PREPARATION AND QUALITY EVALUATION OF MALTED SORGHUM INCORPORATED BREAD

by

Diwash Acharya

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

2021

Preparation and quality evaluation of malted sorghum incorporated bread

A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment of the requirements for the degree of B.Tech. in Food Technology

by

Diwash Acharya

Department of Food Technology

Central Campus of Technology, Dharan

Institute of Science and Technology

Tribhuvan University, Nepal

March, 2021

Tribhuvan University

Institute of Science and Technology

Department of Food Technology

Central Campus of Technology, Dharan

Approval Letter

This *dissertation* entitled *Preparation and Quality Evaluation of Malted Sorghum Incorporated Bread* presented by Diwash Acharya has been accepted as the partial fulfillment of the requirement for the B. Tech. degree in Food Technology

Dissertation Committee

1. **Head of the Department ___________________________________**

   (Mr. Basanta Kumar Rai, Prof.)

2. **External Examiner _______________________________________**

   (Mr. Raj Kumar Rijal, DFTQC Chief)

3. **Supervisor ____**

   (Mr. Dambar Bahadur Khadka, Asst.Prof.)

4. **Internal Examiner _______________________________________**

   (Mrs. Babita Adhikari, Assoc. Prof.)

March, 2021

Acknowledgements

I express my deep sense of gratitude to my supervisor Asst. prof. Mr. Dambar Bahadur Khadka.

I am also indebted to Prof. Basanta K. Rai (Chairperson, Department of Food Technology) and Prof. Dr. Dhan B. Karki (Campus Chief, Central Campus of Technology) for providing requisite facilities and encouragement for the work. I also would like to acknowledge all my teachers for their participation, encouragement and academic support throughout my study.

I am also grateful to all the laboratory, library and administrative staffs for their generous help. I am thankful to my friends, Subash Sigdel, Saphal Ghimire, Saroj Katwal, Sharad Bhattrai, Archana Bhatta, Stuti Sapkota and my juniors Anup paudel, Trilochan Pandey, Ranjan Shrestha, Prakash Sapkota for their co-operation during my dissertation work.

March, 2021

Diwash Acharya

Abstract

A study was conducted to optimize malted sorghum flour in bread. Malted sorghum flour was obtained by germination the sorghum grains were followed by drying at 50°C for 24 h till the constant weight obtained and finally processed into fine powder.

Different formulations were made by using Design Expert v 7.1.5. varying incorporation of malted sorghum flour 2 to 20% with partial replacement of wheat flour and keeping all other ingredients same.. The Statistical analysis showed that 5.04% malted sorghum flour incorporated bread was superior to all bread formulations in terms of sensory characteristics. Physical analysis of bread formulations showed that the specific loaf volume and volume decreases while the weight increases with the incorporation of malted sorghum flour. The proximate analysis for moisture (db), crude protein (db) , crude fat (db), crude fiber (db), total ash (db), carbohydrate (db) and reducing sugar (db) of malted sorghum flour was done and the values were found to be (5.5, 10.67, 6.59, 3.20, 0.57, 3.19, and 75.34%) respectively. The incorporation of malted sorghum flour significantly improved nutritional attributes in terms of the protein, fat, and crude fiber. The proximate composition of best bread according to which the moisture content, protein (db), fat (db), fiber (db), ash content (db), and carbohydrate are found to be 19.34, 13.43, 5.36, 5.55, 1.13 and 73.63% respectively.

Contents

List of Tables

List of Figures

List of Plates

List of abbreviation

Abbreviation	Full form
ANOVA	Analysis of Variance
ADP	Adenosine Diphosphate
CO_2	Carbon Dioxide
FAO	Food and Agriculture Organization
KMS	Potassium metabisulphite
RSM	Response Surface Methodology

Part I

Introduction

1.1 General introduction

Sorghum [*Sorghum bicolor* (L) Moench] is the fifth most important cereal crop in the world; however, it has a wide range of other applications that are being explored with worldwide interest in renewable resources (Dahlberg *et al.*, 2011). Having been domesticated for a variety of useful products and cultivated in a broad range of environments, sorghum exhibits a great range of phenotypic diversity. Around the world, sorghum is grown for the production of dense grain panicles (for food, feed, and/or energy), tall, thick sweet stalks (for food, feed, and/or energy), and various forage types (for feed and fuel) (Kimber *et al.*, 2013). The sorghum kernel varies in color from white through shades of red and pale yellow to deep purple-brown. The most common colors are white, bronze and brown. Kernels are generally spherical but vary in size and shape. The caryopsis can be rounded and bluntly pointed, 4 to 8 mm in diameter. The grain is partially covered with glumes (FAO, 1995).

Large grains with carotene and xanthophyll increases the nutritive value of sorghum (FAO 1995). The crop is rich in minerals but bioavailability vary from less than 1% for some forms of iron to greater than 90% for sodium and potassium. The reasons for this are varied and complex, since many factors interact to determine the ultimate bioavailability of a nutrient. Like other grains, sorghum protein is generally low in the essential amino acids such as lysine and threonine. Sorghum, like legume and oil seed meals has some limitations, due to the presence of antinutritional factors, such as trypsin and amylase inhibitors, phytic acid, and tannins. These compounds are known to interfere with protein, carbohydrates and mineral metabolism (Mohammed *et al.*, 2011).

Malting is a biotechnological technique which involves the controlled germination of a cereal grain which aims at activating enzyme systems that catalyze the hydrolysis of polymerized reserved food materials, notably, proteins, starches and cell-wall substances, thus, extracting fermentable materials (Gautam *et al.*, 2015). The goal of malting in brewing is to transform the food reserves of the grain, such that they can be dissolved and extracted by hot water during the mashing stage to produce wort, which is an aqueous solution of fermentable carbohydrates and soluble protein. The extent of transformation or modification of the grain during malting is influenced by the sprouting conditions to which the grain is exposed. It has been established that malting conditions such as steeping schedule, duration of germination, drying temperature (kilning) and sorghum cultivar influence the quality characteristics of malt (Djameh *et al.,* 2015).

Bread is baked aerated dough, the primary ingredients of which are wheat flour, yeast, salt and water. The yeast ferments the sugar and thereby evolves carbon dioxide which aerates dough. The purpose of bread making is to present cereals flour to the consumer in an attractive and digestive form (Chamberlain, 1975). The first requirement in bread making is formation of gluten network, the second is the aeration of mixture by incorporation of gas, the third is coagulation of material by heating it in the oven so that the gas is retained in and the structure of the material is stabilized. The advantage of having an aerated, finely vesiculated crumb in the baked product is that it is easily masticated (Kent, 1983). To make good bread, dough made by any process must be extensible enough for it to relax and to expand while it is rising. Good dough is extensible if it will stretch out when pulled. It also must be elastic, that is, have the strength to hold the gases produced while rising, and stable enough to hold its shape and cell structure. Two proteins (gliadin and glutenin) present in flour form gluten when mixed with water and gives dough these special properties.

1.2 Statement of the problem

Bread is food for many people around the world. People are consuming bread made from wheat flour or other sources. In this context, increasing interests in the study of products which are health beneficial as well as nutritious have been in light for consumers. Several studies have used blended flours or composite flours to produce breads. There have also been a number of attempts to improve their nutritional characteristics by partially replacing the wheat flour with non- wheat ingredients in the production of bread. So, the preparation of malted sorghum composite bread quality can increase sensory properties as well as nutritional value of bread may be increased.

1.3 Objectives

1.3.1 General objective

The general objective of this work was to incorporate malted sorghum flour for bread making and its quality evaluation.

1.3.2 Specific objectives

The specific objectives of the work were:

1. To prepare bread from Malted-Sorghum flour partially replacing the wheat flour.
2. To perform physiochemical analysis of the prepared bread.
3. To perform sensory analysis as well.
4. To find best proportion of malted sorghum flour incorporated bread.
5. To evaluate the nutritional properties of the obtained best formulation of malted sorghum incorporated bread.

1.4 Significance of the study

Sorghum is one of the gluten free product and contain less protein as compared to barley. A major objective of malting is to promote the development of hydrolytic enzymes, which are not present in the non-germinated grain (Taylor and Belton, 2002). The amount of reducing sugar increases in the malted flour sorghum varieties. Sorghum in vitro digestion studies show that malting caused an improvement in protein digestibility and other protein quality characteristics, including percentage of protein and content of the first limiting amino acid and lysine (Mella, 2011).

Also during malting, both starch and protein are partially degraded allowing for better digestibility (Mella, 2011). Narsih *et al.* (2012) reported the increase in ash content due to an increase in phytase enzyme activity during germination. Hence by incorporating malted sorghum in bread could increase its nutritional quality.

1.5 Hypothesis

The null hypothesis of this study will be set up as:

Incorporation of malted sorghum may not affect the sensory characteristics and chemical composition of bread.

The alternative hypothesis of this study will be set up as:

Incorporation of malted sorghum may affect the sensory characteristics and chemical composition of bread.

1.6 Limitation

1. Only one variety of sorghum will be used for the study.

2. Germination of sorghum couldn't be done at controlled condition.

Part II

Literature review

2.1 Sorghum

Globally, sorghum is the dietary staple of more than 500 million people in more than 30 countries. Only rice, wheat, maize, and potatoes surpass it in the quantity eaten. For all that, however, it produces merely a fraction of what it could. Indeed, if the 20th century has been the century of wheat, rice, and maize, the 21st could become the century of sorghum (*Sorghum bicolor*) (NRC, 1996). It belongs to family Poaceae family, tribe Andropogoneae, subtribe Sorghinae, genus *Sorghum* (Smith and Frederiksen, 2000).

2.1.1 Origin and historical background

Sorghum was originated in north east Africa. Domestication of sorghum started in Ethiopia and Egypt around 3000 years back. It progenitor races of durra, guinea and caffra were found to grow wild in different parts of Eastern, Western and Central Africa. In India, it might have been introduced through early sailors well before the Christian era but not earlier to 1500 BC. It was introduced to America and Australia about 125 years back, and Mediterranean/Middle Eastern countries started sorghum cultivation 300 years back (Joshi, 2015).

Sorghum (Holcus) *saccharatum* (Halapense andropogon), a variety of *S. vulgare*, or of the Durrha, is the sugarcane of Northern China and by the Zulu Kaffirs called Imphee. The Japanese cultivate it only for the sugar and the alcohol, and for the same purpose it is now cultivated in the United States (Collier, 1884).

The common sorghum (vulgare) is the principle grain food in Africa. It is used to make bread, or eaten as musb. It is the principle nutriment in many parts of India, where it is called Jovari, and in the dry regions of Arabia, in Syria, where it has been cultivated since time immemorial. Sorghum bicolor is cultivated in Abyssinia at 8000 feet above the sea (Collier, 1884).

Sorghum has not yet attracted the same amount of research as the other major cereals, wheat, rice and corn. However, with rapidly increasing interest in its food and industrial properties, cultivation of this crop, ranking fourth amongst cereals in world production, is likely to expand (Nesbitt, 2012).

2.1.2 Production of sorghum

The total production of sorghum in the world in 1990 was 58 million tonnes, a decrease from 60 million tonnes in the year 1989 and 62 million tonnes in 1988. A decrease in yield from 1340 kg/ha in 1989 to 1312 kg/ha in 1990 was reported, while the area remained around 44 million hectares in both years. Table 2.1 provides data on area, yield and production of sorghum in various regions of the world (FAO, 1995). In 2007, the world planted 43.8 million hectares of sorghum, with over 80% of the area devoted to the crop being found in Africa and Asia (FAO, 2008).

In statistics collected from 1992-1994 about general millet, Nepal had an area of 0.21 million ha , with an yield rate of 1.14 (t/ha), and produced about 0.24 million tons of sorghum.

An estimation of the world-wide tonnage produced in 2007-2008 is shown in Table 2.1.

Table 2.1 Area, yield and production of sorghum by region

Countries	Production (tones x 1000)	% of total
United states	12,827	20
Nigeria	10,000	16
India	7,780	12
Mexico	6,100	10
Sudan	4,500	7
Ethiopia	3,230	5
Argentina	2,900	5
Australia	2,691	4
China	1,900	3
Burkina faso	1,800	3
Brazil	1,700	3
Other countries	6,800	12
Total	62,308	100

Source: U.S. Grain Council (2008)

The five largest producers of sorghum in the world are the United States (25%), India (21 .5%), Mexico (almost 11%), China (9%) and Nigeria (almost 7%). Together these five countries account for 73% of total world production (FAO, 1995).

2.1.3 Structure of the sorghum grain

Examination of microscopic view of a section through a mature sorghum kernel helps to divide the kernel between the outer seed cover or pericarp, the embryo or germ, and the endosperm (Wall and Blessin, 1969). The structure of sorghum is shown in Fig. 2.1.

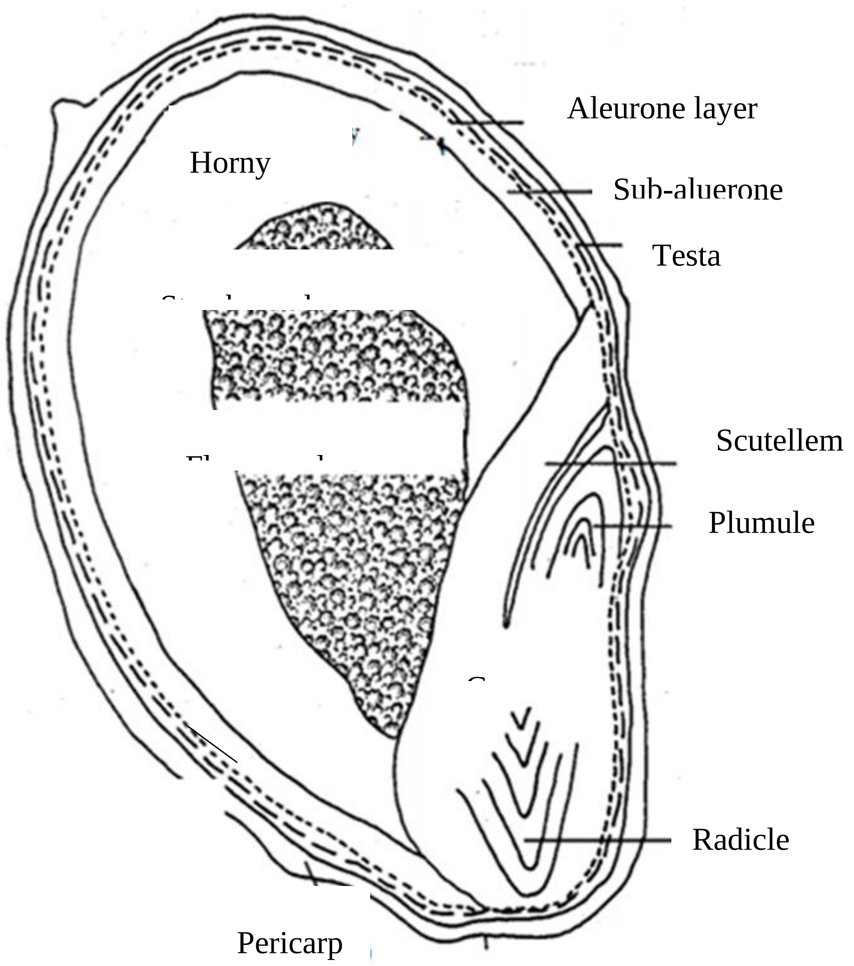

Fig. 2.1 Structure of Sorghum grain .

Source: Sautier and O'Deye (1989)

2.1.3.1 Pericarp

The pericarp constitutes 4.3% to 8.7% of the sorghum caryopsis (Waniska and Rooney, 2000). It has a thickness of 8 to 160 μm varying within individual mature caryopses (Earp, McDonough, and Rooney, 2004).It is subdivided into three tissues: epicarp, mesocarp and endocarp. The epicarp is covered with a thin layer of wax and is usually pigmented. The sorghum mesocarp contains starch granules, a characteristic unique to sorghum (Serna-Saldivar *et al.*, 1994). The tube cells, which are part of the pericarp, conduct water during germination while, the cross cells form a layer that impedes moisture loss. The pericarp contains approximately 5% to 8% of the grain protein (Waniska and Rooney, 2000).

2.1.3.2 Testa

Some sorghum cultivars have pigmented sub-coat (testa) located between the pericarp and the endosperm as shown in Fig. 2.1 (Earp, *et al.*, 2004) . The pigmented testa contains tannins (proanthocyanidins) (Waniska and Rooney, 2000). Tannins protect the grain against insects, birds and fungal attack but condensed tannins are associated with nutritional disadvantages and reduced food quality (Serna-Saldivar and Rooney, 1995). The nutritional disadvantages of sorghum tannins lie primarily in their ability to form poorly digestible complexes with dietary protein (Butler *et al.*, 1984).

2.1.3.3 Aluerone layer

The endosperm consists of an outer single-cell layer of aleurone tissue. Aleurone cells are rich in oil, protein, and ash (Wall and Blessin, 1970).

2.1.3.4 Endosperm

The endosperm constitutes 82% to 87% of the sorghum grain (Waniska and Rooney, 2000). It is composed of peripheral, and floury and corneous (horny, vitreous, glassy) areas as shown in Fig. 2.1 (Serna-Saldivar *et al.*, 1994). The peripheral region has several layers of dense cells containing more protein bodies and smaller starch granules than the corneous area. The peripheral and corneous areas affect processing and nutrient digestibility (Waniska and Rooney, 2000). In a review of the composition of the sorghum endosperm cells, Taylor *et al.* (2006) noted that both the floury and corneous endosperm cells are composed of starch granules, protein matrix, protein bodies and the cell walls are predominated by water insoluble glucuronoarabinoxylans (GAX). The endosperm contains approximately 81% of sorghum protein (Waniska and Rooney, 2000). In normal sorghum cultivars, most of the proteins in the endosperm are prolamin (soluble in alcohol-water mixtures) as well as some limited amounts of glutelins (soluble in dilute acid and dilute alkali) (Taylor and Schussler, 1986).

To understand the phenomenon of sorghum endosperm hardness and factors responsible for it, Shull *et al.* (1990) observed the differences in developing sorghums of varying hardness. They found that corneous sorghum endosperm had more and evenly distributed proteins. Similarly, in a review of biochemical basis and implications of hardness and grain strength in sorghum and maize, Chandrashekar and Mazhar (1999) noted that the protein bodies in the corneous endosperm contained more γ-prolamin, which seemed to be cross-linked by disulphide bonds, than in soft grains. These authors suggested that the amounts of α- and γ- prolamin relative to the total prolamin content may be essential for corneous texture, in which these prolamin are usually higher in hard grains than in soft grains. Furthermore, Ioerger *et al.* (2007) investigated the role of cross-linking of sorghum storage proteins (kafirins) into larger polymeric groups in influencing grain hardness. They used a number of protein analytical techniques to study the protein composition of isolated corneous and floury endosperm. These authors found that corneous endosperm had a greater level of kafirin crosslinking than did floury endosperm and that the cross-linking produced a larger molecular weight distribution than in the floury endosperm. These workers also reiterated that the γ-kafirins in the corneous endosperm may have the most obvious relationships to indicators of kafirin cross-linking in the corneous endosperm (Ioerger *et al.*, 2007).

