EFFECT OF INCORPORATION OF MALTED SORGHUM IN THE QUALITY OF BISCUIT

Name: Miss. Shusma Poudel
Address: Bharatpur, Chitwan
Email: shusmapaudel6@gmail.com
Mobile No.: 9865035009
Faculty: B. Tech (Batch: 072-076)
Enrollment: 20/072

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by

Shusma Paudel

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

2021

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

by

Shusma Paudel

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

Jan, 2021

Tribhuvan University

Institute of Science and Technology

Department of Food Technology

Central Campus of technology, Dharan

Approval Letter

This *dissertation* entitled *Effect of Incorporation of Malted Sorghum in the Quality of Biscuit* presented by Shusma Paudel has been accepted as the partial fulfilment of the requirement for the B. Tech. degree in Food Technology.

<u>Dissertation Committee</u>

1. **Head of the Department** __________________________________

   (Mr. Basanta K. Rai, Prof.)

2. **External Examiner** __________________________________

   (Mr. Sanjay Bhandari, FTQCO, Biratnagar)

3. **Supervisor** __________________________________

   (Mr. Pashupati Mishra, Prof.)

4. **Internal Examiner** __________________________________

   (Mrs. Mahalaxmi Pradhananga, Asst. Prof.)

Jan, 2021

Acknowledgements

I would like to express my heartfelt gratitude to my respected guide Prof. Pashupati Mishra for his kind support, encouragement and constructive recommendation on doing this research.

I am really thankful to Prof. Basanta kumar Rai, Chairperson, Department of Food Technology and Prof. Dr. Dhan Bahadur Karki, former Campus Chief, Central Campus of Technology for making available facilities to carry out the best in this dissertation work.

I cannot stay without thanking all my classmates for their help in preparing the final work. Special thanks must be bestowed to my senior Krishna Chalise and my friends, Subash Sigdel, Sumitra Shrestha and Ashish Koirala for their support during the completion of this work. I salute all those whose perceptions, observation and inputs have helped me directly or indirectly.

I also express my sincere thanks to my teachers, staff of library and laboratory for their direct and indirect co-operation and suggestions.

No words in this world can ever express the love and encouragement given by my parents during my tough days in thesis work.

Date of submission: February, 2021

Shusma Paudel

Abstract

Malted sorghum incorporated biscuit is a thin, small, baked, unleavened cake, typically crisp, flat and sweet by using malted sorghum flour and wheat flour as the major ingredients. The aim of this study was to prepare malted sorghum incorporated biscuit and evaluation of its effect on biscuit quality. Response Surface Methods was used for the formulation of recipe for this, DOE (Design Expert) v7.1.5 software was used. Malted Sorghum incorporated biscuit was prepared in lab by soft dough process with the incorporation of malted sorghum flour in different parts namely A, B, C, D, E, F and G with 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts and 50 parts respectively with wheat flour. The sensory analysis of malted sorghum incorporated biscuit of different concentration was carried out for consumer acceptability. The obtained data were statistically analyzed using two way ANOVA (no blocking) at 5% level of significance.

Sample D i.e. the biscuit with the incorporation of 37.5 parts of malted sorghum flour was selected as the best formulation and subjected for further physiochemical analysis. The moisture content, crude protein, fat, fibre, total ash and total carbohydrate of malted sorghum flour incorporated biscuit were found to be 2.65%, 6.25%, 17.60%, 2.05%, 3.50% and 67% (db) respectively whereas the same parameters for wheat flour biscuit were found to be 2.82%, 6.8%, 15.8%, 1.23%, 1.30%, 72% respectively. These findings suggest that malted sorghum flour can be successfully incorporated in refined wheat flour up to the concentration of 37.5 parts without any adverse effect on sensory attributes. The iron content and calcium content of the sorghum grain and malt were also calculated and found to be 4.13 mg/100g; 8.0 mg/100g and 62.11 mg/100g; 159.62 mg/100g. Iron and calcium were increased by 93.70% and 157% respectively during malting. Malting of sorghum significantly increases amylase activity, increasing the level of reducing sugar. The calcium, fat, fiber and ash content were found to be higher in malted sorghum incorporated biscuit in comparison to normal wheat flour biscuit.

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List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of Variation
CCT	Central Campus of Technology
CFTRI	Central Food Technology Research Institute
db	Dry Basis
FAO	Food and Agriculture Organization
LI-BIRD	Local Initiatives for Biodiversity, Research and Development
NARC	Nepal Agriculture Research Council
SMP	Skim Milk Powder

Part I

Introduction

1.1 General introduction

Humans have consumed bakery products for hundreds of years. Among the different bakery products, biscuits constitute the most popular group. Biscuits are confectionery dried to very low moisture content. Biscuit is defined as a thin flat baked product made from flour, salt, sweetening agent, fat and preservatives. They are crisps, unleavened and sometimes sweet pastry produced by the addition of baking powder or soda, sometimes with chocolate or fruit input. Biscuit can also be defined as a baked product having not less than 8% of flour content calculated. Bohn (1956) Stated that biscuits are termed “cookies” in USA but the word biscuit means a small cake like bun.

Wheat flour is a principal raw material in biscuit production. Its superiority over other cereals is due to the presence of gluten, which inherently imparts all the essential qualities to their products. The absence of this simple protein in non-wheat flour makes them unsuitable as substitutes for wheat flour. Choice of raw materials is generally done as per the quality and organoleptic requirement of the final product (Terrel, 1981).

Raw materials for biscuit preparation can be divided into major and minor ingredients; those raw materials, which are used in bulk and are the must for biscuit making, are considered as major ingredients. For example, flour, water, sugar and fat are used in bulk in biscuit making procedure. Salt, skim milk powder (SMP), ammonium bi-carbonate, sodium bi-carbonate, coloring agents, flavoring agents, emulsifiers, fortifying agents, improvers etc. are used in small amounts and aren’t must for all sort of biscuits. These ingredients are used for developing the taste, texture, flavor and aesthetic value of the product. Therefore, these minor ingredients are also known as the product improvers. All these ingredients are individually important to obtain more palatable and satisfactory products. However, the majority of flour used is wheat, other cereal flour (malted or unmalted) can also be incorporated with it. The raw materials are found in the form of solid, liquid and paste (Shrestha, 1995).

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 imports (N. L. Kent and Evers, 2004). Buck wheat flour has been used industrially in India since last few years for the production of biscuit and bread. Similarly, sorghum (both malted and unmalted) flour has been used in Nigeria and other African country since last 10 years for the production of beer, bread and malt based energy drinks (Arora, 1980).

The production of noodles from composite flour has been started in Nepal too. 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) with similar objectives in Kaski and Nuwakot districts of Nepal and had success to some extent. Several other similar works have been done at technical colleges of Nepal in this field, but the incorporation of sorghum in biscuit has not yet been done. The popularity of biscuit is increasing these days in our country and such attempt with biscuit will produce a newer and nutritious product and provide a choice for biscuit lovers.

Malting process involves soaking, germination and drying, aims to change grains into malt with high enzymes and vitamins content. Malting induces important beneficial biochemical changes in sorghum grains. Indeed, soaking generates grain softening and increase water availability. The enzymes produced during germination lead to the hydrolysis of starch and proteins with release of sugar and amino acids directly available. Proteolytic enzymes improve amino acid availability, particularly lysine, methionine and tryptophan that are lacking in cereals. Malting process also reduces the phytate level of grain and improves iron and zinc availability, decreases tannins and total phenols contents, increase in vitamins (A, B, C, and E) content and develop characteristics flavor to the derive products (Taur *et al.*, 1984). Malting also reduces the milling energy (Swanstoo, 1994).

1.2 Statement of the problem

Wheat flour used for the production of biscuits is deficient in several nutrients including some vitamins, mineral elements as well as dietary fiber (Awan *et al.*, 1991). Sorghum is 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 our daily recommended intake. High-fiber content of sorghum is important for digestion, hormone production and cardiovascular health (Anon., 2017).

Wheat flour lacks certain essential amino acids such as lysine, tryptophan and threonine (Kent, 1983); hence, the low nutritive value of biscuits is an issue of great concern because biscuits are the most commonly eaten snacks by school children who need more protein per unit body weight than adults. Malting of sorghum helps in the production of simple sugar and free amino acids i.e. it improves amino acid availability, particularly lysine, methionine and tryptophan that are lacking in cereals.

Sorghum has been used for the production of lagers, stout, malta, hot malt drinks, malt based cereal breakfast etc. in Africa but industrial scale production and utilization of sorghum has not been practiced yet in Nepal. It can be grown easily in all climatic conditions ranging from sea level to Himalayas. It doesn't require more fertile soil as that is required for the wheat production, thus reducing the cost of production (Ogbonna *et al.*, 2012).

Thus, incorporation of malted sorghum flour for biscuits production can be milestone to overcome the nutritional short-comes mentioned above as well as it may be introduced in baking industries.

1.3 Objectives of the study

1.3.1 General objectives

The general objective of the dissertation work is to study the effect of incorporation of malted sorghum flour on quality of biscuit.

1.3.2 Specific objectives

1. Preparation of flour of malted sorghum.
2. Analysis of malted and un-malted sorghum flour and wheat flour.
3. Evaluation of sensory properties of prepared biscuits, and
4. Chemical analysis of control and most rated biscuit.
5. Calculate the cost of prepared biscuit.

1.4 Significance of the study

In fact, sorghum incorporation to produce biscuits is the first step to get sorghum enrolled in baking industries in Nepal. Sorghum is easily producible and blending of it with wheat flour in the preparation of biscuits (and to other confections too) will go a long way in reducing the country's heavy reliance on imported wheat and conserve the Nation Foreign Exchange.

Malting produces hydrolytic enzymes (amylases, proteases, lipase, phytase etc.). These enzymes help to modify sorghum grain structure so that flour is more easily solubilized during dough preparation. Malting also helps in the production of simple sugar and free amino acids i.e. it improves amino acid availability, particularly lysine, methionine and tryptophan that are lacking in cereals. Furthermore, it reduces phytate level of grain and improve iron and zinc availability and increase vitamins level. Malting facilitates caramelization to give malt its attractive brown color and malty flavor and thus to the biscuits.

Therefore, incorporation of malted sorghum flour with wheat flour to make biscuits provides a good opportunity to improve the nutritional quality of vitamins and minerals consumed by many people especially growing children.

1.5 Limitations of the study

1. Study was silent about the packaging material and shelf life of the product.
2. Texture analysis of the product wasn't carried out due to the lack of instrument.

Part II

Literature review

2.1 Biscuit

Biscuit, the word has come from the Latin word Bix-means twice and cuit means baked. In French, it is called bi-cuire- to cook twice (Smith, 1972). Reader's Digest Encyclopedia Dictionary defines Biscuit as a kind of crisp dry bread, more of less hard, variously flavored and usually unleavened, prepared usually in small, flat, thin cakes (Smith, 1972).

The definition of biscuit may differ from place to place, for example, biscuit is known as biscuit in the UK but called cookie in the USA. The USA biscuit may mean the equivalent of the English muffin.

2.1.1 Classification of biscuits

Biscuits are mainly classified as soft dough and hard dough type. The soft dough group includes all the sweet biscuits having many factors in common, but hard dough biscuits fall naturally into three sections: fermented dough, puff dough, and the semi-sweet dough (Whitely, 1971).

2.1.1.1 Soft dough biscuits

Soft dough biscuits are generally sweet, thin and have smooth un-cracked surface with dimensions they are much more regular and consistent than hard dough biscuits. They generally contain high fat (15-25%) and are low in moisture. The development of gluten is to be avoided here and this is achieved by using:

a) Flour of only 8.1 to 8.2% protein
b) More tenderizing agents
c) Less aerating agents
d) Less water and
e) Short mixing time

Although by varying the ingredients or their proportions, many varieties of biscuits can be formed. Sort dough biscuits are the least versatile because of the inherent nature of the dough required by moulding process in that it should be stiff, crumbly, low in moisture and relatively high in shortening. This limits inclusion of all ingredients that would contribute syrup, eggs and fat beyond a certain quantity. The dough requires no pre-treatment. One stage mixing is often perfectly satisfactory, but a creaming with most of minor ingredients ensures homogeneity.

