UTILIZATION OF BANANA PSEUDOSTEM FOR BISCUIT MAKING

by

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Approval Letter

This *dissertation* entitled *Utilization of Banana Pseudostem for Biscuit Making* presented by Pradeep Sangroula has been accepted as the partial fulfilment of the requirement for the B. Tech. degree in Food Technology.

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Abstract

Banana pseudostem incorporated biscuit is a small baked unleavened cake, typically crisp, flat and sweet by using banana pseudostem powder as the major ingredient. The aim of this research was to develop the formulation for banana pseudostem powder incorporated biscuit and to study its effect on biscuit quality. Design expert was employed for formulating the recipe of biscuit. The obtained 5 formulations with 0, 2.5, 5, 7.5 and 10 parts pseudostem powder with wheat flour were prepared in lab. The samples were subjected to sensory evaluation for consumer acceptability. The obtained data were statistically analysed using two way ANOVA (no blocking) at 5% level of significance.

From the mean sensory scores, 2.5 parts pseudostem incorporation was selected as the best formulation and subjected for further proximate analysis. Banana pseudostem incorporated biscuit and wheat biscuit were subjected to calcium, potassium and sodium content evaluation. At 5% level of significance, control and optimized product were significantly different from each other. The product was further analysed for prediction of shelf life based on acid value, peroxide value and moisture content found to be 0.33 mg KOH/g oil, 7.25 meq O_2/kg fat and 3.72% respectively at the end of 3 months which were all within the acceptable limits. These findings suggest that banana pseudostem flour can be successfully incorporated in refined wheat flour up to the concentration of 2.5 parts without any adverse effect on sensory attributes. The calcium, potassium, sodium, ash, fibre and fat content were found to be higher in banana pseudostem incorporated biscuit in comparison to normal wheat flour biscuit.

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List of Abbrevations

Abbreviation	Full form
ANOVA	Analysis of Variation
AOAC	Association of Analytical Communities
AV	Acid Value
BHA	Butylated Hydroyl Anisole
BHT	Butylated Hydroyl Toluene
BPIB	Banana Pseudostem Incorporated Biscuit
CCT	Central Campus of Technology
CHD	Coronary Heart Disease
CI	Crystallinity Index
GI	Glycemic Index
HDPE	High Density Polethylene
KMS	Potassium Metabisulfite
LDPE	Low Density Polyethylene
MC	Moisture Content
NBS	Nepal Bureau of Standards
NGA	Nordihydro Guaiaretic acid
PG	Propyl Gallate
PODs	Peroxidase
PPOs	Polyphenol Oxidases
PV	Peroxide Value
PVC	Poly Vinyl Chloride
SMP	Skim Milk Powder
SNF	Solid Not Fat
WHC	Water Holding Capacity
WHO	World Health Organization

Part I

Introduction

1.1 General introduction

Biscuits are ready to eat, convenient and inexpensive food products containing digestive and dietary principles of vital importance (Agarwal, 1990). These biscuits become popular due to low cost, good nutritional quality and availability in different varieties, varied taste, easy availability and longer shelf life (Sudha *et al.*, 2007). The baked products have about 6-7% proteins. Biscuits owing to their long shelf life are considered useful for nutritional enrichment in feeding program (Agarwal, 1990). In recent years, consumption of biscuits has increased in most of countries as they served as important source of nutrients (Ranhota, 1980). However several studies indicated that the nutritional, physical and sensory characteristic of biscuits depend on both physiochemical properties of the flour and processing method employed for flour preparation (Asifulalam *et al.*, 2014). Usually the production of biscuit has placed wheat flour as its sole composition, but addition of other valuable flour at a certain extent can be done for nutritional value addition of the produce without adversely affecting the must properties of the biscuit.

Banana is a herbaceous plant of the family Musaceae. In terms of overall production, it is in the second place after citrus, accounting for about 16% of the world's total fruit production (Deharveng *et al.*, 1999). The stem of the banana plant, which is also called pseudostem produces a single bunch of bananas before dying and is replaced by a new pseudostem (Anhwange *et al.*, 2009). This crop generates a large amount of residue, due to the fact that each plant produces only one bunch of bananas. After the harvest, the bare pseudostem is cut and usually left on the plantation or burned, which could ultimately cause environment issues (Cordeiro *et al.*, 2004). Thus the utilization of the banana waste pseudostems has gained more attention in recent years. The banana pseudostem has been used as material for paper, furniture and forage (Buragohain *et al.*, 2010; Umaz *et al.*, 2005). Moreover, it has been reported that these banana waste materials are rich in minerals and nutrients, especially dietary fibre (Aziz *et al.*, 2011). The banana pseudostem could potentially be used more in food rather than in other industries. The exploitation of waste banana pseudostems into products could significantly benefit the environment and increase its economic value.

Pseudostem have low glycemic index and have a high content of dietary fibre and antioxidant which is good for diabetes (Bhaskar *et al.*, 2011). Its high fibre content creates a feeling of satiation and hence, reduces the intake of food. It also helps ease constipation. Banana stem is rich in potassium and vitamin B_6 just like the fruit. Vitamin B_6 helps in production of haemoglobin and insulin. Again, it improves the ability of the body to fight infection. Potassium helps in the proper functioning of muscles, including the cardiac muscles. It also helps prevent high blood pressure, and maintain fluid balance within the body. Banana stem is said to be a diuretic and helps detoxify the body. It is used prevent and treat kidney stones. It has been reported that a high dietary fibre intake has beneficial effects on human health (Kaddumukasa *et al.*, 2005). The importance of food fibres has led to the development of a large and potential market for fibre rich products and ingredients and in recent years, there is a trend to find new sources of dietary fibre that can be used in the food industry. Supplementation has been used to enhance fibre content of foods and has been focused on cookies, crackers and other cereal-based products, enhancement of fibre content in snack foods, beverages etc. (Dhingra *et al.*, 2012).

Flour blends with high-dietary fibre flour have been commonly applied in the bakery industry to reduce the utilisation of large quantities of flour as well as to increase the dietary fibre intake of the consumer. The substitution of dietary flour into food may also contribute to the reduction of malnutrition. Cookies hold an important position in snack foods due to variety in taste, crispiness and digestibility. These are popular among all age groups especially in children. Commercially available cookies are prepared from white flour that is nutritionally inferior to whole wheat flour (Shahzad *et al.*, 2006). Traditional biscuits are claimed to lack other essential nutritional components such as dietary fibre, vitamins and minerals which are lost during wheat flour refinement. Thus, biscuits which represent a major enduse of wheat is suitable for enhancing health after incorporating sources of fibre and essential nutrients (Asifulalam *et al.*, 2014).

