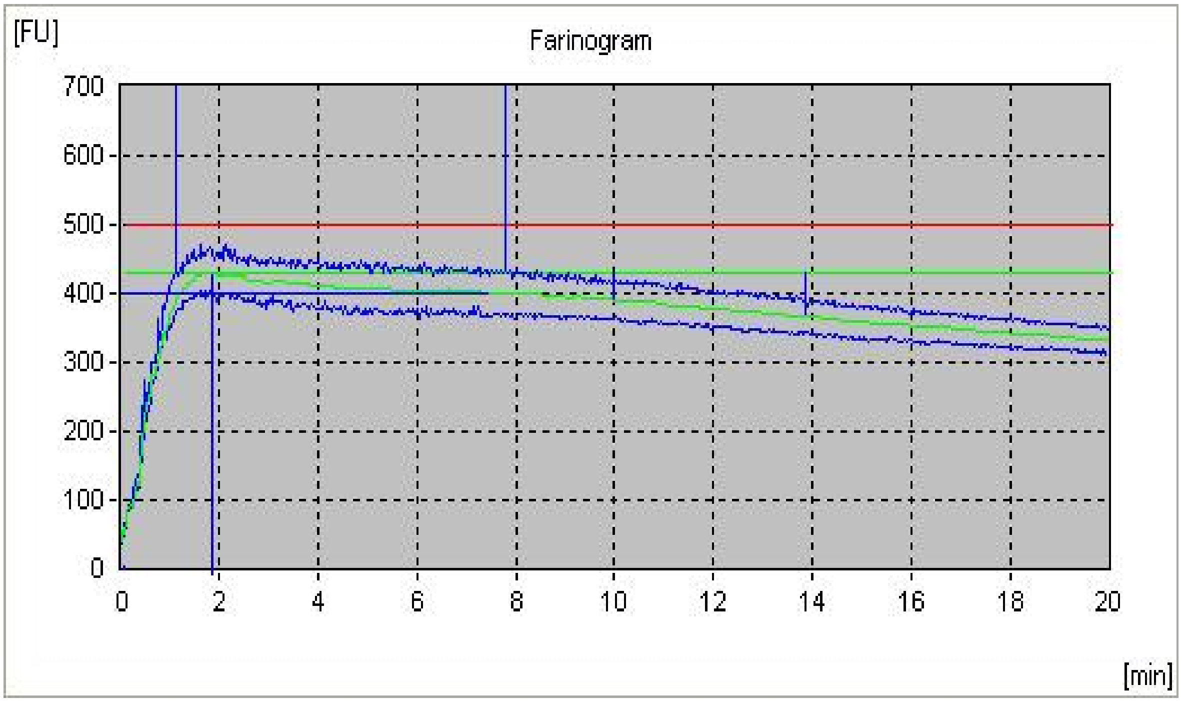


Figure 4.1: Farinograph results for 100 % wheat flour

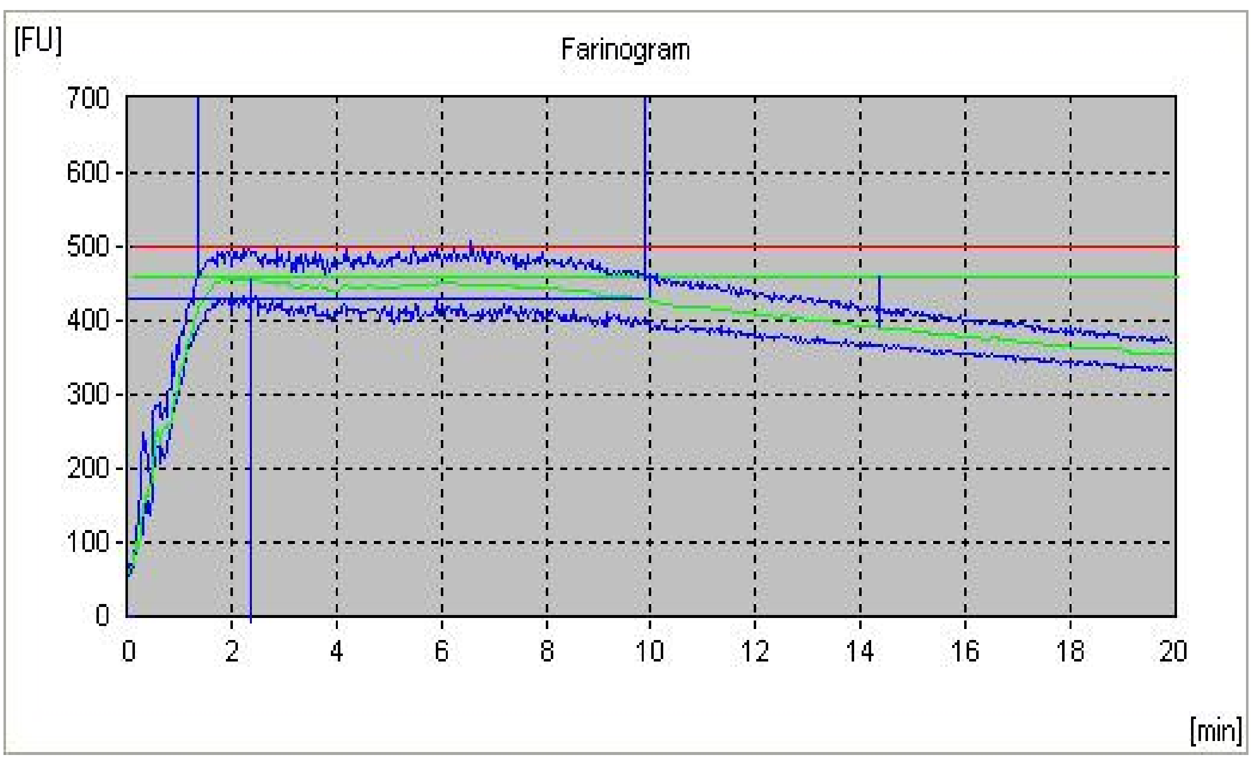


Figure 4.2: Farinograph result for 5 % oat flour + 95 % wheat flour

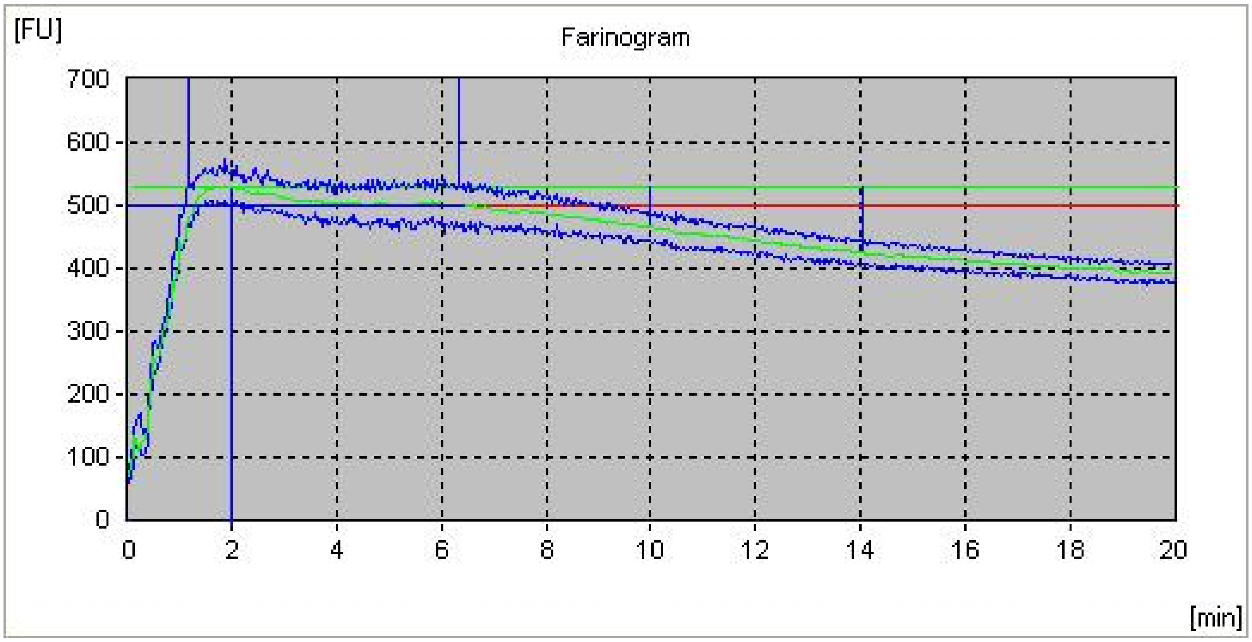


Figure 4.3: Farinograph result for 10% oat flour + 90 % wheat flour

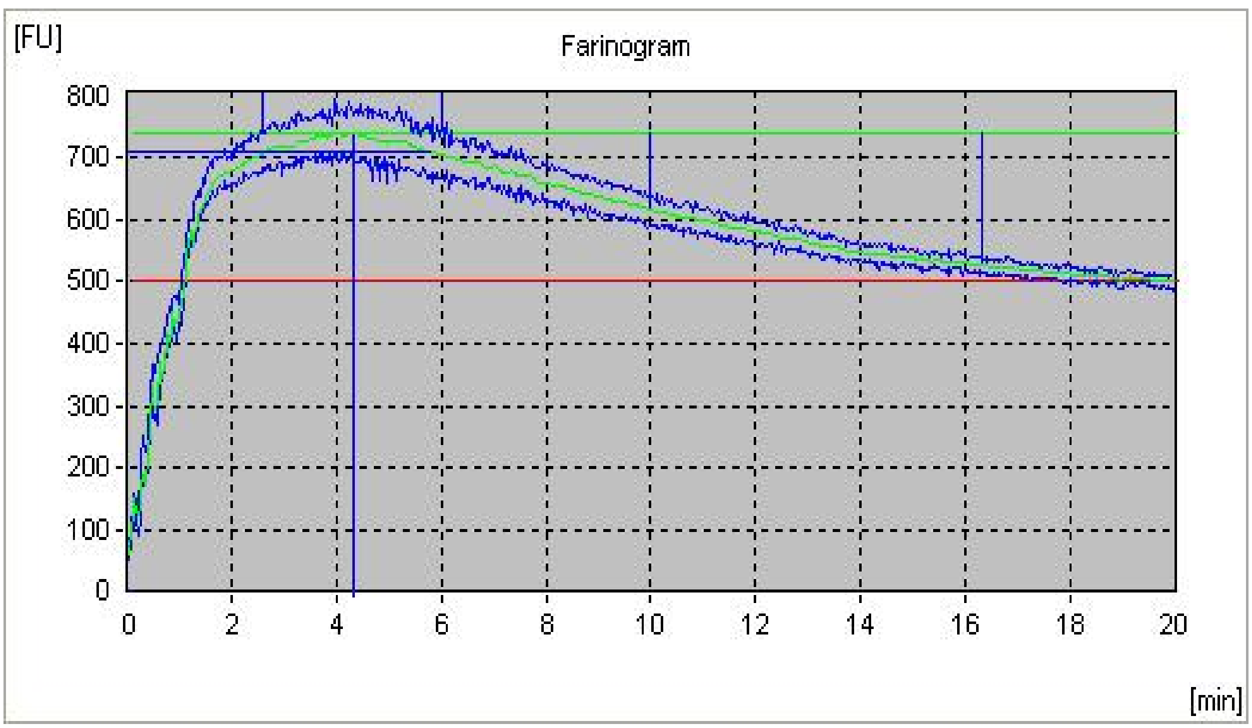


Figure 4.4: Farinograph result for 15% oat flour + 85 % wheat flour

4.1.4. Color grade and falling number

The color test on flour sample indicates the whiteness, which is considered as a quality attribute as it affects appearance of final product. The color of the flour depends on extraction rate of flour, amount of pigments and flour particle size. The darkness or whiteness of the flour is due to contamination of bran particles. Higher the flour extraction rate, darker the color of the flour and vice versa. The coarse flour generally looks dull and darker than its finer counter part due to the shadow effects of the larger particles (Khatkar, 2009).

The addition of oat flour resulted in a loss of flour brightness, probably due to oat bran color in the flour (Table 4.8). The particle size of oat flours was larger than wheat flour and it was also due to using whole oat flour and the presence of bran particles in the flour (Webster, 1986).The results for the composite flours are shown in the following table.

The brightest color grade value (3.5) was recorded in a control sample. The color grade value significantly increased from 3.5 (control) to 17.21 (15% oat flour supplemented SGF). There was a significant increase in the color grade value with the increase in the level of oat flour supplementation in SGF.

The level of enzyme activity measured by the falling number test affects product quality. Yeast in bread dough, for example, requires sugars to develop properly and therefore needs some level of enzyme activity in the dough. Too much enzyme activity, however, means that too much sugar and too little starch are present. Since starch provides the supporting structure of bread, too much activity results in sticky dough during processing and poor texture in the finished product. According to Sologuk and Sorenson (2005), a falling number value of 300 seconds or longer indicates a low enzyme activity. As the amount of enzyme activity increases the falling number decreases. Values below 200 seconds (Sologuk and Sorenson, 2005; German, 2006; ICC, 2000) indicates high levels of enzyme activity. If the falling number is too high (>400 sec), enzymes can be added to the flour in various ways to compensate. If the falling number is too low (<200 sec), enzymes cannot be removed from the flour or wheat, which results in a serious problem that makes the flour unusable (German, 2006).

Table 4.5 indicated that supplementation (10% and 15% oat flour) had a significant ($p<0.05$) effect on the reduction of falling number by increased enzymatic activity of the flour. The percentage of oat flour on the composite wheat flour significantly ($p<0.05$) decreased a falling number from 200 to 184. 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 with the supplementation of oat flour to wheat flour.

Table 4.5: Color grade and falling number values

Blended flours ratio (OF:WF)	**Color grade**	**Falling number(sec)**
0:100 (control)	3.5 ± 0.32^{c}	200.0 ± 8.00^{a}
5:95	11.87 ± 3.2^{b}	198.4 ± 0.45^{a}
10:90	15.30 ± 0.86^{a}	185.7 ± 0.81^{b}
15:85	17.21 ± 0.21^{a}	184.0 ± 0.98^{b}

OF – oat flour, WF - wheat flour
All values are means of triplicate ± standard deviation
$^{a-c}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

4.1.5. Functional properties