2.1.1.2 Hard dough biscuits

Hard dough biscuits generally contain low fat (10-20%) and low or no sugar (0-8%). The dough adheres due to its high water content and relatively low amounts of fat and sugar, produces and extensive gluten system and structure. The long mixing time develops the gluten and the mixer action stretches and orients the gluten strands to a point where much of the elasticity is destroyed. Lamination and fermentation are also employed depending upon the rotary and reciprocating cutters. Hard dough biscuits can be broadly divided into:

a) Semi-sweet biscuits

The flour used in semi-sweet biscuits should be the weakest possible to obtain. This is because of the low amount of fat and sugar and high amount of water. The dough produces and extensive gluten structure and system. To prevent this, a long mixing time and addition of sodium metabisulphite are followed. Slow cooling is important as this is notoriously susceptible to checking (George, 1981).

b) Puff dough biscuits

This is hard biscuit being well layered and puffed to a low density and has a typical flavor vaguely reminiscent of fried goods such as doughnuts. These biscuits are comparatively expensive to produce. The leavening in the dough is by fat application in the biscuits in between the dough sheets, the most efficient manner being with an actual layering of an elastic dough phase and sheets of fats. The dough and fat should have nearly the same flow properties and care need to be taken that the fat does not become part of the homogeneous dough phase as this will not contribute to layering but instead reduces the elasticity of the dough and gives undesirable outcome.

In order to ensure proper thickness of each layer and proper retention of each layer in this final dough piece, the following conditions need to be maintained:

- The gluten must be developed to a point which will properly stretch during reduction.
- The roll in, though plastic and semi-solid, must gradually stretch along with the dough in order to break the continuity of its ultimate shape.

After mixing (15 min) and relaxation (30 min) 60% of the puff dough margarine is applied and sheeted. The sheet is laid off for 15 minutes and rest of the fat is applied (George, 1981).

c) Fermented biscuits

These biscuits include the cream and soda crackers. Crackers (salty biscuits) are prepared from large amount of flour containing protein (8-11 %) but small amount of sugar, oil of fat. Yeast is required for fermentation. Crackers have a flaky texture and crunchy bite. These biscuits can be either made by straight dough method or sponge dough method.

2.2 Chemical composition of biscuits

The chemical composition of biscuit may vary from type of biscuits, method of preparation and consumers' nutritional aspects, which is presented in Table 2.1.

Table 2.1 %Chemical composition of biscuit

Type	Protein	Fat	Total sugar	Other carbohydrate	Moisture	Salt and chemicals
Soft dough	6.00	15.80	25.88	49.18	1.25	1.34
Hard dough	7.18	12.26	19.15	59.40	0.90	0.56
Fermented dough	7.20	27.40	7.20	54.10	1.50	2.10

Source: Rao *et al.* (1991)

2.3 Raw materials for biscuit making

A variety of raw materials are used in biscuits industry whereas raw materials requirements for conventional biscuits produced in mechanized units are well defined. Wheat flour and cereal products, sugar, fat, and water etc. are the major of primary ingredients because they are used in bulk on dough according to the quality of the products.

Salt, skim milk powder (SMP), ammonium bicarbonate, sodium bicarbonate etc. are minor ingredients. Beside these, many coloring and flavoring agents, emulsifiers and other product improvers are used for developing the taste, texture, flavor and appearance of the biscuits. Therefore, these minor ingredients are known as product improvers (Shrestha, 1995). All the ingredients are individually important to obtain more palatable and satisfactory products. These raw materials are found in the form of solid, liquid and paste (Shrestha, 1995).

2.3.1 The major ingredients

1. Flour

Flour is the basic raw material of biscuit production and probably the most variable (Whitely, 1971) and flours for biscuits and cracker use vary in strength and baking characteristics (Bohn, 1956).

Wheat is only the grain, which could yield flour capable of being made into low-density baked products. Wheat is known botanically as *Triticum vulgare.* Wheat flour is obtained by endosperm in the form of particle small enough to pass through a flour sieve, for example one having 100 mesh per linear inch (Kent., 1983).

Wheat flour is unique among cereal flours in that it forms an elastic mass when mixed with correct proportion of water. This unique property is due to the presence of insoluble proteins, collectively called gluten. The gluten forming proteins (glutenin and gliadin) constitute about 75-80% of the total flour proteins. Glutenin gives solidity to the product whilst gliadin is the binding agent imparting the soft sticky character to the gluten. Gliadin is soluble in 70% alcohol and may be extracted from flour whereas glutenin is not soluble in alcohol and water.

Gluten is elastic, cohesive and rubbery and holds together the various ingredients of the dough. It has the property of holding the gases during fermentation and gases given off by the leavening agent during baking. It sets in the oven to form the firm, porous, open texture during baking which are necessary in the production of biscuits and crackers. Thus, gluten is the necessary framework forming the sustain wall of the whole structure of baked products (Bohn, 1956).

The general requirements for flour characteristics is mentioned in Table 2.2.

Table 2.2 Requirements for flour characteristics

Characteristics	Requirements
Moisture content	13.0% max
Gluten content (on dry basis)	7.5 % max
Total ash (on dry basis)	0.5% max
Acid insoluble ash (on dry basis)	0.05% max
Protein (Nx5.7) (on dry basis)	9.0% max
Alcoholic acidity (as H_2SO_4) in 90% alcohol	0.1% max
Water absorption	55% min
Sedimentation value	22% min
Uric acid (mg/100g)	10% max
Granularity	To satisfy the test

Source: Arora (1980)

Wheat flour (maida) used for making biscuit should be the product obtained by milling cleaned hard or soft wheat or their blends in a roller flourmill and bolting. Considerable importance is attached to the flour protein level in determining the suitability of flour for a particular type of biscuit. However, protein quality is the factor of most interest to biscuits makers in the context of flour quality. The gluten may be strong and difficult to stretch or weak and easy to stretch. The former is preferred to bread and some crackers and the latter for biscuits. Soft wheat flour is found to be better for making the biscuits.

The flour should be free flowing, dry to touch, should be creamy in color and free from any visible bran particles. It should also have a characteristic taste and should be free from musty flavor and rancid taste. Requirement for flour characteristics are given in above Table 2.2.

I. Other cereal products

- Corn Flour: Corn flour and maize starch are prepared from the cereal *Zea mays*. Maize is Indian corn. The two chief varieties are known respectively as flint maize and dent maize. Corn flour is milled from the endosperm of maize and is very nearly pure starch. Because of its high starch content, it can be used to weaken flour which is too strong.
- Oat flour: It has high nutritive value owing to high proportion of protein and fats.
- Rice flour: It is prepared from the cereal *Oryzea sative* or ordinary cultivated rice plant.
- Soy flour: The main function of soy flour when used in dough is as an emulsifying agent owing to presence of lecithin. It will result in an increase of biscuit color and bloom (Whitely, 1971).

II. Fats and shortening

Fats are one of the most important ingredients in biscuit making after wheat flour. One of the most important function of fat is to shorten baked products which otherwise might be solid masses firmly held together by strands of gluten. Being insoluble in water, fat prevents to cohesion of gluten strands during mixing. Thus, literally shortening then adds making the product tender (Whitely, 1971).

The action of fat in dough is more one of preventing the gluten forming than actually modifying. Gluten does not form until the flour is in contact with water and mixing action, thus inclusion of fat tends to insulate the gluten forming proteins from the water and consequently, a less tough dough results. Eating qualities after baking are less hard, shorter and more inclined to melt in the mouth (Whitely, 1971).

The secondary action of fat is to lubricate the gluten, which has formed allowing it to slip into a new position when sheeted or formed into biscuit shapes without the same desire to return to its original position. The fat also improves the softness, texture, palatability and keeping quality of biscuit. During mixing, fat also encourages entrapment and retention of considerable quantities of air, thereby contributing to the texture of the baked products (Whitely, 1971).

To achieve the best performance, hydrogenated vegetable oils to be used in crackers and sweet goods production should have the following desired qualities:

- The material should have the good white to creamy color.
- After keeping the fat at 50˚C for 24 h and filtering, the color may be compared with control or standard.
- The fat should have a smooth, uniform texture, free from aby oil separation and large grains.
- The fat should have bland "clear" odor and taste.
- Melting point of the fat should be less than normal human body temperature.
- The fat should have a wide plastic range to suit particular production techniques and the product.
- The fat should have stability of crystal structure both at mixing stage and ager baking.
- The fat should have reasonable shelf-life on its own and in the baked product.
- The fat should be prepared from a blend of oils, which will not cause fat bloom during shelf life of biscuits.

III. Sweetening agents

The majority of sweetening agents are obtained from sugar in one form or another, and sugar (sucrose) is derived from two sources. The main source is sugar cane and the secondary source is sugar beet (Whitely, 1971).

Sugar is another very important ingredient for the manufacture of biscuit of any variety. Quantity and crystal size of sugar exert a big influence on biscuit dimension and texture. Sugar being hygroscopic in nature as it assists moisture retention in the products and thus improves shelf life. It caramelizes during the process of baking and thus imparting appetizing crust color and acts as sweeteners, increases tenderness, contributes the volume and improves the flavor and controls the spread of the biscuit (Smith, 1972).

2.3.2 The minor ingredients

1. Leavening agents

Leavening agents is the term used to indicate a source of gas, which caused dough or batter to spring, giving a porous, open texture in the finished product. This gas can be released during mixing, after mixing and during baking by the influence of the heat of the oven (Bohn, 1956).

To increase the palatability and to improve texture, bite and appearance, it is necessary to achieve some form of aeration, which is done by mechanical, biological and chemical means.

- Mechanical aeration: Mechanical aeration is achieved without the use of ingredients, but by the method of handling the product. Beating and whisking are the main methods, and in these air is introduced to the product. Another method of mechanical aeration is in the use of layers of dough with an insulating material in between. Examples of this are production of crackers and puff biscuits (Whitely, 1971).
- Biological aeration: To bring about aeration by biological means, yeast is used. Yeast is a microscopic, unicellular organism that relies mainly upon sugars in solution for life and reproduction. It is capable of breaking down sucrose and maltose into monosaccharides and glucose and fructose into alcohol and carbon dioxide (Whitely, 1971).
- Chemical aeration: The most commonly used chemicals are sodium bicarbonate and ammonium bicarbonate. These chemicals when heated, volatilize or evolve a gas or mixture of gases. Ammonium bicarbonate, which is completely decomposed to give CO2, ammonia and steam and sodium bicarbonate that gives off CO_2 and steam.

$$NH_4HCO_3 \longrightarrow NH_3 + CO_2 + H_2O$$

(Ammonium bicarbonate)

$$(NH_4)_2CO_3 \longrightarrow 2NH_3 + CO_2 + H_2O$$

(Ammonium carbonate)

The chemical equation for the reaction of soda and the commonly use baking acid are as follows:

$$NaHCO_3 + HX \longrightarrow NaX + CO_2 + H_2O$$

(Sodium bicarbonate/soda) (acid)

$NaHCO_3$ + $C_4H_5O_6K$ $\longrightarrow$ $C_4H_4O_6NaK + CO_2 + H_2O$

(Sodium bicarbonate/soda) (cream of tartar) (sod.pot.tartarete)

Both sodium bicarbonate and ammonium bicarbonate react with acidic ingredients if any, in the dough. Use of an excess ammonium bicarbonate makes the dough more alkaline and thereby may affect the protein structure of the dough. Use of an excess sodium bicarbonate will affect the crumb and crust color often with an accompanying unpleasant of soapy taste, unless any acidic material is used to neutralize the residual sodium carbonate (Smith, 1972).

2. Emulsifying agents

Emulsifying agents are surface active agents promoting the formulation and stabilization of emulsions. These products play a very important role in biscuit formulation ensuring proper mixing of lipid and aqueous fraction and good texture. The unifying property of emulsion is the presence of a hydrophobic and lipophilic group on the same molecule. Most commonly used emulsifiers are lecithin, eggs, mono and diglycerides etc. Lecithin may be much more useful as an antioxidant also (Smith, 1972).

3. Milk solids

Milk solids increase the nutritive quality of the biscuit and also help in the retention of the improved flavor and also improve crust color. Milk solids in biscuit also enhance crust bloom tenderness and texture without altering the symmetry and crumb color.

Lactose helps the formation of melanoids, the principle coloring substance, formed by the reaction of sugars and amino acids from the proteins under influence of heat (Smith, 1972).

4. Common salt

Salt, though is least respected, is one of the most important ingredient in biscuits. It enhances the natural or others added flavors. Salt is used in almost all recipes for its flavor and flavor enhancing properties. Biscuits without salt do not always lack flavors but insipid. Its most effective concentration is about 1.0-1.5% based on the flour weight, but at a level more than 2.5%, the taste becomes unpleasant (Smith, 1972).

5. Flavoring agents

The majority of the flavors used in biscuits making are derived from natural sources and these are in many ways most satisfactory. To get good distribution in a dough, the flavor should be creamed with the sugar and shortening at the beginning of mixing. Commonly used flavoring materials are common salt, yeast, extracts, spices and essences (Whitely, 1971).