Reviewing the traditional food applications of sorghum, Murty and Kumar (1995) reported that sorghum endosperm texture determines the food making properties of sorghum. However, there are differing reports on the preferences for traditional sorghum foods based on the endosperm hardness. For example, Bello *et al.* (1990) and Da *et al.* (1982)found that to (a West African thick porridge) prepared using corneous endosperm sorghum produced desirable firmer texture than floury endosperm sorghum. On the other hand, Fliedel (1995), working on tuwo and Aboubacar *et al.* (1999) using tuwo (a sorghum porridge consumed in Niger) did not find any correlation between thick porridge firmness and endosperm texture. However, there is a consensus that corneous endosperm sorghum is not suitable for preparation of fermented and unfermented flatbreads as it produces undesirable stiffer bread (Rooney *et al.*, 1988; Yetneberk *et al.*, 2004).

2.1.3.5 Germ

The germ is the living part of the sorghum grain. It consists of two main parts: embryonic axis and scutellum as shown in Fig. 2.1. The embryonic axis contains the new plant. During germination and development the radicle forms the primary roots while the plumule forms the shoot (Evers and Millar, 2002). The scutellum is the cotyledon and has reserve nutrients: moderate quantity of oil, protein, enzymes, and minerals, doubling up as a link between endosperm and germ (Waniska and Rooney, 2000). The germ contains approximately 15% of the protein in sorghum. It is rich in albumin (water-soluble) and globulins (soluble in dilute salt solution) which are rich in lysine and other essential amino acids (Taylor and Schussler, 1986).

2.1.4 Utilization of sorghum

The traditional method of consumption as a food grain staple (roti, porridge, or mixed with rice) continue to dominate sorghum use for some time, particularly in India, Pakistan, and Burma. But more importantly, sorghum use (and its perception) as a source of feed for livestock and poultry has developed rapidly during recent times. Presently, a little less than 20% of the sorghum produced in Asia goes for animal feed (Kelley *et al.*, 1992).

Grain sorghum has long been a potential source of industrial raw material. The grits obtained from the endosperm can be used in brewing, just as corn grits and broken rice are now used. Until methods of milling that permitted a satisfactory separation of the germ from the endosperm were developed in 1947, sorghum grits were too high in oil for the best use in fermentation industries. Most of the oil of the grain is in the germ. The oil is suitable for salad oils. The starch from grain sorghum can be used for food products, adhesives, and sizing for paper and fabrics (Martin and Macmasters, 1950-1951).

2.1.4.1 Human food

While total food consumption of all cereals has risen considerably during the past 35 years, world food consumption of sorghum has remained stagnant, mainly because, although nutritionally sorghum compares well with other grains, it is regarded in many countries as an inferior grain. Per caput consumption of sorghum is high in countries or areas where climate does not allow the economic production of other cereals and where per caput incomes are relatively low. These include especially the countries bordering the southern fringes of the Sahara, including Ethiopia and Somalia, where the national average per caput consumption of sorghum can reach up to 100 kg per year. Other countries with significant per caput consumption include Botswana, Lesotho, Yemen and certain provinces in China and states in India. In most other countries, food consumption of sorghum is relatively small or negligible compared to that of other cereals (FAO, 1989).

More than 95% of total food use of sorghum occurs in countries of Africa and Asia. In Africa, human consumption accounts for almost three-quarters of total utilization and sorghum represents a large portion of the total calorie intake in many countries. For example, in Burkina Faso about 45% of the total annual calorie intake from cereals comes from sorghum, although its share has declined from 55% in the early 1960s. China and India account for about 90 % of total food use in Asia (FAO, 1989).

Available data from Africa indicate that despite an increase in total food use between the early 1960s and the mid-1980s, the average per caput consumption declined from 20 to 15 kg per year. Decreases were concentrated in Kenya, Mozambique, Nigeria and Somalia but occurred also in Botswana, Ethiopia, Lesotho and Zimbabwe. In Asia, both total and per caput food use of sorghum declined (FAO, 1989).

This decline in per caput consumption in many countries was due in part to shifts in consumer habits brought about by a number of factors: the rapid rate of urbanization, the time and energy required to prepare food based on sorghum, inadequate domestic structure, poor marketing facilities and processing techniques, unstable supplies and relative unavailability of sorghum products, including flour, compared with other foodstuffs. Changes in consumption habits were concentrated in urban areas. Per capita food consumption of sorghum in rural producing areas remained considerably higher than in the towns. In addition, national policies in a number of countries had a negative influence on sorghum utilization as food. For instance, large imports of cheap wheat and rice and policies to subsidize production of those crops in some countries had considerable negative impact on the production of sorghum (FAO, 1989).

2.1.4.2 Alcohol distilleries

Although the quantity of sorghum grain presently used by the alcohol sector is comparatively low, it seems to be the most "enthusiastic" user of the crop as an industrial raw material. With recent changes in government policies on licensing alcohol production and trade, the use of grains to produce potable alcohol is being promoted, thereby providing an opportunity for sorghum to gain greater acceptability as a raw material in the industry (Kleih *et al.*, 2007).

There are few complaints about sorghum, although some distillers indicated a preference for varieties with a higher starch content and less protein. Distilleries had no objection to using severely blackened grain as long as the starch content was acceptable (Kleih *et al.*, 2007).

In general, like most other industrial users, distilleries purchase rainy-season sorghum through traders or brokers in main producing centers. Though there were few complaints about this system, some distillers felt that brokers sometimes abused their position to "control" the market. In this context, contract farming may be an option providing better linkages between producers and industrial users (Kleih *et al.*, 2007).

2.1.4.3 Animal feed sector

While discussing sorghum utilization for animal feed in India, one has to distinguish between poultry and dairy production. Although the latter has a solid foundation in the co-operative sector, the poultry industry appears to be more dynamic. According to poultry producers and feed millers, very little sorghum was used in poultry feed in 1998/99 due to the availability of maize and its price advantage. Nevertheless, it was acknowledged that in the past, when maize was expensive, sorghum had been used at an inclusion rate of up to 10% in the case of broilers and up to 15% in the case of layers. The demand for sorghum in poultry feed largely depends on the price of maize, which is the energy source preferred by poultry producers. According to industry sources, to make sorghum competitive, its price should be 20 - 30% lower than that of maize (Kleih *et al.*, 2007).

2.1.4.4 Starch industries

Some of the India's main starch manufacturers, who are primarily based in Ahmedabad, have used up to 50000 MT of sorghum in the past when maize was in short supply. Starch producers have even undertaken their own research into sorghum-based starch manufacturing technologies, and their conclusion was that sorghum was not a preferred raw material and would only be used if there were no alternatives (Kleih *et al.*, 2007).

2.1.4.5 Other industries

Although brewers are aware of sorghum-based beer production in Africa, they prefer barley malt as the principal raw material. In addition, broken rice or flaked maize are used as adjuncts. However, one brewery (i.e., Hindustan Breweries in Mumbai) expressed interest in undertaking trials using sorghum as an adjunct (Kleih *et al.*, 2007).

With the exception of a small market for speciality breads in urban centers, sorghum is not accepted as a raw material for industrial food processing. Wheat flour or maize starch are the preferred ingredients. Composite flours do not currently appear to be an option in bread baking or biscuit manufacturing (Kleih *et al.*, 2007).

Export of sorghum does not appear to be an option for the time being. Moreover, Indian sorghum at present is not globally competitive and export quotas for coarse grains are usually taken up by maize (Kleih *et al.*, 2007).

2.1.5 Physical properties

Sorghum is a naked kernel, free from hull. In terms of size and shape, sorghum varieties differ widely. The average dimensions of a sorghum caryopsis (grain) are length 4 mm, width 2 mm and weigh about 25 to 35 mg (Haussmann *et al.*, 1999). The shape varies from obovoid to ellipsoid with 1000 kernel weight varying from 20 to 80 g (Serna-Saldivar and Rooney, 1995). The mean particle and bulk density of sorghum grain obtained were 1.02 g/cm^3 and 568.5 g/cm^3 respectively. The particle density of sorghum grain decreased with increasing moisture within the moisture range of 8.89-16.50% wb (Simonyan *et al.*, 2007). The value of sphericity, 1000 kernel wt., bulk density, particle density (specific gravity), and porosity as 0.67, 32.41 g, 69.9 kg/HL, 1.18 g/cm^3 and 40.80% of sorghum grain (Ndirika and Mohammed, 2005).

Botanically, the sorghum kernel is dry, indehiscent, single seeded fruit. The caryopsis is composed of three major portions: the outer covering (pericarp), the storage tissue (endosperm), and the germ (Johnson and Peterson, 1974).

2.1.6 Chemical composition of sorghum

The sorghum grain has the composition as that of the corn which are as follows.

2.1.6.1 Protein

A typical mature sorghum seed of one of the common hybrids might contain about 15% protein, of which around half would be prolamines, or alcohol soluble proteins, about a third would be glutelin type proteins, 7-9% would be globulins, and the remainder, usually near 5-6%, would be albumin. The tissues differ in their percentage contents of protein, and in the types of proteins which make up the total. There is very little prolamine in the germ and hull, while they predominate in the endosperm. The aleurone layer is rich in albumin and globulins. A major factor affecting the amino acid composition of the proteins is the cultivar, variety and hybrid. During germination, starch and protein were degraded to soluble sugars and amino acids, respectively. Their degradations indicated the metabolic system interference to reserve starch and protein by amylases and proteases (Elbaloula *et al.*, 2014). Amino acids found in malted sorghum are threonine, methionine, phenylalanine, lysine and tryptophan (Matz, 1991) whereas aspartic, serine, glycine, alanine, arginine, tyrosine, cystine, proline, threonine, histidine are found in wheat (Yetneberk *et al.*, 2004).

2.1.6.2 Carbohydrate

Carbohydrates other than starch are present only in small amounts. Both waxy and regular types average 1.20% sugars composed of approximately 0.85% sucrose, 0.09% glucose, 0.09% D-fructose and 0.11% raffinose. Sweet variety contain about 2.8% of these sugars (Matz, 1991).

Starch content of sorghum ranges from 61 to 74%. Gelatinization temperature of sorghum starch is quite high compared to those from other cereals. Most sorghum starches start to gelatinize at c. 70-75°C and reach maximum gelatinization far above these temperatures until about 90-97°C (Verbruggen, 1996).

On a 1 kg basis, sorghum starch contain 200–300 g of amylose and 700–800 g of amylopectin, with waxy varieties containing 0–150 g of amylose and 850–1000 g of amylopectin (Li *et al.*, 2015).

2.1.6.3 Lipids

Average oil content of the whole grain is 3.6%, with oil contents of the endosperm, germ, and bran, 0.6, 28.1, and 4.9%, respectively. The endosperm contains 13% of the total oil in the kernel; the germ, 76%; and the bran, 11%. The petroleum ether extract from sorghum bran consists mostly of wax rather than oil (Wall and Blessin, 1970).

Free lipids make up 2-4% of the grain and bound lipids 0.1-0.5%. The oil's properties are similar to those of maize oil. In other words, the fatty acids are highly unsaturated. Oleic and linoleic acids account for 76% of the total (NRC, 1996).

2.1.6.4 Vitamin and minerals

Compared to maize, sorghum contains higher levels of the B vitamin pantothenic acid, niacin, folate, and biotin; similar levels of riboflavin and pyridoxine; and lower levels of vitamin A (carotene). Most B-vitamin are located in the germ.

The grain's ash content ranges from about 1-2%. As in most cereals, potassium and phosphorus are the major minerals. The calcium and zinc levels tend to be low. Sorghum has been reported to be a good source of more than 20 micronutrients (NRC, 1996).

Table 2.2 Chemical composition of sorghum whole grain and its fractions

Kernel fraction	%of kernel weight	Protein (%)	Ash (%)	Oil (%)	Starch (%)
Whole kernel	100	12.3	1.67	3.6	73.8
Endosperm	82.3	12.3	0.37	0.6	82.5
Germ	9.8	18.9	10.4	28.1	13.4
Bran	7 9	6.7	2	4.9	34.6

Source: FAO (1995)

2.1.7 Health benefits of sorghum

2.1.7.1 Good source of vitamin, minerals and fibers

Sorghum, like other cereals, is an excellent source of the fat-soluble and B-complex vitamin. Amongst the B vitamin, concentrations of thiamine, riboflavin and niacin in sorghum were comparable to those in maize. The detectable fat-soluble vitamin are vitamin B, E and K. It is also an important source of mineral and amongst them, phosphorus is the most abundant. Minerals and vitamin are located at the pericarp and germ; therefore, refined sorghum products lose part of these important nutrients. Sorghum is also one of the best sources of dietary fiber. Sorghum does not have an inedible hull so that the whole grain could be eaten. This means it supplies even more fiber, in addition to many other crucial nutrients. One serving of sorghum grain contains 12 g of dietary fiber which is 48% of your daily recommended intake. High-fiber content of sorghum is important for digestion, hormone production and cardiovascular health (Anon., 2017b).

2.1.7.2 Sorghum may inhibit cancer tumor growth

Compounds in sorghum called 3-Deoxyanthoxyanins (3-DXA) are present in darker-colored sorgums, and to a lesser extent in white sorghum. Scientists at the University of Missouri tested extracts of black, red, and white sorghums and found that all three extracts had strong antiproliferative activity against human colon cancer cells (Yang *et al.*, 2009).

2.1.7.3 Rich in antioxidant

Sorghum contains polyphenol compounds in its pericarp which have the health-protective effect that is superior to many of the more popular consumed grains, fruits and vegetables. The antioxidant activity of sorghum was even 3-4 time higher than some of other whole grains. Black sorghum is especially rich in antioxidants because of its high content of anthocyanins. The antioxidants found in sorghum has anti-inflammatory, anti-cancer, anti-diabetic effects (Anon., 2017b).

2.1.7.4 Protect against diabetes and insulin resistance

Advanced glycation end products (AGEs) are increasingly implicated in the complications of diabetes. A study from the University of Georgia Neutraceutical Research Libraries showed that sorghum brans with a high phenolic content and high anti-oxidant properties inhibit protein glycation, whereas wheat, rice or oat bran, and low-phenolic sorghum bran did not. These results suggest that "certain varieties of sorghum bran may affect critical biological processes that are important in diabetes and insulin resistance" (Farrar *et al.*, 2008).

2.1.7.5 Sorghum is safe for people with celiac disease

Up to one % of the U.S. population (and about 0.5% worldwide) is believed to have Celiac Disease, an autoimmune reaction to gluten proteins found in wheat, barley and rye. While sorghum has long been thought safe for celiacs, no clinical testing had been done until researchers in Italy made a study. First, they conducted laboratory tests; after those tests established the likely safety, they fed celiac patients sorghum-derived food products for five days. The patients experienced no symptoms and the level of disease markers (anti-transglutaminase antibodies) was unchanged at the end of the five day period (Ciacci *et al.*, 2007).

2.1.7.6 Sorghum may help to manage cholesterol

Scientists at the University of Nebraska observed that sorghum is a rich source of phytochemicals, and decided to study sorghum's potential for managing cholesterol. They fed different levels of sorghum lipids to hamsters for four weeks, and found that the healthy fats in sorghum significantly reduced "bad" (non-HDL) cholesterol. Reductions ranged from 18% in hamsters fed a diet including 0.5% sorghum lipids, to 69% in hamsters fed a diet including 5% sorghum lipids. "Good" (HDL) cholesterol was not affected. Researchers concluded that "grain sorghum contains beneficial components that could be used as food ingredients or dietary supplements to manage cholesterol levels in humans" (Carr *et al.*, 2005).

2.1.7.7 Sorghum may help to treat human melanoma

Scientists in Madrid studied the effect of three different components from wine and one from sorghum, to gauge their effects on the growth of human melanoma cells. While results were mixed, they concluded that all four components (phenolic fractions) "have potential as therapeutic agents in the treatments of human melanoma" although the way in which each slowed cancer growth may differ (Gomez-Cordoves *et al.*, 2001).

2.2 Malting

Malted barley, or 'Malt' as it is most commonly known, is a wonderful package of starch, enzymes, protein, vitamin, and minerals plus many other minor constituents that provide the brewer and distiller with their main raw material. 60-65% of the weight of malt is un-degraded starch and malt contains all the key enzymes for starch degradation during the mashing stage of both the brewing and distilling process. These enzymes produce fermentable sugars to supplement the other key nutrients for yeast growth that malt provides. These include amino acids, vitamin, and minerals (Anon., 2017a).

The Malting Process consists of 4 stages which are steeping, germination, kilning and roasting.

a) Steeping

The purpose of steeping is to increase the moisture in the grain from around 12% to approximately 45%. This is achieved through successive immersions and air rests over a period of 2-3 days. During this process, the grain begins to germinate and therefore produces heat and carbon dioxide. In the immersion cycles, the grain is immersed in water and air is blown through the wet grain to keep the level of dissolved oxygen in the water high enough so as to not stifle the developing embryos. In the air rests, the carbon dioxide is removed (Anon., 2017a).

Due to the varying degree of moisture tolerance of the different grains, steeping is a crucial step in the malting process. When the steeping process is complete, all of the grain should be evenly hydrated and show signs of germination (Anon., 2017a).

b) Germination

The Germination phase is the 'control' phase of malting. Germination continues for a further 4-5 days depending on the product type being made. The germinating grain bed is kept at temperature and oxygenated by providing a constant flow of humidified air through the bed at specific temperatures. The grain is turned regularly to prevent rootlets matting and to maintain a loosely packed grain bed. The maltster manipulates the germination conditions to vary the type of malt being manufactured (Anon., 2017a).

c) Kilning

Kilning, the third phase of malting, dries the grain down to 3-5% moisture and arrests germination. Large volumes of hot air are blown through the grain bed. By varying air flows and kiln temperatures, malts of different colors can be produced with varying flavor profiles. At the end of kilning the malt is cooled and the tiny rootlets removed before analysis and storage. The final malt is analyzed extensively according to malt type and customer profile. The malt may be dispatched in bags, in containers or in bulk (Anon., 2017a).

d) Roasting

Roasting is done in 4 distinct stages: steeping, germinating, roasting and cooling. At GWM Malt, grain spends 34-46 h in steep tanks where we aim for a target moisture of 42-44%. The grain is transferred to germination which lasts for around 4 days in Wanderhaufen style streets. This is a semi continuous moving batch germination process. Once germination is complete, the green malt is then transferred to the roasting drum (Anon., 2017a).

The roasting takes place in two roasting drums. The average roasting time is 2.5-3 h with an air on temperatures of up to 460°C. Our roasters take a batch size of 2.4–3.5 tonnes. The roasted malt is then transferred to the cooler and spends 35-60 min there in order to drop the temperature to <15°C and fix the color and flavor compounds. The malt is analyzed before storage and thereafter awaits dispatch to our customers (Anon., 2017a).

The general flow chart for malting is shown in Fig. 2.1.

Sorghum grain

↓

Cleaning

↓

Steeping

↓

Germination

↓

Drying/ Kilning (50°C for 6 h)

↓

Removal of acrospires

↓

Milling

↓

Malt flour

Fig. 2.1 General flow chart of malting

Source: Ratnavati and Chavan (2016)

2.2.1 History of malting

Malt, in substantially the same form as we know it today, was an important product long before the days of recorded history. Although its actual origin is buried in antiquity, there is a legend that early Egyptians manufactured malt by placing it in a wicker basket, which was then lowered into the open wells of that time. It was first lowered into the water for steeping, after which it was raised above the water level for germination (Anon., 2018).

The rate of germination was controlled by adjusting the height of the basket within the well. As germination progressed and heat developed, the basket would be lowered to a lower temperature level thus retarding growth and dissipating heat. To accelerate germination, the basket was simply raised to a higher level (Anon., 2018).