4.1.5.1. Oil absorption

Oil absorption capacity (OAC) is another important functional property since it plays an important role in enhancing the mouth feel while retaining the flavor of food products (Kinsella, 1976). The OAC of oat flour (1.60 ml/g) was higher than that of the wheat flour (0.9 ml/g). The result showed that (Table 4.6) oat flour may be a better flavor retainer than the wheat flour. It has been reported that variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil among the flour, explain differences in the oil binding capacity of the flour (Adebowale and Lawal, 2004). It might be concluded that the lower OAC of wheat flour is due to the lower extent of hydrophobic proteins when compared to oat flour.

4.1.5.2. Sedimentation value

The sedimentation test provides information on the protein quality of ground wheat and composite flour samples. Positive correlations were observed between sedimentation value and gluten strength or loaf volume attributes.

A useful parameter which can be used to determine the quality of protein in flour is the sedimentation value. Differences in the sedimentation values for blends containing oat flour, was insignificant (Table 4.6). Increasing the content of this additive led to a decrease in the sedimentation value. When viewed from the perspective of baking technologies, it indicates the deterioration of hydration properties of protein composition (Anna *et al.,* 2005).

The sedimentation value of flour depends on the wheat protein composition and is mostly correlated to the protein content, the wheat hardness, and the volume of pan and hearth loaves.

Table 4.6: Oil absorption and Sedimentation values of flours used in the study

Blended flours ratio (OF:WF)	**Oil absorption(ml/g)**	**Sedimentation value(ml)**
0:100 (control)	0.90 ± 0.14^{b}	87 ± 1.41^{a}
5:95	0.91 ± 0.01^{b}	85 ± 1.41^{a}
10:90	0.95 ± 0.35^{ab}	83 ± 1.54^{a}
15:85	1.0 ± 0.14^{ab}	82 ± 1.46^{a}
100:0	1.60 ± 0.42^{a}	46 ± 4.24^{b}

OF – oat flour, WF - wheat flour
All values are means of triplicate ± standard deviation
$^{a-b}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

4.2. Bread quality

The simplest bread making procedure is the straight-dough method whereby all the ingredients in bread formulation are mixed to form developed homogenous dough in one-step were used (Sahlström and Bråthen, 1997). Dough formation for straight-dough method require low amount of energy during mixing process to produce a suitable bread quality (Cauvain, 1998b). Subsequently, the resting periods of the dough in this method varied depending on the flour quality, yeast level, dough temperature and the specificity in types of bread produced (Mondal and Datta, 2007). A typical white wheat flour protein content used in this bread making procedure is 12% or higher to obtained an optimum dough development. However, addition of non-wheat flour resulted in lower bread quality due to lower flour quality and strength (Cauvain, 1998b). Bread properties are very often influenced by flour components (Dowell *et al.,* 2008; Edwards *et al.,* 2007; Perez Borla *et al.,* 2004) and the rheological properties of the dough (Andersson *et al.,* 1994; Armero and Collar, 1997; Bloksma, 1990; Gras *et al.,* 2000; Oliver and Allen, 1992).

4.2.1. Chemical composition of composite bread

4.3.1.1. Moisture content

The moisture content is one of most important and commonly measured properties of different food products. It is measured for a number of reasons including legal and label requirements, economic importance, food quality, better processing operations and storage stability considerations.