6. Coloring agents

Color should be used to enhance the eye appeal of the product, and the use of correct color to suggest flavor should be linked directly to the type of flavor in use. Caramel is the most widely used color in biscuit making. The use of caramel is sage and will also impart a distinctive flavor of burnt sugar when used in fairly large quantities (Whitely, 1971).

Coloring agents, flavoring agents, jams, jellies, fruits and nuts offer variety to the manufacturers (George, 1981).

7. Water

Quality of water has greater effect on the baking product. Dissolved mineral and organic matters present in water can affect the flavors, color and physical attributes of the finished baked products.

2.4 General requirements for biscuit according to Nepal Bureau of Standard

Biscuits should have been properly baked, crisp and uniform in texture and appearance. They should have characteristic flavor and should be free from bitterness after eating. They should be free from fungus, rancid taste, off odor and any insect infestation. For filled biscuits, any of filling materials like jam, jelly, marshmallow, cream, caramel, raisins etc. may be used. The biscuits may be coated with caramel of chocolate. The requirements for biscuit according to Nepal Bureau of Standard is presented in Table 2.3.

Table 2.3 Compulsory requirement of biscuit according to Nepal Bureau of Standard

Characteristics	Requirements
Moisture	6.00% max
Acid insoluble ash (on dry basis)	0.05% max
Acidity of extracted fat (as oleic acid)	1.00% max

Source : NBSM (2040)

2.5 Nutritive value of biscuits

Biscuit is a good source of nutrients because it contains carbohydrates, fats, proteins, minerals and vitamins. Carbohydrate and fats provide heat and energy to the body. The proteins are materials for growth and repair of tissues whilst minerals provide materials for bone growth and repair and in association with vitamins for the regulation of the processes and maintaining normal vitality. Nutritive value of biscuits is given in Table 2.4.

Table 2.4 Nutritive value of biscuit

Weight per serving (g)	100
Calories (Kcal)	480
Protein (g)	5.2
Fat (g)	20.2
Carbohydrate (g)	71.0
Calcium (g)	0.004
Phosphorus (g)	0.16
Iron (mg)	1.8
Thiamine (mg)	0.003
Riboflavin (mg)	0.004
Nicotinic acid (mg)	0.8

Source: Swaminathan (1991)

2.5.1 Effect on nutritive value of biscuit during baking

Since biscuit is cereal based product, cereals have been studied in depth form the standpoint of their nutritive value. It usually contains valuable nutrients for the human being such as vitamins, mineral, salts, proteins, and enzyme. Biscuit needs to be processed at higher temperature. Nutritive value is modified during baking. The most interesting and evident phenomenon is the caramelization consisting of a series of modifications that occur specially in the presence of high temperature, between reducing sugar and amino acid of protein. Lysine by being present in protein is the most effective amino acid in this reaction. In the case of wheat, although it is the limiting amino acid, it would be first partly blocked and then destroyed leading to the loss in protein value. The caramelization finds ideal conditions in those oven product that belongs to the category of sweet.

2.6 Sorghum

2.6.1 Origin of sorghum

Sorghum (*Sorghum bicolor* L. Moench) is a member of the subfamily *Panicoideae* in the family *Gramineae*. Sorghum Moench is a large and heterogeneous genus belonging to the Andropogoneae tribe in the botanical family Poaceae (Johnson and Peterson, 1974). Sorghum is the term used to refer to the kernels or caryopsis produced by sorghum.

"Milo" and "grain sorghum" are popular terms used to refer to sorghum in US. Other terms still used to describe sorghum are milo maize, gyp corn, hiegar, grain and kafir corn. Similarly, Jowar, Juar and Cholan are common names for sorghum in India and Junelo in Nepal. Likewise, kafir corn in South Africa, Guinea corn in West Africa, Kaoliang in China and Great millet in England (Johnson and Peterson, 1974). Five sorghum races, bicolor, guinea, durra, caudatum, and kafir are identified, each with a distinctive geographic range and place in indigenous African and Asian agriculture as well as morphological and use differences (Fig. 2.1). Bicolor is the first evolved race, and most cultivated sorghum around the Asia and can be incorporated in biscuit by malting or without malting (Ogbonna *et al.*, 2012).

Sorghum originated in Central Africa with various hypotheses placing the domestication of sorghum sometime between 4500 and 1000 B.C., after which it spread to Asia and India

(Kimber, 2000). It is adapted to semi-arid regions with a minimum average rainfall of 350-400 mm. The sorghum plant is uniquely well adapted to these conditions in that it is drought resistant and will withstand periods of flooding. In fact, sorghum can produce a crop in these regions, where other cereals such as barley and maize cannot be economically cultivated (Doggett, 1988).

Sorghum is considered the fifth most important cereal crop in the world behind wheat, rice, maize, and barley. Sorghum is Africa's second most important cereal in terms of both area harvested and annual production. According to the latest global statistics (FAO, 2008), Africa contributed over 60% to the total land area dedicated to cultivation of sorghum.

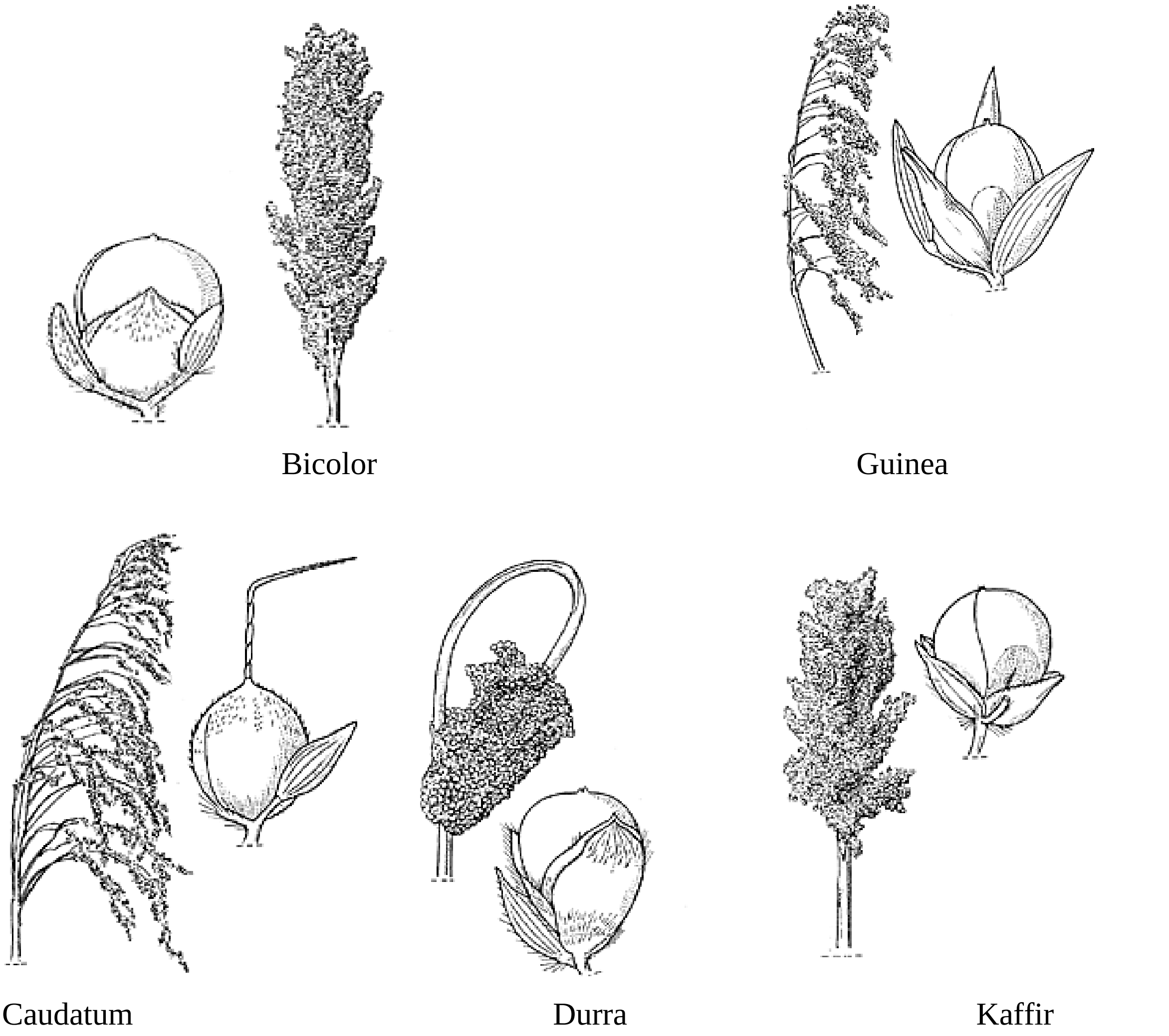

Fig. 2.1 Panicles and mature grains still enclosed within their glumes for each of the five sorghum races.

Source: Wrigley *et al.* (2004)

Johnson and Peterson (1974) classified the cultivated sorghum into four major categories based on agronomics, plant and major uses:

a) Grain sorghum

- dwarf breed specially for grain production

b) Sweet/ forage sorghum

- tall, sweet, juicy stalks used for forage, syrup and sugar production.

c) Grassy sorghum

- have thin stems, narrow leaves and numerous tillers which make them useful for hay or grazing of livestock.

d) Broom corns

-have long panicle branches which are useful for production of brooms.

Sorghum is a staple food crop of millions of poor people in semi-arid tropics of Africa and Asia. Sorghum is an important food staple in many arid parts of the world due to its drought tolerance; it often grows where other cereal crops fail. However, it has gained increasing importance in as a fodder (green/dry) and feed crop in the last decade.

2.6.2 Production

Sorghum forms an important dietary component of many people globally, with the most significant contribution being in the arid and semi-arid lands in many African and Asian countries. 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 as shown in Fig. 2.2 (FAO, 2008).

Sorghum is grown on approximately 44 million hectares in 99 countries. An estimation of the world-wide tonnage produced in 2007-2008 is shown in Table 2.5.

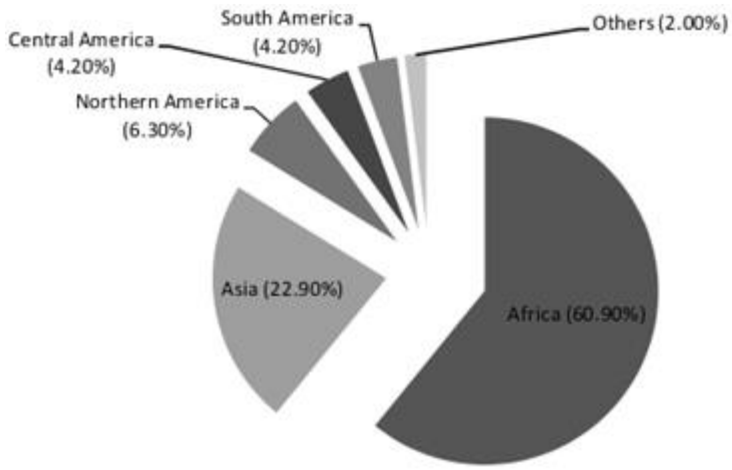

Fig 2.2 Proportion of area devoted globally to sorghum production in the year 2008

Source: FAO (2008).

Table 2.5 World sorghum production 2007-2008

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: FAO (2008)

2.6.3 Physical properties

Sorghum is a naked kernel, free from hull. In terms of size and shape, sorghum varieties differ widely. The general size of sorghum is 4 mm long, 2 mm wide and the test weight is 25-35 mg, with a density usually in the range of 1.15-1.38 g/cm^3 (Serna-Saldivar and Rooney, 1995). The shape varies from obovoid to ellipsoid with 1000 kernel weight varying from 30 to 80 g.

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). The general structure of Sorghum kernel is shown in Fig. 2.3.