The malt was kept from matting by raising it to the top of the well and agitating the basket. Drying was by natural means, probably a simple process of spreading on the ground, and subjecting it to the direct rays of the sun. The use of malt at this time was thought to be exclusively for beverage purposes (Anon., 2018).

The making and selling of malts was often controlled, in Nurnberg in 1290 only barley was allowed to be malted, while in Augsberg between 1433 and 1550 beer was only to be made from malted oats. In England malt carried a tax for many years until 1880. By 1588, European settlers in North America were trying to make beer from malted maize. Beer can be brewed from a range of cereals, but by the 17th century beers brewed from barley malt predominated in Europe. By the 17th century floor malting was the method being used to malt larger quantities. Floor malting was the only method of malting in use until the 1850's. In floor malting, steeped barley is laid in piles on tiled or concrete floors and allowed to build up some heat and begin growth. The malt is turned manually with wooden shovels to reduce heat buildup and aerate the grain. This method is very labor intensive and time consuming (Briggs, 1998).

By the 19th century the development of large breweries led to the industrialization of malting and an increase in the size of production units. Pneumatic malting was developed and reached commercial success in the late 1800s. Two Belgian malting engineers; Galland and Saladin are considered to be the fathers of the modern malting equipment. Galland introduced the first aerated rectangular boxes in 1873 and Saladin introduced turning machines in 1880s. Saladin boxes are in common use today (Briggs, 1998).

With the expansion of trade and the discovery of the New World, making beer from barley malt spread across the globe. Currently, approximately 1,400 million hectolitres of beer are brewed annually around the world (Mallett, 2014).

2.2.2 Change on physical structure

During germination enzymes migrate from the germ and partially break down the endosperm starch granules and protein bodies and matrix (Hough, 1985).

During steeping, the grain swells and increases its volume by about a quarter. Space is allowed in the steep tanks to accommodate the swollen grain. The first microscopic indication of germination after casting is the appearance of the ‘chit’. The white coleorhizae or root – sheath that breaks through the pericarp and testa and produces from the base of the corn. In time seminal roots also called rootlets, culms, cooms, or malt sprouts bursts, through root sheath and form a tough at end of the grain, at the same time the first ‘leaf- seat’ or coleoptiles. Variously called by maltsters the ‘acrospires’, ‘spire’, ‘blade’, penetrates the apex between pericarp and the husk. In conventional malting practice, the malt is kilned and growth terminated before the acrospires grows beyond the end of the grain (Hough, 1985).

Starch appears in small amounts in the embryonic structures after the onset of germination. Coincident with the appearance of this starch the first sign of the breakdown of the starchy endosperm are seen as an enzymes partial dissolution of some cell walls. This process, cytolysis, begins in the compressed layer, adjacent to the scutellum and progressively spreads through the starchy endosperm towards the apex of the grains (Hough, 1985).

As these hydrolytic breakdown processes precede alterations may be detected in protoplasm of cells of the aleuronic layer of columnar cells between the compressed cells endosperm and the scutellum. As germination proceeds, the cells of epithelium tend to separate and elongate so forming a ‘pile’ which projects into the solubilized part of the endosperm. This alteration in similar form greatly increases the surface area of the cells and makes the epithelium a more efficient absorptive organ (Hough, 1985).

Partial dissolution of the cell walls and reduction of starch grains are both characteristics of physical modification of sorghum. ‘Modification’ progresses form the embryo parallel to the scutellum towards the apex of the grain advancing fastest on the dorsal side of the grain beneath the aleuronic layer (Hough, 1985).

The softening of endosperm that occurs during malting is easily and conveniently detected by ‘rubbing out’ the green malt by hand. Chewing grains to see that they are ‘crunchy’ and devoid of hard tips may check the degree of modification of finished malt (Hough, 1985).

Kernel density decreased during malting. Density of malted sorghum correlated with diastatic power and reduction in pasting viscosity (Beta *et al.*, 1995). Physical and biochemical properties such as kernel weight, diastatic properties, malt yield and fermentable sugars are critical in the preliminary evaluation and selection of grain for malting. However, further studies on the optimum modification conditions for the cultivars, friability index of the malts, component fermentable sugars and free amino nitrogen (FAN) need to be undertaken before final certification of the cultivars for malting purposes (Makeri *et al.*, 2013).

2.2.3 Chemical changes during malting

The chemical changes occurring during malting are complex. They can only be understood by appreciating the range of, sometimes conflicting, processes that occur during steeping, germination and kilning, and the effects of deculming and dressing the malt. Polymeric reserve substances, such as starch and proteins, are partly hydrolysed in the endosperm; the low molecular weight degradation products diffuse through the grain. Those reaching the living tissues may be metabolized, together with the reserves of these tissues (e.g. sugars, lipids). The aleurone may release some of its metabolic products. There is a net movement of materials to the embryo where they may be respired, converted into new substances and/or be incorporated into the growing tissues of the acrospire and the rootlets. Thus the synthesis of new, complex molecules (proteins, polysaccharides) in the embryo partly offsets the degradative changes that occur elsewhere in the grain chiefly in the starchy endosperm (Briggs, 1998).

2.2.3.1 Proximate composition

The moisture content increased significantly by 37.13% which is a normal indication of rapid water uptake by a viable grain expected during steeping. This hydration process activated a wide array of enzyme systems which hydrolysed and solubilised food reserves during germination. The moisture content of Sorghum malt was found to be 10.7% for tabat and 10.1% for faterita (Abbas, 2000). Elshewaya (2003) reported lower moisture content values for tabat malt (3.72%) and faterita malt (4.17%). Bolarinwa *et al.* (2015) also reported the very low moisture content of sorghum malt as 6.76%. While Wall and Blessin (1970) obtained the moisture content and crude fiber content of sorghum grain as 12-14% and 2.7-2.9% respectively.

The crude protein showed an initial significant decrease of 28.53% before a later increase of 0.1%. This may be due to the fact that storage nitrogen reserves may have been mobilized during sprouting after hydrolysis by proteolytic enzymes (which digest the macromolecular proteins into the more easily assimilable peptides and amino acids) to play a role in the synthesis of its cellular materials for the rapidly growing roots and shoots during germination. The carbohydrate content of the malted samples decreased significantly by 24.33%. This significant decrease could be attributed to metabolism (Ogbonna *et al.*, 2012). The carbohydrates may have been digested into simple sugars by amylolytic enzymes which are rapidly taken up by the growing embryo to serve as its energy source during germination (Elkhier and Hamid, 2008). The reducing sugar increase with increase in time and relative humidity. It may be due to favorable condition established for the breakdown of starch at high relative humidity. As the time increase more starch will breakdown due to exposure of starch to amylase for long time (Tejinder, 2007). The total ash content of the malted samples decreased significantly by 34.38% from that of the control. This may be due to the incorporation of mineral elements into cell constituents during the germination process (Ogbonna *et al.*, 2012).

Mineral ions play vital roles in metabolism as enzyme stabilizers and transport cofactors. The crude fibre content of the malted samples increased significantly by 72.5% during the malting period compared to the control (Ogbonna *et al.*, 2012). Crude fibre consists mainly of cellulose, lignin and hemicellulose (Eggum *et al.*, 1981). This increase could be attributed to increased bran matter and the building of dry matter during the growth and development (germination) of the plant. A highly significant increase of 111.82% in the crude fat levels of the malted samples was observed at first and later decreased significantly by 22.75%. This suggests that there was a change in the crude fat content during the malting stage which may be due to its proportional increase as a result of decrease in the other food reserves like carbohydrates (Ogbonna *et al.*, 2012). Lipase activity increased during germination and the proportion of lipid bodies during germination will decrease due to the synthesis of lipase (Narsih *et al.*, 2012).

2.3 Composite bread

Composite bread is a baked product, the primary ingredients of which are composite flour, yeast, salt and water. As discussed earlier, technically composite bread may be different from the whole wheat flour bread in having composite flour, instead of wheat flour alone and other ingredients remaining same. Composite flours are the mixture of flours from tubers rich in starch (e.g., cassava, yam, sweet potato) and/or protein-rich flours (e.g. soy, peanut) and/or cereals (e.g., maize, rice, millet, buckwheat), with or without wheat flour (Popper *et al.*, 2006). The use of composite flours with or without wheat gives rise to technical problems in the production of baked goods, particularly composite bread. From the baker's point of view the most important component of wheat flour is the protein of the gluten that plays a decisive role in dough formation, gas retention and the structure of the crumb. So, in order to produce bread with its characteristic structure and firmness, wheat containing gluten cannot be completely eliminated from bread.

According to Kent and Evers (2004), wheat flour can be substituted up to 30% with non-gluten millet flour in preparation of bread. The percentage of non-gluten millet flour that can substitute wheat flour also depends upon the strength of the wheat flour. The substitution can be increased further in case of other baked but unleavened goods like biscuits, cookies, pastry, pasta, etc. Bread has been man's food for at least 6000 years. The purpose of bread making is to present the cereal flours to the consumer in an attractive, palatable and digestive form (Chamberlain, 1975; Herringshaw, 1969). It was probably the first processed food ever produced and remains the most widely acceptable. Bread is one of the few universal staples which is complete in it and requires no additional preparation. Though it is not perfect nutritional source of protein, it is however, a principal source of both calories and protein for a lot of people because of unique structural properties of hydrated wheat protein.

2.3.1 Developments in Composite Flour Program

The Composite Flour Program was established by the Food and Agriculture Organization in 1964 to find new ways of using flours other than wheat, particularly maize, millet and sorghum, in bakery and pasta products, with the objective of stimulating local agricultural production, and saving foreign exchange, in those countries heavily dependent on wheat 21 imports (Kent and

Evers, 2004). Since, then several researches work and trails have already proven the success of composite baked products. The ingredients used in composite flours must take account of the raw materials available in the country concerned. The objective is to save as much expensive imported wheat as possible when making bakery products. In the late 1960s, tests were carried out in Brazil in which 75% wheat flour was mixed with the relevant amounts of potato, maize or cassava flour. The baking tests were conducted on the basis of the Chorleywood bread process. The same flours were used as raw materials for biscuits, but the proportion of wheat flour was reduced to 50%. Most of the trails with composite flours have been carried out in Africa because of its continually growing population. Reports are available from Senegal, Niger and Sudan (Berghofer, 2000).

In the bread sector the task here was to produce typical French bread with composite flour. The proportion of wheat flour in the different mixtures varied greatly, the maximum being 70%. Europe and North America produce sufficient quantities of bread cereals, so theoretically they have no need to market and use composite flours at all. But constantly widening ranges of bread and small baked goods and the emergence of certain types of bread as "functional food" have led to an interest in mixtures of wheat flour with other agricultural raw materials. Composite flours are an ideal partner in programs to combat celiac disease (Kader, 2000; Kim and de Ruiter, 1969). In Asia, traditionally, rice and tapioca have been cultivated as carbohydrate sources. Flour from tapioca (tapioca starch) is used to replace wheat flour in some applications, mainly in pastry (Popper *et al.*, 2006).

2.3.2 Composite flour program in Nepal

Local initiatives for Biodiversity, Research and Development (LI-BIRD) in collaboration with Nepal Agriculture Research Council (NARC) carried out research and development work for 3 years (2002-2004) in finger millet with similar objectives in Kaski and Nuwakot districts of Nepal. The various public awareness activities conducted by the project on nutritional importance of finger millet through FM radio, print materials, food fairs and festivals, workshops, school programs raised awareness among consumers and producers. This resulted increase demand in millet products by conscious groups (intellectuals, diabetics, young generation and foreigners) in Pokhara. According to entrepreneurs, departmental stores and many shops requested for supplying millet bread, cookies and *namkin* to sale in Pokhara. Several research works related to composite flour have been carried out at Central Campus of Technology, Dharan. Composite breads and biscuits incorporated with soya flour, millet, buckwheat, cassava, rapeseed, etc., have already been tested and several other similar works are in progress.

2.4 History of bread making in Nepal

Before 2007 BS (1950 AD), production of bread loaf was started by Rana's family. For several years, bread for public was produced in small bakeries. The dough was made by hand and baked in small wood charcoal heated bhatties. Bread is made in this manner still in parts of Nepal. Upgrading this traditional method of bread making means using dough mixer and several accessory machineries added in the unit. The ovens in many places are fired by wood. In Kathmandu and some other big towns, several big scale bakeries with electrical ovens and big scale machinery have come into operation. The quality of breads produced by these bakeries is very standard and can be compared with developed countries. Most of the big hotels in Kathmandu and Pokhara are having their own bakeries and showrooms (Khanal, 1997).

The first professional bread industry in Nepal was Krishna Pauroti Bhandar, located in Kathmandu is professionally still famous in Kathmandu valley. Many professional bakers are not intended to improve the quality of bread. The concerned department should give 11 simple, hygienic and economic technologies to the bakers so that bakery industry can flourish. Bread produced by such technology will be of better quality and cheap to consumer (Khanal, 1997).

2.5 Modern bread making process

The main object of the bread making is to present cereal flours in an attractive palatable and digestible form the actual baking process is really the last and most important steps in the production of baking products. At its simplest this is achieved by baking portions of kneaded mixtures of crushed grains and water, usually with salt added to enhance flavor and wheat are still consumed in this form in many communities. Bread is fundamentally foamed gluten. It was in 1962 that two research workers C.O. Swanson and E.B. working of the Kansas state agricultural college designed a laboratory mixer, which combined a pack squeeze pull tear action and demonstrated that intense mechanical working of dough modified its structure in such a way that bulk fermentation could be omitted without loss of bread quality (William, 1975).

In 1950, the British baking industrial research association laboratory in Chorleywood led by Dr. Chamberlin researched in to the basic chemicals and physical principals of mechanical dough development. Further discoveries followed which designed other conditions which had to be fulfilled for the production of good quality bread and eventually these are collected together in to a set of rules and published in 1961 under the name of Chorley wood Bread Process (CBP) (Chamberlain, 1975). At the same time, mechanical development was being quantified in Britain as the CBP, the second alternative to bulk fermentation as means of developing dough made its appearance, in the USA as chemical dough development although initially it was introduced by Hemika and Zenner as instant dough development process and made use of a balanced blend of reducing and oxidizing agents added as dough ingredients. This method later developed as a chemical dough development process. The principal of chemical dough development was further explored in Britain (Chamberlain, 1975) and modification made to suit local circumstance the Chorley Wood workers christened the process.

2.6 Method of dough making process

The protein in wheat flour has the special property that when hydrated with water and mixed in to dough, they form a 3-dimensional viscoelastic matrix known as gluten. This matrix surrounds the small air cells which expand and form the basic characteristic of the loaf contributing to the overall texture and structure. Similarly they lose their organized granular characteristics during baking (Priestley, 1979). When the basic ingredients ae mixed together the intermediate resultant coherent mixture is in elastic, and the desired elastic and gas retaining properties are obtained by the process of dough development (William, 1975). There are several procedures for achievements of this effect and consequently bread making procedures have been developed on the basic of dough development technique. Basically, there are three making process. Firstly, the fermentation system which is the traditional method of bread making, secondly the mechanical dough development (MDD) system which is generally known as Chorleywood bread making process (CBP) and thirdly a chemical system called activated dough development system (ADD).

2.6.1 Traditional straight-dough process

This process involves mixing of flour, yeast, salt and water, plus any other desired ingredients, in bulk for up to 20 min. The dough in the bowl is put to one side, covered and allowed to ferment for three hours at 27ºC. Thereafter, the dough is mechanically divided and molded into ball-type shapes of the desired weight, which are allowed to stand for 15 to 20 min. This is known as the first proof. The process continues with remolding into the final shaped dough piece, which is placed on a baking sheet or in a baking tin. The final proof continues for 45 min to one hour in a proofer (or "prove"), which has humidity controlled at up to 48ºC. The dough is then baked for up to 30 min at 225ºC in a travelling oven. The total time of process, from flour mixing to the oven outlet, is about 5h.

The bread is cooled and then sliced and wrapped if required. Cooling on a large scale is carried out industrially over times ranging from one hour to two hours, 30 min or more in a large ambient air cooler, sometimes air conditioned. The interior crumb temperature is reduced ideally to 27ºC or less to optimize slicing performance. Variants include the sponge-and-dough process, which extends the processing time by two hours or more. In this method, fermentation is split into two stages: sponge and dough. The sponge stage mixes part of the flour and water and often all of the yeast; the dough stage contains the remaining ingredients. This process, which demands strong flour, was popular in the United States, Canada and Scotland during the 1950s and 1960s.

2.7 Raw materials for bread making

Four basic ingredients are required for the manufacture of bread, namely, wheat flour, yeast, salt and water. If anyone of these four is omitted, bread as we know it cannot be made. Two other ingredients are often added, fat to improve softness and keeping quality and sugar in many areas to increase sweetness. Nowadays, whole range of additives is employed for various reasons, for example to improve fermentation, keeping properties, moisture retention, volume, crumb structure and to prevent mould growth (Flynn and James, 1981). Eggs, milk and milk products are also used in bread according to their varieties. Eggs are excellent improver and they improve the handing properties by stabilizing the dough, so that the result of increased volume and boldness are obtained (Bennion, 1967).

2.7.1 Wheat flour

For normal bread making, flour from grist containing a large proportion of strong wheat is required. Good bread making flour is characterized by having protein which is in quantity and of satisfactory quality in respect of elasticity, strength and stability, satisfactory gassing properties and amylase activity, satisfactory moisture content not higher than about 14% to permit safe storage and satisfactory color. Starch is a major component of wheat flour (69%) which is composed of amylase and amylopectin. It is the main factor imparting softness in crumb. Some of the starch granules in flour become damaged during the milling process. It is believed that flour amylases are able to attack only the damaged or available starch to supply sugar during fermentation. Excessive starch damage however, has an adverse effect on the quality of bread, loaf volume is decreased and the bread is less attractive in appearance (Bennion, 1967; Kent, 1983). Flour contains small but important amounts of various sugars such as sucrose, maltose and dextrose without which in the presence of yeast there could be no fermentation. The bread making quality of freshly milled flour tends to improve during storage for a period of 1-2 months (Kent (1983).

2.7.2 Yeast

Yeast or *Saccharoromyces cerevisiae* is group of minute fungi capable of fermenting a sugar solution producing carbon dioxide and alcohol. Baker's yeast is a different strain and it must be fresh and active. The quantity used is related inversely to the time of fermentation and to the temperature of the dough (Bennion, 1967; Kent, 1983). Yeast action in fermentation has three main functions according to Bennion (1967).

1. To produce carbon dioxide, in sufficient quantities and at the right time to inflate the dough and produce a light spongy texture which will result in palatable bread when correctly baked.

2. To produce a complex mixture of chemical compounds of many types, which contribute to the flavor of the bread.

3. To help bring about the essential changes in the gluten structure known ripening or maturing of the dough.

The activity of yeast depends upon its enzymes, coenzymes and activator contents. There is little or no growth during the first 2 h after the yeast is added to the dough, but some growth in 2 to 4 h, if that time is allowed before baking and then a decline in growth in 4 to 6 h. Fermentation by the yeast begins as soon as the dough is mixed and continues until the temperature of the oven inactivates the yeast enzymes (Frazier and Westhoff, 2005).

2.7.3 Salt

Functions of salt in bread making are (Bennion, 1967).

1. Primarily to give flavor to the bread.
2. To confer bloom or wholesome appearance on the finished loaf.
3. To tighten up and give stability to the gluten of the flour and enable a bold loaf to be produced with firm cutting crumb.
4. To prevent yeast working too fast in process dough and to control the action of acid producing bacteria in dough.
5. To help to keep the loaf moist after with drawl from the oven.