1.2 Statement of the problem

Banana pseudostem which once constitute waste and environmental problem can now be greatly utilized for nutritious food (Elanthikkal *et al.*, 2010). Banana pseudostem, regarded as waste, are rich in minerals such as potassium, calcium, sodium, magnesium, phosphorus, copper and iron (Aziz *et al.*, 2011). Banana pseudostem is used for animal feeding and if not properly discarded can constitute environmental problem (Happi *et al.*, 2008).

Banana pseudostem has been known as a potential cellulose source. Presently, this biomass is discarded as waste in many countries (Khan *et al.*, 2013). In past, some researchers have successfully demonstrated the use of banana pseudostem and leaves for extraction of fibres on a small scale. At present, the banana pseudostem are dumped on road side or burnt which causes environmental pollution. The centre core of banana is edible and used to prepare dish in the southern part of Asia. It is also used to prepare candies and pickles. Banana centre core is normally consumed because of its fibre content which aids to avoid constipation. Banana stem is a rich source of fibre and helps in weight loss (Chandrasekaran, 2012).

Traditional biscuits are claimed to lack other essential nutritional components such as dietary fibre, vitamins and minerals which are lost during wheat flour refinement. Thus, biscuits which represent a major enduse of wheat is suitable for enhancing health after incorporating sources of fibre and essential nutrients.

1.3 Objectives

1.3.1 General objective

The general objective of the dissertation work is to utilize the banana pseudostem for biscuit making.

1.3.2 Specific objectives

- To study the effect of incorporation of pseudostem powder on sensory quality of biscuits.
- To manufacture pseudostem incorported biscuits having high fibre and mineral content.
- To study the retention of calcium, potassium and sodium in the product at baking temperature.
- To determine the shelf life of the product.

1.4 Significance of the study

Snacks are the major food bulk consumed by a human every day. Hence, alike lunch, dinner and breakfast, snacks also should be rich in nutritional value. Biscuits have become a famous snack in developing country like ours due to its low price and ready to eat instant characteristics. Hence, such food must be nutritionally as rich as possible.

Many researches have been carried out in context of the nutritional value of normal wheat flour biscuits. Wheat biscuit is considered nutritionally poor due to deficiency of most indispensable amino acids especially lysine and fortification of wheat flour with non-wheat proteins and fibre at different ratios resulted in increase the protein and fibre quality through improving its amino acid profile (Stark *et al.*, 1975). Pseudostem is one of the source which has great potential due to the presence of high dietary fibre (Kaddumukasa *et al.*, 2005). Pseudostem have low glycemic index and have a high content of dietary fibre and antioxidant which is good for diabetes (Bhaskar *et al.*, 2011).

Therefore, incorporation of wheat flour with banana pseudostem flour to make biscuits provides a good opportunity to improve the nutritional quality of dietary fibre, vitamins and mineral consumed by many people especially growing children due to which helps to rise the nutritional status of the population. Such products can also be targeted to specific people like diabetic patients, health conscious people, intellectuals, etc.

1.5 Limitations of the study

Some of the hurdles that came during the thesis are listed as follows:

1. Only one type of banana pseudostem (*Musa acuminata*) was taken for the present study.
2. Microbial analysis of the product like total plate count and yeast and mold count was not be carried.

Part II

Literature review

2.1 Biscuits

Biscuit, this word has its origin from the Latin word *Bixcuit* where Bix- means twice and cuit- means baked (Balfour, 1976). Biscuit is a kind of crispy dry bread, more or less hard, variously flavoured and usually unleavened, prepared usually in small, flat, thin cakes (Smith, 1972).

Biscuits are ideal for nutrient availability, palatability, compactness and convenience. They differ from other baked products like bred and cakes because of having low moisture content, comparatively free from microbial spoilage and long shelf life of the product (wade and Peter, 1988). Although the first biscuit were dried-out rusks, useful as long-life food for sea journeys, early cooks making confections wit fat and sugar would have found that if little dough pieces are baked in a typical hot oven and taken out when they have a good colour and a stable structure they would not have been dry enough to be entirely crispy. Putting them back into somewhat cooler oven to dry them out improved their eating qualities and also their shelf life. Baking from the start in a cooler oven for a longer period allows drying but results in less coloration and structure development. However, the term biscuit was applied originally to dried bread pieces. These were also sweetened and flavoured with spices. Other products like our modern biscuits were made but called by more cake-like names for example: shortcake ad shortbread etc. (Manley, 2000).

Now biscuit are made mostly in factories on large production plants, these plants are large and complex and involve considerable mechanical sophistication. Forming, baking and packaging are largely continuous operations but metering ingredients and dough mixing are typically done in batches (Manley, 1998).

All flour confectionery is developed from human skill in baking and very much research has been directed to improving our knowledge of the science of what happens when flour is hydrated, mixed with other materials and baked. It is this research that has been the main driving force in the development of the biscuit industry. It is therefore correct to say that without science there is no innovation and innovation there is no competitiveness (Manley, 2000).

2.2 Classification of biscuits

Biscuits are generally classified as hard dough and soft dough type of biscuits as per the protein composition of the flour used. In case of the hard dough biscuits the flour used should be the weakest possible to obtain and vice versa in case of soft dough biscuit (Smith, 1972). The soft dough group comprises all the sweet biscuits having many factors in common whereas the hard dough biscuits fall naturally into three sections: fermented dough, puff dough and the semi-sweet dough (Whitely, 1971).

2.2.1 Soft dough biscuits

Soft dough biscuits are generally sweet, thin and possess smooth surface with dimensions that are much more regular and consistence than the hard dough biscuits. Generally they contain higher fat content (25%-35%) and sugar (30%-45%) and are low in moisture. The higher gluten network development should be avoided which can be achieved by:

a) Weak flour
b) Lower moisture content
c) Short mixing time
d) Less aerating agents

Soft dough biscuits are less versatile because of the inherent nature of the dough (Manley, 1983).