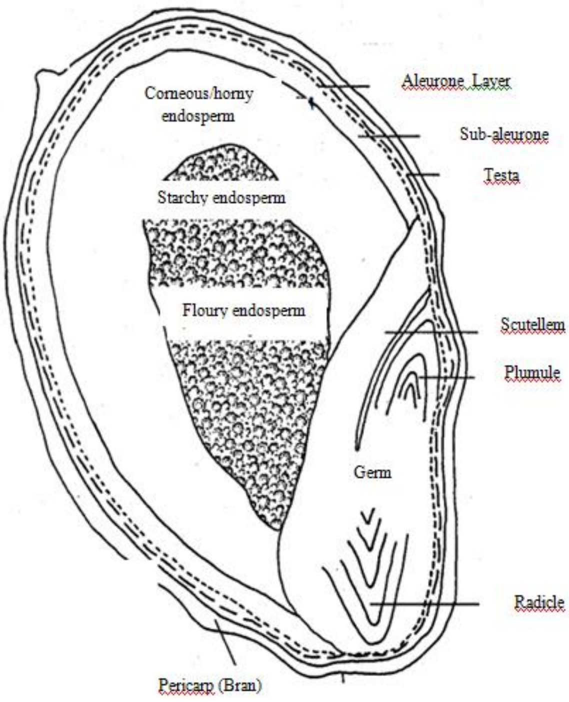

Fig 2.3 Structure of Sorghum Kernel

Source: Mugode (2009)

The pericarp is three-layered with epicarp, mesocarp, and endocarp of cross cells, tube cells, and aleurone cells. The aleurone layer cells could have been absorbed and absent, or in other circumstances, this layer persists and is present in mature seed as the testa. Below the pericarp is the corneous endosperm, which may surround (fully or partially) the inner floury endosperm. The starchy endosperm consists of cells in which starch granules are encapsulated in a matrix of protein. At the base of the seed, in an angle, is the scutellum (towards the endosperm) covering over the embryo. The embryo consists of the embryonic axis at the top of which is the shoot (develops into stem, leaves, and inflorescence) and at the bottom is the radicle (develops into roots). The physiologically mature seed has a dark hilum at the base, where it was connected to the ovary. The hilum consists of dried up transfer cells, placento-chalazal pod, and phloem parenchyma (Wrigley *et al.*, 2004).

2.6.4 Chemical properties

The proximate composition of sorghum grain varies significantly partly because of wide varietal differences but mainly due to the diversity of environmental conditions (such as water availability, soil fertility and temperature) under which sorghum is grown (Klopfenstein and Honesey, 1995). The chemical composition of the components of the kernel by weight are pericarp (outer bran part) 7.9%, endosperm (storage organ) 82.3% and germ 9.8% (FAO, 1995). Brief composition of whole fractions as well as its fractions is given in Table 2.6.

Table 2.6 Composition of whole kernel and its fractions

Kernel Fraction	%of kernel fraction	Starch (%)	Ash (%)	Oil (%)	Protein (%)
Whole Kernel	100	73.8	01.67	3.6	12.3
Endosperm	82.3	82.5	00.37	0.6	12.3
Germ	9.8	13.4	10.4	28.1	18.9
Bran	7.9	34.6	2.00	4.9	6.7

Source: FAO (1995)

2.6.5 Sorghum utilization

Total consumption of sorghum closely follows the global pattern of output, since most of it is consumed in the countries where it is grown. Sorghum is used for two distinct purposes: human food and animal feed. Although in the early 1960s a very large part of the sorghum output was used directly as human food, its share has continuously declined since then. In fact, consumption of sorghum as animal feed has more than doubled, from 30 to 60 percent, since the early 1960s, while the volume of total food use has remained unchanged or has slightly declined. In North and Central America, South America and Oceania most of the sorghum produced is used for animal feed. The average Sorghum utilization in terms of million tons in the year 1981-85 is presented in Table 2.7.

Table 2.7 Sorghum utilization, 1981-85 average

Region	1981-85 average (million tons)			
	Food	Feed	Other uses	Total
Africa	8.0	0.4	2.3	10.7
Asia	15.1	6.3	2.1	23.5
Central America	0.3	8.4	0.2	8.9
South America	-	4.6	0.3	4.9
North America	-	12.6	0.1	12.7
Europe	-	1.4	-	1.4
World	23.4	36.4	5 3	65.1
Developing countries	23.2	15.6	4.8	43.6
Developed countries	0.2	20.8	0.5	21.5

Source: FAO (2008)

A. 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 capita consumption of sorghum is high in countries or areas where climate does not allow the economic production of other cereals and where per capita 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 capita consumption of sorghum can reach up to 100 kg per year. Other countries with significant per capita 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 (Table 2.7). 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 capita 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 capita food use of sorghum declined (FAO, 1989).

This decline in per capita 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).

A. 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).

B. Starch industries

Some of the India's main starch manufacturers, who are primarily based in Ahmedabad, have used up to 50000 t 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).

C. Other industries

Although beer 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).

During the 1970s, when there was a shortage of wheat in India, the Government tried to encourage the use of composite flours, which, however, failed. The Central Food Technology Research Institute (CFTRI) at Mysore carried out extensive research on the constitution of composite flours and their suitability for different uses in the food industry (Kleih *et al.*, 2007).

Bread manufacturer in Mumbai (seven-grain bread) is using sorghum along with other flour for making bread. As Nepal is not independent of wheat used in baking industry, the sorghum incorporation can be the potential alternative (Kleih *et al.*, 2007).

D. Animal feed

Grain use for animal feed has been a dynamic element in the stimulation of global sorghum consumption. The demand for sorghum for feed purposes has been the main driving force in raising global production and international trade since the early 1960s. The demand is heavily concentrated in the developed countries, where animal feed accounts for about 97 percent of total use, and in some higher-income developing countries, especially in Latin America where 80 percent of all sorghum is utilized as animal feed. The United States, Mexico and Japan are the main consuming countries, followed by Argentina, the former Soviet Union and Venezuela. These countries together, account for over 80 percent of world use of sorghum as animal feed (Kleih *et al.*, 2007).

2.7 Malting

Malting is controlled germination process which produces a complement of enzymes which are able to convert cereal starches (endosperm) to fermentable sugars, to secure an adequate supply of amino acids and other minor nutrient for yeast and modify the quality of the micro molecules which have such important effects on physical quality of beer.

The maltster is concerned with both degradation of the endosperm and the accumulation of the enzymes in the grains. But the growth of the germs of embryo is an incidental to making of malt and leads to unwanted depletion of the endosperm material through respiration of the embryo when degradation of the endosperm has progressed to only a limited extent, the maltsters terminates the growth of embryo by drying the grain. In order that the storage of malt is possible for long period in stable periods, it has been customary for the maltsters to continue the drying, beyond that required arresting growth, by kilning (Anon., 2017a).

2.7.1 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).

2.7.2 Effect of malting on sorghum

2.7.2.1 Effect on protein quality

A major objective of malting is to promote the development of hydrolytic enzymes, which are not present in the non-germinated grain. Sorghum malt quality (at least for sorghum brewing) is assessed primarily in terms of DP and FAN. DP is a measure of the joint activity of α- and ß-amylase. In general, the DP of the malts increased with increasing germination time to about 6 days.

FAN is produced during malting by the action of endogenous proteinase and peptidase enzymes on the protein reserves of the grain and the breakdown products are collectively referred to as FAN. For all the sorghum varieties tested malting improved malt FAN, which increased with increasing germination time over the 8-days malting (Dewar *et al.*, 1997). The effect of malting time on the diastatic power and free amino nitrogen content of sorghum malts is presented in Table 2.8.

Malting also significantly ($p<0.05$) improved the in-vitro digestibility and the quality of the sorghum protein, which increased with increasing malting time. For the Kenyan local white variety malting improved the digestibility of the protein by a staggering 110% and increased the percentage protein, the nitrogen solubility index and lysine content by as much as approximately 8.5, 251 and 32%, respectively. It should be noted that the improvement in lysine content is not simply a consequence of protein concentration but rather a true increase in lysine. The significant increase in the NSI supports the idea that the increase in in-vitro protein digestibility is probably due to structural changes and the enzymic hydrolysis of proteins into more digestible forms such as amino acids and small peptides. The evidence would seem to support the suggestion that the simple technology of malting offers a means by which to improve the quality and digestibility of sorghum protein (Dewar *et al.*, 1997).

Table 2.8 Effect of malting time on the diastatic power and free amino nitrogen content of sorghum malts

Sorghum grain	Malting time (days)			
	3	4	6	8
Diastatic Power (SDU/g)				
NK 283	9	18	27	23
PAN 8564	13	21	32	27
KAT 369	7	13	12	9
Local white	13	26	25	6
Free amino nitrogen (mg/100 g)				
NK 283	50	78	110	117
PAN 8564	53	85	122	135
KAT 369	53	74	109	113
Local white	85	118	195	199

Source: Dewar *et al.* (1997)

2.7.2.2 Change on physical structure

During germination enzymes migrate from the germ and partially break down the endosperm starch granules and protein bodies and matrix. The general pattern of migration of enzyme during germination is as shown in Fig. 2.4.

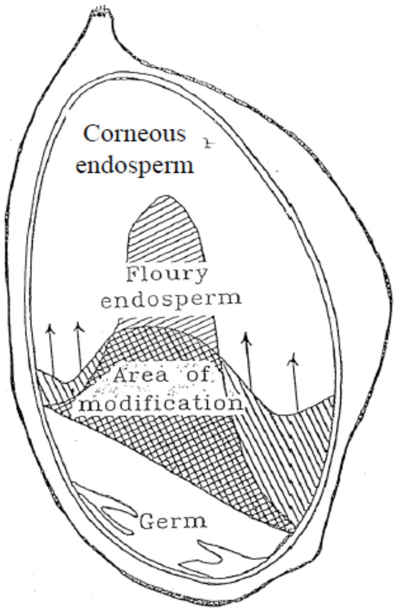

Fig 2.4 Showing the migration pattern of enzyme during germination

Source: Dewar *et al.* (1997)

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.

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.

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. 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 (Dewar *et al.*, 1997).

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 (Dewar *et al.*, 1997).

2.7.2.3 Change in minerals

The mineral composition of the malted sorghum increased above the values of the unmalted sorghum with increasing steeping and germination periods. As result of malting, sodium can be increased up to 123%, potassium 29.55%, phosphorus 45.71%, calcium 157% and magnesium 93.33% (Ogbonna *et al.*, 2012).

2.7.2.4 Change in anti-nutritional factors

Calcium is released from oxalate complexes and iron from protein-tannin complexes (Emmanbux and Taylor, 2003). The rate of reduction depended on the age of the malt. However, the rate of reduction in tannin is less than that of phytate possibly because while phytate is degraded by malt enzymes, tannins are only leached out (Idris *et al.*, 2007). Hence, the combined effects of the physical and enzymatic actions on the sorghum grain during malting dramatically decreases the concentration of anti-nutritional factors in the malted sorghum grist.

2.7.2.5 Enzyme activation during sprouting

In germination seed, enzymes may arise from two sources:

1. They may be released or activated from existing proteins or
2. They may be synthesized through nucleic acid-directed protein synthesis.

Enzymes of the particular interest are starch degrading enzymes, α- amylase and β-amylase. Germination leads to the production of both enzymes, with α – amylase is formed and the quantity of β-amylase increases; the β-amylases predominating in the final malt. Generally, the temperate climate cereals, sorghum, wheat and rye produce on germination high diastatic power. The hot climate cereals, sorghum, maize, millets produce much lower diastatic powers. The diastatic power developed during malting depends on (McDonald, 2014)

1. Temperature of malting;
2. The moisture level;
3. The percentage of germination, germination vigour;
4. Duration of malting; and
5. The cultivar employed.

Synthesis of enzyme is inactivated by puromycin, a specific inhibitor of ribosomal protein synthesis. So it is clear that α- amylase is synthesized de novo from amino acid in the aleuronic layer and that the synthesis involves the decoding of mRNA by ribosomes. It has been proved that α- amylase is more de novo germinating sorghum-aleuronic cells. On imbibitions the embryonic axis secretes into either the aleuronic layer or which of the seed where it stimulates the total synthesis of α- amylase.

β - amylase, which normally represents the minor portion of the total amylolytic activity, is resent in the unfermented seed in an inactive form probably attacked in wheat at least by disulphide linkages to glutenin. Its activation is due to its release from the glutenin with the formation of active SH groups. The mediator of this reaction is unknown (McDonald, 2014).

It has been reported low temperature kilning schedule produce malts with greater α-amylase activity. According to (Dewar *et al.*, 2004), germination with the high watering regime gave the highest level of total β-amylase activity. They also reported that α – amylase enzyme is inactivated at the high water regime.

2.7.3 Malting operation

The sequence of operation in malting is as follows:

1) The collection of stocks of suitable sorghum,
2) The storage of the cereals until it is required,
3) Steeping the grains in water, germination of the grains, and
4) Drying and curing on a kiln.

Steeping an arranged so that sufficient moisture outers the grain to initiate germination. The moisture content of 42-46 % (wet weight basic) that is eventually achieved is sufficient to support growth and biochemical alteration in the grains during the malting period, without, however, allowing excessive growth (Dewar *et al.*, 2004).