Salt is largely responsible for crust color in bread made from normal flour because of its controlling influence on fermentation. If the speed of fermentation is retarded by the use of increased amount of salt there will be less sugar used by the yeast to produce gas. In consequence, there will be more sugar caramelized on the crust producing a high crust color. If there is too little salt used, the opposite happens and there is little crust color (Fance, 1972).

2.7.4 Water

Water is an essential part of bread formulation and helps in the following manner.

1. The most important function of water is the formation of bread gluten from flour which makes the dough flexible.

2. Helps in controlling the viscosity or toughness of dough.
3. Helps in making the starch digestible.
4. Helps in controlling the temperature of dough and also contributes towards proper mixing of minor ingredients in flour.
5. Helps in the fermentation process.

The water to be used in for bread formulation should be fresh, clean, soft water and free from any microorganism and limited mineral content. Dissolved mineral and organic matter present in the water can affect the flavor, color and physical attributes of the finished baked goods (Arora, 1980). Dough should have a pH value of 5-6, that is acidic. If sufficient alkaline water were mixed in dough so as to give an alkaline condition, the activities of the yeast, diastase and lactic acid bacteria would be restrained so that the production of gas and acidity would be slow and the time necessary for ripening the dough greatly increased.

When flour is mixed with water at dough making both the gluten and starch absorb water within the range of dough temperature which may be stated as 21-32°C. There is no doubt that proteins of the flour take up the water much more readily then the starch. Determination of the moisture percentage in a piece of wet gluten washed out at 21°C from an average flour show that the dry gluten holds nearly twice its own weight of water, whereas somewhat similar experiments with starch would indicate that at the same temperature the dry starch does not hold more than 40% of its own weight of water (Bennion, 1967). Njintang *et al.* (2008) and Olaoye *et al.* (2006) found that the moisture content of the composite breads increased with the increase in the non-wheat flour substitution. And this was attributed to the greater water holding capacity of the non-wheat flour substitution (Tekle, 2009).

The flour from strong wheat (with higher protein content) and flour from hard wheat (with a higher damaged starch grain) require more water than is needed by flour from weak (lower protein) or soft (less damaged starch) wheat to make a dough of standard consistency (Kent, 1983).

2.7.5 Sugar

Although sugar is not an essential ingredient of the bread formulation, yet it is added to improve the texture, taste and flavor of the bread. In very small and cottage scale unit it is added as crystallized sugar while mechanized units incorporate it as corn syrups, sucrose or invert syrup (Arora, 1980). Ordinary cane sugar is used not so much to increase gas production as to improve the color and bloom of the loaf, for there is naturally present in a normal flour sufficient sugar for gas production. Cane sugar can be used at the rate 1 lb per sac to supplement any deficiency in the natural product as in those flours obtained from some of the white wheat. With dough lying for a long period especially in overnight dough added sugar may prove a danger, for it is readily broken down by lactic acid bacteria, thus increasing the acidity. Too much sucrose however will slow down fermentation. If very sweet dough is prepared adding 10% or more of sucrose at once, the growth of the yeast and the formation of carbon dioxide may be slow (Meyer, 1987).

Glucose can also be used. This will be fermented by the yeast directly; it can used in quantities up to 1½ lb per sac to improve the bloom and color of the bread. Invert sugar at the rate of 3 lb per sac is a very effective bread improver, bringing about the physical modification of the gluten so that well-conditioned dough is produced and bread with a more mature moist crumb and good crust color results (Bennion, 1967).

2.7.6 Fat

Shortenings are used in bread for increased calorific value longer preservation period, better finish and taste and to improve its gas retaining characteristics. Generally, hydrogenated oils are used. Research over many years has shown that fats are better improvers than vegetable oils. Fats have power of preventing the toughness of gluten, according to the methods and amount used. All fats are therefore shortening agents. Fats confer flavor according to the type used (Arora, 1980; Bennion, 1967; Fance, 1972).

2.7.7 Milk and milk products

The advantages derived from the use of milk products are as follows.

1. They confer a delicate flavor on the crumb of the loaf.

2. They improve the bloom and color of the bread.
3. They assist in the production of a thin, biscuit like crust.
4. They improve the texture and sheen of the crumb.
5. Skimmed milk powder enables the flour to take up slightly more water and the softer dough obtained can be worked more easily.
6. They increase the mineral content of the loaf and hence its value as a food especially for children.

When any type milk product is used other than fresh whole milk, it should always be used in conjunction with fat generally in the proportion half the weight. Skim milk powder (SMP) alone will always tend to produce drier eating bread due to influence of the casein. The milk sugar is not fermentable by yeast so that milk is essentially an enriching agent and improver. When higher proportion of milk are used, attention must be paid to baking temperature because of the amount of sugar in dough which readily caramelizes and can cause excessive crust color (Bennion, 1967). The addition of milk to the dough raises the pH because of the presence of butter salts in the milk. Milk consequently retards amylase activity. However, in presence of acid salts such as calcium hydrogen phosphate or the acetic acid of vinegar this retardation may be eliminated and gas formation may even be increased by the milk through the improved nutrition of yeast. Raw or pasteurized milk decreases the baking qualities of flour unless the milk is first heated. It is believed that milk contains some substance which increase the activity of proteolytic enzyme and consequently during fermentation period faster the formation of gluten which is too sticky (Meyer, 1987).

2.7.8 Malt products

Malt products are available to the baker in three forms malt flour, malt extract (which is thick, viscous and amber colored syrup) and dehydrated malt extracts which in the dry crystal form . Some patents flours are low in amylase activity and this is rectified by the addition of malted wheat flour or malted barley flour with the diastatic value of the malt extract and malt extract greater proportion than the dried product (Meyer, 1987). Malt flour is manufactured by passing the malted grain through fluted rollers, similar to the break rollers used in the milling of wheat.

It is then sieved to remove the coarse particles. Malt being very dry and brittle the outer coating breaks up into fine particles so that the resultant flour is reddish brown in color (Fance, 1972).

2.7.9 Malt extract

The malt is disintegrated and mixed with an equal volume of water and macerated for 6 hours. Four times the amount of water is then added and the mixture is digested for 1 hour at a room temperature not exceeding 54.44°C so that the maximum conversion of starch to sugar is obtained. The sweet liquors are separated and transferred to vacuum pans where concentration is carried out at such a temperature that the diastase is not destroyed when the correct consistency is obtained the syrup is transferred to drum. Ordinary malt extract may be converted into a dry crystalline powder by removing the remaining water in travelling band vacuum oven (Bennion, 1967).

2.7.10 Custard powder

Making of custard powder requires edible starch, corn flour, food colors and flavors. The cook combines several tablespoons of the custard powder with sugar and enough milk to form a paste. The paste is then slowly added to hot milk and stirred until completely dissolved. The result is a thick custard sauce, not identical to traditional egg custard, but still good over bread, cake, pudding or other desserts. The addition of custard makes the bread pudding luscious and creamy in texture. Old fashioned custard bread puddings are the ultimate in comfort foods.

2.7.11 Other improvers

Soya flour, lecithin, eggs, gelatinized starch or scalded flour are generally used as improvers (Bennion, 1967). A rapid acting reducing agent, L-cysteine and a slow acting oxidizing agent potassium bromate or a mixture of potassium bromate and ascorbic acid are added at the dough mixing stage using convectional slow speed mixing equipment. The reducing agent accelerates the uncoiling and reorientation of the protein molecules and the oxidizing agent follows up by stimulating the formation of cross links stabilize the desired elastic three dimensional gluten network (Kent, 1983).

Rao and Rao (1993) studied on the effect of potassium bromate or ascorbic acid on rheological characteristics and bread making quality of commercial wheat flours. Ascorbic acid brought about greater changes in the baking qualities as compared to the potassium bromate. Soft wheat flour responded more than medium or hard wheat flours to improvers. The effect of potassium bromate on rheological characteristics was more pronounced, when the pH of the dough was lowered to less than 5.0, potassium bromate and ascorbic acid brought about greater improvement in the milk bread as compared to other varieties such as plain sugar and fruit bread (Khanal, 1997).

2.8 Bread making process

There are three stages in the manufacture of bread, mixing and development of the dough, aeration of the dough and oven baking of the dough (Kent, 1983).

2.8.1 Dough mixing

Main ingredients of bread are wheat flour, water, yeast and salt. Other ingredients may be malt flour, soya flour, yeast food, milk and milk products, fats, fruits and gluten. When these ingredients are mixed in correct proportions, the following phenomena take place.

1. The proteins in the flour begins to hydrate i.e., to combine with some of the water to form a cohesive material called gluten which has peculiar extensible properties, it can be stretched like elastic and possess a certain degree of recoil or spring. The elastic properties which are developed during mixing appear to involve sulfhydryl groups possibly their oxidation to disulphide bonds, possibly the formation of new bonds.

2. Evolution of the carbon dioxide gas by action of the enzymes produced by the yeast upon the sugars. These are mixed using water at temperature that will bring the mixture to about 27°C (80°F). The yeast is dispersed in some of the water and the salt dissolved in another portion, yeast suspension, the salt solution and the rest of the water are then blended with the flour. Thorough mixing and correct dough development demand correct absorption of water to produce ideal clear dough. Such dough will produce a loaf with qualities superior to any loaf made from dough which is badly mixed. Dough processed correctly gives even texture and uniform, soft and moist crumb (Bennion, 1967; Kent, 1983).

2.8.2 Dough fermentation

Enzymes for panary fermentation are diastase (α and β amylase) in flour, maltase, invertase and the zymase complex in the yeast. Starch in the flour is broken down into maltose by amylase enzymes. Maltose is splitted to glucose by maltase. Cane sugar added is splitted to glucose and fructose by invertase enzyme and these products are converted into carbon dioxide and alcohol by zymase complex. Most of alcohol thus produced is driven off during the baking process. Secondary product e.g., acids, carbonyls and esters may affect the gluten or import flavor to the bread (Kent, 1983). During the fermentation, conditioning of the dough takes place when the flour proteins (gluten) mature i.e., become elastic and springy and therefore capable of retaining a maximum amount of carbon dioxide gas produced by the yeasts. The conditioning results from action on the gluten by (1) proteolytic enzymes from the yeast, from the malt or added otherwise and (2) the reduction in pH by acids added and formed (Frazier and Westhoff, 2005). Adequate gas should be produced during fermentation process; otherwise the loaf will not be inflated sufficiently. Gas production depends upon quantity of soluble sugar present in flour, its diastatic power and granulation (Kent, 1983).

2.8.3 Knock back

As the fermentation is going on, volume of fermenting dough increases continuously. As the dough rises, the interior contains intimate cell like structure in the form of very network. Each cell is filled with carbon dioxide, knocking the dough removes carbon dioxide and develops gluten, rendering it more elastic and capable of producing a better and more even textured loaf, knock back should be carried out at the early stages of fermentation, otherwise, it has little effect on the desired texture of finished product (Bennion, 1967).

2.8.4 Dividing

The next step in bread making is the division of the dough into the sizes required for the finished bread, either by hand or machine. Hand division is coupled with weighing of each piece. Machine division is by volume and results in greater accuracy and hence uniformity in size of product. The pieces of divided by unshaped dough are next rolled into a ball. This has two fold objectives. Firstly, it expels the spent gas which has accumulated during the fermentation stage and secondly it allows a regular shaped piece of dough to be presented to the final shaper or molding machine (Flynn and James, 1981).

2.8.5 Proofing

The ball of dough is given an intermediate proofing, a resting period of about ten minutes before final shaping to allow it to recover its extensibility and elasticity. The ball of dough is then shaped as required. After shaping, there is final proofing period which is again a continuation of fermentation, allowing the shaped dough piece to double its size prior to baking. This period lasts from 45 min to 60 min (Flynn and James, 1981).

2.8.6 Baking of dough

When the dough is in fully expanded state (called "full proof") baking is started. Once the loaf is in oven, physical, chemical and biological changes become rapid (Fance, 1972). As the temperature of loaf rises in oven, baking the yeast works faster and produces large quantities of gases. This condition in oven is termed as oven spring. After attaining of temperature 42.22°C, the yeast cells are inactivated and they are killed when loaf center reaches 54.44°C. Gelatinization of starch and its degradation takes place as temperature rises gradually to 76.67°C. Diastase enzyme becomes inactivated after the temperature 170ºF has reached. At a temperature of 50°C the process of denaturation and coagulation of protein starts and proceed rapidly up to 80°C. Steam and alcohol escapes from the center of the loaf, while its surface loses a large proportion of its moisture and the crust begins to form. As baking proceeds, evaporation of water takes place and at 110-120°C, and yellow dextrins are produced and these change into brown dextrins and caramel to form the red brown color at 160°F. The dark brown color is produced at temperature beyond 200°C. It is also interesting to note that yeast activity ceases after 20 min and diastatic activity after 26-30 min according to temperature of the oven (Bennion, 1967). Humidity of the oven is also of importance for the expansion of loaf to good shape. If the humidity is too great, the bread has tough leathery crust and an excessive shine which is unattractive. Insufficient humidity in oven causes rapid evaporation of moisture from skin of the loaf.

2.8.7 Bread cooling

After taking out bread loaves from oven it should be cooled rapidly so that it can be packed for distribution. During cooling moisture moves from interior outward towards the crust and to atmosphere, if the moisture content of the crust rises considerably during cooling, the texture of the crust becomes leathery and tough and attractive crispness of freshly baked bread is lost. Excessive drying during cooling results in weight loss and poor crumb characteristics. The aim of cooling is to lower the temperature without much loss of moisture. Bread loaf can be cooled by counter flow of air at 21.11°C and 80% relative humidity within 2-3 h. If bread is packed before cooling, steam coming from loaf condensates on the crust surface called sweating (Fance, 1972; Kent, 1983).

2.9 The technology involved in dough formation

Wheat gluten consists mainly of the storage protein of wheat endosperm, i.e., gliadin and glutenin. Upon hydration and during processing, gliadin and glutenin interact to a unique viscoelastic glutein network, envisaged as being necessary for holding the gases and for producing light porous crumb textured bread. Recent work has confirmed that the elastic properties of gluten are due to the glutenin fraction, whilst the viscous properties come from the gliadin fraction. An appropriate balance in the amount of these two major protein components of wheat gluten is required for achieving the desired bread quality (Khatkar and Schofield, 1997). The glutenin polypeptides are joined head-to-tail via S-S (disulphide) bonds in a linear chain. The glutenin polymerise into a linear chain by intermolecular S-S bonds between the cysteine residues located in the α-helical regions near N- and C terminal ends of high molecular glutenin subunits. The central domain is thought to be rich in repetitive β-turns which form stable β-spiral structure. Under stress conditions, the β- spiral structures undergo deformation and on release of stress, the β-spirals resume the energetically more favorable original conformation. The presence of cysteine residues at either end of glutenin molecules allows deformation/reformation to occur in the central spiral region (Schofield and Booth, 1983; Shewry *et al.*, 1992).

Wheat proteins favor hydrophobic interactions due to their low solubility; on the other hand, soy proteins are more water soluble and they exhibit hydrophilic characteristics in a soy-wheat composite dough system. An initial step towards improving the dough and baking quality of soy-wheat composites has been reported; it involves the use of a heat treatment that increases the size distribution of the soy protein and its hydrophobicity, thereby increasing the contribution to the ‘‘unextractable polymeric protein’’ (UPP) of the soy in the composite dough. A higher % UPP is reported to contribute to dough strength in wheat dough (Maforimbo *et al.*, 2008).

2.10 Factors affecting the bread quality

Good bread is made from good ingredient. Therefore, the selection of raw materials in making of bread is very important to do to achieve expected quality of the final product. Some of the factors that affect the quality of bread are as follows:

2.10.1 Flour

The main ingredient in making of bread is flour. The most suitable flour in making of good bread is the flour. The most suitable flour in making of good bread is the flour that has high protein content (> 12.5%). Eighty-five percent of proteins in the flour are glutenin and gliadin, and the rest are globulin, albumin and protease. When flour is mixed with water, it will make a gluten form which has a cohesive and extensive characteristic. This gluten will have an influence in holding the forming of carbon dioxide gas in the dough during the fermentation by yeast (Zr, 2010). Summer and M.A. (1976) concluded that the incorporation of more than 10% sorghum flour in bread formulation darkened the internal and external loaf color of the bread. (Munak, 1995). The corneous endosperm of sorghum adversely affects the breads crumb and crust texture (Munak, 1995). Non wheat flour in bread increases color darkness in baked product (Banks *et al.*, 1997). Perten (1977) reported that high levels of malted sorghum flour substation in wheat flour are detrimental to bread characteristics and loaf volume. Abdelghafor *et al.*, (2010) reported similar results for taste of bread from composite flour of sorghum and hard white winter wheat.

2.10.2 Water

Water when mixed with flour will form gluten base. Besides that, the function of water is to be a dissolve agent and distributes the other materials in dough to be well blended and also controlling the structure of dough (Zr, 2010). loaf weight is directly proportional to absorption of water as revealed by Rao and Hemamalini (1991). Incorporating high levels of sorghum flour depresses the loaf volume (Fleming and Sosulski, 1978).

2.10.3 Leavening agent

Leaven is used in bread making to produce carbon dioxide and ethyl alcohol through sugar fermentation. Bread leaven is a kind of yeast (Saccharomyces cerevisiae). Leaven could be classified into two types of yeast. The first is wet yeast which contain 60-70% of water and the second is dry yeast which contain 7-8% of water (Zr, 2010).

2.10.4 Salt

Salt is required in the manufacture of bread to give a taste. It helps controlling the rate of fermentation and strengthens the gluten and improves dough extensibility and the ability of holding the gas. Dough that does not have enough salt will be soft, the rate of fermentation will be too fast, will produce bland bread and also will make a rough texture of bread (Zr, 2010).

2.10.5 Sugar

There are several types of sugar that can be used, which are sucrose, dextrose, fructose, and maltose. Each has a different degree of sweetness. Sugar in bread making is used as a food for yeast. The remaining sugar after being used by yeast is to provide sweetness and an influence factor in the process of caramelization during roasting and also contribute in the forming of brown color in the bread (Zr, 2010).

2.10.6 Fat

The use of fat in bread making will give an influence in gluten lubrication, increasing the volume of the dough and in an easy way during cutting. Fat in the dough also could increase the extensibility and elasticity of the dough. So the dough becomes more adaptive to the machine and easy to handle. Fats also influence in good flavor and aroma and also help to control water evaporation, so it can maintain the tenderness of bread during storage (Zr, 2010).

2.11 Nutritional value of bread

Bread is one of the complete foods available for human consumption. Most lacking factor in bread is fat which is generally compensated by the addition of butter, margarine. Typical composition of bread is shown in the Table 2.3.

Table 2.3 Typical composition of bread

Constituents	White bread	Whole bread
Water (%)	40	45
Protein (%)	6.5	6.3
Fat (%)	1.0	1.2
Starch, sugar, etc (%)	51.2	44.8
Cellulose (%)	0.3	1.5
Mineral matters (%)	1.0	1.2

Source: Bennion (1967)

Normal bread contains all the amino acids but lysine is deficient in it. Enriched bread e.g., composite bread, egg bread, milk bread, etc., supplement the deficiency (Fance, 1972). The most important vitamins in bread are those of vitamin B_1 and B_2. Vitamin C is absent in bread. Vitamin D exists in two major forms D_2 and D_3. Three main minerals in flour are calcium, phosphorus and iron and in bread sodium is added in the form of sodium chloride.Calcium content of whole meal bread is greater than white bread but is unavailable to the body. All cereals are poor source of calcium so that chalk is added to all white flour by statute (14 oz per sac), whole meal also has more iron content than wheat flour.Again, less of it is absorbed in the body so that iron is added in white flour by statuate (1.65 mg/100 g flour).