Determining moisture content is an essential first step in analyzing bread quality since this data is used for other tests. Flour millers adjust the moisture in wheat to a standard level before milling. Moisture content of 14 percent is commonly used as a conversion factor for other tests in which the results are affected by moisture content. Moisture is also an indicator of grain storability. Bread with a high moisture content attracts mold, bacteria, and insects, all of which cause deterioration during storage. Bread with low moisture content is more stable during storage. The statistical results for moisture content of different composite flour bread is presented in Table 4.7 indicates that the moisture content was not significantly affected by the supplementation levels of oat flour in straight grade flour (SGF).

The statistical results indicated non significant changes in moisture content with the increase in level of supplementation of oat flour in wheat flours. It is obvious from the results that moisture content of the composite flour bread non significantly ($p > 0.05$) decreased from 27.75% (control) to 25.89% (15% 0at flour supplementation).

4.2.1.2. Ash content

The ash content is an inorganic residue remaining after the removal of water and organic matter by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals in a food. Since ash is primarily concentrated in the bran, ash content in flour and bread is an indication of the yield that can be expected during milling. Ash content also indicates milling performance by indirectly revealing the amount of bran contamination in flour. Ash in bread can obviously seen in affecting the color, imparting a darker color to the bread. Some specialty products requiring particularly white flour call for low ash content while other products, such as whole wheat flour, have high ash content.

The analyses of variance regarding ash content of different composite flour breads is given in Table 4.7 indicated that the ash content differed significantly during 5% supplementation, and the rest becomes non significantly different in the composite flour breads. It is evident from the results given in Table 4.7 that the highest ash content (1.75%) was found in a composite flour bread which was supplemented with 15% oat flour and the lowest (1.3%) was found in the control wheat flour bread. The ash content significantly increased from 1.3% (control) to 1.75% (15% supplementation).

4.2.1.3. Crude fat

The lipids including fats and oils are one of the major constituents of foods, and are important in our diet for a number of reasons. They are a major source of energy and provide essential lipid nutrients. In many foods the lipid component plays a major role in determining the overall physical characteristics, such as flavor, texture, mouth-feel and appearance.

The statistical results presented in the Table 4.7 indicated that the fat content in oat flour supplemented SGF varied significantly due to variation in supplementation levels. The effect of supplementation level on the fat content of different composite flour breads is given in Table 4.7. The fat content was significantly increased with the supplementation level. The highest fat content (4.11%) was found in the composite flour bread supplemented with 15% oat flour and the lowest fat content (0.98%) was found on the 100% wheat flour bread.

4.2.1.4. Crude fiber

The crude fiber is a measure of the quantity of indigestible cellulose, pentosans, lignins and other components of this type present in foods. The crude fiber has little food value but it gives bulk to the food and also helps to regulate certain physiological functions.

The statistical results regarding crude fiber content of different composite flour breads have been presented in Table 4.7. The results indicated that crude fiber content was significantly increased with a 5% supplementation of oat flour. It is evident from the results that crude fiber content of composite flour breads increased significantly from 0.45% (control) to 2.56% (5%) in the composite flour breads. The increase in level supplementation improved the crude fiber contents, from 0.45% (control) to 4.11% (15% oat flour).

4.2.1.5. Crude protein

The proteins are polymers of amino acids and their amount in a sample represents its quality index. The crude protein is normally determined by measuring the amount of nitrogen in a sample.

The statistical results regarding protein content of composite flour breads supplemented with different levels of oat flour is presented in Table 4.7, indicated that treatments (supplementation levels) affected the protein contents of composite flour breads. It is obvious from the results (Table 4.7) that protein content of composite flour breads increased significantly by increasing the level of oat flour supplementation. It is evident that significantly the highest protein content (19.60%) was found in the SGF supplemented with 15% oat flour followed by the SGF supplemented with 10% oat flour (18.93%). Kim (1997) observed that increasing the protein content of composite flours, diluted the starch and decreased the rate of staling.

Table 4.7: Proximate composition of composite bread

Composition (%)	**Control(100%wf)**	**5%of+95%wf**	**10%of+90%wf**	**15%of+85%wf**
Moisture	27.75 ± 2.47^a	26.30 ± 2.67^a	26.01 ± 1.83^a	25.89 ± 1.42^a
Crude protein	13.45 ± 0.63^c	14.60 ± 0.84^b	15.93 ± 5.56^b	15.98 ± 0.84^a
Crude fat	0.98 ± 0.11^c	2.44 ± 0.05^b	2.56 ± 0.08^b	4.00 ± 0.00^a
Ash	1.3 ± 0.14^b	1.53 ± 0.04^a	1.71 ± 0.01^a	1.75 ± 0.07^a
Crude fiber	0.45 ± 0.04^b	2.56 ± 0.08^a	3.21 ± 1.43^a	4.11 ± 0.01^a
Total carbohydrates*	56.52 ± 8.58^a	51.13 ± 2.22^b	50.79 ± 6.44^b	48.76 ± 2.33^b

All values are means of triplicate ± standard deviation
$^{a-c}$ Means with the same superscript letters within a column are not significantly different (p>0.05)
Values except moisture are expressed in dry weight basis (DWB).

of = oat flour wf = wheat flour
*% Carbohydrates is by difference, i.e. 100 – (crude protein + crude fat + ash + moisture)

The supplementation of oat flour in wheat flour significantly improved the nutrient profile of the composite flour breads. The results of the present study are in line with the earlier study conducted by Hussain (2004) in which he has found significant improvement in the proximate composition (ash, fat, crude protein and crude fiber) of oat flour supplemented wheat flours. These results are also supported by the findings of Zaib-un-Nisa (2000), who reported that bread made from composite flour containing 5% oat flour had increased in protein content from 6.50% to 8.52%, fat content from 26.13% to 31.45%, fiber content from 0.15% to 3.78% and ash content from 0.26% to 1.00%.

4.2.2. Mineral composition of composite bread

The statistical results pertaining to the effect of oat flour supplementation in wheat flour on macro minerals contents like potassium (K), calcium (Ca) and magnesium (Mg) of composite flour breads are shown in Table 4.8. The results indicate that supplementation of oat flour into SGF significantly affected the contents of macro minerals of composite flour breads.

The K content of composite flour breads non significantly decreased from 470.0 mg/100g (100% SGF) to 459.50 mg/100g in 15% oat supplementation (Table 4.8).

The results regarding calcium content of different composite flour breads presented in Table 4.8 revealed that Ca content was found 56 mg/100g in 100% SGF, non significantly decreased to 51 mg/100g in 10% oat flour supplemented SGF and significantly decreased to 23.1mg/100g in 15% oat flour supplementation .

The results regarding the magnesium content of different composite flour breads given in Table 4.8 indicated that significantly the lowest magnesium content (180.6 mg/100g) was found in 100% SGF while 15% oat flour supplemented SGF had significantly the highest Mg content (216.7mg/100g).

Table 4.8: Mineral composition of composite breads (mg/100 g)

Sample	K	Ca	Mg
control	470.0 ± 7.07^a	56.0 ± 2.82^a	180.6 ± 14.14^b
5% oat flour	468.3 ± 11.73^a	53.6 ± 2.26^a	200.5 ± 2.12^a
10% oat flour	463.3 ± 4.66^a	51.9 ± 2.68^a	207.5 ± 3.53^a
15% oat flour	459.5 ± 3.53^a	23.8 ± 1.13^b	216.7 ± 2.12^a

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

4.2.3. Physical characteristics of bread

The loaves were packed in polyethylene bags and analyzed for volume, weight and specific volume. The statistical analysis for volume of bread samples prepared from oat flour supplemented in wheat flour is presented in Table 4.9. The results indicated that volume of breads was affected by the level of oat flour supplementation.

Table 4.9: Bread loaf weight, volume and specific volume

Sample	Loaf weight(g)	Loaf volume(cm^3)	Specific volume(g/cm^3)
Wheat flour	86.0 ± 0.32^b	340.6 ± 4.26^a	3.96
5% oat flour	89.1 ± 0.32^b	323.5 ± 3.32^a	3.63
10% oat flour	94.5 ± 1.23^b	298.4 ± 0.98^b	3.16
15% oat flour	98.6 ± 0.92^b	250.3 ± 0.34^c	2.53
Oat flour	101.7 ± 0.39^a	210.9 ± 1.43^d	2.07

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

Loaf volume was significantly decreased with increase in level of incorporation of oat flour whereas loaf weight at 5%, 10% and 15% level of oat incorporation was significantly higher as compared to 100% oat supplementation. Specific volume was also found to decrease with increase in level of supplementation. This might be due to the dilution of gluten protein. The decrease in loaf volume upon the incorporation of low gluten flour is expected as indicated by previous investigators (Czuchajowska and Paszczynska, 1996).