Since growth, results in the production of largely unwanted rootlets and loses in dry weight due to grain respiration. A balance must be struck between achieving sufficient growth to adequately alter the sorghum into malt but without excessive growth that would reduce the quality of malt eventually produced. In newer malting processes, the wetted grain may be drained and aerated at intervals and germination may commence before the grain contains sufficient to malt adequately. Thus, the steeping and germination tend to merge (Dewar *et al.*, 2004).

Germination traditionally carried out in darkness at relatively low temperature 12-15˚C for choice but this could not be easily controlled. Originally it was processed in autumn, winter and spring to take advantage of the cool weather but never malting have temperature-controlled atmosphere. Regulating the moisture and temperature of the grain controls the intensity of germination process. The changes occurring in germination that are essential in converting sorghum into malt are collectively termed as "modification" and may be summarized as follows. First may hydrolytic enzymes appear and increase in amount, adding to those that are already present in the sorghum. These enzymes began to catalyze the hydrolytic degradation of the reserve substances at the starchy and endosperm and in the particular cell wall are partially or completely degraded resulting in loss of storage. Consequently, simple roller may readily crush dry malt in contrast to dry sorghum. Gummy polysaccharides are also degraded during malting so that the work derived from malt has a low viscosity compared with extracts of raw sorghum. Simple water-soluble product of hydrolysis accumulates in the grain during malting (Dewar *et al.*, 2004).

Kilning, the hot air drying and cooking stages, terminates germination and produces a dry, easily milled products from which the dry, brittle, rootlets are easily separated. The pored products belling dry, can be stored for long periods, in addition to drying, killing removes a raw flavor from the green malt and imparts other flavors and colors to the products, at the same time, the chemical composition of the malt is modified in particular enzyme content is reduced (Dewar *et al.*, 2004).

2.7.4 Moisture content and its effect

The moisture content is needed to control the germination process. Water sensitive grain will usually germinate only if steeped to about 35% moisture. Following and air rest and the onset of germination, the moisture of water sensitive grain may safely be increased further to allow satisfactory modification. In the past in floor malting, low nitrogen-grain was steeped to 43% moisture, steeply grain to about 45% moisture. However, in pneumatic malting where evaporation from the grain is inevitable, the grain has to be sprinkled with water during germination to maintain its moisture content. At higher moisture content, modification proceeds more rapidly than at lower moisture content. Without the methods of control, however, embryo growth and hence rootlet production and total malting loss may be proportionately greater (Hough, 1985).

2.7.5 Temperature and its effect

In traditional floor malting, a long cool germination period of up to 13 days at 12 - 14˚ C was preferred. As the temperature of malting increases, the respiration rate of the grain, the rate of growth of roots and the rates at which enzymes formed also increases. However, these changes are not all accelerated in the same proportion by increases temperature so that carrying out germination at progressively higher temperature do not merely produce the same malt in shorter time. This is illustrated by the fact that at lower germination temperature enzymes such as a-amylase and protease increases in amount slowly but ultimately reach levels higher than those attained at higher germination temperature (Hough, 1985).

2.8 Technology involved in biscuit making

All over the world, manufacturing processes have been replaced by new and advanced automatic machines with high output. Although why and where forces of material and chemical changes inherent in biscuit manufacturing have been analyzed and studied. The general flowsheet of manufacturing process of biscuits is as shown in Fig. 2.5.

Preparation of ingredients

↓

Creaming, mixing and kneading

↓

(Performing is done for hard dough and fermented dough process)

↓

Forming (moulding, cutting etc)

↓

(Moulding for soft dough biscuit)

↓

Baking (temp. 150 to 250°C, time 6 to 7 min)

↓

Cooling (6 to 7 min)

↓

Wrapping and packaging

↓

Storing (RH 40 to 59%, temperature: 23 to 27°C)

Fig. 2.5 Flow sheet of general manufacturing process of biscuits

Source: Smith (1972)

2.8.1 Mixing biscuit dough

Various types of mixer with different blade configurations and motor speeds carry out mixing operations. The main objective of such mixing machines is blending together a variety of ingredients to form homogeneous mass. Therefore, mixing is the heart or the most important unit operation of the biscuit industry. Proper mixing equipments and mixing methods play a vital role in good biscuit production (Whitely, 1971).

There are two basic methods for mixing soft dough but each may have variations designed to achieve the best result under the particular circumstance prevailing and depending upon the equipment used.

1. Creaming method

This consists of blending of sugar and fat (including syrup and other general ingredients) together with water to form a smooth homogeneous cream. During this stage; color, essence are added. While the cream is being prepared, aerating chemicals and salt are dissolved in some of the dough water and added to the cream for a short period. The flour is fed into the machine and as it starts to blend in with the cream and remaining water is added. Mixing continued until desired dough consistency is obtained (Whitely, 1971).

2. All in one method

In this method, all ingredients are fed into the machine and as blending commences, the dissolved aerating chemical, salt, color, essence and water are added. This method is more direct and straight forward but produces dough rather more dense and tough than one produced by the creaming method (Whitely, 1971).

2.8.2 Performing and forming

Hard dough and fermented dough are laminated and gauged (reduced) to suitable thickness according to the requirements. The dough sheets are cut or stamped and dough scraps are sent back to the laminator.

Soft dough are directly fed into moulding disc and mould according to requirements, there is no dough scraped in soft dough.

2.8.3 Baking

The objective of baking is to remove extra moisture present in the dough pieces by gradually heating. The dough contains more than 25% moisture part of which is bound moisture in flour and other ingredients and balance due to the added water tender the dough machinable.

Heat is transferred by three means that is conduction, convection and radiation. Within the oven dough pieces undergo two types of changes; i.e. physical and chemical. The changes taking place sequentially at different temperature during baking is mentioned in Table 2.9.

1. Physical changes
    - Crust formation on top.
    - Melting of the fat in the dough.
    - Gas release and volume expansion.
2. Chemical changes
    - Starch gelatinizing
    - Protein changes
    - Caramelization of sugar and dextrinization

Source: Smith (1972)

Table 2.9 Sequential changes at different temperature during baking

Temperature (˚F)	Changes take place
90-100	Top crust skin formation (evaporation of surface moisture)
90-120	Evolution of CO_2 within crumb (less solubility of CO_2)
90-150	Increase in volume due to CO_2
90-210	Gas expansion (CO_2 and steam)
125-210	Starch gelatinization (biscuit structure)
170-190	Evaporation of alcohol, yeast action ceases.
170-250	Coagulation of protein
350-400	Caramelization (combustion of sugar like fructose and glucose)
370-400	Dextrinization (surface gloss)

Source: Smith (1972)

It may be noted that these changes all take place within specified baking time, which is shown in Fig. 2.6. The baking time for the biscuit is different from type of product.

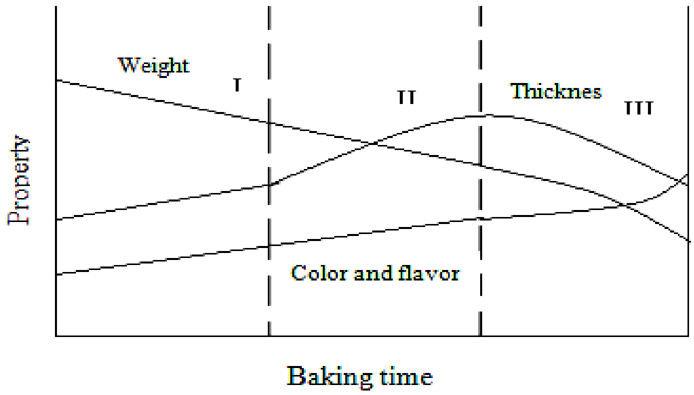

Fig 2.6 Changes taking place during baking of biscuit dough

Source: Smith (1972)

I. Expansion of dough and loss of moisture starts.
II. Expansion of dough and moisture loss reaches maximum, coloration starts.
III. Thickness and moisture loss decreases, color continues to increase.

2.8.4 Cooling

The biscuit coming out from the oven are in elastic form. They can easily bend without breaking while hot. This is attributed to the behavior of sugar in the product, which on cooling imparts physical strength and stiffness to the products. There is also appreciable loss of moisture as the biscuit cool and this is beneficial to the quality and shelf-life.

2.8.5 Packaging

As biscuits are dried food products whose moisture content is low. The relative humidity of freshly baked biscuit is very low and hence to prevent rapid uptake of moisture from the atmosphere, packaging of good water vapor resistance is required. Since biscuit also contains fat which is sensitive to odor, a non-tainting material with good grease resistant properties is necessary. This may be achieved by wrapping the biscuit tightly together, which provides a mutual reinforcing effect, e.g. at retail level, they are generally packaged in triple laminates consisting of polyethylene, aluminum foil and paper. Some of the characteristics of packaging materials is presented in Table 2.10.

Table 2.10 Some characteristics of packaging materials

Component	Properties
Low density polyethylene	Moisture and water vapor barrier, heat sealing medium.
Paper	Stiffness, low cost, opacity and printable
Aluminum foil	Opacity, decorative effects, 100% barrier to gases
Oriented polyethylene terepthalate	Gas barrier, strength, grease resistance.
Poly vinyl chloride (PVC)	Transparency, rigidity, gas barrier

Source: Smith (1972)

2.9 Sensory attributes of biscuits

Biscuit is a low moisture product generally used as snack item. Moisture content has very significant bearing on overall sensory quality of product. The crispiness of the biscuit can only be protected by applying suitable quality of packaging material having low permeability of water vapor (moisture) and oxygen. There are numbers of sensory attributes, which are critically desired in a normal quality of biscuit. They are appearance, crispiness, crumb, color, flavor (taste and smell), overall acceptability etc.

Part III

Materials and methodology

3.1 Raw material

White wheat flour (Fortune maida) used for biscuit making was obtained from local market of Dharan. Sorghum was collected from Rampur, Chitwan. The other raw materials such as sugar, salt, fat in the form of vegetable ghee (Delicious fat spread), lecithin, flavor and skimmed milk powder was collected from local market of Dharan. Sodium bicarbonate, ammonium bicarbonate and sodium meta-bisulphite were obtained from the laboratory of Central Campus of Technology, Dharan.

3.2 Preparation of sorghum malt

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) as shown in Fig. 3.1.

3.2.1 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.

3.2.2 Steeping

Cleaned seeds were transferred to the stainless vessel 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±3°C) and drained to remove the excess water. Then it was dipped in KMS solution for 10 min to prevent the mold growth.

3.2.3 Germination

The steeped grain was first collected in a muslin cloth and swirled in order to drain excess water. The grains were placed in dessicator and kept for germination in incubator at 20°C and RH 95% for 5 days.

Sorghum grain

↓

Cleaning

↓

Steeping (sorghum: water=1: 3, 24 h)

↓

Germination (20°C, 95% RH for 5 days)

↓

Drying / Kilning (50°C for 24 h)

↓

Removal of acrospires

↓

Sorghum malt

↓

Milling to obtain flour

↓

Sieving (400 micron sieve)

↓

Sorghum flour

↓

Analysis　　Packaging

Fig. 3.1 Flow diagram for preparation of sorghum malt

Source: Ratnavati and Chavan (2016)

3.2.4 Drying/ malt kilning

Germinating sorghum were dried to stop further germination. Drying was carried out in a cabinet drier at 50°C for 24 h until the constant weight was obtained. After drying, the rootlets were removed and the prepared malt was packed in airtight glass bottles.

3.3 Experimental procedure

3.3.1 Physical analysis of raw materials and final product

3.3.1.1 1000 kernel weight

The 1000 kernel weight of sorghum was 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).

3.3.1.2 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:

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

3.3.1.3 Particle density

True density of grain was measured by turpentine displacement method as mentioned in (Simonyan *et al.*, 2007).

3.3.1.4 Porosity

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

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

3.3.1.5 Sphericity

Sphericity of grain was determined as mentioned in (Simonyan *et al.*, 2007).

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

Where, l = length of grain

b = breadth of grain

t = thickness of grain

3.3.1.6 Spread ratio

The spread ratio of the biscuit was determined by using the formula as per AOAC (2005).

$$\text{Spread ratio} = \frac{\text{Diameter (mm)}}{\text{Thickness (mm)}}$$

Where, diameter was measured in mm by vernier caliper and thickness was measured in mm by screw gauge.