Whole meal bread contains 287 mg of phosphorus per 100 g of meal as compared with mg/100 g of white flour. Phosphorus in cereals antagonizes the absorption of calcium from other sources e.g., cheese, milk and fish. Phosphorus in one pound of whole meal bread would blanket the calcium in 9/10 pint of milk so that whole meal bread is eaten; milk consumption must also be raised. In higher extraction flours, some of the phosphorus is contained in phytic acid which combines with calcium and produces phytates which are not utilized by digestive system. Bread provides about 26% of our total calcium and 30% of total intake of iron. Phytic acid is hydrolyzed to phosphoric acid and inositol by the enzyme phytase, optimum activity occurring at 55°C. Probably 60% of the phytic acid in flour is hydrolyzed during bread making (Bennion, 1967; Fance, 1972; Kent, 1983).

2.12 Wheat flour and bread standards in Nepal

According to Nepal Rajpatra Standards (2057 B.S.), wheat flour and white bread should possess the following criteria as shown in Table 2.4.

Table 2.4 Wheat flour and bread standards in Nepal

Parameters	Wheat flour	Bread
Moisture	≤ 14% (130-133ºC/2 h)	-
Total ash	≤ 0.70% (dry wt. basis)	-
Acid insoluble ash (in HCl)	≤0.1% (dry wt. basis)	0.1% [a],≤ 0.2% [b]
Alcoholic acidity [c] (as H_2SO_4)	≤ 0.12% (dry wt. basis)	≤ eq. of 7.5 ml N NaOH/100
Gluten	≥ 8.0% (dry wt. basis)	-
Guar gum	-	≤ 0.5%
Total soluble solids	-	≥ 60%
Improvers (e.g., $CaPO_4$)	-	≤ 0.25%
Anti-mold agent (e.g., Ca-propionate)	-	≤ 0.5%

a= simple bread, b= spice/fruit bread and c= 90% alc

Source: Nepal Rajpatra Standards, (2057) B.S.

Part III

Materials and methods

3.1 Raw material

3.1.1 Wheat flour

Wheat flour in the form of maida was used for bread making. The maida was purchased from local market of Dharan.

3.1.2 Sorghum (Junelo)

A common variety of sorghum were purchased from the local market of Kathmandu.

3.1.3 Butter

Butter (amul butter) was used as shortening agent. It was obtained from Bhatbhateni Super Market of Dharan.

3.1.4 Baker's Yeast

Yeast was obtained from the lab of Central Campus of Technology.

3.1.5 Sugar and salt

Sugar and salt were brought from local market of Dharan.

3.2 Apparatus required

➢ Burette	➢ Soxhlet assembly
➢ Conical flask	➢ Dessicator
➢ Measuring cylinder	➢ Heating arrangement
➢ Beaker	➢ Bunchner filter assembly
➢ Pipette	➢ Suction pump
➢ Cabinet dryer	➢ Crucible

➢ Weighing balance	➢ Whatman filter paper
➢ Hot air oven	➢ Muffle furnace
➢ Silica crucible	➢ Petridish
➢ Kjeldahl digestion and distillation set	➢ Spectrophotometer
➢ Measuring scale	➢ Caliper

3.3 Procedure for malting

The malting procedure was adopted from Ratnavati and Chavan (2016) with slight modification. The steeping period and drying period were increased to obtain the similar condition that was described by Ratnavati and Chavan (2016). The modified process that was adopted is shown in Fig. 3.1.

Sorghum grain

↓

Cleaning

↓

Steeping (24 h at 26ºC)

↓

Germination

↓

Drying/kilning (50ºC for 24 h)

↓

Removal of acrospires

↓

Milling

↓

Malt flour

Fig. 3.1 Flowchart for malting process as (Ratnavati and Chavan, 2016).

3.3.1 Cleaning

Sorghum grain was first winnowed with woven bamboo trays (nanglo). In this step; husk, immature grains and light particles was winnowed away and heavier particles such as specks and stones was separated by gravity during winnowing.

3.3.2 Steeping

Cleaned seeds were transferred to the plastic containers and water was added 3 times that of sorghum. Light materials present in the sample were skimmed off. Agitation was done to clean the seed. The grain was steeped for 24 h at room temperature (28±3ºC) and drained to remove the excess water. Then it was dipped in KMS solution for 10 min to prevent the mold growth.

3.3.3 Germination

The steeped grain was first collected in a muslin cloth and swirled in order to drain excess water. The grains were spread over another muslin cloth and left for germination.

3.3.4 Drying/ Malt kilning

Germinating sorghum were taken and were dried to stop further germination. Drying was carried out in a cabinet drier at 50°C until the constant weight was obtained.

After drying, the rootlets were removed and the prepared malt was packed in airtight containers.

3.4 Method of experiment

Design Expert v 7.1.5 software is used to create the recipe. D-optimal design is used to formulate the recipe. The independent variable for the experiment is the concentration of sorghum flour whereas concentration of fat, sugar, salt and yeast are kept constant.

3.4.1 Formulation of recipe

The recipe formulation for the sorghum flour incorporated bread was carried out as given in Table 3.1.

Table 3.1 Recipe formulation for bread

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Wheat flour (parts)	100	97.48	94.95	92.45	90	85.04	82.52	80
Sorghum flour (parts)	0	2.52	5.04	7.54	10	14.95	17.48	20
Fat (%)	4	4	4	4	4	4	4	4
Sugar (%)	8	8	8	8	8	8	8	8
Yeast (%)	2	2	2	2	2	2	2	2
Salt (%)	1	1	1	1	1	1	1	1
Water (parts)	65	65	65	65	65	65	65	65

The bread was made as per the recipe formulation done and coded name A, B, C, D, E, F, G, and H were given to each recipe. Composite breads were prepared using the straight dough development method as in Fig. 3.2.

3.5 Method of preparation of malted sorghum incorporated bread

The method of preparation of malted sorghum incorporated bread is given in Fig 3.2

Wheat flour + Malted sorghum flour

↓

Addition of water + salt + sugar ← Activation of yeast with little flour and

↓

Dough mixing (20 min)

↓

Fermentation (1/2 -1 h)

↓

Knock-Back

↓

Scaling and dividing by weighing

↓

First proofing (20 min)

↓

Moulding

↓

Panning

↓

Final proofing (1 h)

↓

Baking in oven (225°C for 30 min)

↓

Depanning

↓

Cooling

↓

Slicing and packing

Fig. 3.2 Flowchart for bread making process as (Kent and Evers, 2004).

3.6 Analytical procedure

3.6.1 Physical analysis of raw materials and final product

3.6.1.1 1000 kernel weight

The 1000 kernel weight of raw materials and final products were determined by measuring the weight of 1000 kernels of sorghum grains after selecting the appropriate sample size by quartering method as stated in Buffo *et al.* (1998).

3.6.1.2 Bulk density

The bulk density was measured as mentioned in Clementson *et al.* (2010) by pouring the grains into the funnel-shaped hopper, the hopper was centered over the measuring bushel, the hopper valve was opened quickly, and the grains were allowed to flow freely into the measuring bushel. After the bushel was filled, the excess material was leveled off with gentle zigzag strokes using the standard Seedburo striking stick. The filled measuring bushel was then weighed, and the mass of grains in the bushel was determined by subtracting the mass of the measuring bushel itself. The bulk density (ρ) of grain was then calculated using the following expression:

$$\text{Bulk density} = \frac{\text{Mass of grain}}{\text{Volume of bushel}}$$

3.6.1.3 Particle density

True density of grain was measured by turpentine displacement method as mentioned in Simonyan *et al.* (2007).At first weight is measured and volume was determined by water displacement method.

3.6.1.4 Porosity

Porisity of grain was measured as mentioned in Ndirika and Mohammed (2005).

$$\text{Porosity} = [1 - \text{Bulk density} / \text{Particle density}] \times 100$$

3.6.1.5 Sphericity

Sphericity of grain was determined as mentioned in Simonyan *et al.* (2007).Each kernel sample was measured for its length, breadth and thickness by using grain caliper and sphericity is calculated.

$$\text{Sphericity} = (lbt)^{1/3} / l$$

Where, l = length of grain

b = breadth of grain

t = thickness of grain

3.6.1.6 Volume

Volume of bread was determined by rapeseed displacement method as mentioned in white bread.

3.6.1.7 Specific loaf volume of the bread

Specific loaf volume of bread is defined as the ratio of the volume of bread to the weight of bread. The specific loaf volume of bread was determined as illustrated in Al-Saleh and Brennan (2012).

$$\text{Specific loaf volume} = \frac{\text{volume of bread}}{\text{weight of bread}}$$

3.6.2 Chemical analysis

3.6.2.1 Proximate analysis

3.6.2.1.1 Moisture content

The moisture content was determined by using hot air oven method. 5 g of sample was weighted and heated in an insulated oven at 110°C to constant weight. The difference in weight was the water that has evaporated as Ranganna (1986).

3.6.2.1.2 Crude fat

The fat content was determined by Soxhlet method. Solvent extraction of 10 g sample was done by recycling hot solvent for number of times until complete extraction and fat was recovered by evaporating away the solvent as standard method of Ranganna (1986).

3.6.2.1.3 Crude protein

The crude protein was determined by using Kjeldahl's method. 2 g fatless sample was digested, steam distillated after decomposing the former NaOH. Titration of entrapped NH_3 boric acid was done with standard acid as standard method of Ranganna (1986).

3.6.2.1.4 Crude fiber

Crude fiber was determined by using chemical process, the sample was treated with boiling dilute Sulphuric acid, boiling sodium hydroxide and then with alcohol as standard method of Ranganna (1986).

3.6.2.1.5 Total ash

Ash content was determined using muffle furnaces according to Ranganna (1986). 5 g of weighed sample in silica crucible was charred in hot plate till no smoke raise from it and finally, ashing was done in muffle furnace at 550°C to the constant weight. The difference in weight was the total ash content remaining in crucible, under standardized condition (Ranganna, 1986).

Part IV

Results and discussion

The malting of sorghum was done and malted sorghum incorporated bread was prepared. Physical properties and chemical composition of wheat flour, malted sorghum flour and bread was done.

4.1 Chemical analysis of wheat flour

The proximate composition of wheat flour was determined. The results obtained are presented in Table 4.1

Table 4.1 Composition of wheat flour

Proximate composition in % (db)	Wheat flour
Moisture content (g/100 g)	12.37 (0.15)
Crude protein	10.3 (0.21)
Crude fat	0.94 (0.51)
Crude fiber	0.36 (0.31)
Total ash	0.94 (1.23)
Carbohydrate	74.88 (0.45)
Gluten content	8.1 (0.41)

* The values are the means of triplicate samples and the values in the parenthesis are standard deviation.

The moisture content of wheat flour was 12.37% which is common in commercial wheat flour as previously reported by Kent and Evers (2004).The protein and fat content was found to be 10.3% and 0.94% respectively which was similar to the findings by Kent and Evers (2004).It was found that ash content was found to be 0.94% which is similar to the results obtained by Adhikari *et al.* (2016).The carbohydrate and gluten content was found to be 74.88% and 8.1% respectively as reported by Kent and Evers (2004).

4.2 Chemical analysis of unmalted and malted sorghum flour

The proximate composition of unmalted and malted sorghum flour was determined. The results obtained are presented in Table 4.2

Table 4.2 Composition of unmalted and malted sorghum flour

Proximate composition in % (db)	Unmalted flour	Malted flour
Moisture content (g/100 g)	12.2	5.5
Crude protein (%, db)	11.46[a] ±0.10	10.67[b]±0.05
Crude fat (%, db)	3.66[a]±0.08	3.72[a]±0.07
Crude fiber (%, db)	2.21[a]±0.03	3.20[b]±0.04
Total ash (%, db)	0.55[a]±0.07	0.57[a]±0.05
Carbohydrate (%, db)	80.36[a]±1.08	3.19[b]±0.87
Reducing sugar (%, db)	1.57[a]±0.51	75.86[b]±0.87

*values are the means of triplicate determinations ± S.D

*[ab] means with the different superscripts on the same row are significantly different

The moisture content increased initially during germination. But the moisture content of malted flour is decreased significantly at p ($\leq$0.05) by 54.91% which is due to enzyme inactivation process during malting i.e. kilning. The hydration process during germination activated a wide array of enzyme which hydrolyzed and solubilized food reserves. There crude protein content of the malted flour sample decreased significantly at p ($\leq$0.05). The slight change in protein content may attributed to the fact that water soluble nitrogen was lost during soaking of seeds and also, during seed germination, part of the protein was utilized for the growth and development of the embryo. During germination, starch and protein were degraded to soluble sugars and amino acids, respectively. Their degradations indicated the metabolic system interference to reserve starch and protein by amylases and proteases (Elbaloula *et al.*, 2014). The crude fat content of the malted flour slightly increased which may be due to its proportional increase as a result of decrease in other food reserves like non-reducing carbohydrate.

The crude fiber content of the malted sample increased significantly p ($\leq$0.05).This increased could be attributed to increased bran matter and the building of dry matter during the growth and development (germination) of plant. Narsih *et al.* (2012) reported the increase in ash content of sorghum malt which is similar to the results of our study. Germination would increase the mineral content due to an increase in fitase enzyme activity during germination. The enzyme will hydrolyze the bond between the protein-enzyme minerals become free, therefore increasing the availability of minerals (Narsih *et al.*, 2012).The carbohydrate content was also found to be decreased in malted flour this significant decrease may be due to the activity of enzymes. The carbohydrate may have been digested to simple sugar by amylolytic enzymes as a result there is significant increase of reducing sugar on the malted sample at p ($\leq$0.05).

4.3 Physical properties of sorghum grain and malt

The physical properties of sorghum grain and malt was determined. The results obtained are presented in Table 4.3

Table 4.3 physical properties of sorghum grain and malt

Physical properties	Sorghum grain	Sorghum malt
Sphericity	0.65±0.52	0.75±0.39
1000 kernel wt. (g)	29.89±0.54	25.24±0.58
Bulk density (kg/HL)	81.30±0.59	72.33±0.53
Particle density	1.22±0.64	1.07±0.39
Porosity	0.34±0.63	0.31±0.75

*values are the means of triplicate determinations ± S.D

Ndirika and Mohammed (2005) reported the value of sphericity, 1000 kernel wt., bulk density, particle density (specific gravity), and porosity as 0.67, 32.41 g, 69.9 kg/HL, 1.18 g/cm^3 and 40.80% of sorghum grain (Farafara variety) which is similar to the mean values of unmalted sorghum grain of our study. Similar values were obtained by Simonyan *et al.* (2007) in their study.

The 1000 kernel wt., bulk density, and particle density decreased on malting. Similar result was observed by Beta *et al.* (1995) during malting of different varieties of sorghum grains. This decrease may due to hydrolysis of heavier starch molecules in lighter disaccharides like maltose by high amylase activity. Also decrease in weight may results due to the dry matter loss during malting and utilization of nutrients by growing shoots. This decrease may also be due to respiration of growing shoots during germination Beta *et al.*

(1995). But Makeri *et al.* (2013) reported that there were not significant changes in most of the physical properties of barley grain after malting.

4.4 Physical properties of malted sorghum flour incorporated bread

Physical parameters of bread such as loaf volume, weight and specific loaf volume were affected by the substation increment of the level of malted sorghum flour which is presented in the Table 4.4 The result indicated that the weight of the bread slightly increased with increasing substitution percentage of MSF.20 parts MSF incorporated bread revealed the maximum weight (92.15 g).Increase in loaf weight is due to increased absorption of water as revealed by Rao and Hemamalini (1991).

Also, the results of loaf volume and specific loaf volume of bread revealed a reduction in loaf volume from 211.70 to 184.52 cm^3 and specific loaf volume from 2.91 to 2.00 cm^3/g. It is clear that increased in MSF proportion results decrease in loaf volume and specific loaf volume for different bread which may be due to decrease in gluten network in dough and less ability of dough to rise, due to weaker cell structure (Maforimbo *et al.,* 2008). The physical parameters of bread are presented in Table 4.4

Table 4.4 physical parameters of malted sorghum flour incorporated bread

Samples	Loaf volume (cm^3)	Weight (g)	Specific loaf volume (cm^3/g)
A	211.70±0.34	72.68±0.48	2.91
B	206.62±0.18	75.45±0.67	2.73
C	204.79±0.38	78.67±0.34	2.60
D	203.13±0.45	80.35±0.18	2.52
E	198.38±0.48	83.29±0.38	2.38
F	193.68±0.86	87.23±0.76	2.22
G	188.35±0.64	89.16±0.43	2.11
H	184.52±0.84	92.15±0.68	2.00

4.5 Sensory properties of bread

Statistical analysis of the sensory scores was obtained from 12 semi-trained panelists using 9-point hedonic rating scale (9=like extremely, 1= dislike extremely) for composite bread formulations. Sensory analysis was performed with the aid of different panelists evaluating color, flavor, appearance, mouth feel and overall acceptability of malted sorghum incorporated bread against the blank.

4.5.1 Color

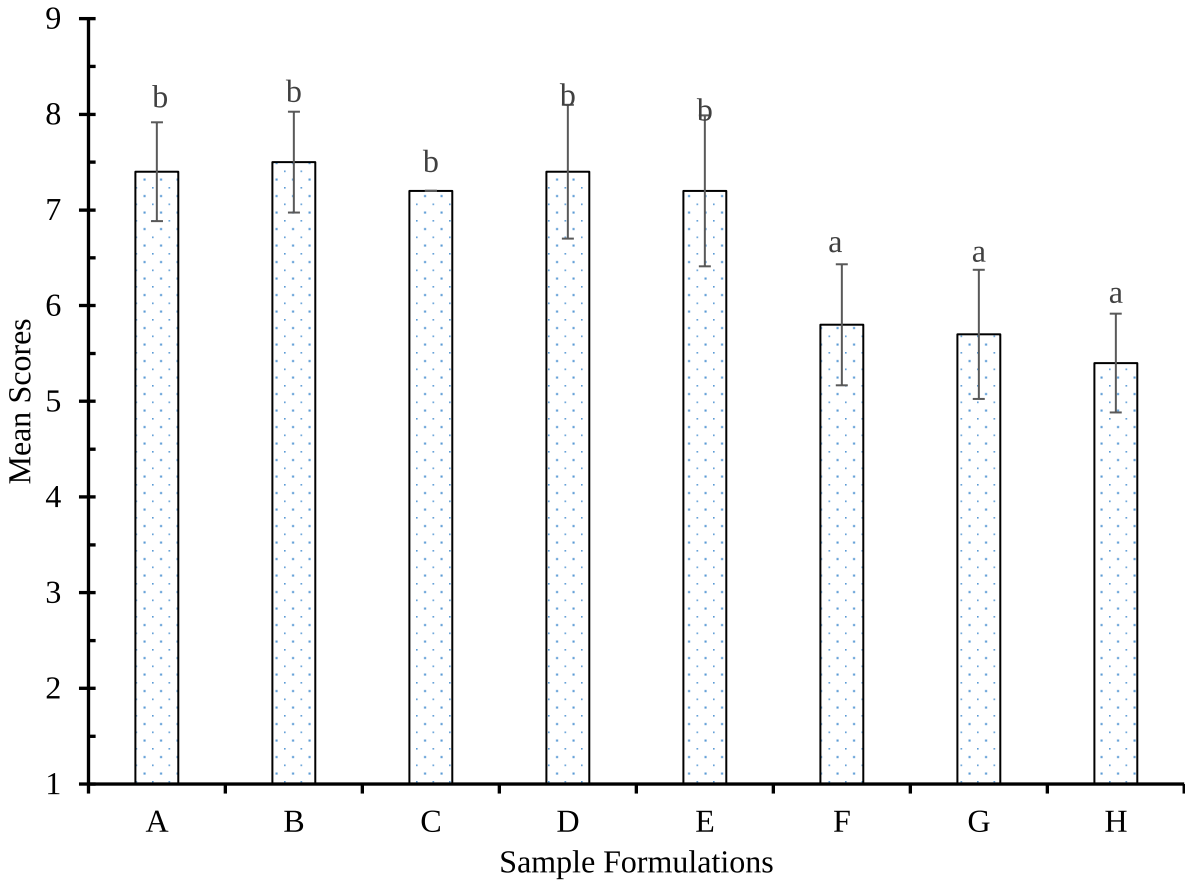

Fig. 4.1 Mean scores for color of bread samples of different formulations (where A is control, B, C, D, E, F, G, and H contains 2.52%, 5.04%, 7.54%, 10%, 14.95%,17.48% and 20 % malted sorghum flour respectively). Means with different subscript are significantly different at p< 0.05.