2.2.2 Hard dough biscuits

Hard dough biscuits generally contain less fat (10%-20%) and low sugar content (10%-18%). The dough adheres due to its higher water content and relatively lower fat content. This type of formulation produces an extensive gluten 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. The water content varies in accordance with the flour strength, which might be as high as 20% of the flour weight (George, 1981). Further according to the variance in composition of one or more parameters hard dough biscuits can be further divided into:

2.2.2.1 Semi sweet biscuits

The flour used in this type of biscuits should be as weak as possible. Its higher water content and relatively low amount of sugar and fat produces an extensive gluten system and structure. Many flour formulations contain corn starch or arrowroot to an extent of 10% of the flour weight in order to weaken the flour strength. Further to prevent excessive gluten development, a long mixing time followed by addition of sodium met bisulphite is carried out. Rapid cooling should be avoided as these types of biscuits are highly susceptible to checking (Dunn and Bailey, 1988).

2.2.2.2 Fermented dough biscuits

This type of biscuits include two groups the cream crackers and the soda crackers. Although these two types have variations within them in case of composition and process of manufacture, both of them have basic mode of production as fermentation. Studies show that the manufacture process of salt crackers is standardized whereas a lot of variations might be seen in the manufacture process of cream crackers. Ingredients commonly include flour of medium strength, protein (9.0-9.5) % , shortenings 12% for cream crackers to 14% for salt crackers, sugar basically is used as yeast food only, salt (2-3)%, malt for rapid fermentation due to its diastase activating effect (Smith, 1972).

2.2.2.3 Puff dough biscuit

This hard dough biscuit is leavened with well layered fat between the dough sheets. The dough and the fat should possess nearly the same flow properties and care must be taken that the fat doesn't become the part of the homogenous dough phase as it will not contribute to layering but instead reduce the elasticity of the dough and might give undesirable properties. During preparation the dough is mixed for 15 min and then relaxed for 30 min then after 60% of the puff dough margarine is applied and sheeted. Rest of the fat is applied after the sheet is laid off for 15 min (George, 1981).

2.3 Types of biscuits

2.3.1 Cream crackers

These have a simple recipe of flour, fat and salt, which is always fermented with yeast and the dough is laminated prior to cutting and baking. These have characteristic flaky and variously blistered biscuits (Manley, 1983).

2.3.2 Soda crackers

It is a square biscuit about 50 × 50 mm and 4 mm thick. The biscuits are produced with scrapless cutters so the edges are white and broken after baking. The fermentation is usually in two stages with a wet sponge lying for 18 h followed by a dough stage, which is left to ferment for about 4 h. It has alkaline reaction after baking hence the name soda crackers (Manley, 1983).

2.3.3 Savory crackers

These are variously salted, flavored and fat sprayed after baking. Depending upon their size, because they are made in a very wide range of shapes and sizes, they can be regarded as savoury snacks (Manley, 1983).

2.3.4 Water biscuits and matzos

Water biscuits have a simple recipe of flour, fat, salt and water in the ratio 100:6.5:1:29. The dough is undeveloped and crumbly or in balls after mixing. Matzos are a Jewish product and recipe is about 100 parts of flour to 38 of water (Manley, 1983).

2.3.5 Puff biscuits

Puff biscuits are all made from puffed dough in which there is a non-homogeneous distribution of fat. When this dough is laminated the fat causes discontinuities between the layers of dough and during subsequent baking these layers separated to give a flaky structure. The dough is not fermented and is invariably cold and under developed. Puff biscuits are eaten cold so the fat used must not have waxy tail after eating (Manley, 1983).

2.3.6 Short dough biscuits

These are made from cohesive dough that lacks extensibility and elasticity without the formation of gluten stands from the wheat flour. The texture of the baked biscuit is attributable to starch gelatinization and super cooled sugar rather than a protein or starch structure (Manley, 1983).

2.3.7 Deposited soft dough and sponge drop biscuits

Short dough, which are soft enough to be just pourable, are referred to as soft dough. The biscuits are rich in fat or based on egg whites whipped to stable foam (Manley, 1983).

2.3.8 Wafers

They are formed from a batter, which is baked between pairs of heated metal plates. The majority of wafer biscuits are based on the large flat sheets. The wafer sheet itself is baked from a simple batter containing little or no sugar. It is a tasteless product, which has a smooth surface and a very open cellular structure within (Manley, 1983).

2.3.9 Miscellaneous biscuit-like products

These include crisp breads, pizza bases, sausage rusk etc. (Manley, 1983).

2.4 Chemical composition of biscuits

Chemical composition of biscuit varies within the biscuit types due to their difference in the raw material composition, method of preparation, end purpose of the biscuit and various other factors. The major and most common difference between the biscuit type namely hard dough, soft dough and fermented dough biscuit 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	20.80	25.88	44.73	1.25	1.34
Hard dough	7.18	12.26	19.15	59.40	0.90	0.56
Fermented dough	7.20	15.00	7.20	67.00	1.50	2.10

Source: Rao *et al.* (1991)

2.5 Raw materials for biscuit making

Mostly the common raw materials for biscuit making includes wheat flour, water, emulsifier, sugar and salt. Apart from these various other raw materials are used for biscuit making in industries. Choice of raw materials is generally done as per the quality and organoleptic requirement of the final product.

Raw materials can be divided into major and minor ingredients, those raw materials which are used in bulk and are a 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, flavouring agents, emulsifiers, fortifying agents, improvers etc. are used in small amounts and aren't a must for all sort of biscuits. These ingredients are used for developing the taste, texture, flavour and aesthetic value of the product. Therefore these minor ingredients are also known as the product improvers (Shrestha, 1995).

All these ingredients are individually important to obtain more palatable and satisfactory products. The raw materials are found in the form of solid, liquid and paste (Shrestha, 1995).

2.5.1 Major ingredients

2.5.1.1 Flour

Flour is the basic raw material for biscuit making responsible for the major bulk of biscuit (Whitely, 1971). The flour used in biscuit and cracker vary in strength and baking characteristics (Bohn, 1956). Wheat grain is the only grain naturally capable of producing flour capable of being made into a low density baked product (Kent and Amos, 1983). Soy flour is used in dough due to emulsifying property and higher level of protein content (Whitely, 1971).

a. Wheat flour

Wheat is botanically named as *Triticum vulgare*. Wheat flour for biscuit making is obtained from the endosperm in the form of particle size enough to pass through a flour sieve usually 100 mesh per linear inch (Kent and Amos, 1983). Wheat flour is unique among all the 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 (Mukhopadhyay, 1990).