However, the incorporation of oat flour or the use of whole grain flour (usually from wheat) or bran all diminish bread quality, particularly loaf volume, of wheat composite breads (Bhatty, 1986; Gill *et al.,* 2002; Lai *et al.,* 1989). This deteriorating effect has been shown to be more than solely the dilution of wheat gluten. Fiber, especially insoluble fiber, may mechanically interfere with gluten network formation (Gill *et al.,* 2002; Salmenkallio-Marttila *et al.,* 2001) and cause rupture of gas cells (Courtin and Delcour, 2002). Both soluble and insoluble fibers, tightly bind high amounts of water, which may make it less available for the development of the gluten network and may further result in less steam production during baking (Gill *et al.,* 2002). It is therefore crucial to compensate for the high water binding capacity of cereal β-glucans when baking with oat flour in order to obtain good quality of oat or barley enriched wheat bread (Holtekjolen *et al.,* 2008).

The addition of oat products to wheat flour caused diffusion of gluten proteins, which resulted in a loss of dough strength and a decrease in loaf volume (Zhang *et al.*, 1998). The smaller loaf volumes obtained from oat substituted flours might have been caused by poor gas formation and poor gas retention in the dough. Gluten dilution and gums present in the oat flour may have had a strong influence on bread quality.

4.2.4. Sensory quality evaluation of bread

Breads were evaluated for color, appearance, flavor, taste, mouth feel, and overall acceptability by taste panel using 5-Point Hedonic Score System (Meilgaard *et al.,* 2007) with following individual scores: 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1 = Poor, to find out the most suitable composition of bread for commercialization. The sensory hedonic mean scores of the bread samples are shown in the following table

Table 4.10: Sensory evaluation of bread samples

Product code	Sensory attributes						
	Color	Appearance	Odor	Taste	Mouth feel	Flavor	Overall acceptability
01	3.2±1.95^a	3.4±1.00^a	3.8±1.00^a	4.3±0.52^a	4.3±0.50^a	4.2±0.22^a	4.0±0.93^a
02	2.5±2.00^b	3.2±2.27^a	3.6±0.90^a	4.0±1.99^a	3.2±0.26^b	3.0±2.1^b	3.0±2.10^a
03	2.4±2.07^b	3.2±3.56^a	3.4±1.78^a	3.5±0.48^a	3.0±1.81^b	2.5±3.5^b	2.7±0.80^b
04	2.0±3.2^c	2.5±0.9^b	2.3±3.2^b	1.8±1.8^b	2.0±0.3^c	1.9±9.0^c	1.0±2.8^b

All values are means of triplicates ± SD

$^{a\text{-}c}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

01=control, 02= 5% oat flour + 95% wheat flour, 03= 10% oat flour + 90% wheat flour, 04= 15% oat flour + 85% wheat flour

The 15% oat flour supplemented bread had a significantly softer texture than all other breads. This probably due to the higher levels of fat from oats compared with wheat (see Table 4.1). Fats have softening properties and act as a lubricant in bread (Rogers, 1988) Also, the dilution of wheat gluten with the addition of oat flour affects bread texture (Pomeranz, 1971).

Based on the sensory evaluation, bread made with 5% oat flour + wheat flour and wheat flour was the good quality bread which fulfilled most of the quality attributes. The samples with code 01 and 02 are generally acceptable by consumers while the samples with code 03 and 04 were less acceptable by the panelists.

4.3. Oat flake

4.3.1. Quality parameters

Oatmeal or oat flakes have been staple foods in human diet for a long time and there is a continuous demand for the desired “oaty” and “toasted” flavour in these products (Bryngelsson *et al.,* 2002). Oat flakes were prepared from locally grown varieties. The major parameters (specific weight, flake thickness and moisture content) which mostly affect the quality of oat flakes were measured and compared with the control oat flake which I bought from the supermarket (manufactured by Golden crops corporation in Taiwan).

Table 4.11: Quality attributes of oat flake

Sample	**Flake thickness(mm)**	**Moisture content**	**Specific weight(g/L)**
Laboratory prepared	0.51	9.5	0.53
Control	0.36	9.0	0.31

a. Specific weight

Millers use specific weight as a measure of flake thickness, and it is equally important in its own right as it determines the fill volume of the pack. Specific weight determined in containers with different geometries was shown to be comparable; providing the filling procedure was the same (i.e. free flow of flakes was allowed). Although the correlation between flake thickness and specific weight was highly significant (Gates *et al.,* 1996), processing conditions influenced the relationship between these properties. Since industrial users, such as biscuit or breakfast cereal producers, generally require compliance across a range of quality measures (e.g. specific weight, water absorption and flake texture), it may be possible to make fine adjustments to product quality by means of the heat treatment

The movement of water out of the flake during drying and into the flake during food processing (water absorption) has implications on quality. Flake thickness influences the rate of diffusion of water during drying. This was reflected by a significant, albeit weak correlation between flake thickness and moisture content (Gates *et al.,* 1996). This supports the findings of Machado *et al.,* (1998), who found that moisture uptake of extruded breakfast cereal flakes was mainly a relaxation rather than a diffusion phenomenon.

4.3.2. Sensory evaluation

Oat flakes were evaluated for color, appearance, flavor, taste, mouth feel, and overall acceptability by test panel using 5-Point Hedonic Score System (Meilgaard *et al.,* 2007) with following individual scores: 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1 = Poor, to find out the most suitable composition of bread for commercialization.

The sensory hedonic mean scores of the flake samples are shown in the following table

Table 4.12: Sensory evaluation of oat flake

Product code	**Sensory attributes**						
	Color	**Appearance**	**Odor**	**Taste**	**Mouth feel**	**Flavor**	**Overall acceptability**
01	3.2±1.95^{a}	3.4±1.00^{a}	3.8±1.00^{a}	4.3±0.52^{a}	4.3±0.50^{a}	4.2±0.22^{a}	4.0±0.93^{a}
02	2.5±2.00^{a}	3.2±2.27^{a}	3.6±0.90^{a}	4.0±1.99^{b}	3.2±0.26^{b}	3.0±2.10^{a}	3.0±2.10^{a}

All values are means of triplicates ± SD

01=Control, 02= Laboratory prepared flake

$^{a-b}$ Means with the same superscript letters within a column are not significantly different (p>0.05)

CHAPTER FIVE

Techno-economic analysis of bread production

5.1 Process Description

The process of preparing bread from composite flour of wheat and oat passed the following procedures. It was prepared by straight dough method of bread production process. The preliminary operations comprises of mixing and kneading, bulk fermentation, molding, rounding, intermediate proofing, molding, final proofing, baking, cooling and packaging. 5%, 10% and 15 % oat flour were employed in the production of bread. Generally, the following flow sheet clearly describes the process for production of bread from oat and wheat blended flours.