3.3.1.7 Volume

Volume of the biscuit was determined by the area of biscuit multiplied by thickness as per AOAC (2005).

$$\text{Volume (cm}^3\text{)} = \frac{\pi d^2 t}{4}$$

Where, t = Average thickness of biscuit (mm)

d = Diameter of biscuit (mm)

3.3.1.8 Density

Density of biscuit was obtained by the ratio of mass to the volume of the biscuit as per AOAC (2005).

$$\text{Density(g/cm}^3\text{)} = \frac{\text{Mass (g)}}{\text{Volume(cm}^3\text{)}}$$

3.4 Determination of threshold of malted sorghum flour

The independent variable of the experiment is malted sorghum flour. The determination of threshold for malted sorghum flour was carried out with the help of trial experiment. The result of trial experiment concluded that above 50%, the biscuit was not acceptable. Therefore, the threshold for malted sorghum flour is set between 0 to 50%.

3.5 Preparation of biscuits

The biscuit was made as per the recipe formulation done and coded name A, B, C, D, E, F and G were given to each recipe. Composite biscuit were of soft dough type method. Biscuit was prepared at laboratory of Central Campus of Technology. The ingredients used were as follows:

Ingredients /Samples	A	B	C	D	E	F	G
Wheat flour	75	83.33	87.5	62.5	100	66.66	50
Malted sorghum flour	25	16.667	12.5	37.5	0	33.33	50
Sugar	35	35	35	35	35	35	35
Fat	33	33	33	33	33	33	33
Sodium metabisulphite	1	1	1	1	1	1	1
SMP	4	4	4	4	4	4	4
Lecithin	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ammonium bicarbonate	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sodium bicarbonate	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Flavour	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Water	10	10	10	10	10	10	10

The biscuit was baked in an electric oven maintained at suitable temperature profile. The time taken for complete baking is around 6 min. The baked biscuits were then collected, cooled and packed into bags for further analysis.

3.6 Manufacturing process of biscuit

The process for preparing malted sorghum flour incorporated biscuit is shown in Fig. 3.2. Slight changes were made in the preparation of biscuit as that given by (Smith, 1972).

Fat, water and sugar
↓
Creaming (approx. 5 min)
↓
Cream ← Composite flour (Wheat flour: Malted sorghum flour) + Sodium bicarbonate+ Ammonium Bicarbonate+ Lecithin+ Sodium metabisulphite+ SMP+ Flavor
↓
Mixing by hand
↓
Forming (5-6 mm thick)
↓
Cutting and Stumping (55 mm diameter)
↓
Baking (200^{o}C, 15 min)
↓
Cooling (35^{o}C)
↓
Packaging and storage at ambient temperature

Fig. 3.2 Flow sheet of manufacturing process of biscuit

Source:Smith (1972)

3.7 Analytical procedures

3.7.1 Physicochemical analysis

3.7.1.1 Moisture content

Moisture content of the sample was determined by weight loss during heating in a thermostatically controlled oven at 105^{0}C by hot air oven method as given by (Ranganna, 1986).

3.7.1.2 Ash content

Ash content of the biscuit samples and the flour was determined using muffle furnace as described by (Ranganna, 1986).

3.7.1.3 Crude fat

The crude fat content of the sample was determined by solvent extraction method as described by (Ranganna, 1986).

3.7.1.4 Crude fiber

The crude fiber content of the flour and biscuits was determined as described by (Ranganna, 1986).

3.7.1.5 Crude protein

The crude protein content of the flour and the biscuit sample was calculated indirectly by measuring total nitrogen content by micro kjeldahl method. Factor 6.25 was used to convert the nitrogen content to crude protein as described by (KC and Rai, 2007).

3.7.1.6 Carbohydrate

Carbohydrate content was determined by difference method.

3.7.1.7 Reducing sugar

Reducing sugar is determined by Lane and Eynon’s method as mentioned in KC and Rai (2007).

3.7.1.8 Iron content

Iron content in flour samples were determined colorimetrically at 480 nm, as described in (Ranganna, 1986).

3.7.1.9 Calcium content

Calcium content in flour was determined by titration method as described in (Ranganna, 1986).

3.8 Sensory analysis

The sensory evaluation for overall quality was carried out with 8 semi-trained panelist (teachers and student of Central Campus of Technology). The parameters for sensory evaluation are color, flavor, crispiness, texture, taste and overall acceptability. Sensory evaluation was performed by hedonic rating test as described by (Ranganna, 1986).

3.9 Statistical analysis

All the data obtained in this research work was analyzed by the statistical program Genestat Discovery Edition 3. From this mean ANOVA (No blocking at 5% Level of significance), LSD and interaction effects was obtained to determine whether the sample are significantly different from each other and also to determine which one is superior among them.

Part IV

Results and discussions

The wheat flour and the malted sorghum flour were collected to formulate malted sorghum flour incorporated biscuit of 0 parts, 12.5 parts, 16.667 parts, 25 parts, 33.33 parts, 37.5 parts and 50 parts of malted sorghum flour incorporation. Proximate composition of the flour as well as biscuit was carried out. The best product among the six variations was determined by carrying out sensory evaluation and the detailed nutritional value of the best product was analyzed.

4.1 Proximate composition

The proximate composition of unmalted and malted sorghum flour was obtained as given in Table 4.1

Table 4.1 Proximate composition of unmalted and malted sorghum flour

Proximate composition(db)	Unmalted sorghum flour	Malted sorghum flour
Moisture content (%)	12.37±0.5	5.93±0.4
Crude protein (%)	13.01±0.10	10.21±0.05
Crude fat (%)	4.71±0.08	2.25±0.07
Crude fiber (%)	2.0±0.03	2.81±0.04
Total ash (%)	0.56±0.07	2.1±0.05
Starch (%)	68.67±1.08	77.7±0.87
Reducing sugar (%)	1.04±0.51	5.14±0.87
Calcium (mg/100 g)	4.13±0.35	8.0±0.55
Iron (mg/100 g)	62.11±0.70	159.62±0.88

[Values are the means of three determinations ± standard deviations. Figures in the parenthesis are standard deviations.]

The moisture content increased initially during the soaking process of germination. Later, the moisture content of malted flour is reduced to 5.93% 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. The crude protein content of the malted flour sample decreased. The slight change in protein content may attribute 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 hydrolyze 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 fiber content of the malted sample increased. This increase could be attributed due 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 phytase 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 found to be increase in malted flour, this increase 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 increase of reducing sugar on the malted sample.

The proximate composition of malted sorghum flour as well as wheat flour was obtained as given in Table 4.2

Table 4.2 Proximate composition of wheat flour and malted sorghum flour

Proximate Composition (db)	Wheat flour	Malted sorghum flour
Moisture content (%)	12.35±0.25	5.93±0.15
Crude protein (%)	10.47±0.08	10.21±0.01
Crude fat (%)	1.55±0.02	2.25±0.02
Crude fibre (%)	0.61±0.01	1.81±0.03
Total ash (%)	0.57±1.23	2.1±0.01
Carbohydrate (%)	87.11±0.45	77.7±0.25
Gluten content (%)	8.1±0.25	-
Calcium (mg/100 g)	34±0.15	159.62±0.03
Iron (mg/100 g)	3.0±0.3	8.0±0.20

[Values are the means of three determinations ± standard deviations. Figures in the parenthesis are standard deviations.]

The moisture content of wheat flour was 12.35% which is common in commercial wheat flour as previously reported by J. Kent and Amos (1983). The moisture content of the malted sorghum flour was found to be 5.93%. Bolarinwa *et al.* (2015) reported the very low moisture content of sorghum malt as 6.76%. The value obtained was slight lower than those obtained in literature and the reasons for this difference could be attributed to species and intense drying of malt after germination. During drying the moisture content at final stage should be about 5%.

The protein content was found to be 10.21% in malted sorghum flour. However, compared to wheat flour, which was 10.47%, the protein content in malted sorghum flour is low.

Malted sorghum contains a lot of minerals, confirmed by its higher ash content as 2.1%. The ash content of in the present study (2.1%) is higher than ash contents of wheat flour (0.57%). Higher ash content indicates higher mineral contents.

The calcium content in malted sorghum flour was found to be 159.62 mg/gdm, which varies from the calcium content as calculated by (Gerrano *et al.*, 2015). In his literature, Ca content obtained in genotypes Macia-SA (279.85 mg/kg) and 97MW6127 (218.70 mg/kg) respectively. The iron content in malted sorghum flour was found to be 8 mg/gdm. The concentration of Fe varied from 22.59 mg /kg to 37.65 mg/kg (Gerrano *et al.*, 2015). The differences in value may be because 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 crude fiber of the malted sorghum flour was found to be 1.81% (db) which is comparatively greater than that of wheat flour 0.61% (db). The reason for high fibre content in sorghum is that 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., 2017).

4.2 Physical properties of sorghum grain and prepared biscuits

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	0.66±0.52	0.75±0.39
1000 kernel wt. (g)	30.81±0.54	19.42±0.58
Bulk density (kg/HL)	82.53±0.59	67.00±0.53
Particle density(g/ml) (g/ml)	1.23±0.64	0.94±0.39
Porosity	0.26±0.63	0.35±0.75

[Values are the means of three determinations ± standard deviations. Figures in the parenthesis are standard deviations.]

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.

Physical characteristics of biscuits such as thickness, diameter, spread ratio, weight, volume and density were affected by the substitution increment of the level of malted sorghum flour which is presented in Table 4.4. The results indicated that diameter and thickness of biscuit were slightly increased with increasing substitution percentage of malted sorghum flour. 50 parts malted sorghum flour incorporated biscuit revealed the maximum diameter and thickness (54 and 6.92 mm). The results agree with work done by Hussain *et al.* (2006) who found that diameter and thickness of cookies showed gradually increase as the level of flour substitution.

Moreover, the results of spread ratio of biscuit revealed a reduction in spread ratio from 8.35 to 7.80. It is clear that as the malted sorghum flour level increased, spread ratio for different treated biscuits gradually decreased. These results are on the line with the findings of Ganorkar and Jain (2014) who reported that the reduction in spread ratio might be due to increase in dietary fibre percentage with increasing level of malted sorghum flour because dietary fibre has more water binding power. Also, when more water is present, more sugar is dissolved during dough mixing (Ganorkar and Jain, 2014).

Table 4.4 Physical parameters of developed biscuits

Samples	Thickness (mm)	Diameter (mm)	Spread ratio	Weight (g)	Volume (cm^3)	Density (g/ $cm^{3)}$
E	6.14±0.1	51.30±0.2	8.35±0.15	14.09±0.2	12.69±0.1	1.11±0.15
C	6.23±0.2	51.78±0.1	8.31±0.15	13.92±0.3	13.12±0.2	1.06±0.25
B	6.32±0.3	52.30±0.1	8.27±0.2	13.58±0.2	13.58±0.1	1.0±0.15
A	6.45±0.1	52.96±0.1	8.21±0.1	13.14±0.3	14.21±0.2	0.92±0.26
F	6.56±0.2	53.14±0.1	8.10±0.15	12.86±0.2	14.55±0.1	0.88±0.15
D	6.75±0.3	53.58±0.2	7.93±0.16	12.64±0.2	14.88±0.1	0.88±0.10
G	6.92±0.1	54.7±0.2	7.80±0.1	12.38±0.3	15.85±0.1	0.78±0.2

[Values are the means of three determinations ± standard deviations. Figures in the parenthesis are standard deviations.]

4.3 Sensory properties of biscuit

Statistical analysis of the sensory scores was obtained from 8 semi-trained panelists using 9-point hedonic rating scale (9=like extremely, 1= dislike extremely) for composite biscuit formulations. Sensory analysis was performed with the aid of different panelists evaluating color, texture, crispiness, flavor, taste and overall acceptability of malted sorghum flour incorporated biscuit.

4.3.1 Color

The mean sensory score for color of sample A was found to be 7.62 and was highest of all other biscuit formulations which was significantly different ($p<0.05$) from other samples. Statistical analysis showed that the partial substitution of wheat flour with malted sorghum flour has significant effect ($p<0.05$) on the color.