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 soluble in alcohol and water (Gorinstein *et al.*, 2002).Gluten is elastic, cohesive and rubbery and holds together and holds together the various ingredients of the dough. It has the property of holding the gases given off during fermentation and during baking. It sets in 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 sustaining wall of the whole structure of baked products (Bohn, 1956).

Wheat flour used for making biscuit should be the product obtained by milling cleaned hard or soft wheat or a combination of both types. Flour strength is usually defined by the percentage of protein present in the flour. Weak flour is casually accepted as the flour with low percentage of protein. Usually this protein is inferred to be gluten, which when the flour is made into a dough with water, will become very extensible under stress, yet when the stress is removed it will not fully return to its original dimensions. Further, the amount of stress required to facture the dough piece is less than that required under identical conditions when strong flour is used (Smith, 1972).

The strong flour protein has long links with few bonds while weak flour protein has short links with many bonds. During biscuit making weak and easy to stretch, soft wheat flour is found to be better (Kim and Kim, 1999). Beside the natural quality of flour, the modifications in the flour strength can be done by various treatments. Treatment of the flour with sulphur dioxide reduces the flour strength. Heat treated flour added to untreated flour is claimed to strengthen the flour. According to Kent and Amos (1983), improvers have some effect upon the nature and character of the gluten and cause it to behave, during fermentation, like the gluten of the stronger flour.

The flour should be free flowing, dry to touch, should be creamy in colour and free from any visible bran particles. It should also have a characteristic taste and should be free from musty flavour and rancid taste. The characteristics as required in flour is given in Table 2.2.

Table 2.2 Requirements for flour characteristics

S. No	Characteristics	Requirements
1	Moisture content	13.0% max.
2	Gluten content on dry basis	7.5% min.
3	Total ash on dry basis	0.5% max.
4	Acid insoluble ash on dry basis	0.05% max.
5	Protein (N×7.5) on dry basis	9.0%
6	Alcohol acidity as H_2SO_4 in 90% alcohol	0.1%
7	Water absorption	55%
8	Sedimentation value	22%
9	Uric acid (mg/100 gm)	10% max.
10	Granularity	To satisfy the taste

Source: Aroma (1980)

b. Corn flour

Corn flour is a yellowish power, the direct result of mixing sound corn, and containing about 2.5% of fat. Corn starch is the nearly pure starch obtained from the maize kernel. Because of its high starch content; it can be used to weaken flour which is too strong (Smith, 1972).

c. Rice flour

It is prepared from the cereal *Oryza sativa*. Rice contains a larger proportion of starch than any other cereals. Although rice is deficient in minerals, fat and protein its use in biscuit making is due to its very easily digestible carbohydrate (Correa *et al.*, 2007). Apart from nutritional value its used in biscuit making is done as dusting agent, when dough release from a rotary moulder die is not effective, dies are lightly dusted with rice cones before they receive the dough (Smith, 1972).

d. Oat flour

The use of oat products in biscuit making is due to its high nutritive value owing to high proportion of protein and fats. Generally the oat meal contains higher level of fat (about 6%). The major drawback of its use is due to the off flavour development during baking and during long storage and baking. However stabilizers may be used to inhibit this problem (Worgan, 1960).

e. Soya flour

Soya flour is used in dough due to its emulsifying property and higher level of protein content. The emulsifying action is due to its higher level of lecithin content (Whitely, 1971).

f. Arrowroot flour

The flour is obtained from the root stock of arrowroot plant. This flour is mainly used in biscuit making due to its easily digestible starch and proved to be beneficial for teething children. It also works as a flour weakener an adjunct to pallet smoothness (Smith, 1972).

2.5.1.2 Fat or shortening

Fat is one of the major ingredients in biscuit making. Shortening function of fat during biscuit making is a must step without which the baked product will be a solid mass held firmly together by strands of gluten (Schober, 2003). Fat itself being insoluble in water prevents the extra cohesion of the gluten strands during mixing. The greatest attribute a shortening can possess is that it should have a plastic nature over a wide range of temperatures as it is likely to be encountered in its use for biscuit making (Smith, 1972).

The main action of the fat or shortening during mixing is to avoid the gluten forming proteins to come in contact with water by insulating the gluten forming protein molecules due to its hydrophobic nature. Hence, less tough dough with desired amount of gluten formation can be obtained. Thus shortened baked products possess less hard, crispier nature and can easily melt in mouth (Mukhopadhyay, 1990).

During mixing fat also helps in entrapment and retention of the air, which is highly necessary for a product for its good texture. Fat also lubricates the formed gluten molecules to distribute it to various sites during sheeting and hence preventing the agglomeration of the gluten molecules. Fat also plays a vital role in the softness, texture palatability and keeping quality of the product (Manley, 1983).

In the earlier days of biscuit making animal lard was used for biscuit making which has now been totally replaced by hydrogenated vegetable oils. The molecules that exist in oil are built up of unsaturated fatty acid chains, some of which are loosely joined together by double bonds which are weak bonds hence, making the fat prone to easy oxidative rancidity of the oil. During hydrogenation the added hydrogen replaces the double bonds present to convert it to single bonds hence a stable solid fatty acid molecule is formed from weak bonded liquid fatty acid molecule (Smith, 1972).

Hydrogenated Vegetable fat are superior to the lards recently used in various aspects. Furthermore in order to obtain the best product the hydrogenated vegetable oil to be used for biscuit making should possess the following properties (Mukhopadhyay, 1990):

1. It should possess good white to creamy color.
2. After keeping the fat at 50°c for 24 h and filtering, its color should be comparable with the control sample of oil.
3. The fat should have a smooth, uniform texture, free from any oil separation and large grains.
4. The fat should have a bland ‘clear’ odour and taste.
5. The fat should have a wide plastic range to suit particular production techniques and the product.
6. The crystalline structure of fat should be stable during mixing and after baking.
7. The fat should possess reasonable shelf life on its own without the addition of antioxidants. The acid value and peroxide value of the extracted fat should not exceed 0.5 mg KOH/ gm oil and 10 meqv peroxide/kg fat respectively.
8. The fat should be prepared from the blend of oils, which will not cause fat bloom during the storage of biscuit.