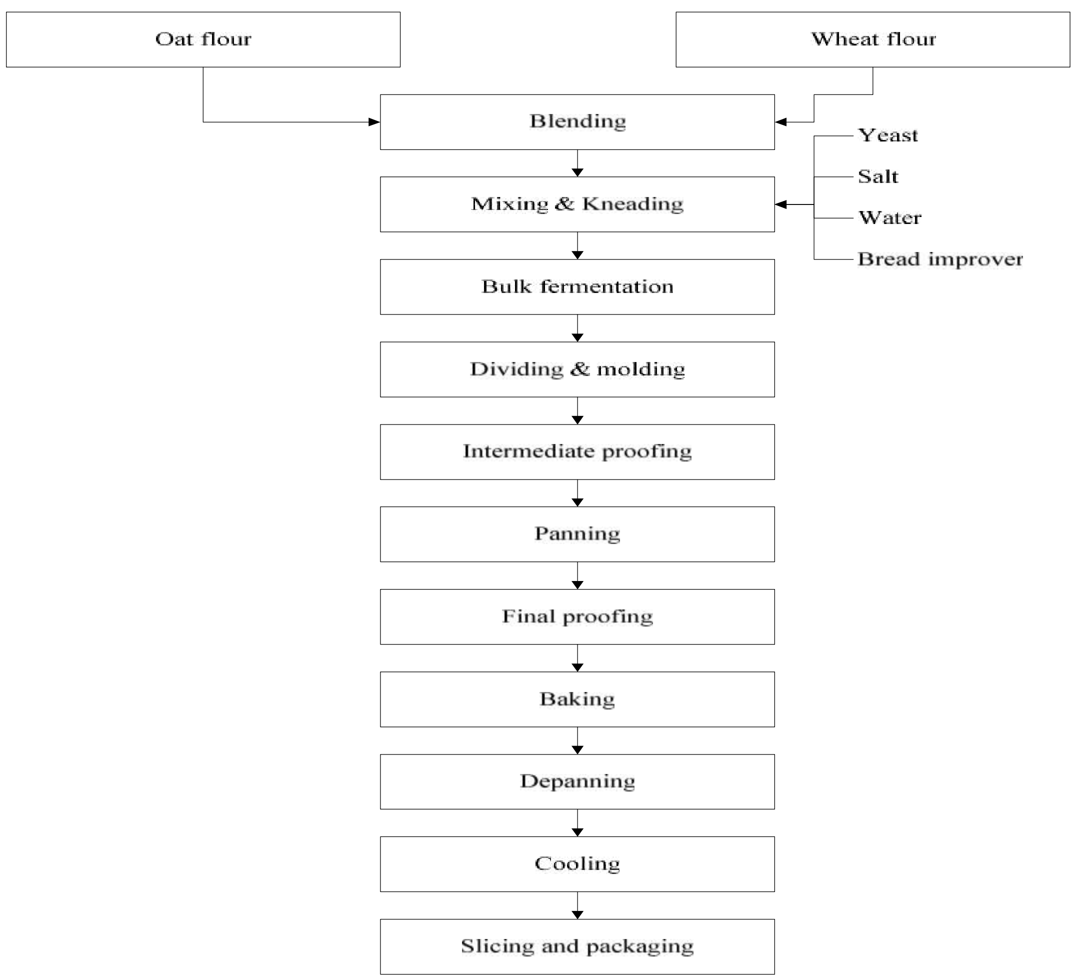


Figure 5.1: Process descriptions for bread production

5.2 Material and energy balance in major unit operations

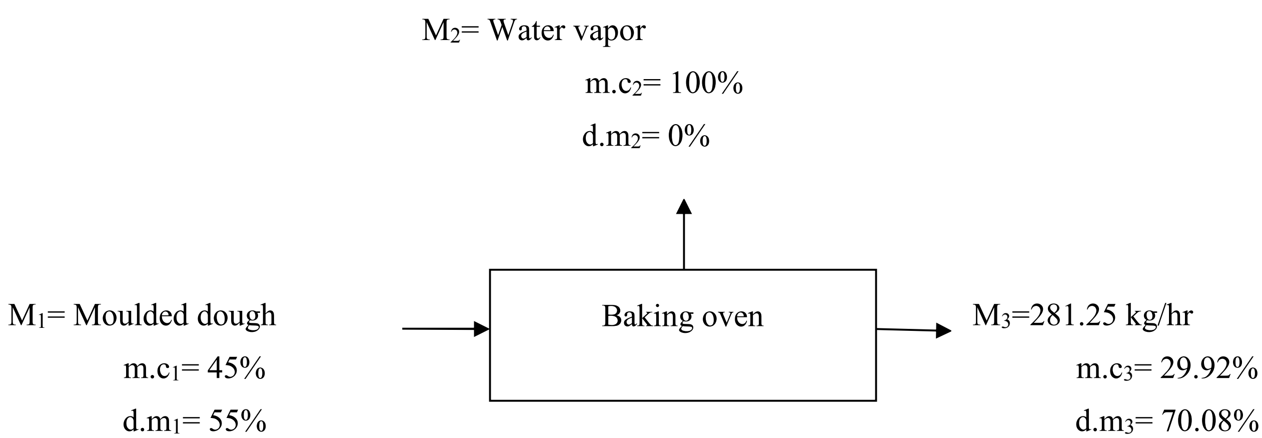
The overall material and energy balance on bread producing plant is conducted based on Figure 5.1.

Assumptions

- The plant has the capacity 4500kg/day (281.25kg/hr) selected based on assessment of local industries (Kality Food Share Company)
- Maximum acceptable impurity and loss is 8%
- The plant operates 16h/day
- All raw materials are industrial quality

5.2.1. Material balance

Material balance during baking (oven drying) of bread



Where: - M_1- Moulded dough

M_2 -Water vapor

M_3 - Composite flour bread

m.c- Moisture content

d.m- dry matter

Over all mass balance

$M_1 = M_2 + M_3$

$M_1 = M_2 + 281.25$kg/hr

Moisture content balance

$M_1 \times m.c_1 = M_2 \times m.c_2 + M_3 \times m.c_3$

$M_1 \times 0.45 = M_2 \times 1 + 281.25$kg/hr $\times 0.29$

$0.45M_1 = M_2 + 84.15$ Kg/hr

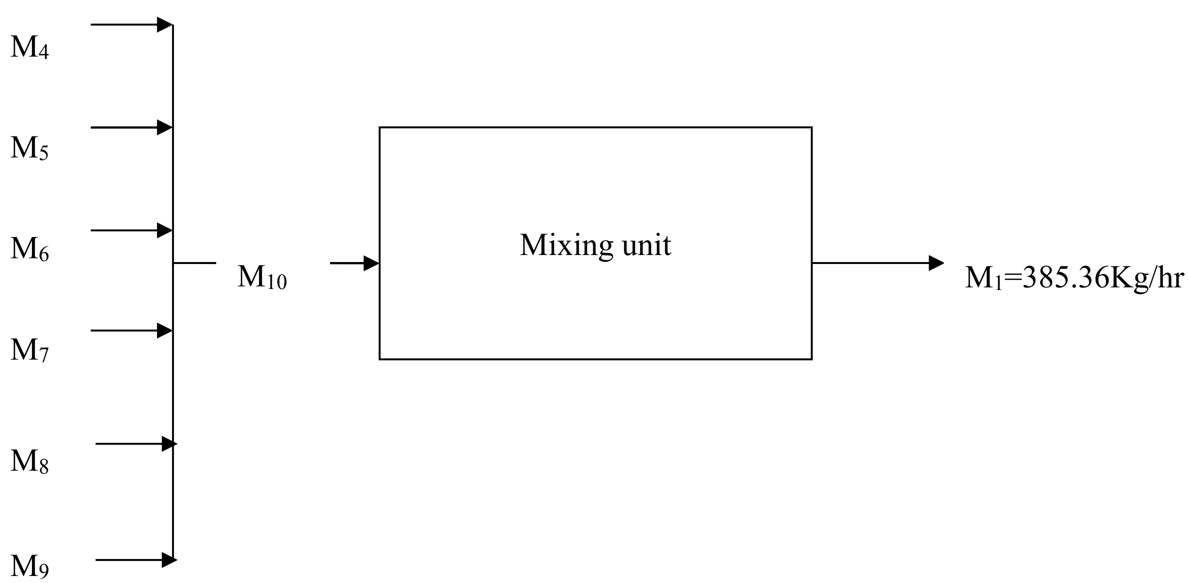
There are two equations and two unknowns M_1 and M_2, and then solving these two equations simultaneously yields:

$M_1 = 358.36$kg/hr

$M_2 = 76.93$kg/hr

Material balance during mixing of ingredients

The baking formula was 62% of the blend flour , 0.3 % yeast, 0.3% bread improver 0.6 % salt and 37.0 % water.



Where:-

M_4 - Wheat flour = 58.9% M_{10}

M_5 - Oat flour = 3.1% M_{10}

M_6 - Salt = 0.6% M_{10}

M_7 - Yeast = 0.3%M_{10}

M_8 - Bread improver = 0.3%M_{10}

M_9 - Water = 37%M_{10}

Over all mass balance around the mixing unit

M_{10}=M_1

M_{10}=385.36 Kg/hr

Substituting this on the above relations yields the following results

M_4 = 58.9% M_{10} = 226.98 Kg/hr

M_5 = 3.1% M_{10} = 11.95 Kg/hr

M_6 = 0.6% M_{10}= 2.31 Kg/hr

M_7 = 0.3%M_{10} = 1.15 Kg/hr

M_8 = 0.3%M_{10} = 1.15 Kg/hr

M_9 = 37%M_{10} = 142.58 L/hr

5.2.2. Energy balance

The energy balance for production of bread from wheat flour and oat flour can be simply described by the heat required to make the flour, dough, and bread. The source of heat for the milling, mixing and baking is electricity. The major unit operation where heat and energy flow change in bread production is in the Oven. The oven uses electrical energy as a source of heat. This electrical energy is converted to heat through the process of conduction, convection, and radiation in oven. The given parameters to calculate the energy balance are given bellow:

Total mass of dough (M_{dough}) = 358.36kg/hr
Mass of bread out of oven (M_{bread}) = 281.25kg/hr
Assume Temperature of dough after mixing ($T_{ref.}$) = 25^0C
Temperature of dough before interring to oven (T_{dough}) = 35^0C

Initial moisture of dough = 45%

Temperature of bread when it go out of oven (T_{bread}) =250^0C

Final moisture content of bread = 29.92%

Latent heat of evaporation, λ for water (@100 ºC) =2257kJ/kg

Change in temperature (ΔT) = T1 – T2 (5.1)

$= 250^0C-35^0C=215^0C$ (K)

Composition of dough (M=45, P=9.77, F=0.65, CHO=41.96, and A=1.16)

Composition of bread (M=29.92, P=15.85, F=0.95, CHO=44.86, and A=5.56)

$Cp_{\text{of dough}} = 1.424Xc+1.549Xp+1.675Xf+0.837Xa+4.187Xw$ (kJ/kg.k) (5.2)