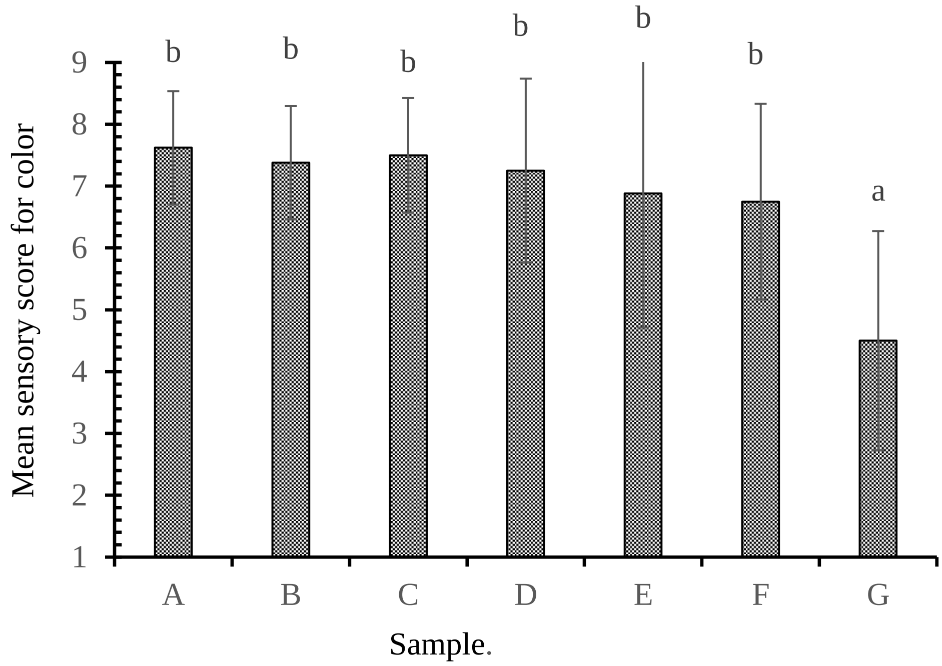

Fig. 4.1 Mean sensory scores for color of biscuit samples of different formulation

[A, B, C, D, E, F, G denotes 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts, 50 parts. Vertical errors bar represent ± standard deviation of scores given by 8 panelists.]

The product A got the higher score may be due to the appropriate amount of malted sorghum flour (25%). The effect of higher amount of incorporation of the malted sorghum flour may be the cause of dark brown color that is observed in the case of sample G which could be the cause of lower acceptance of the color. The result is in accordance with Masoodi and Bashir (2012) who found that the color of the fortified biscuits attained more dark color as the supplementation was increased.

4.3.2 Texture

The mean sensory score for texture of sample E was found to be 8 which was the highest score of all the biscuit formulations. Statistical analysis showed that the partial substitution of wheat flour with malted sorghum flour had significant effect ($p<0.05$) on the texture.

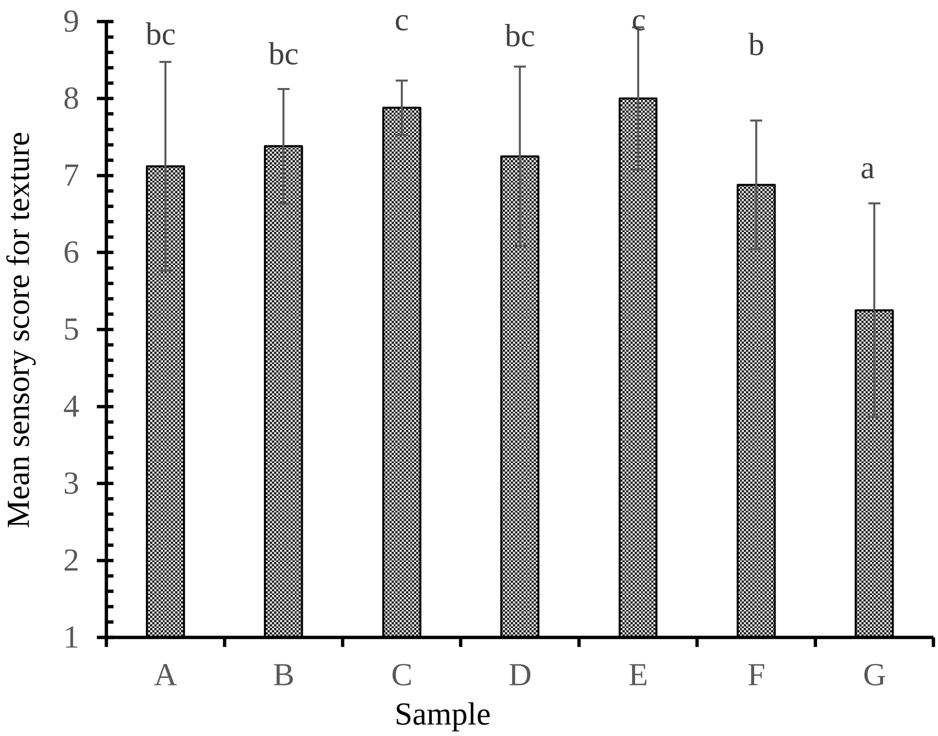

Fig. 4.2 Mean score for texture on biscuit samples of different formulations

[A, B, C, D, E, F, G denotes 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts, 50 parts. Vertical errors bar represent ± standard deviation of scores given by 8 panelists.]

The probable cause for higher score for control than malted sorghum flour incorporated biscuit may be due to the least gluten development as higher amount of sorghum flour is used which is gluten-free affecting the formation of gluten development in wheat flour resulting in the tougher texture and cracks on the crust. The result is in accordance with Sudha *et al.* (2007) who found similar result with the increase in the level of substituted flour in biscuit.

Samples F and G were found to have the lowest mean score due to the least gluten development as higher amount of malted sorghum flour is used which is gluten less affecting the formation of gluten development in wheat flour. As proportion of malted sorghum flour increases texture score decreased which may be due to tougher texture and cracks on the crust. Sample E showed firm texture and no cracks, which might be due to adequate amount of gluten development. Texture is an important factor of comparing the biscuit as it greatly affects consumer acceptance of the product (Eisa, 2006).

4.3.3 Crispiness

Statistical analysis showed that partial substitution of wheat flour with malted sorghum flour had significant effect ($p<0.05$) on the crispiness. The sample C and E got the same highest score while G rank lowest score because incorporation of high level of malted sorghum flour depresses the water holding capacity.

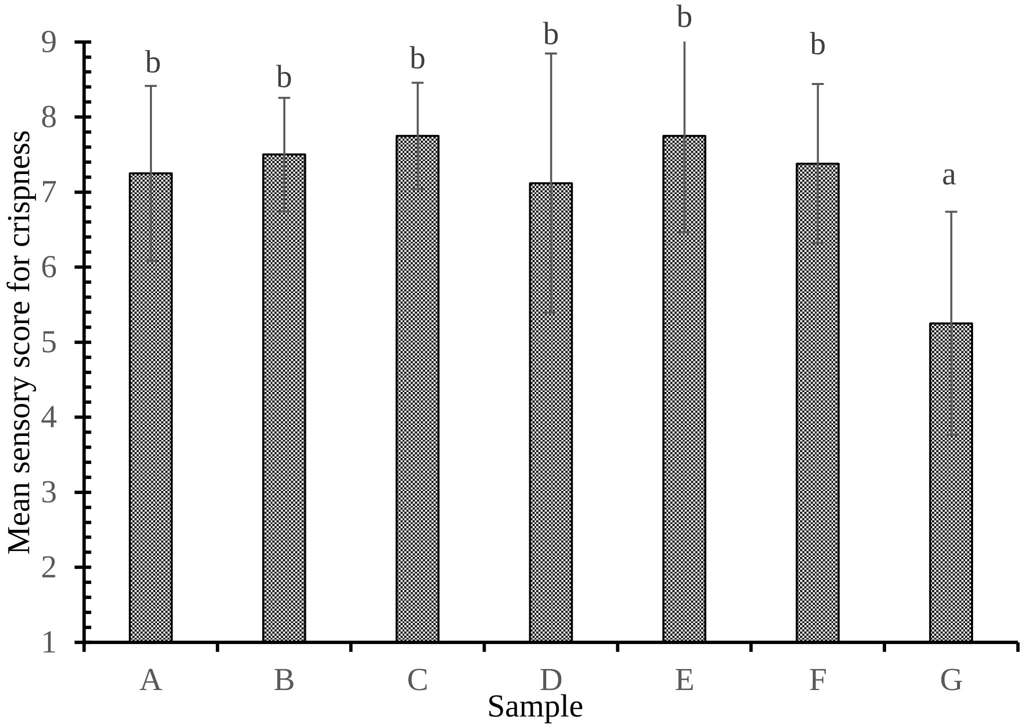

Fig. 4.3 Mean sensory scores for crispiness of biscuit samples of different formulation

[A, B, C, D, E, F, G denotes 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts, 50 parts. Vertical errors bar represent ± standard deviation of scores given by 8 panelists.]

The reduced water content increases the glass transition temperature of the crust and contributes to the development of the crust crispiness. A glassy state of the solids would provide brittleness to the product, but the porous structure of the product and the solid, thin pore membranes may significantly contribute to the sensory properties of the product as stated by Roos (1995).

4.3.4 Flavor

The mean sensory score for flavor of sample D was 7.88 and was the highest score scored among the different formulations. The lowest mean sensory score was of sample G. Statistical analysis showed that the partial substitution of wheat flour with malted sorghum flour had significant effect ($p < 0.05$) on the flavor.

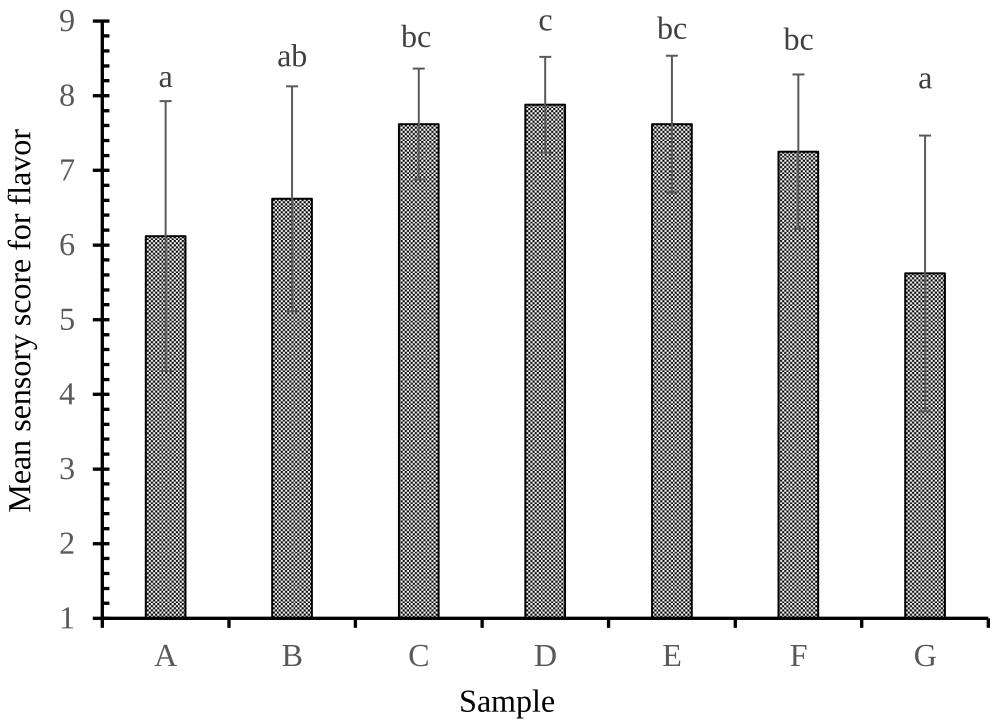

Fig. 4.4 Mean sensory scores for flavor of biscuit samples of different formulations

[A, B, C, D, E, F, G denotes 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts, 50 parts. Vertical errors bar represent ± standard deviation of scores given by 8 panelists.]

The biscuit with the highest amount of malted sorghum such as sample G had low score which could indicate that due to the more amount of total phenolic and flavonoid content in malted sorghum it resulted unacceptable flavor to the panelists. The phenolic compounds identified in the extracts of finger millet and sorghum malt were flavan-3-ols (catechin, epicatechin), flavononol (taxifolin), flavonols (quercetin), proanthocyanidins (proanthocyanidin A1/A2), flavanones (hesperitin), and benzoic acid derivative (protocatechuic acid)(Henry *et al.*, 2018). The flavor of sample D was found to be of balanced flavor giving as a whole of blended flavor which was preferable to other product formulations.

4.3.5 Taste

Statistical analysis showed that the partial substitution of wheat flour with malted sorghum flour had significant effect ($p<0.05$) on the taste.