2.5.1.3 Sweetening agents

Sugar is another major ingredient in biscuit making. Sugar generally used in biscuit making is obtained from sugarcane and sugar beet. The sugarcane consists of 16-22% of sucrose while sugar beet consists of 8-9% of sucrose. During biscuit making various forms of sugar namely crystalline, pulverised, liquid, brown or soft sugar are used as per product requirement. Generally most commonly used form of sugar in biscuit making is pulverised sugar. The reason behind this may be due to its readily soluble characteristic which causes the palate to be deceived in sweetness. The crystalline size also has effect on sweetness, shortness and better spread capacity of biscuit (Whitely, 1971).

Use of crystal size varies according to the final product. Medium fine powdered sugar, with or without very fine granulation is more suitable for rotary doughs; while a coarser sugar is tolerable in hard semi-sweet doughs because of the larger quantities of water used, the longer mixing time and higher final dough temperature. Use of coarser sugar gives fissured tops or cracks which is desirable in case of crunchier and ginger biscuits. Apart from these sugar types, lactose sugar from milk, and brown sugar which gives both colour and delicious flavour to the product also are used.

Another type of sugar used in biscuit making is invert sugar syrup or simply invert syrup. Due to its lower caramelization temperature compared to sucrose the crust coloration of the biscuit takes on a browner appearance much quickly which is desirable in many products. If the crust coloration becomes too darker than requirement then a part of invert syrup can be replaced with glucose syrup. Experiments also show that use of invert syrup also reduces the baking time. Invert syrup also helps in preventing checking problem in biscuits. It also helps in moisture retention in biscuits. As a whole, sugar may be of any form helps in imparting sweetness, increasing tenderness, maintaining volume, crust colour development, flavour improvement, moisture retention and proper spread of the biscuit (Smith, 1972).

2.5.2 The minor ingredients

2.5.2.1 Emulsifying agents

Emulsifying agents are surface-active agents promoting the formulation and stabilization of emulsions during biscuit making. It helps proper mixing of lipid and aqueous fraction and helps in maintaining good texture of the product. The unifying property of emulsion is due to the presence of a hydrophobic and a lipophilic group on the same molecule.

Various recipes in biscuit making include those from high fat recipe to low fat recipe, with low water and high water respectively. In the low fat recipes, process problems are associated with gluten development and dough machinability but in high fat recipes, there is more concern for the fat, to give maximum textural effects, dough stickiness and control of spread while baking (Manley, 1983).

Most commonly used emulsifiers are lecithin, eggs, mono and diglycerides etc. In creaming stage where the fat, sugar etc. are combined with all or no part of water, lecithin does exert an emulsifying action to give a smooth homogeneous mixture. Lecithin may be much more useful as an antioxidant also (Smith, 1972).

2.5.2.2 Leavening agents

Leavening are the gassing agents which causes the dough to spring off or puff up to give a porous open texture to the final product. Ammonium and sodium bicarbonate are the major chemical leaveners, while yeasts are the biological leaveners. Similarly, mechanical leavening can be done by incorporating the air within the dough matrix by mechanical agitation. Reaction of two or more chemicals also leads to production and incorporation of gas, mainly the reaction takes place between bicarbonates of ammonia as well as sodium with acidulants. To discuss about the major and most common leavening agent the baking powder, it should possess the following properties (Smith, 1972):

a. Maximum gas strength-greatest volume of gas for least weight of the product.
b. Proper balance of ingredients to prevent any impairment of the taste or appearance of the biscuit.
c. Innocuous ingredients and residues.
d. Optimum velocity of reaction to be susceptible to control.
e. Keeping quality under diverse and extreme conditions to remain unimpaired over reasonable periods of time.
f. Minimum cost of production, economical in use.

The chemical reaction during use of chemical leaveners and acidulants is as given as follows:

$$NH_4HCO_3 \xrightarrow{\text{heat}} NH_3 + CO_2 + H_2O$$

Ammonium bicarbonate → Ammonia + Carbon dioxide + Water

$$(NH_4)_2CO_3 \xrightarrow{\text{heat}} 2NH_3 + CO_2 + H_2O$$

Ammonium carbonate → Ammonia + Carbon dioxide + Water

The chemical equations for the reaction of soda and the commonly used acidulants are as below:

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

Sodium bicarbonate + Acid → NaX + Carbon dioxide + Water

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

Cream of tartar → Sod. Pot. Tartarate

Both sodium 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 colour often with an accompanying unpleasant or soapy taste, unless any acidic material is used to neutralise the residual sodium carbonate (Bohn, 1956).

2.5.2.3 Milk solids

Milk and milk solids are considered to be the ingredients of value addition during biscuit making. Apart from increasing the nutritive value of the biscuit, milk and milk solids help in retention of flavours. Usually use of milk in biscuit making is done in SMP and full cream form due to its higher stability and easy storage facility. Milk solid when used in biscuit making have proved to enhance crust bloom and colour, tenderness and texture without altering the symmetry and crumb colour. The coloration may be due to the fact that the lactose in milk solid remains as lactose in the biscuit because it is not fermentable by yeast. Lactose helps in the formation of melanoids, the principle crust colouring substances, formed by the reaction of sugars and amino acids from the proteins under the influence of heat. Probably this reaction takes place in all biscuit dough baking (Smith, 1972).

Higher milk flavour can be obtained by the use of condensed milk during biscuit making. Similarly among all the milk products butter is the potent product for better flavour development but due to economical aspect their use have nearly completely been replaced by butter flavours. Other milk products that are also sometimes used are cheese, whey, butter milk etc. (Shrestha, 1995).

2.5.2.4 Salt (Sodium chloride)

Use of salt during biscuit making is not mainly to increase saltiness except in some salty biscuits. It helps to enhance the natural or other added flavours. Salt can reduce the sourness of acids and increase the sweetness of sugars in their effect in the palate (Fabriani, 1977). In fermented dough salt helps to develop the gluten of the flour besides acting as a fermentation rate controller. Flours which lack a bit of ageing can be readily used with good gluten fermentation by use of a little bit higher dosage of salt. Salt to be used during biscuit making should be magnesium and calcium chloride free as the minerals may cause rancidity. Use of salt in the range of 1.0-1.5% of the flour weight is thought to be best but above 2.5% it may become objectionable or even nauseous (Mukhopadhyay, 1990).

2.5.2.5 Flavouring and colouring agents

Flavour is the quality of the thing that affects the sense of taste and smell. The majority of the flavours used in biscuit making are derived from natural sources and these are in many ways most satisfactory. To get good distribution in a dough, the flavour should be creamed with the sugar and shortening at the beginning of mixing. Except from the added flavours, flavour can also be obtained from the various ingredients such as nuts, fruits etc. Most commonly used flavoring agents are common salt, yeast, extracts, spices and essences (Whitely, 1971).