The average mean scores of colors are shown in Fig 4.4. Statistical analysis showed that partial substitution of wheat flour with malted sorghum flour had significant effect (p< 0.05) on the color. The mean sensory score for color of sample B was 7.50 and was the highest score scored among the different formulations. Samples A (control), C, D, and E were not significantly different to sample B. The lowest mean sensory score was of sample H. It can be also noticed that samples F and G were not significantly different from sample H. The bread with the higher amount of malted sorghum such as samples F, G, and H had low score which could be due to the darker color of sorghum flour as compared to wheat flour.(Summer and M.A., 1976) concluded that the incorporation of more than 10% sorghum flour in bread formulation darkened the internal and external loaf color of the bread. The darker crust color may be because of the greater amount of the milliard reaction between reducing sugars and proteins (Raidi and Klein, 1983). Non wheat flour in bread formulation has been shown to increase color darkness in baked product (Banks *et al.*, 1997).

4.5.2 Texture

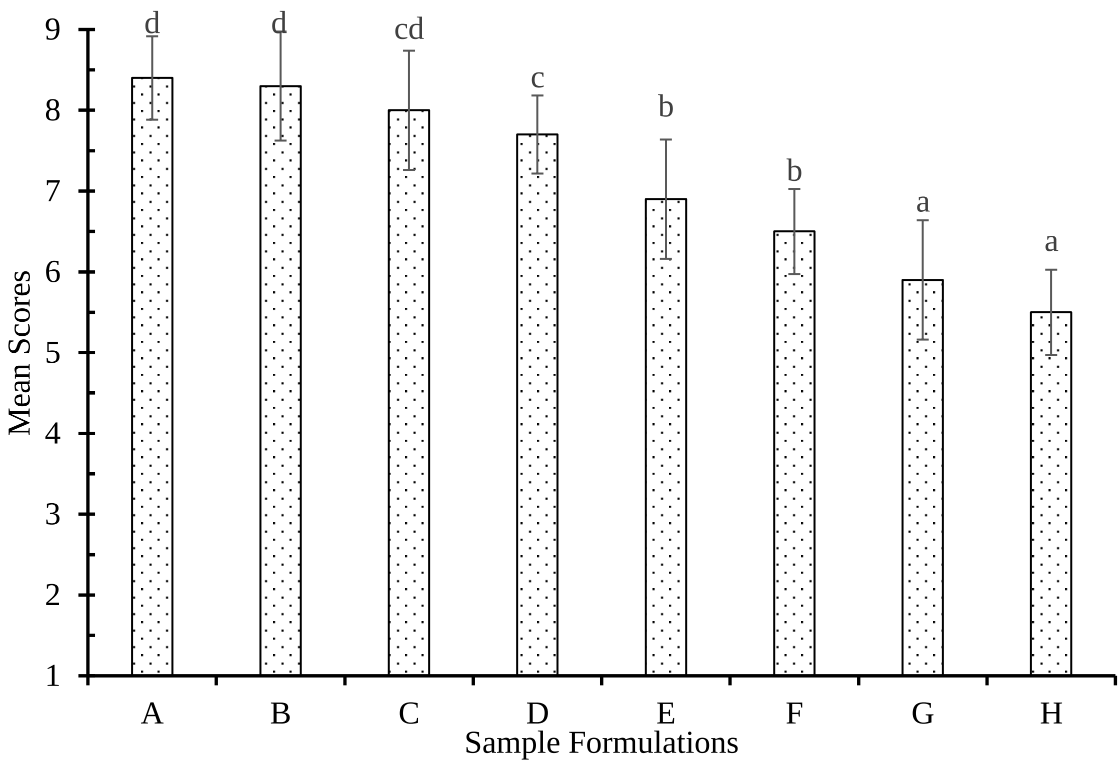

Fig. 4.2 Mean scores for texture of bread samples of different formulations (where A is control, B, C, D, E, F, G, and H contains 2.52%, 5.04%, 7.54%, 10%, 14.95%,17.48% and 20 % malted sorghum flour respectively). Means with different subscript are significantly different at $p < 0.05$.

The mean sensory score for texture of bread samples of different formulations are shown in Fig 4.6. The mean sensory score for texture of sample A (control) was found to be 8.4 which was the highest score of all the bread formulations. Samples B and C were not significantly different from sample A (control). Statistical analysis showed that partial substitution of wheat flour with malted sorghum flour had significant effect ($p < 0.05$) on the texture. Product G and H were not significantly different to each other and scored lowest in texture because sorghum flour tend to give drier and gritty (sandy) texture to sorghum and wheat composite breads (Munak, 1995).It was generally accepted that it was the corneous endosperm of sorghum which adversely affects the breads crumb and crust texture (Munak, 1995).It was reported that since wheat flours contain gluten protein which by suitable development gives the bread its unique and most desired texture; the inclusion of sorghum flour dilutes wheat gluten and consequently weakens its strength.

4.5.3 Taste

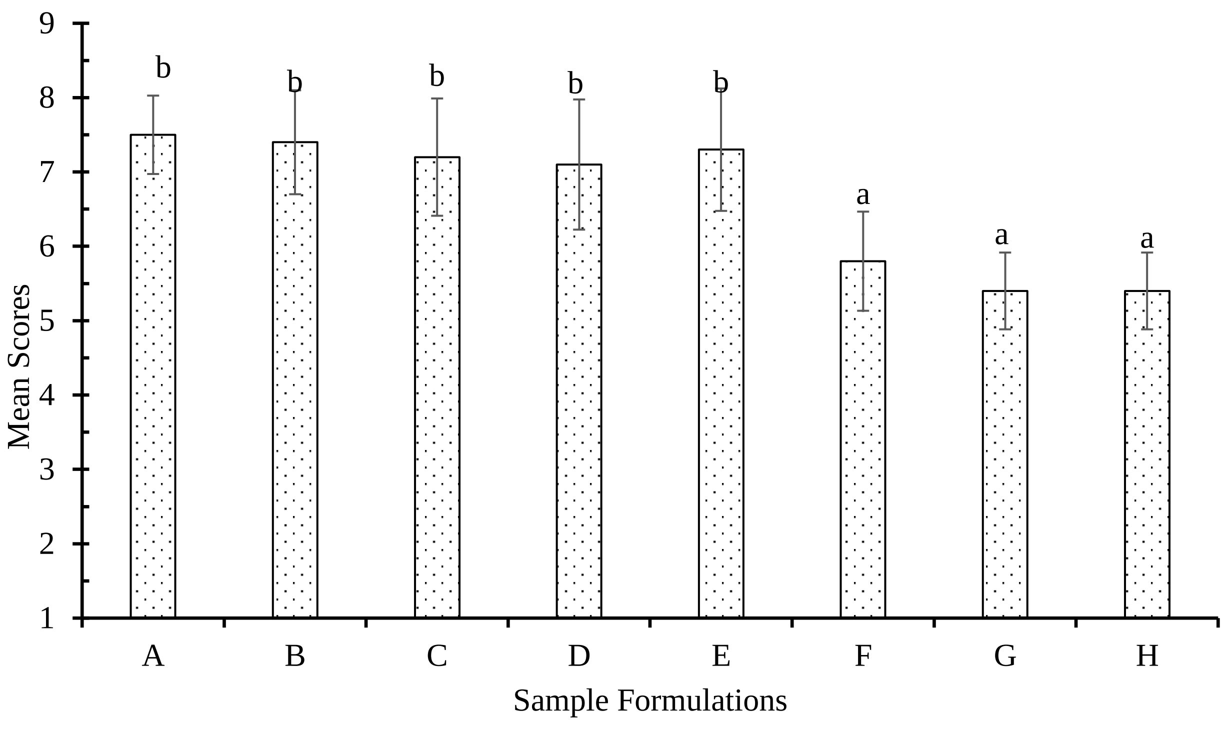

Fig. 4.3 Mean scores for taste of bread samples of different formulations (where A is control, B, C, D, E, F, G, and H contains 2.52%, 5.04%, 7.54%, 10%, 14.95%,17.48% and 20 % malted sorghum flour respectively). Means with different subscript are significantly different at p<

0.05.

The mean sensory score for taste of bread samples of different formulations are shown in Fig 4.6 above. The mean sensory score for taste of sample A (control) was found to be 7.50 which was the highest score of all the bread formulations. Samples B, C, D, and E were not significantly different from sample A (control). Statistical analysis showed that partial substitution of wheat flour with malted sorghum flour had significant effect ($p < 0.05$) on the taste. Samples F, G, and H were not significantly different and scored low in terms of taste which are in accordance with the findings of Perten (1977) who reported that high levels of malted sorghum flour substation in wheat flour were detrimental to bread characteristics and loaf volume. Abdelghafor *et al.*, (2010) reported similar results for taste of bread from composite flour of sorghum and hard white winter wheat.

4.5.4 Crumb appearance

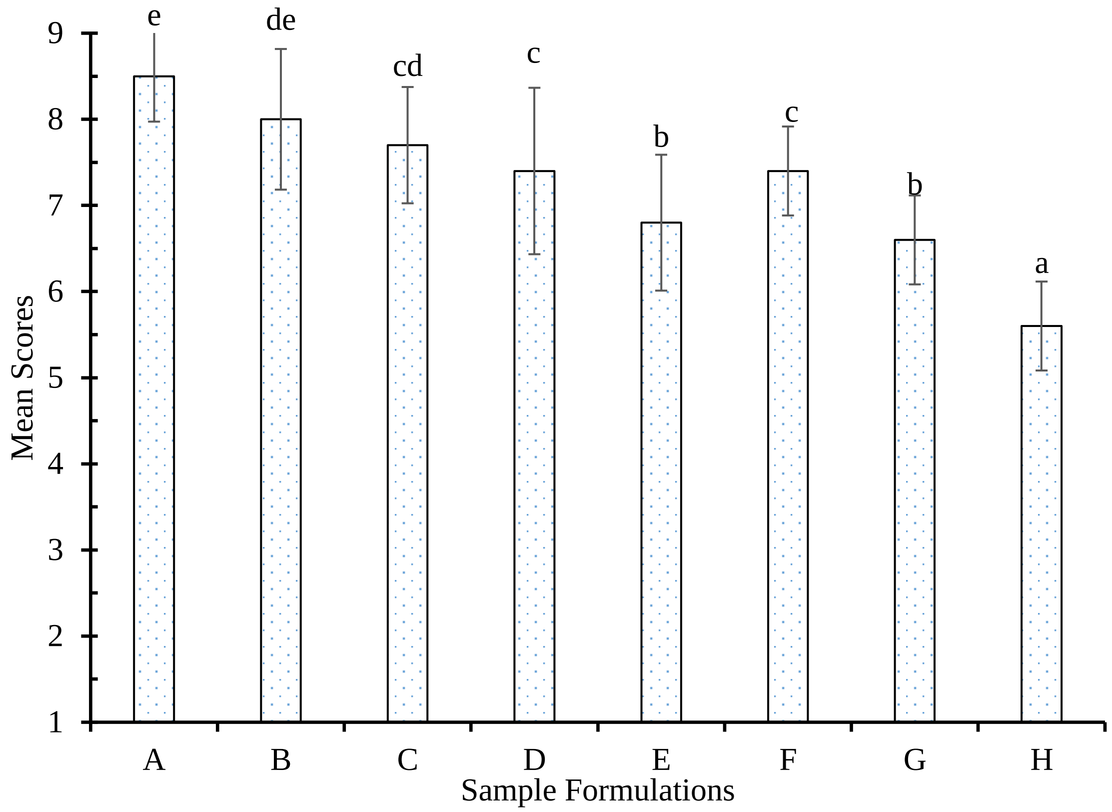

Fig. 4.4 Mean scores for crumb appearance of bread samples of different formulations (where A is control, B, C, D, E, F, G, and H contains 2.52%, 5.04%, 7.54%, 10%, 14.95%,17.48% and 20 % malted sorghum flour respectively). Means with different subscript are significantly different at p< 0.05.

The mean sensory score for taste of bread samples of different formulations are shown in Fig 4.6. The mean sensory score for crumb appearance of sample A (control) was found to be 8.50 which was the highest score of all the bread formulations. Sample B was found similar to sample A (control). Similarly, as we can see sample C is not significantly different from samples B, D, and F. Statistical analysis showed that partial substitution of wheat flour with malted sorghum flour had significant effect (p< 0.05) on the crumb appearance. Sample H has got lowest scores as compared to other samples score because incorporating high levels of sorghum flour depresses the loaf volume, which gives poor crumb characteristics and decreases acceptability

(Fleming and Sosulski, 1978). An appropriate balance in the amount of two major protein components (glutenin & gliadin) of wheat gluten is required for achieving the desired bread quality. But malted sorghum flour contains less gluten as compared to wheat flour and more incorporation of sorghum flour dilutes gluten giving poor crumb characteristics.

4.5.5 Flavor

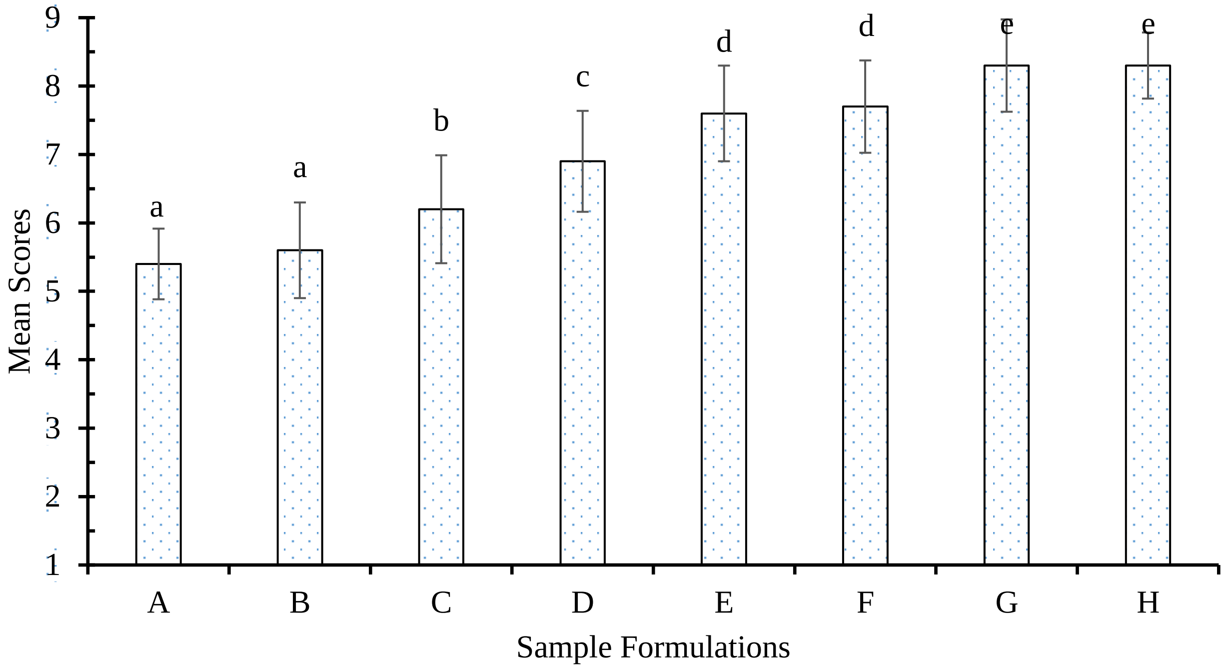

Fig. 4.5 Mean scores for flavor of bread samples of different formulations (where A is control, B, C, D, E, F, G, and H contains 2.52%, 5.04%, 7.54%, 10%, 14.95%,17.48% and 20 % malted sorghum flour respectively). Means with different subscript are significantly different at $p< 0.05$.

Mean sensory score for flavor of bread samples of different formulations are shown in Fig 4.6. Statistical analysis showed that partial substitution of wheat flour with malted sorghum flour had significant effect ($p< 0.05$) on the flavor. The mean sensory score for flavor of sample G and H was found to be 8.30 which was the highest score of all the bread formulations. It means there is no any significant difference between sample G and H. Samples A and B are similar in nature and has lower score than other samples. Sample E, F, G, and H has got higher score as compared to others because typical malt flavor is produced during malting of sorghum; flavoring compounds such as aldehyde and ketones may be increased during malting. A similar increase in malt flavor with the supplement of sorghum flour was noticed by (Briggs, 1998).

4.5.6 Overall acceptability

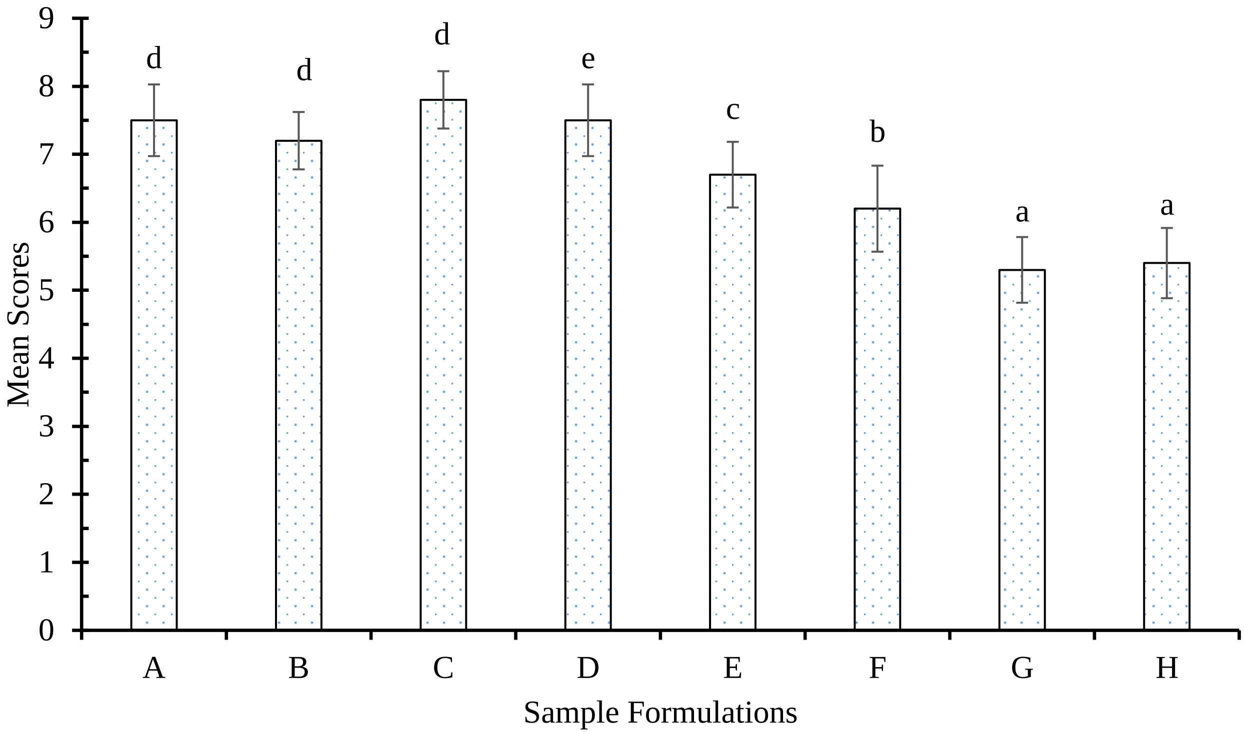

Fig. 4.6 Mean scores for overall acceptability of bread samples of different formulations (where A is control, B, C, D, E, F, G, and H contains 2.52%, 5.04%, 7.54%, 10%, 14.95%,17.48% and 20 % malted sorghum flour respectively). Means with different subscript are significantly different at p< 0.05.