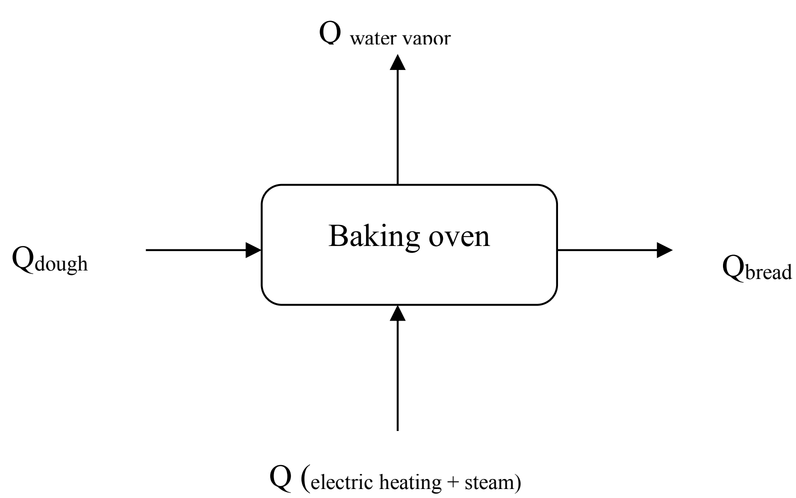
$Cp_{\text{of dough}} = 1.424(0.4196) + 1.549(0.0977) + 1.675(0.0065) + 0.837(0.0116) + 4.187(0.45)$

$Cp_{\text{of dough}} = 2.65$ kJ/kg.k

$Cp_{\text{of bread}} = 1.424Xc+1.549Xp+1.675Xf+0.837Xa+4.187Xw$ (J/kg.k)

$Cp_{\text{of bread}} = 1.424(0.4486) + 1.549(0.1586) + 1.675(0.0095) + 0.837(0.0056) + 4.187(0.2992)$

$Cp_{\text{of bread}} = 2.2$ kJ/kg.k



General

$Q_{dough} + Q_{(electric\ heating\ +\ steam)} = Q_{water\ vapor} + Q_{bread}$ (5.3)

$Q_{dough} = M_{dough}\ Cp_{of\ dough}\ (T_{dough} - T_{ref})$

Q_{dough} = 358.36 kg/hr x 2.6 kJ/kg.K (35-25)

$Q_{dough} = 9.5 \times 10^6$ J/ hr (5.4)

$Q_{bread} = M_{bread}\ Cp_{of\ bread}\ (T_{bread} - T_{ref})$

Q_{bread} = 281.25kg/hr x 2.2 kJ/kg.K (250-25)k

$Q_{bread} = 1.39 \times 10^8$ J/ (5.5)

$Q_{water\ vapor} = M_{Wv}\ \lambda_{water\ vapour}$ (@100 ^oC)

$Q_{water\ vapor}$ = 54.04 kg/hr x 2257 kJ/kg

$Q_{water\ vapor} = 1.22 \times 10^8$ J/ hr (5.6)