Colouring agents are mostly not added externally during biscuit making. Other ingredients like sugar, invert syrup, milk solids etc. provide color to the product mainly due to caramelisation. Colouring agents not only include the synthetic as well as natural colours only but various ingredients used during biscuit making also serve to provide appealing colour to the product (George, 1981).

2.5.2.6 Water

Water is one of the most important ingredients during biscuit making. Quality of water used has a great effect on the product. Dissolved minerals and organic matters present in water can affect the flavour, colour and physical attributes of the finished baked product (Smith, 1972).

The water used in the baking product should be potable and odourless if required, although no significant effect has been noticed due to the hardness, but demineralization is recommended if the mineral content is too higher which might cause a adverse in product colour (Aroma, 1980).

2.5.2.7 Anti-oxidants

Anti-oxidants act as a retarding or inhibiting agent in the onset of oxidation rancidity. As biscuit is rich in nutrients and fat content, it is highly prone to oxidative rancidity, so role of antioxidant is essential for prolonging the shelf life of the product. There are a number of naturally occurring substances as well as many man-made chemicals which possess antioxidant properties which can be used during biscuit making. Use of antioxidants should be done in the early stage of biscuit making as antioxidants cannot hide or remove the incipient rancidity (Smith, 1972).

Most commonly used antioxidants are, BHA (Butylated hydroxyl anisole), BHT (Butylated hydroxyl toluene), PG (Propyl gallate), NGA (Nordihydro guaiaretic acid). Nearly all the added antioxidants are added with the shortenings for use. An antioxidant should possess the following properties:

- Non-toxic
- Very little or effect on color, flavour or odour of the fat or the product.
- Be readily incorporated- soluble in fat and oil.
- Be effective in as low a concentration as possible.
- Be stable to baking or frying temperatures.
- Be stable to heat, even in alkaline media, such as biscuit doughs.

Apart from all these major and minor ingredients sodium met bisulphite and potassium meta bisulphite are used as conditioning agents. Special fortifying agents like protein, vitamins, fruits, nuts, chocolates etc. can also be mixed with biscuit (Smith, 1972).

2.6 The banana plant

2.6.1 Origin and world production

The origin of the banana plant is complex because of the nature of the banana's taxonomic origins themselves. It is believed by the archeologists that the first domesticated banana was grown in New Guinea around 8,000 BC. From New Guinea, the domesticated banana appears to have spread to the Philippines, and then radiated widely across the tropics. It took probably two millennia for the banana after domestication to arrive in India, Indonesia, Australia and Malaysia. Plantains may have been grown in eastern Africa as early as 3,000 BC and in Madagascar by 1,000 BC. Buddhist literature records indicate that Indian traders travelling through the Malaysian region had tasted the fruit and brought plants back with them in 600 BC. In 327 BC, when Alexander the Great and his army invaded India, he discovered banana crop and tasted the fruit in the Indian Valley. Then he introduced this new discovered crop to the Western world (DeLanghe, 1995).

By 200 AD banana had spread to China and grew only in the southern region of China at that time. The Chinese never really popularised this fruit until the 20^{th} Century as they were considered to be a strange and exotic alien fruit. At about 650 AD, bananas began to be grown in Africa.

2.6.1.1 Production in Nepal

Banana is a high-value agricultural product and a major fruit in Nepal in terms of the potential growing area, production, and domestic consumption. It is currently grown in 68 of Nepal's 75 districts, and the total productive area of banana plantations in 2012/2013 was 11,864 hactars, with a total production of about 182,005 tonnes.

Although there is great potential for banana production in Nepal, there are few commercial banana plantations and current productivity is low. According to the Ministry of Agriculture, the current average productivity is 13.2 tonnes per hectare, with maximum yields reaching up to 20 tonnes per hectare. The top producers of banana in the world 2017 is shown in Table 2.3.

Table 2.3 The top Producers of bananas in the world 2017

Rank	Country	Production (in tonnes)
1	India	27,575,000
2	China (mainland)	12,075,238
3	Philippines	8,645,749
4	Brazil	6,892,622
5	Ecuador	5,995,527

Source: Anon (2017)

2.6.2 Taxonomy of banana

Banana (*Musa sp*) belongs to the Musaceae family. Over 70 species of *Musa* were recognized by the World Checklist of Selected Plant Families, but only few species are edible. There are two wild species of banana, including *Musa acuminata* and *Musa balbisiana*. Almost all modern edible parthenocarpic bananas come from these two species. The hybrid of *Musa acuminata* and *Musa balbisiana* is named *Musa paradisiaca* (Valmayor *et al.*, 1999). The systematic position of *Musa acuminate* is shown in Table 2.4.

Table 2.4 Systematic position of *Musa acuminate*

Kingdom : Plantae

Subkingdom : Tracheobionta

Division : Magnoliophyta

Class : Liliopsida

Order : Zingiberales

Family : Musaceae

Genus : *Musa*

2.6.3 Banana pseudostem

2.6.3.1 Introduction of banana pseudostem

Banana pseudostem is the stem of banana plant; it produces a single bunch of banana before dying and then is replaced by new pseudostem (Anhwange *et al.*, 2009). Since each plant produces only one bunch of bananas and cannot be used for the next harvest, this agricultural activity generates a large amount of residue (Cordeiro *et al.*, 2004). It has been reported that banana is the second largest produced fruit in terms of quantity, contributing about 16% of the world's total fruit production (Mohapatra *et al.*, 2010). Therefore, every year after harvesting, a large amount of bare pseudostem is cut and left behind as waste worldwide, which ultimately causes contamination of water sources as well as can affect the environment and health of living microorganisms (Aziz *et al.*, 2011; Hossain *et al.*, 2011). Hence, the exploitation of waste banana pseudostems into products could significantly benefit the environment and increase its economic value.

2.6.3.2 Structure of banana pseudostem

The plant is normally tall and fairly sturdy, as a result is often mistaken for a tree. However, the trunk of the banana plant is actually a false stem or pseudostem (Stover and Simmonds, 1972). The pseudostem is normally 5 to 7.6 m tall (varies from species to species) growing from a corm (Nelson *et al.*, 2006). The pseudostem consists of a tender core and several outer sheaths. The tender core inside the pseudostem carries the immature inflorescence until eventually it emerges at the top. Therefore most of the nutrients of the pseudostem are present in the tender core.