Mean scores of overall acceptability of breads of different formulations are shown in Fig 4.9. Sample C scored highest in overall acceptability of the sensory conducted among the panelists.It was found to be almost similar to the control sample A but it was found better in maximum sensory attributes. Statistical analysis from the experimental data showed that the partial substitution of malted sorghum flour in samples showed significant difference (p<0.05) in overall acceptability of samples. Sample G showed lowest score in overall acceptability which could be as a result of higher amount of malted sorghum flour incorporated in it.. On the other hand, sample C scored highest in overall acceptability which maybe as a result of optimum malted sorghum flour incorporated in it. The overall acceptability mean showed that the product C with 5.04% of malted sorghum flour to be of the highest score.

4.6 Composition of optimized bread

The composition of the best product and the control bread from chemical analysis was carried out. The result of the analysis is given in the Table 4.5.

Table 4.5 Composition of product

Parameters	Product A (wheat bread)	Product C (malted sorghum bread containing 5.04% malted sorghum)
Moisture content (g/100 g)	18.25	19.34
Crude protein (%, db)	12.96^{a} ±0.54	13.43^{b}±0.25
Crude fat (%, db)	5.13^{a}±0.12	5.36^{b}±0.42
Crude fiber (%, db)	5.43^{a}±0.42	5.55^{b}±0.45
Total ash (%, db)	1.23^{a}±0.15	1.13^{b}±0.13
Carbohydrate (%, db)	74.55^{a}±0.99	73.63^{b}±0.63

*values are the means of triplicate determinations ± S.D

*^{ab} means with the different superscripts on the same column are significantly different

Moisture content, protein, fat, crude fiber, ash, and carbohydrate of the product C were found to be 19.34, 13.43, 5.36, 5.55, 1.13, and 73.63% respectively and that of product A were found to be 18.25, 12.96, 5.13, 5.43, 1.23, and 74.55% respectively.

Moisture content increased in product C because Njintang *et al.* (2008) and Olaoye *et al.* (2006) found that the moisture content of the composite breads increased with the increase in the non-wheat flour substitution. And this was attributed to the greater water holding capacity of the non-wheat flour substitution (Tekle, 2009).

Protein content of product A (control) is significantly different to the protein content of sample C at p (≤0.05). The protein content is significantly increased in malted sorghum flour incorporated bread which is due to more protein in sorghum flour than that of wheat flour (Matz, 1991).It was found that crude fat content of wheat bread was 5.13 and that of malted sorghum flour bread was 5.36. Statistical analysis showed that there is significant increase in fat content at p(≤0.05).It may be probably due to the fact that in which samples fortified with malted sorghum flour requires more fat during kneading operation in order to get dough of smooth consistency in addition to pleasant flavor and acceptable taste for the bread samples.

It was observrd that crude fibre content is also significantly increased in malted sorghum flour incorporated bread which was due to higher crude fibre content in sorghum flour than that of wheat flour.Ash content of malted sorghum flour incorporated bread is significanly drecased than that of wheat bread this may be because wheat as a cereal crops are known to be very rich in minerals such as Ca, P, and K as a result substution of malted sorghum flour results in decrease in ash content.

It was found that the amount of carbohydrate decreased significantly in malted sorghum incorporated bread. It may be due to the carbohydrates may have been digested into simple sugars by amylolytic enzymes which are rapidly taken up by the growing embryo to serve as its energy source during germination (Elkhier and Hamid, 2008).

.

PART V

Conclusions and recommendations

5.1 Conclusions

Despite some limitations the research was completed and on the basis of research, following conclusions can be drawn:

1. The proximate composition of malted sorghum is significantly different from the unmalted sorghum at 5% level of significance. The malted sorghum is superior in crude fibre, crude fat, crude ash as compared to the unmalted sorghum.Sphericity is also increased in malted sorghum.

2. Preparation of malted sorghum flour incorporated bread can be carried out successfully. The statistical analysis showed that formulation with 5.04% malted sorghum flour was significantly superior in terms of color, texture, taste and overall acceptability among formulations.

3. Cost of bread per 100 g was found to be Rs.6.95 that excludes processing, packaging, manpower and profit margin.

4. Crude protein, crude fat, and crude fibre of the malted sorghum flour incorporated bread was increased due to the supplementation of malted sorghum flour and was higher than control bread.

5.2 Recommendations

On the basis of the study done here, following recommendations can be given from the study of malted sorghum flour incorporated bread:

1. The 5.04% malted sorghum flour incorporated bread can be used for the commercial production of composite bread.

2. Study on the effect of various parameters on the medicinal components on the malted sorghum flour incorporated bread can be carried out.

Part VI

Summary

Raw material (sorghum) was obtained from the local market of Kathmandu and (wheat,fat e.t.c.) were brought from local market of Dharan. . The sorghum grains were soaked for 24 h at 28°C, at last steeped in KMS solution for 10 min to prevent mold growth and germinated at room temperature . After germination the sorghum grains were dried at 50°C for 24 h to obtain the desired final moisture content and was processed into fine powders. Response Surface Methodology was used for the formulation of recipe and for this, Design Expert v7.1.5 software was used.

Eight different bread formulations, namely A (100% wheat flour), B (2.52% malted sorghum flour), C (5.04% malted sorghum flour), D (7.54% malteds sorghum flour), E (10% malted sorghum flour), F (14.95% malted sorghum flour), G (17.48% malted sorghum flour), and H (20% malted sorghum flour) were prepared by straight dough process with the incorporation of yeast 2%, salt 1%, fat 4%, water 65%, and sugar 8% per 100 parts of flour mixture. The proximate analysis for moisture, crude protein , crude fat, crude fiber, total ash and carbohydrate, of wheat flour was done and the values were found to be (12.37, 10.3, 0.94, 0.36, 0.94, and 74.88%) respectively. . The proximate analysis for moisture (db), crude protein (db) , crude fat (db), crude fiber (db), total ash (db) ,carbohydrate (db) and reducing sugar (db) of sorghum flour and malted sorghum flour was done and the values were found to be ((12.2, 11.46, 3.66, 2.21, 0.55, 80.36, and 1.57%), (5.5, 10.67, 6.59, 3.20, 0.57, 3.19, and 75.34%) respectively.

All the prepared products were subjected to sensory evaluation in terms of crumb appearance, color, taste, flavor, texture, and overall acceptance as their sensory qualities and all the experimental bread were evaluated on a nine-point hedonic rating (1=dislike extremely, 9=like extremely) by different semi-trained panelists. The obtained data was analyzed statistically by Genstat Discovery Edition 3 (DE3), for Analysis of Variance (ANOVA) at 5% level of significance. The Statistical analysis showed that 5.04% malted sorghum flour incorporated bread was superior to all bread formulations. Mean sensory score of formulation C regarding color, taste, texture and overall acceptance was significantly better from other formulations. So product C was selected as the best product. The proximate composition of best bread according

to which the moisture content, protein (db), fat (db), fiber (db), ash content (db), and carbohydrate are found to be 19.34, 13.43, 5.36, 5.55, 1.13 and 73.63% respectively.

It was concluded from the present study that although substitution of MSF resulted slight decrease in loaf volume of bread. Statistical analysis for the proximate composition of bread samples showed that substitution of malted soghum flour significantly improved most of the nutritional attributes compared to whole wheat bread. Substitution significantly increased the protein, fat, and crude fiber. whereas significantly decreased ash and carbohydrate content of bread.

References

Abbas, A. A. A. (2000). Utilization of sorghum malt as bread flour corrector. B.Sc. (Honours) in Agriculture Science Dissertation. Univ. Gezira, Sudan.

Abdelghafor, R., Mustafa, A. I., A.M., I. and Krishnan, P. G. (2010). Quality of bread from composite flour of sorghum and hard white winter wheat. *J. Food Sci. Technol.* **3**, 9-15.

Aboubacar, A., Kirleis, A. W. and Oumarou, M. (1999). Important sensory attributes affecting consumer acceptance of sorghum porridge in West Africa as related to quality tests. *J. Cereal Sci.* **30**, 217-225.

Adhikari, B. M., Bajracharya, A. and Shrestha, A. K. (2016). Comparison of nutritional properties of stinging nettle (*Urtica dioica*) flour with wheat and barley flours. *Food Sci. Nutr.* **4** (1), 119–124.

Anonymous. (2008). Sorghum. U.S. Grain Council. Retrieved from http://www.grains.org/sorghum. [Accessed 19 January, 2018].

Anonymous. (2017a). Malting process. Great Western Malting. Retrieved from http://www.greatwesternmalting.com/gwm/malting-process/. [Accessed 17 January, 2018].

Anonymous. (2017b). Sorghum: health benefits, side effects, fun facts, nutrition facts and history. Wordpress. Retrieved from https://appreciategoods.com/sorghum/. (Last update February 21, 2017). [Accessed 17 January, 2018].

Anonymous. (2018). History of malting. Briess Malt and Ingredients. Retrieved from http://www.briess.com/food/Processes/malthistory.php. [Accessed 17 January, 2018].

Arora, S. M. (1980). "Handbook of Baking Products". SIRI world renowned institute for industrial publications. Roopnagar, Dehli.

Banks, W. T., Wang, C. and Susan, M. (1997). Partially defatted soya flour effects on sensory and physical characteristics of baked product. *J. Consumer Studies. Home Economics.* **21**, 151-156.

Bello, A. B., Rooney, L. W. and Waniska, R. D. (1990). Factors affecting quality of sorghum, a thick porridge. *Cereal Chem.* **67**, 20-24.

Bennion, E. B. (1967). "Bread Making: Its Principles and Practices" (4th ed.). Oxford University Press. London.

Berghofer, E. (2000). Brot als Funktionelles Lebensmittel. *Getreide, Mehl und Brot*. **54** (3), 175-179.

Beta, T., Rooney, L. W. and Waniska, R. D. (1995). Malting characteristics of sorghum cultivars. *Cereal Chem.* **72** (6), 533-538.

Bolarinwa, I. F., Olaniyan, S. A., Adebayo, L. O. and Ademola, A. A. (2015). Malted sorghum-soy composite flour: Preparation, chemical and physico-chemical properties. *J. Food Process. Technol.* **6**, 467.

Briggs, D. E. (1998). "Malts and Malting" (1st ed.). Springer. US.

Buffo, R. A., Weller, C. L. and Parkhurst, A. M. (1998). Relationships among grain sorghum quality factors. *Cereal Chem.* **75** (1), 100-110.

Butler, L. G., Riedl, D. J., Lebryk, D. G. and Blyit, H. J. (1984). Interaction of proteins with sorghum tannin: Mechanism, specificity and significance. *J. Am. Oil Chem. Soc.* **61**, 916-920.

Carr, T. P., Weller, C. L., Schlegel, V. L., Cuppett, S. L., Guderian, D. M. and Johnson, K. R. (2005). Grain sorghum lipid extract reduces cholesterol absorption and plasma non-HDL cholesterol concentration in hamsters. *J. Nutri.* **135** (9), 2236-2240.

Chamberlain, N. (1975). "Bread" (A. Spicer ed.). Applied Science Publisher. London.

Chandrashekar, A. and Mazhar, H. (1999). The biochemical basis and implications of grain strength in sorghum and maize. *J. Cereal Sci.* **30**, 193-207.

Ciacci, C., Maiuri, L., Caporaso, N., Bucci, C., Del Giudice, L., Massardo, R. D., Pontieri, P., Di Fonzo, N., Bean, S. R., Loerger, B. and Londei, M. (2007). Celiac disease: in vitro and in vivo safety and palatability of wheat-free sorghum food products. *Clin. Nutri.* **26** (6), 799-805.

Clementson, C. L., Ileleji, K. E. and Rosentrater, K. A. (2010). Evaluation of measurement procedures used to determine the bulk density of distillers dried grains with solubles (ddgs). *Am. Soc. Agri. Bio. Eng.* **53** (2), 485-490.

Collier, P. (1884). "Sorghum". R. Clarke & Company. Washington, D.C.

Da, S., Akingbala, J. O., Rooney, L. W. and Miller, R. F. (1982). Evaluation of tô quality in a sorghum breeding program. *In:* "Proc. Int. Symp. Sorghum Grain Quality". (L. W. Rooney and D. S. Murty, Eds.). pp. 11-23. Patancheru, India. ICRISAT.

Dahlberg, J., Berenji, J., Sikora, V. and Latkovi, D. (2011). Assessing sorghum [*Sorghum bicolor* (L) Moench] germplasm for new traits: food, fuels and unique uses. *Maydica*. **56**, 85-92.

Djameh, C., Saalia, F. K., Sinayobye, E., Budu, A., Essilfie, G., Brown, H. M. and Dedeh, S. S. (2015). Optimization of the sorghum malting process for pito production in Ghana. *J. Inst. Brew.* **121**, 106–112.

Earp, C. F., McDonough, C. M., Awika, J. and Rooney, L. W. (2004). Testa development in the caryopsis of *Sorghum bicolor* (L.) Moench. *J. Cereal Sci.* **39**, 303-311.

Earp, C. F., McDonough, C. M. and Rooney, L. W. (2004). Microscopy of pericarp development in the caryopsis of *Sorghum bicolor* (L.) Moench. *J. Cereal Sci*. **39**, 21-27.

Eggum, B. O., Monawar, L., BachKnudsen, K. E., Munck, L. and Axtell, J. (1981). Nutritional quality of whole and decorticated sorghum and sorghum food from Sudan. *J. Cereal Sci.* **1**, 122-137.

Elbaloula, M. F., Yang, R., Guo, Q. and Gu, Z. (2014). Major nutrient compositions and functional properties of sorghum flour at 0–3 days of grain germination. *Int. J. Food Sci. Nutri.* **65** (1), 48-52.

Elkhier, M. K. S. and Hamid, A. O. (2008). Effect of malting on the chemical constituents, antinutrition factors and ash composition of two sorghum cultivars (feterita and tabat) grown in Sudan. *Res. J. Agri. Bio. Sci.* **4**, 500-504.

Elshewaya, A. A. (2003). A study on malting conditions of millet and sorghum grains and the use of the malt in bread making. M.Sc. Thesis. Univ. Khartoum, Sudan.

Evers, T. and Millar, S. (2002). Cereal grain structure and development: some implications for quality. *J. Cereal Sci.* **36**, 261-284.

Fance, W. J. (1972). "The Student's Technology of Bread Making & Confectionary". Routledge and Kegan Paul. London.

FAO. (1989). Utilization of tropical foods: cereals. *FAO Food and Nutri.* 47.

FAO. (1995). "Sorghum and Millets in Human Nutrition". Vol. 27. Food and Agriculture Organization of the United Nations. Rome, Italy.

FAO. (2008). Production of sorghum [Report]. FAOSTAT. Retrieved from http://faostat.fao.org. [Accessed 19 January, 2018].

Farrar, J. L., Hartle, D. K., Hargrove, J. L. and Greenspan, P. (2008). A novel nutraceutical property of select sorghum (*Sorghum bicolor*) brans: inhibition of protein glycation. *Phytother Res.* **22** (8), 1052-1058.

Fleming, S. E. and Sosulski, F. W. (1978). Microscopy evaluation of bread fortified with concentrated plant proteins. *Cereal Chemistry*. **55** (3), 373-382.

Fliedel, G. (1995). Appraisal of sorghum quality for making tô. *In:* "Agriculture et Developpement". (H. S. Macary and C. Jourdan-Ruf, Eds.). pp. 34-42. Montpellier, France. Centre de coopération Internationale en Recherche Agronomique pour le Développement

Flynn, G. and James, A. W. (1981). "An Industrial Profile of Bread-making (Report of the Tropical Products Institute)". Natural Resources Institute, 1981. U.S.A.

Frazier, W. C. and Westhoff, D. C. (2005). "Food Microbiology" (4th ed.). Mcgraw-Hill College. Blacklick, Ohio, U.S.A.

Gautam, L., Chaturvedi, N. and Richa, S. (2015). The impact of malting on nutritional composition of foxtail millet, wheat and chickpea. *J. Nutri. Food Sci.* **5** (5), 407.

Gomez-Cordoves, C., Bartolome, B., Vieira, W. and Virador, V. M. (2001). Effects of wine phenolics and sorghum tannins on tyrosinase activity and growth of melanoma cells. *J. Agric. Food Chem.* **49** (3), 1620-1624.

Haussmann, B. I. G., Obilana, A. B., Blum, A., Ayiecho, P. O., Schipprack, W. and Geiger, H. H. (1999). Quantitative-genetic parameters of sorghum [*Sorghum bicolor* (L.) Moench] grown in semi-arid areas of Kenya. *Euphytica*. **105** (2), 109 – 118.

Herringshaw, J. F. (1969). *In:* "Baking in Food Industries". (L. H. Anthony Woollen, Ed.). p. 2. London.

Hough, J. S. (1985). "The Biotechnology of Malting and Brewing". Cambridge University Press.

Ioerger, B., Bean, S. R., Tuinstra, M. R., Pedersen, J. F., Erpelding, J., Lee, K. M. and Herrman, T. J. (2007). Characterization of polymeric proteins from vitreous and floury sorghum endosperm. *J. Agric. Food Chem.* **55**, 10232-10239.

Johnson, A. and Peterson, W. (1974). Encyclopedia of Food Technology. Vol. 2. The Avil Bub Con Inc.

Joshi, M. (2015). "Textbook of Field Crops". PHI Learning. Banglore, India.

Kader, A. Z. M. (2000). Enrichment of Egyptian “Balady” bread. Part 1. Baking studies,physical and sensory evaluation of enrichment with decorticated cracked broadbean flour (Vicia fabia L.). *Molecular Nutr. Food Research*. **44** (6), 418-421.

Kelley, T. G., Rao, P. P. and Singh, R. P. (1992). Trends in sorghum production and utilization in asia [Report]. 108. International Crops Research Institute for the Semi-Arid Tropics. Andhra Pradesh, India.