Substituting equation 5.4, 5.5and 5.6 into equation 5.3

$Q_{dough} + Q_{electric} = Q_{water\ vapor} + Q_{bread}$

$Q_{(electric\ heating\ +\ steam)} = Q_{water\ vapor} + Q_{bread} - Q_{dough}$

= 1.22x 108 J/ hr + 1.39 x 108 J/hr – 9.5 x 106 J/ hr

= 2.52×10^8 J/hr

5.3 Equipment layout of the plant

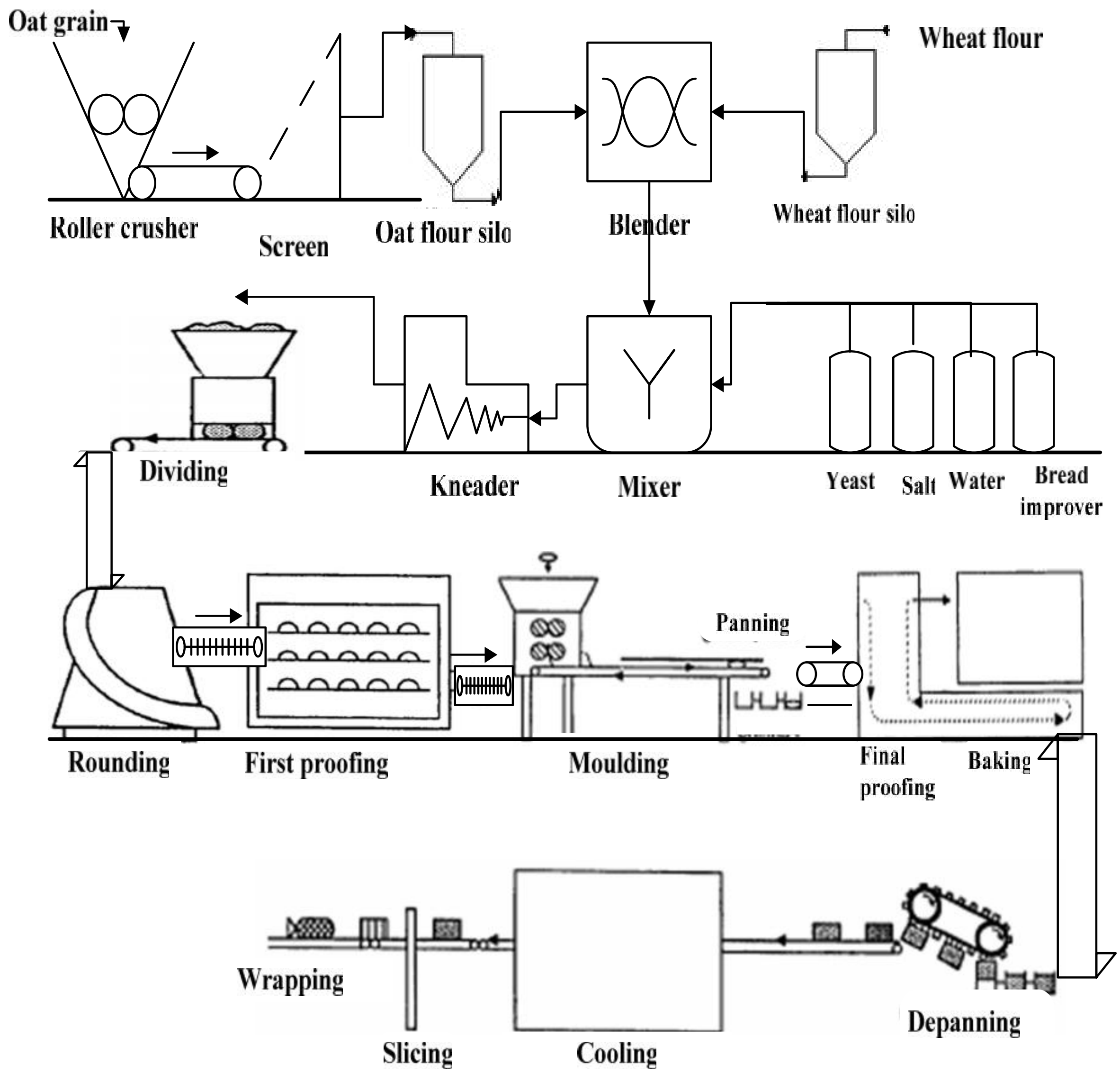


Figure 5.2: Equipment lay out for bread production

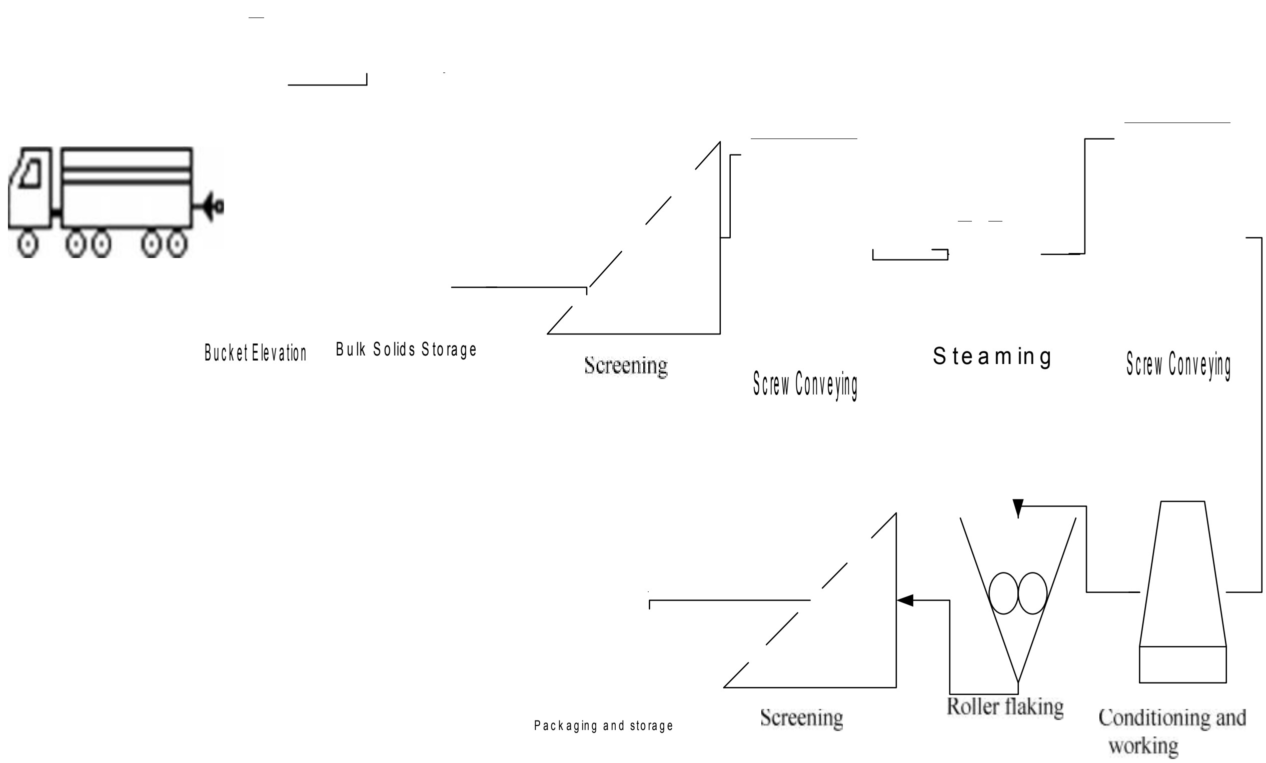


Figure 5.3: Equipment layout for oat flake processing

5.4 Economic evaluation of the plant

5.4.1. Total Capital Investment

5.4.1.1. Equipment Cost

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:

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

Where the value of the exponent, n depends on the type of equipment or plant. And for Food stuffs ,n is assumed to be 0.66 (Perry and Green, 1999).

Table 5.1: Major equipments delivered purchasing cost

SN	Item (birr)	Quantity	Capacity/size	Unit price (birr)	Total price (birr)
1	Universal mixer	1	358.36kg/hr	78,432.60*	78,432.60*
2	Deck oven	1	2.5m × 18m	200,267.56	200,267.56
3	Belt conveyor	2	2.5m × 7m	14,389.38	14,389.38
4	Rotary moulder	1	358.36kg/hr	93,274.43	93,274.43
5	proofer	1	300m^3	1,252,980.00*	1,252,980.00*
5	Water tank	1	10,000 liter	12,604.76	12,604.76
6	Weighing balance	1	--------------	27,589.49	27,589.49
7	Delivery vehicle	1		500,000	500,000
8	Sub-total				926,558.22
9	Contingencies on Equipment	15%			138,983.73
10	Total	9			2,318,521.9

Values for most equipment were taken from local company and personal contact.
*Costs obtained from the internet (http://www.matche.com/EquipCost/Index.htm,)

5.4.1.2. Capital Investment Estimation

Table 5.2:.Estimation of direct cost

COMPONENTS	FACTORS	COST
Purchased equipment cost	PEC	2,318,521.9
Purchased-equipment installation	0.45PEC	1,043,334.9
Instrumentation and controls	0.09PEC	208,666.971
Piping	0.16 PEC	370,963.5
Electrical equipment and materials	0.1 PEC	231,852.19
Buildings (including services)	0.25 PEC	579,630.48
Yard improvements	0.13 PEC	301,407.85
Service facilities	0.4 PEC	927,408.76
Land	0.06PEC	139,111.31
Total direct cost		6,120,897.9

Table 5.3: Estimation of indirect cost

COMPONENTS	FACTORS	COST
Engineering and supervision	0.33 PEC	765,112.23
Construction expenses	0.39 PEC	904,223.54
Contractor's fee	0.17 PEC	394,148.72
Contingency	0.10 PEC	231,852.19
Total indirect cost		2,295,336.7

i. Fixed capital Investment (FCI)

FCI = Direct cost + Indirect cost

= 6,120,897.9 + 2,295,336.7

= 8,416,234.6

ii. Working Capital

Working capital is an additional investment needed above the fixed capital to start up and operate the plant to the point in which income is earned.

Working capital = 15% Fixed capital

WC = 0.15 TCI

TCI = WC + FCI

TCI = 0.15 TCI + FCI

TCI = FCI/0.85

TCI = 8,416,234.6/0.85

TCI = 9,901,452.4 birr

WC = 1,485,217.9 birr

5.4.2. Estimation of Total Production Cost (TPC)

Manufacturing cost

A. Direct production cost

i. Raw materials cost

Raw material cost = 30% total production cost = 0.30 TPC

ii. Operating labor

Operating labor =10% total production cost = 0.10 TPC

iii. Direct supervision

Direct supervision = 10% operating labor = 0.01 TPC

iv. Utilities

Utilities = 10% total production cost = 0.10 TPC

v. Maintenance and repair

Maintenance and repair = 4% Fixed capital investment

= 0.04 x 8,416,234.6birr

=336,649.38 birr

vi. Laboratory charges

Laboratory charges = 10% operating labor = 0.01 TPC

Direct production cost = i + ii + iii + iv + v +vi

= 336,649.38 birr + 0.52 TPC

B. Fixed charges

i. Depreciation

Depreciation = 10 % Fixed capital investment = 0.10 FCI

ii. Capital charge

Capital charge = 1 % Fixed capital investment = 0.01 FCI

iii. Insurance

Insurance = 1 % Fixed capital investment = 0.01 FCI

*Fixed charges = i + ii + iii =0.12 FCI =0.12*8,416,234.6*

= 1,009,948.2 birr

C. Plant overhead costs

Plant overhead costs = 50% operating labor = 50% (10% TPC) = 0.05 TPC

Manufacturing cost = Direct production cost + Fixed charges + Plant overhead costs

= A + B + C = 1,346,597.5 + 0.57 TPC

General expenses

i. Administrative cost

Administrative cost = 3% TPC =0.03 TPC

ii. Distribution and selling cost

Distribution and selling cost = 4% TPC = 0.04 TPC

iii. Research and Development cost

Research and Development cost = 5% TPC = 0.05 TPC

General expenses = i + ii + iii = 0.12 TPC

Total production cost (TPC) = Manufacturing cost + General expenses

TPC = (1,346,597.5 + 0.57 TPC) + 0.12 TPC

TPC = 4,343,863.0 birr/year

Annual production rate of bread = 281.25kg/hr x 16 hours/day x 300 days /year

= 1,350,000 kg/year

5.4.3 Profitability Measurements

Unit product cost = Total production cost/ annual production

= 4,343,863.0 birr/year / 1,350,000 kg/year = 3.22 birr/kg

Let selling price of bread be 5 birr/kg (taking in to account current market situation of Ethiopia)

Total income = (1,350,000 kg/year × 5 birr/kg)

= 6,750,000 birr/year

i. Gross earnings and net earning

Gross earning = Total income – Total production cost

= 6,750,000 birr/year – 4,343,863.0 birr/year

= 2,406,137birr/year

Assume the income tax rate is 35% (the tax rate of Ethiopia),

Net annual earning = Gross earning – Income tax

$= 2,406,137\ (1 - 0.35)$ birr

$= 1,563,398.1$ birr

ii. Return on Investment (ROI)

$$ROI = \frac{Net\ profit}{Total\ Capital\ Investment}\ x\ 100$$

$$ROI = \left(\frac{1,563,398.1}{9,901,452.4}\right)\times 100 = 15.79\%$$

iii. Payback time

Payback time is defined as the period required recovering the original investment outlay through the accumulated net cash flows earned by the project.

$$\text{Payback period} = \frac{FCI}{Net\ profit + Depreciation}\ years$$

$$\text{Payback period} = \left(\frac{8,416,234.6}{1,563,398.1 + 841,623.46}\right) = 3.5 \text{ years}$$

iv. Break-even analysis

The break-even analysis is to determine the point at which sales revenues equal the costs of products sold. When sales are below this point, the plant is making a loss, and at the point where revenues equal costs, the plant is breaking even. The break-even production is the number of units necessary to produce and sell in order fully to cover the annual fixed costs. It can be computed as:

Total product cost = Total income

To calculate the total product cost and total income, unit product cost of 3.22 birr/kg, product selling price of 5 birr/kg, were considered. The break-even point was calculated as:

(Fixed charges + General expenses + Plant overhead costs) + 3.22n = 5n

Where n is the number of kg of product produced.