2.6.3.3 Nutritional value of banana pseudostem

Proximate nutrients

Banana pseudostem has very high content of dietary fibre. It has caughted the attention of food scientist in recent years. It could be used more in food rather than in the feed industry. Aziz *et al.* (2011) and Bhaskar *et al.* (2011) researched the proximate composition of banana pseudostem which are showed in Tables 2.5 and 2.6.

Table 2.5 Proximate composition of banana pseudostem

Nutrients	Content in % (db)
Protein	2.5
Fat	1.7
Free sugar	3.4
Soluble dietary fibre	1.4
Insoluble dietary fibre	27.4
Starch	27.3
Ash	0.3
Moisture	15.1

Source: Bhaskar *et al.* (2011)

Table 2.6 Proximate composition of tender core of banana pseudostem flour

Nutrients	Content in % (db)
Moisture	8.8
Fat	1.2
Protein	3.5
Ash	10.1
Crude fibre	19.5
Total carbohydrate	56.9

Source: Aziz *et al.* (2011)

Minerals

Minerals play an important role in maintaining proper function and good health in the human body (Bhat *et al.*, 2010). Deficiency of minerals in the diet is always associated with increased susceptibility to infectious diseases due to the weakening of the immune system. The minerals of dried ground banana pseudostem are shown in Table 2.7. The mineral content will be affected by maturation stage, species, and collection season and sample preparation (Happi Emaga *et al.*, 2008; Ho *et al.*, 2012; Lahav and Turner, 1985). For instance, with the maturation of the banana pseudostem, the Ca concentrations will increase, while the K will decrease, as a result of the presence of Ca in the tissues.

Table 2.7 Mineral contents of banana pseudostem

Mineral	Content (mg/100 g dry sample)
Sodium	444.1
Potassium	944.1
Calcium	1335.3
Magnesium	255.0
Phosphorus	137.8
Iron	3.3
Zinc	8.1
Magnesium	1.3

Source: Ho *et al.* (2012)

2.6.3.4 The utilization of the banana pseudostem

Nowadays, banana pseudostems are widely used in animal feeding, clothing and paper industry. Buragohain (2010) claimed that banana pseudostem could be used as an important staple food for pigs in banana producing areas. They can be used as feed material in both fresh and sun-dried forms and both whole or chopped forms. Starch extracted from banana pseudostem could also be used to produce the glue used in the manufacture of cartons. Umaz (2005) reported that due to the fact that the fibre of banana pseudostems is widely recognized for its good qualities vs. synthetic fibres, it is used for making apparels, garments and home furnishing. Banana pseudostem has been seen as a kind of vegetable in some countries. For example, in India and Malaysia, the fresh tender core of banana pseudostem is cooked and consumed, whereas the consumption of banana pseudostem as food in Nepal is rare.

2.6.4 Pretreatment - Anti-browning

Harvested banana pseudostem easily turns brown when it is exposed to air. This browning reaction will change sensory properties and decrease nutritional quality of the banana pseudostem, hence, eventually reducing consumer acceptance. Since the browning reaction can affect the quality of food products mentioned above, it can cause considerable economic losses. Hence, in order to protect the original quality of banana pseudostem during processing and storage, the following paragraphs will review the causes of browning reactions and the prevention methods of these reactions in food processing.

2.6.4.1 Causes of browning

Browning reaction is one of the most important and common reactions that takes place during food processing and storage. There are three main causes of browning reactions in food processing - enzymatic browning, non-enzymatic browning and microorganism caused browning.

a. Enzymatic browning

It is estimated that enzymatic browning is the main cause in plant material and one of the most important colour reactions that affects the quality of fruits and vegetables, such as apple, banana and potato. After harvest, the cell wall of plant material is disrupted and the enzymes form brown or sometimes yellow, black or pink pigments(Caballero *et al.*, 2003). Enzymatic browning is catalyzed by the enzymes polyphenol oxidases (PPOs), (Corzo *et al.*, 2012) and peroxidases (PODs) (Cano *et al.*, 1997).

b. Non-enzymatic browning

Non-enzymatic browning is one of the most complex reactions in food chemistry since a large number of food components are participating in this reaction through different pathways, which gives rise to a complex mixture of products (Corzo *et al.*, 2012). The non-enzymatic browning is produced by heat treatment, including a wide number of reactions such as Maillard reaction, caramelisation, chemical oxidation of phenols and maderisation (Manzocco *et al.*, 2000). These reactions can promote nutritional changes such as loss of nutritional quality. For instance, they contribute to the destruction of essential amino acids, reduction of protein digestibility and amino acid availability. Maillard reaction is the most important non-enzymatic browning reaction. It occurs as a result of the reaction between free amino groups from amino acids, peptides or proteins and the carbonyl group of a reducing sugar. In this stage, the reaction loses a molecule of water and forms glycosylamines. Then, the Amadori rearrangement produces Amadori compounds followed by breakdown to form degradation products - sugar reductones. Finally, nitrogen containing brown polymers and copolymers known as melanoidins are formed (Lee and Whitaker, 1995).

2.6.4.2 Browning prevention methods

Since browning, especially enzymatic browning affects the quality of numerous plant organs which are rich in oxidizable phenols such as fruits and vegetables and decrease their economic returns in the food industry, measures should be taken to protect both nutritional and economical value of foods subjected to browning. There are various methods that can be used for browning prevention. They can be divided into two categories - physical methods and chemical methods. Various methods in these two categories will be reviewed below:

Physical methods of prevention

Although there are several methods to prevent enzymatic browning, they have the same principle, which is to reduce or inactivate the enzyme, and thus to prevent browning. As a prevention method, physical methods reduce or inactivate enzyme activity by controlling the external environment, such as temperature and oxygen level.