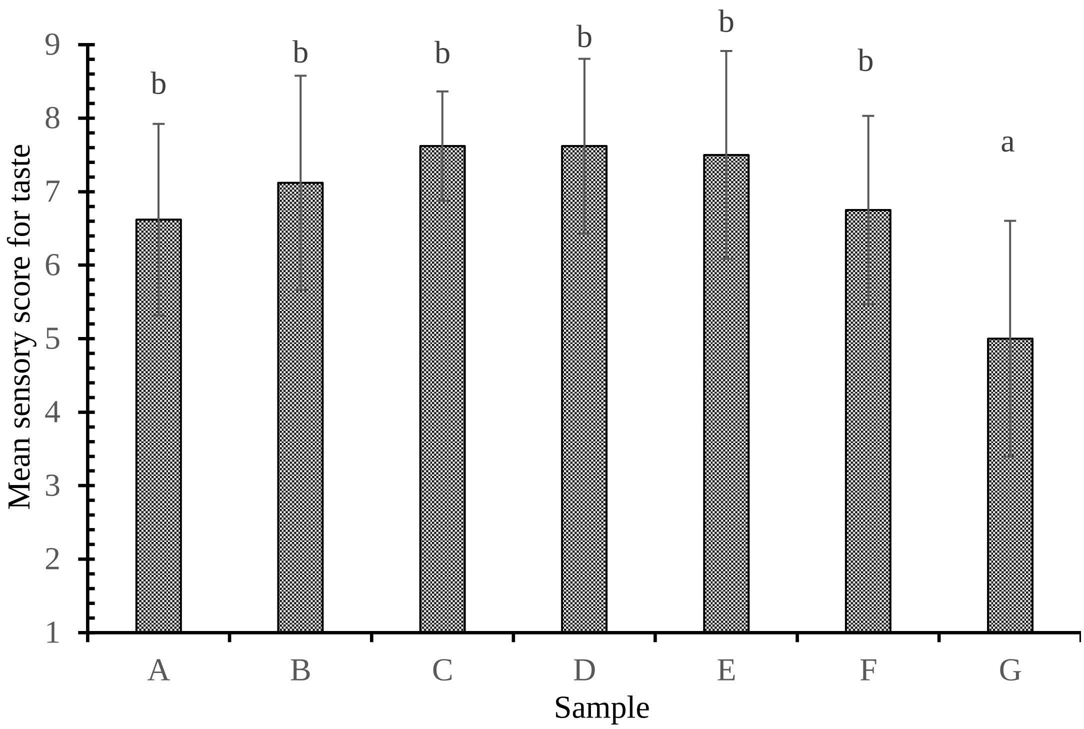

Fig. 4.5 Mean sensory scores for taste of biscuit samples of different formulations

[A, B, C, D, E, F, G denotes 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts, 50 parts. Vertical errors bar represent ± standard deviation of scores given by 8 panelists.]

Sample C and D was found to be scoring highest in taste as compared to other samples with incorporation of malted sorghum flour. However, it is found to be not different from sample E. Sample G is the lowest scoring formulations of all which indicates that higher amount of malted sorghum flour in the formulations could lower the score and acceptability for taste of the product. Taste of biscuits were improved with the incorporation of malted sorghum flour as theses have typical pleasant malty flavor.

4.3.6 Overall acceptability

Sample D scored highest in overall acceptability of the sensory conducted among the panelists. It was found to be not significantly different from the control sample E. 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.

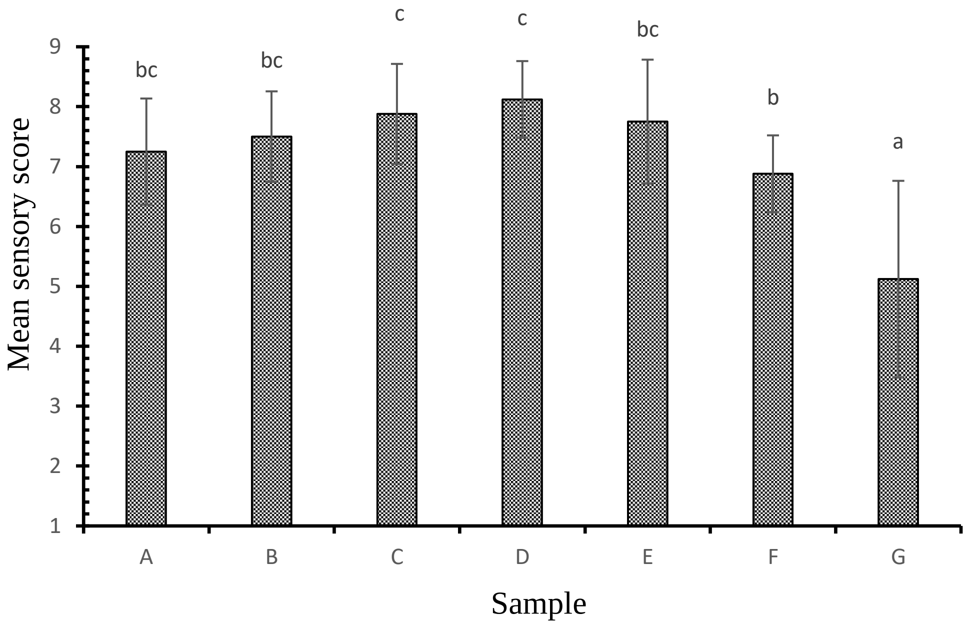

Fig. 4.6 Mean scores for overall acceptability of biscuits of different formulations

[A, B, C, D, E, F, G denotes 25 parts, 16.667 parts, 12.5 parts, 37.5 parts, 0 parts, 33.33 parts, 50 parts. Vertical errors bar represent ± standard deviation of scores given by 8 panelists.]

Sample G showed lowest score in overall acceptability which could be as a result of highest amount of malted sorghum flour incorporated in it. In case of texture and crispiness only the control got higher score than product D. Hence, product D is the best product (optimized product).

4.3 Optimized product

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

Table 4.5 Composition of product

Proximte composition (db)	Product A (Whole biscuit)	Product B (Malted sorghum biscuit)
Moisture content (%)	2.82±0.18	2.65±0.15
Crude protein (%)	6.8±0.12	6.25±0.19
Crude fat (%)	15.80±0.25	17.6±0.19
Crude fibre (%)	1.23±0.01	2.05±0.02
Total ash (%)	1.30±0.02	3.5±0.08
Carbohydrate (%)	72±0.5	67±0.95
Calcium (mg/100 g)	52.3±0.13	57.7±0.21

[Values are the means of three determinations ± standard deviations. Figures in the parenthesis are standard deviations.]

The ash content of biscuits increased in malted sorghum flour incorporated biscuit. The increase in ash content may be due to the high mineral content in the malted sorghum flour incorporated biscuit i.e. calcium and iron. The high ash content in the malted sorghum flour supplemented food would be of nutritional importance in most developing countries like Nepal. Sorghum flour contains a lot of minerals, confirmed by its higher ash content. The higher level of minerals in sorghum incorporated biscuit is also demonstrated by higher level of the Ca content obtained in genotypes Macia-SA (279.85 mg/ kg) and 97MW6127 (218.70 mg /kg) respectively. The concentration of Fe varied from 22.59 mg /kg to 37.65 mg/kg (Gerrano *et al.*, 2015).

The moisture content ranged from 2.82% in wheat biscuit to 2.65% in the malted sorghum flour incorporated biscuit. The decrease in moisture content may be due to the decrease in protein content. Mustafa *et al.* (1986) reported a decrease in moisture content of bakery products with decrease in protein content. The fat content of malted sorghum flour incorporated biscuit was higher than wheat flour biscuits. This is due to the higher fat content of malted sorghum flour than wheat flour. Sorghum is also found to be one of the richest sources of crude fiber. Therefore, malted sorghum flour incorporated biscuit showed an increase in the fiber content. The cost of malted sorghum incorporated biscuit was found to be Rs. 13.98 which excludes the processing, packaging, manpower cost and profit margin.

Part V

Conclusion and recommendations

5.1 Conclusions

On the basis of the work done, following conclusions can be drawn.

1. Malting of sorghum was carried out and the malted flour was incorporated in different proportions to make biscuits of different formulations.
2. Analysis of wheat flour and malt flour showed the significant increase in case of fat, fiber, ash and minerals in the latter as a result of which the nutritional quality of the biscuit also seemed to be enhanced in the case of the same.
3. Biscuit formulation containing 37.5 parts (w/w) malted sorghum flour was found to be appropriate formulation on the basis of sensory score.
4. Cost of biscuit per 100 g was found to be Rs.13.98 that excludes processing, packaging, manpower cost as well as profit margin.

5.2 Recommendations

1. Entrepreneur can utilize malted sorghum flour upto 37.5 parts to enrich nutritional value of general biscuits without hampering consumer acceptance.
2. Study of the shelf life of biscuit and texture analysis can be carried out.

Part VI

Summary

Biscuits are the low cost, processed food which offers good taste along with nutritional values at affordable price with convenient availability. Biscuits have in general, a good shelf life in comparison to most of the other snack items. Since, biscuit is a kind of dry food having a long shelf life, the problem of deterioration is very low in comparison to other bakery products. Biscuits owing to their shelf life can be beneficial for feeding programmes and other immediate catastrophic conditions. Further value of biscuit can be added by incorporating malted sorghum flour. Incorporation of wheat flour with malted sorghum flourr to make biscuits provides a good opportunity to improve the nutritional quality of the fibre and minerals consumed by many people especially growing children and old people due to which helps to rise the nutritional status of the population.

A study was carried out to know about the effects of incorporation of malted sorghum on biscuit quality. Design expert (Central composite rotatable design) was used to design the experiment for formulating the recipe of biscuit. Sorghum collected from Chitwan district was used for malting. Grains were steeped for 24 h at 28°C, at last grains were dipped in KMS solution for 10 min to prevent the mold growth during germination. After steeping the grains were germinated for 5 days at 20ºC and 95% RH. Then, the germinated grains were dried in cabinet dryer at 50°C for 24 h to obtain desired moisture content of 3-5%. The dried malt samples were then taken for analysis. Analysis of physical, chemical and functional properties of both grain and malt samples were performed.

The 1000 kernel wt., bulk density and particle density were found to decrease after malting from 30.81 g to 19.42 g, 82.53 kg/HL to 67 kg/HL and 1.23 g/ml to 0.94 g/ml respectively. While porosity and sphericity of grain varies after malting from 0.26 to 0.35 and 0.66 to 0.75. Protein, crude fat and moisture content were found to decrease after malting from 13.01% to 10.21%, 4.71% to 2.25% and 12.37% to 5.93% respectively. While starch, crude fibre, ash content and reducing sugar were increased after malting from 68.67 to 77.7, 2% to 1.81%, 0.56% to 2.10% and 1.04% to 5.14%

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Appendices

Sensory evaluation score sheet for biscuit

Date:

Name of Panelist:

Name of the product: Malted sorghum flour incorporated biscuits

Dear panelist, you are provided 5 samples of Malted Sorghum Incorporated Biscuit on each proportion with variation on malted sorghum flour content. Please test the following samples of biscuit 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 characteristics on the 1-9 scale as below:

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

Parameters	Sample Code						
	A	B	C	D	E	F	G
Color							
Texture							
Crispiness							
Flavor							
Taste							
Overall							

Any comments:

Signature:

Appendix B

Two way ANOVA (No blocking) for Color

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	55.929	9.321	4.80	<.001
Panelist	7	24.125	3.446	1.78	0.118
Residual	42	81.500	1.940		
Total	55	161.554			

Two way ANOVA (No blocking) for Crispiness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	36.1071	6.0179	9.98	<.001
Panelist	7	47.4286	6.7755	11.24	<.001
Residual	42	25.3214	0.6029		
Total	55	108.8571			

Two way ANOVA (No blocking) for Flavor

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	35.179	5.863	5.49	<.001
Panelist	7	37.929	5.418	5.08	<.001
Residual	42	44.821	1.067		
Total	55	117.929			

Two way ANOVA (No blocking) for Overall_acceptability

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	48.9286	8.1548	10.73	<.001
Panelist	7	14.5714	2.0816	2.74	0.020
Residual	42	31.9286	0.7602		
Total	55	95.4286			

Two way ANOVA (No blocking) for Taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	41.357	6.893	4.22	0.002
Panelist	7	15.357	2.194	1.34	0.255
Residual	42	68.643	1.634		
Total	55	125.357			

Two way ANOVA (No blocking) for Texture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Sample	6	39.8571	6.6429	7.91	<.001
Panelist	7	16.2143	2.3163	2.76	0.019
Residual	42	35.2857	0.8401		
Total	55	91.3571			

Appendix C

Cost calculation of malted sorghum biscuits

Materials	Weight in lot(g)	Cost per Kg (NRs)	Cost (NRs)
Wheat flour	87.5	40	3.5
Sorghum flour	12.5	100	1.25
Sugar	35	65	2.275
Fat	33	140	4.62
Salt	0.75	18	0.0135
Sodium bicarbonate	3.25	125	0.40625
Skimmed milk powder	4	480	1.92
Cost of Malted sorghum Biscuit (NRs/ 100g)			13.98475

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

Color plates

Plate 1: Germination of sorghum

Plate 2: Drying chamber

Plate 3: Baking in oven

Plate 4: Vacuum packaging