⇒ 1,009,948.2 birr + 0.12 TPC + 0.05 TPC

TPC = 4,343,863.0 birr/year

⇒ 1,748404.9 = 1.78n

⇒ n = 982,249.95 kg

This is the quantity of product at break-even point. It is 72.75% of the plant capacity. Based on the preliminary economic evaluation, the suggested project has a return on investment (ROI) of 15.79% and payback period of 3.5 years. The break-even production capacity is at 72.75%, showing that there is good profit margin. Thus, the suggested project is financially feasible.

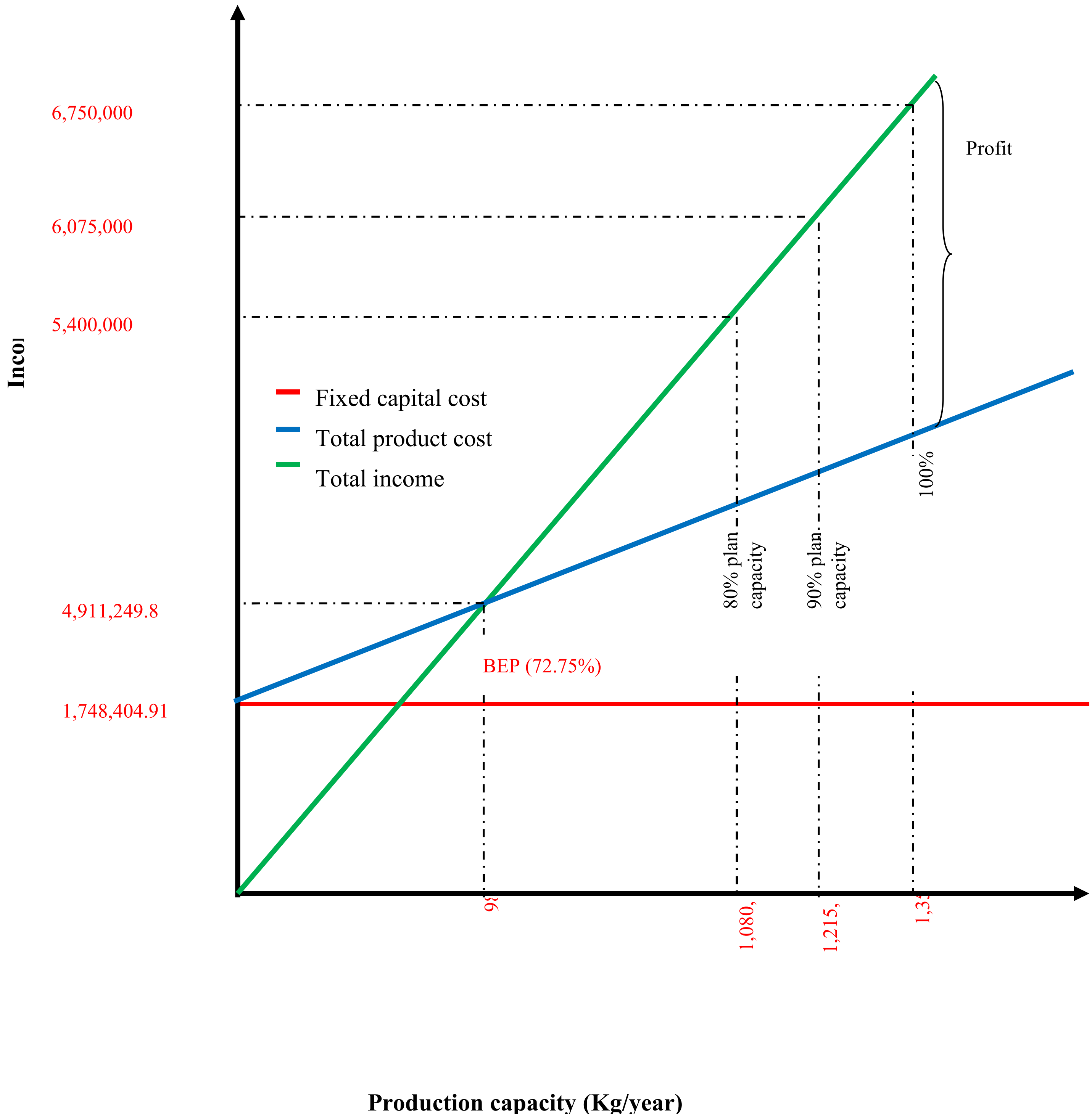


Figure 5.4: Break even analysis graph

5.5 Plant location

To select proper locations and sites, certain key requirements or criteria should be set, that would allow the assessment of a number of potential locations, and the rejection of those not fulfilling those requirements. The remaining alternatives are subject to a more in-depth qualitative and quantitative analysis of technical and financial criteria, including social, environmental and economic aspects of location and site selection. For the composite bread producing plant, based on proximity to market, availability of utilities such as water, electricity and other infrastructures, ease of access and handling of human resource, Addis Ababa was selected to locate the plant.

CHAPTER SIX

Conclusions and Recommendation

6.1. Conclusions

The study was aimed at investigating the influence of oat flour supplementation in wheat flour for the production of bread and its effect on sensory attributes and quality characteristics of those products. The study was also aimed in investigating the potential of producing oat flake from locally grown variety.

The results of the present study indicated that oat flour supplementation into straight grade wheat flour improved the chemical constituents of the composite flours. The crude protein and crude fat of the composite bread increases from 13.45% (100% wheat flour) to 15.98 (15% oat flour) and 0.98% (100% wheat flour) to 4.00% (15% oat flour) ; respectively. This reflects the potential for use of oat into wheat flour for enhancement of these nutrients/chemical constituents. The improvement in the chemical constituents such as protein, fat, fiber and ash was due to the fact that oat flour had higher content of these constituents.

Mg and K content of bread increased as a result of the addition of oat flour. The decrease in loaf volume of the bread from 340.6 cm^3 (for 100% wheat flour) to 250.3 cm^3 (15% oat flour)can be attributed to low gluten content of the blend of wheat flour and oat flour. The production of oat is abundant in our country. Thus the research work has indicated the utilization of this oat flour by supplementing it with wheat flour.

The sensory evaluation of bread samples has showed that some formulations were highly accepted by panelists and they had overall acceptability. The sensory evaluation of oat flake has showed that was highly accepted by panelists .The technology is familiar and can be adopted in the bakeries without the necessity of purchasing novel ingredients or new equipment. The feasibility study also showed that the suggested composite bread production is both technically and financially feasible. Thus, the production of bread from the oat flour supplemented wheat flour can be considered as the economical and nutritive food for developing countries.

6.2. Recommendations

During the process of undergoing this research paper, there had been some constraints and results. Based on this, the following recommendations are made.

- ✓ Oat should be included in daily diet plan through its incorporation into wheat flour used for production of breads and flake.
- ✓ Baking industry should focus on the fortification of bakery products with oat flour.
- ✓ Industrial utilization of locally-grown crops for manufacture of convenient local recipes including fortified products has to be stressed by International agencies as the most effective channel for addressing an intensifying world food problem.
- ✓ It is also recommended for researches to conduct other more functional properties such as emulsion activity & stability; foaming capacity & stability; and water solubility index. In addition to this, physic-chemical properties like seed density, hydration & swelling coefficient, and hydration, swelling capacities & indices.
- ✓ Active ingredients from oat flour (like β- glucans) should be extracted and used as nutraceuticals in different food products including bread and other traditional products.

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Appendices

Appendix I : Score Sheet for Sensory evaluation of bread and flake

Instructions

You are provided with four bread samples and two flake samples coded 01, 02, 03 and 04. You are free to taste, feel, shake and rub between the fingers and indicate your perception for each parameter by using the values 1 (poor) to 5 (excellent) as shown below: Water is provided to rinse your mouth after tasting each sample.

Name: ----------------------------------- Date: ---------------------

Product code: --

Quality attributes	Hedonic scales				
	5	4	3	2	1
Color					
Appearance					
Texture					
Flavor					
Taste					
Over all acceptability					

Key: 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1 = Poor

Comments: --

Signature: -------------------------------------

Appendix II : Factors with separation of materials and labor

	Total factor	Materials factor	Labor factor
Equipment delivered	1.00		
Installation	0.09		0.09
Instruments installed	0.13	0.09	0.04
Piping	0.29	0.155	0.135
Foundations and steel	0.18	0.08	0.10
Insulation painting	0.11	0.025	0.085
Electrical	0.18	0.06	0.12
Battery-limit building	0.21	0.13	0.08
Site preparation	0.08		
Auxiliaries	0.55		
Physical-plant cost	2.82		
Engineering and home office	0.31	0.01	0.30
Field expense	0.43	0.30	0.13
Direct plant cost	3.56		
Contractor's fees	0.17		
Contingency	0.39		
Fixed-capital cost	4.12		

Appendix III : Photos of laboratory equipments during laboratory session

Falling number measuring equipment

Sieving of flours

Farinograph equipment

Dough mixer

Moisture content and color grade

Laboratory prepared oat flake

Oat flour

Dough after proofing