Kent. (1983). "Technology of Cereals" (3rd ed.). Pergamon Press Ltd. London.

Kent, N. L. and Evers, A. D. (2004). "Technology of Cereals" (4rth ed.). Woodhead Publ. Ltd. Cambridge, England.

Khanal, T. R. (1997). Preparation of bread using wheat malt flour. B. Tech. Thesis. Tribhuvan Univ., Nepal.

Khatkar, B. S. and Schofield, J. D. (1997). Molecular and physico-chemical basis of breadmaking-properties of wheat gluten proteins: a critical appraisal. *J. Food Sci. Technol.* **34** (2), 85-102.

Kim, J. C. and de Ruiter, D. (1969). Bakery products with non-wheat flours. *Baker's Digest*. **43** (3), 58-63.

Kimber, T. C., Dahlberg, J. A. and Kresovich, S. (2013). The gene pool of sorghum bicolor and its improvement. *In:* "Genomics of Saccharinae". (A. Peaterson, Ed.). pp. 23-41. New York. Springer Science and Business Media.

Kleih, U., Ravi, S. B., Rao, B. D. and Yoganand, B. (2007). Industrial utilization of sorghum in India. *SAT eJournal*. **3** (1).

Li, J., Danao, M. G. C., Chen, S. F., Li, S., Singh, V. and Brown, P. J. (2015). Prediction of starch content and ethanol yields of sorghum grain using near infrared spectroscopy. *J. Near Infrared Spectrosc.* **23**, 85–92.

Maforimbo, E., Skurray, G., Uthayakumaran, S. and Wrigley, C. (2008). Incorporation of soy proteins into the wheat–gluten matrix during dough mixing. *J. Cereal Sci.* **47**, 380-385.

Makeri, M. U., Nkama, I. and Badau, M. H. (2013). Physico-chemical, malting and biochemical properties of some improved Nigerian barley cultivars and their malts. *Int. Food Res. J.* **20** (4), 1563-1568.

Mallett, J. (2014). "Malt: A Practical Guide from Field to Brewhouse". Brewers Publications.

Martin, J. H. and Macmasters, M. M. (1950-1951). Industrial uses for grain sorghum. *In:* "The Year Book of Agriculture, 1950-1951 : Crops in Peace and War". (UADA, Ed.). pp. 349-352. Washington. Superintendent of Documents.

Matz, S. A. (1991). "Chemistry and Technology of Cereals as Food and Feed" (2nd ed.). Springer Science and Business Media. USA.

Mella, O. N. O. (2011). Effects of malting and fermentation on the composition and functionality of sorghum flour. M.Sc. Dissertation. Univ. Nebraska, USA.

Meyer, L. H. (2004). "Food Chemistry". CBS publication. New Delhi.

Mohammed, A. N., Mohamed Ahmed, I. A., Babiker, E. E. and Sikora, V. (2011). Nutritional Evaluation of Sorghum Flour (*Sorghum bicolor* L. Moench) During Processing of Injera. *Int. J. Nutri. Food Eng.* **5** (3), 99-103.

Munak, L. (1995). New milling technologies and products *Whole plant utilization by milling and seperation of the botanical and chemical component* (pp. 223-281): American Association St. Paul. M.N.

Murty, D. S. and Kumar, K. A. (1995). Traditional uses of sorghum and millets. *In:* "Sorghum and Millets: Chemistry and Technology". (D. A. V. Dendy, Ed.). pp. 223-281. St. Paul, MN.

Narsih, Yunianta and Harijono. (2012). The study of germination and soaking time to improve nutritional quality of sorghum seed. *Int. Food Res. J.* **19** (4), 1429-1432.

Ndirika, V. I. O. and Mohammed, S. S. (2005). Determination of selected physical properties and their relationship with moisture content for sorghum crop. *J. Food Technol.* **3** (3), 314-318.

Nesbitt, M. (2012). Grains. *In:* "The Cultural History of Plants". (S. G. Prance and M. Nesbitt, Eds.). p. 57. New York. Routledge.

Njintang, N. Y., Carl, M. F., Facho, B., Pierre, K. and Joel, S. (2008). Effect of taro (*Colocasia esculenta*) flour addition on the functional and alveographic properties of wheat flour and dough. *J. Sci. Food Agric.* **88**, 273-279.

NRC. (1996). "Lost Crops of Africa: Volume I: Grains". The National Academies Press. Washington, DC.

Ogbonna, A. C., Abuajah, C. I., Ide, E. O. and Udofia, U. S. (2012). Effects of malting conditions on the nutritional and anti-nutritional factors of sorghum grist. *AUDJG – Food Technol.* **36** (2), 64-72.

Olaoye, O. A., Onilude, A. A. and Idowu, O. A. (2006). Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. *Afr. J. Biotech.* **5** (11), 1102-1106.

Perten, H. (1977). Sorghum processing project in sudan proceeding symposium sorghum and millets for human food: International Association for Cereal Chemistry.

Popper, L., Schäfer, W. and Freund, W. (2006). "Future of Flour". Vol. 16. AgriMedia GmbH.

Priestley, R. (1979). "Effect of Heating on Food Stuffs". Applied Science Publisher. London.

Raidi, M. A. and Klein, B. P. (1983). "Principles and Practice". Vol. 60.

Ranganna, S. (1986). "Handbook of Analysis and Quality Control of Fruit and Vegetables". Tata McGerw Hill Pub. Co. Ltd. . New Delhi.

Rao, G. V. and Rao, P. H. (1993). Methods of determining rheological characteristics of dough. *J. Food Sci. Technol.* **30** (2), 77-88.

Rao, P. H. and Hemamalini, R. (1991). Effect of incorporating wheat bran on rheological charaterstics and bread making quality flour. *J. Food Sci. Technol.* **28**, 92-97.

Ratnavati, C. V. and Chavan, U. D. (2016). Malting and brewing of sorghum. *In:* "Sorghum Biochemistry: An Industrial Perspective". (C. V. Ratnavati, U. D. Chavan and J. V. Patil, Eds.). pp. 63-106. USA. Academic Press.

Rooney, L. W., Kirleis, A. W. and Murty, D. S. (1988). Traditional foods from sorghum: Their production, evaluation and nutritional value. *In:* "Proc. Int. Symp. on Advances in Cereal Science and Technology" (Vol. 9). (Y. Pomeranz, Ed.). pp. 317-353. St. Paul, MN.

Sautier, D. and O'Deye, M. (1989). "Mil, Mais, Sorgho - Techniques et alimentation au Sahel". Cirad. Paris.

Schofield, J. D. and Booth, M. R. (1983). Wheat proteins and their technological significance. *Dev Food Proteins*. **2**, 1-60.

Serna-Saldivar, S. O., Clegg, C. and Rooney, L. W. (1994). Effects of parboiling and decortication on the nutritional value of sorghum (*Sorghum bicolor* L. Moench) and pearl millet (*Pennisetum glaucum* L.). *J. Cereal Sci.* **19**, 83-89.

Serna-Saldivar, S. O. and Rooney, L. W. (1995). Structure and chemistry of sorghum and millets. *In:* "Sorghum and Millets: Chemistry and Technology". (D. A. V. Dendy, Ed.). pp. 69-124. St. Paul, MN. AACC International.

Shewry, P. R., Halford, N. G. and Tathum, A. S. (1992). High mr subunits of wheat glutenin. *J. Cereal Sci.* **15**, 105-120.

Shull, J. M., Chandrashekar, A., Kirleis, A. W. and Ejeta, G. (1990). Development of sorghum (*Sorghum bicolor* (L.) Moench) endosperm in varieties of varying hardness. *Food Struct.* **9**, 253-267.

Simonyan, K. J., EL-Okene, A. M. and Yiljep, Y. D. (2007). Some physical properties of Samaru sorghum 17 grains. *Agri. Eng. Int. CIGR Ejournal*. **9**, 1-15.

Smith, C. W. and Frederiksen, R. A. (2000). "Sorghum: Origin, History, Technology, and Production". Wiley. New York.

Summer, A. K. and M.A., N. (1976). Sorghum and the millets their composition and nutritive value (pp. 439-448). London: Acedamic press.

Taylor, J. R. N. and Belton, P. S. (2002). Sorghum. *In:* "Pseudocereals and Less Common Cereals: Grain Properties and Utilization Potential". (P. S. B. a. J. R. N. Taylor, Ed.). pp. 25-82. Berlin. Springer.

Taylor, J. R. N., Schober, T. J. and Bean, S. R. (2006). Novel food and non-food uses for sorghum and millets. *J. Cereal Sci.* **44**, 252-271.

Taylor, J. R. N. and Schussler, L. (1986). The protein compositions of the different anatomical parts of sorghum grain. *J. Cereal Sci.* **4**, 361-369.

Tekle, A. (2009). The effect of blend proportion and baking condition on the quality of cookie made from taro and wheat flour blend. School of graduate studies, Addis Ababa University. Retrieved from http://etd.aau.edu.et/dspace/bitstream/123456789/2882/1/Abent's.pdf. [Accessed 20.11.2010].

Verbruggen, M. A. (1996). Glucuronoarabinoxylans from sorghum grain. Thesis. Wageningen Agricultural Univ., Netherland.

Wall, J. S. and Blessin, C. W. (1969). Composition and structure of sorghum grains. *Cereal Sci. Today*. **14** (8), 264-270.

Wall, J. S. and Blessin, C. W. (1970). Composition of sorghum plant and grain. *In:* "Sorghum production and utilization". (J. S. Wall and W. M. Ross, Eds.). pp. 118-166. Westport. AVI publishing Company, Inc.

Waniska, R. D. and Rooney, L. W. (2000). Structure and chemistry of the sorghum caryopsis. *In:* "Sorghum: Origin, History, Technology, and Production". (C. W. Smith and R. A. Frederiksen, Eds.). pp. 649-688. New York. Wiley.

William, A. (1975). "Breadmaking: The Modern Revolution" (1st ed.). Hutchinson Benham. London.

Yang, L., Browning, J. D. and Awika, J. M. (2009). Sorghum 3-deoxyanthocyanins possess strong phase II enzyme inducer activity and cancer cell growth inhibition properties. *J. Agric. Food Chem.* **57** (5), 1797-1804.

Yetneberk, S., de Kock, H. L., Rooney, L. W. and Taylor, J. R. N. (2004). Effects of sorghum cultivar on injera quality. *Cereal Chem.* **81**, 314-321.

Zr. (2010). Factors that affect in bread quality. Food Info. Retrieved from http://1st-foodinfo.blogspot.com/2010/02/factors-that-affect-in-bread-quality.html. [Accessed 4 May, 2017].

Appendices

Appendix A

Sensory evaluation score sheet for bread

Date:

Hedonic rating test

Name of the panelist: …………………………………

Name of the product: Bread

Please test the following samples of Bread and check how much you prefer for each of the samples. Give the points for your degree of preferences for each parameter for each sample as shown below:

Judge the above characteristics on the 1-9 scale as below:

Like extremely – 9   Like Slightly – 6   Dislike moderately – 3
Like very much – 8   Neither like nor dislike -5   Dislike very much - 2
Like moderately – 7   Dislike slightly – 4   Dislike extremely – 1

Formulations	A	B	C	D	E	F	G	H
Attributes								
Crumb								
Color								
Taste								
Texture								
Flavor								
Overall acceptability								

Any Comments:……………………..   Signature……………………..

Appendix B

Table B.1 Paired t test for two sample of means of crude protein content of raw and malted sorghum

	Variable 1	*Variable 2*
Mean	11.46666667	10.67
Variance	0.010833333	0.0031
Observations	3	3
Pearson Correlation	0.603957174	
Hypothesized Mean Difference	0	
Df	2	
t Stat	16.57166836	
P(T<=t) one-tail	0.001810812	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.003621623	
t Critical two-tail	4.30265273	

Table B.2 Paired t test for two sample of means of crude fat content of raw and malted sorghum

	Variable 1	*Variable 2*
Mean	3.666666667	3.72
Variance	0.007433333	0.0036
Observations	3	3
Pearson Correlation	-0.985886958	
Hypothesized Mean Difference	0	
df	2	
t Stat	-0.633943081	
P(T<=t) one-tail	0.295476003	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.590952006	
t Critical two-tail	4.30265273	

Table B.3 Paired t test for two sample means of crude fiber content of raw and malted sorghum

	Variable 1	*Variable 2*
Mean	2.21	3.206667
Variance	0.0013	0.001633
Observations	3	3
Pearson Correlation	0.789203	
Hypothesized Mean Difference	0	
Df	2	
t Stat	-68.5953	
P(T<=t) one-tail	0.000106	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.000212	
t Critical two-tail	4.302653	

Table B.4 Paired t test for two sample of means of ash content of raw and malted sorghum

	Variable 1	Variable 2
Mean	0.556666667	0.57
Variance	0.005233333	0.0004
Observations	3	3
Pearson Correlation	-0.898512571	
Hypothesized Mean Difference	0	
df	2	
t Stat	-0.254513905	
P(T<=t) one-tail	0.411438511	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.822877023	
t Critical two-tail	4.30265273	

Table B.5 Paired t test for two sample of means of reducing sugar content of raw and malted sorghum

	Variable 1	*Variable 2*
Mean	1.573333333	75.34333333
Variance	0.268133333	0.416033333
Observations	3	3
Pearson Correlation	-0.539729257	
Hypothesized Mean Difference	0	
df	2	
t Stat	-125.0099592	
P(T<=t) one-tail	3.19918E-05	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	6.39837E-05	
t Critical two-tail	4.30265273	

Table B.6 Paired t test for two sample of means of carbohydrate content of raw and malted sorghum

	Variable 1	*Variable 2*
Mean	80.36333333	3.196666667
Variance	1.171033333	0.770033333
Observations	3	3
Pearson Correlation	-0.997247472	
Hypothesized Mean Difference	0	
df	2	
t Stat	68.25049357	
P(T<=t) one-tail	0.000107305	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.000214609	
t Critical two-tail	4.30265273	

Appendix C

Table C.1 Paired t test for two sample of means of crude protein content of control and best product.

	Variable 1	*Variable 2*
Mean	12.96	13.43
Variance	0.2916	0.0625
Observations	3	3
Pearson Correlation	-1	
Hypothesized Mean Difference	0	
df	2	
t Stat	-1.030460607	
P(T<=t) one-tail	0.205551389	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.411102779	
t Critical two-tail	4.30265273	

Table C.2 Paired t test for two sample of means of crude fat content of control and best product.

	Variable 1	*Variable 2*
Mean	5.13	5.366666667
Variance	0.0144	0.180833333
Observations	3	3
Pearson Correlation	-0.999423797	
Hypothesized Mean Difference	0	
Df	2	
t Stat	-0.751880749	
P(T<=t) one-tail	0.26528124	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.530562481	
t Critical two-tail	4.30265273	

Table C.3 Paired t test for two sample of means of crude fiber content of control and best product.

	Variable 1	*Variable 2*
Mean	5.43	5.55
Variance	0.1764	0.2025
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	-6.92820323	
P(T<=t) one-tail	0.010102051	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.020204103	
t Critical two-tail	4.30265273	

Table C.4 Paired t test for two sample of means of ash content of control and best product.

	Variable 1	*Variable 2*
Mean	1.233333333	1.133333333
Variance	0.023333333	0.015633333
Observations	3	3
Pearson Correlation	0.986081944	
Hypothesized Mean Difference	0	
Df	2	
t Stat	4.803844614	
P(T<=t) one-tail	0.02035289	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.040705781	
t Critical two-tail	4.30265273	

Table C.5 Paired t test for two sample of means of carbohydrate content of control and best product.

	Variable 1	*Variable 2*
Mean	74.55	73.63
Variance	0.9801	0.3969
Observations	3	3
Pearson Correlation	1	
Hypothesized Mean Difference	0	
df	2	
t Stat	4.426352064	
P(T<=t) one-tail	0.023718664	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.047437328	
t Critical two-tail	4.30265273	

Appendix D

ANOVA for physical analysis of samples

Table D.1 Two-way ANOVA (No blocking) For color

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	7	56.2000	8.0286	18.03	<.001
panelist	9	2.5500	0.2833	0.64	0.762
Residual	63	28.0500	0.4452		
Total	79	86.8000			

Table D.2 Two-way ANOVA (No blocking) For crumb appearance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	7	57.2000	8.1714	18.35	<.001
panelist	9	5.7500	0.6389	1.43	0.193
Residual	63	28.0500	0.4452		
Total	79	91.0000			

Table D.3 Two-way ANOVA (No blocking) For flavor

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	7	94.0000	13.4286	30.49	<.001
panelist	9	4.2500	0.4722	1.07	0.396
Residual	63	27.7500	0.4405		
Total	79	126.0000			

Table D.4 Two-way ANOVA (No blocking) For taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	7	60.5875	8.6554	19.11	<.001
panelist	9	5.3625	0.5958	1.32	0.247
Residual	63	28.5375	0.4530		
Total	79	94.4875			

Table D.5 Two-way ANOVA (No blocking) For texture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	7	86.8000	12.4000	36.42	<.001
panelist	9	5.9500	0.6611	1.94	0.062
Residual	63	21.4500	0.3405		
Total	79	114.2000			

Table D.6 Two-way ANOVA (No blocking) For overall acceptability

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	7	97.1500	13.8786	50.39	<.001
panelist	9	1.0500	0.1167	0.42	0.918
Residual	63	17.3500	0.2754		
Total	79	115.5500			

Appendix E

Two-way ANOVA (no blocking) for sensory analysis of different bread formulations.

Table E. 1 Mean sensory scores for different attributes

	Quality Attributes					
Sample	Crumb	Color	Flavor	Texture	Taste	Overall Acceptability
A	8.5^{e}	7.4^{b}	5.4^{a}	8.4^{d}	7.5^{b}	7.5^{d}
B	8^{de}	7.5^{b}	5.6^{a}	8.3^{d}	7.4^{b}	7.2^{d}
C	7.7^{cd}	7.2^{b}	6.2^{b}	8^{cd}	7.2^{b}	8.8^{e}
D	7.4^{c}	7.4^{b}	6.9^{c}	7.7^{c}	7.1^{b}	7.5^{d}
E	6.8^{b}	7.2^{b}	7.6^{d}	6.9^{b}	7.3^{b}	6.7^{e}
F	7.4^{c}	5.8^{a}	7.7^{d}	6.5^{b}	5.8^{a}	6.2^{b}
G	6.6^{b}	5.7^{a}	8.3^{e}	5.9^{a}	5.4^{a}	5.3^{a}
H	5.6^{a}	5.4^{a}	8.3^{e}	5.5^{a}	5.4^{a}	5.4^{a}
LSD	0.5963	0.5936	0.5931	0.5215	0.0.6015	0.4690

The values are the mean of 12 panelist score. The values having same superscript in column did not vary significantly at 5% level of significance.

F-ratio ≤ 0.05 indicate significant difference at 5% level of significance.

Cost calculation of malted sorghum incorporated bread

Materials	Weight in lot (g)	Cost per Kg (NRs)	Cost (NRs)
Wheat flour	94.95	40	3.79
Sorghum flour	5.04	100	0.50
Fat	4	310	1.24
Sugar	8	65	0.52
Yeast	2	440	0.88
Salt	1	20	0.02
Cost of malted sorghum bread (NRs/100g)			6.95

Note: The cost excludes processing, packaging, manpower cost and profit margin.

Color plates

P.1 Germination of sorghum

P.2 Steeping of sorghum

P.3 semi trained panelist doing sensory analysis

P.4 Malted sorghum incorporated bread samples