Temperature control

a) Freezing

Freezing (below -18°C) is estimated to block colour changes due to the fact that enzymes such as PPOs could be inactive under this condition. However, when the temperature rises, browning starts again, and will be even more visible if the cellular structures of the plant organ have been severely damaged by freezing, chemical peeling and slicing (Caballero *et al.*, 2003). Cano *et al.* (1997) support this viewpoint by indicating freezing/thawing processes, which produced a significant increase in phenol levels due to cellular breakdown.

b) Blanching

Heat treatment or blanching is believed to be one of the simplest and most direct methods of enzyme inactivation and inhibition of colour deterioration, due to the fact that blanching could reduce the microbial load and inactivate deleterious enzymes, such as PPOs and PODs. Castro *et al.* (2008) implied that thermal blanching treatments could progressively decrease PPO activities from 25% to 75% in green peppers. Additionally, Cano *et al.* (1990) demonstrated that blanching peeled bananas in boiling water produced significant inactivation of PPO and POD (96-100%). Bahceci *et al.* (2005) also agreed that blanching could inactivate enzymes. They found that a blanching treatment at 90°C for 3 min was able to inactivate 90% of the activities of PODs in green beans.

There are two major methods that are widely used in the food industry for blanching. One is hot water blanching and the other is steam blanching. Hot water blanching is achieved by plunging vegetables or fruits into hot water to inactive enzymes, while steam blanching is accomplished by utilizing the heat from steam to inactive enzymes. Compared with hot water blanching, steam blanching uses less energy and water. Johnson (2011) illustrated that when steam blanching was applied directly to the food products, it used approximately half the amount of water vs. that used in water blanching. It could save approximately $4000- $8000 in energy cost by steam blanching one million lbs (454 metric tons) of carrots or peas than water blanching. Moreover, steam blanching achieved better nutrient retention than water blanching. The nutrient loss of steam blanching is only one third of hot water blanching (Lee and Whitaker, 1995). When food enters hot water, some soluble nutrients such as soluble vitamins may dissolve in the hot water and the nutrients in the hot water blanched food could be lost. Because steam blanching minimizes the leaching of soluble solids, this method could leave more nutrients and natural sugars in food products, thus it could improve flavour retention and colour retention to produce a final product with better flavour, texture and colour than hot water blanching (Johnson, 2011).

However, blanching still has some disadvantages. Over-heating causes loss of sensory (texture, taste, flavour and colour) and nutritional quality attributes (Castro *et al.*, 2008). Jackson *et al.* (1996) Blanched whole green bananas at 50, 60, 70, 80, 90 and 100°C for 2, 15 and 30 min, then fried peeled and sliced banana to make chips. They suggested blanching for 22 min at 69°C as the optimized blanching condition for crispness of banana chips. If the blanching temperature is higher than 69°C and time is longer than 22 min it would have negative effects on crispness. Castro *et al.* (2008) Stated that ascorbic acid content decreased progressively as blanching conditions were more severe. The higher the temperature and longer treatment time, the lower the ascorbic acid content in the samples. The retained ascorbic acid content in green and red peppers was 45% and 30% respectively. Therefore, blanching temperature and time should be well controlled. The optimal temperature and duration time is the condition that could both inhibit enzyme activities and maintain the quality of food samples.

Other physical methods

Other techniques, such as high pressure, ultrasound and nitrogen preservation, are also used in the food industry to protect the colour of foodstuff. Palou *et al.* (1999) indicated that peroxidase, catalase, phosphatase and PPOs, which cause browning, were resistant to pressures of 600-700 MPa at 25°C. Caballero *et al.* (2003) stated that browning can also be prevented by keeping the food products in low oxygen atmospheres. Nowadays, food industry uses the carbon dioxide or pure nitrogen atmospheres to protect freshness of fruits and vegetables against enzymatic browning. Between these two gases, Nitrogen provides better protection of the original flavour and aroma. Segovia *et al.* (2012) measured damaged olives by keeping them in N_2 atmosphere for 24 h. They found that the browning of bruised areas of the olives was very similar to that suffered by healthy olives maintained in the air, which meant the N_2 atmosphere was able to prevent the browning. However, N_2 atmosphere is not suitable for any food. There is evidence showing that treatment of bananas in N_2 atmosphere is not effective (Segovia *et al.*, 2012).

Chemical prevention

Chemical prevention utilizes the chemical reaction of compounds, which cause browning, and the functional group of some compounds, acting as antioxidant agents, enzyme inhibitors, acidulants, chelating agents or complexing agents, are used to inhibit browning (Queiroz *et al.*, 2011). Some of the compounds could also prevent both enzymatic and non-enzymatic browning. Despite the fact that some compounds, such as sulphur dioxide, have significant effects on colour and flavour preservation, they cause safety issues and thus are forbidden in many countries. In the case of plant foodstuffs, the legislation in most countries allows only ascorbic acid and its derivatives, sodium chloride and, within stricter limits, citric acid (Caballero *et al.*, 2003) to be used for this purpose. The browning inhibition effects of some chemicals and their synergistic effects will be reviewed in the following paragraphs.

It has been reported that ascorbic acid showed strong inhibition of PPO, causing full enzyme inactivation even at low concentration. Ascorbic acid with its first oxidation product dehydroascorbic acid, which constitutes vitamin C, reduces O-quinones progressively as they are formed (Caballero *et al.*, 2003). Unal and Sener (2006) proved that ascorbic acid at 0.2 mM and 0.8 mM resulted in 99% and 100% inhibition of banana

PPO, respectively (Queiroz *et al.*, 2011). Taufel and Voigt (1964) claimed that concentrations between 0.5 to 1% of sodium chloride had an inhibiting effect on the enzymatic browning of whole apples or apple pieces, whereas Pizzocaro *et al.* (1993) argued that sodium chloride in concentrations between 0.2 g/L to 1 g/L activated PPO and 1 g/L even increased PPO activity by about 90%.

The synergistic effect of different compounds for browning inhibition is stronger than that of single compounds. Pizzocaro *et al.* (1993) studied the synergistic effect of ascorbic acid and citric acid plus ascorbic acid and sodium chloride. They discovered that both citric acid and sodium chloride increased the inhibiting effect of ascorbic acid. They concluded that compared with citric acid, sodium chloride is more efficient. Adding 0.5 g/L of sodium chloride instead of 2 g/L of citric acid to 10 g/L of ascorbic acid showed that the PPO inhibition was 100% instead of 87%.

2.6.5 Drying

Drying is one of the most effective methods used to preserve fruit and vegetables, because fruits and vegetables have high moisture and this method can remove the moisture in food by evaporation. The rate of microbial activity and other deteriorative reactions in fresh fruit and vegetables therefore can be slowed. Also, other important advantages include nutritive value (66-90% carbohydrate) maintenance and shelf life prolongation (Hui *et al.*, 2006); reduction of transportation and storage costs and the convenience of use (Fellows, 2002). Drying processes are also reported as causing modification to the physical properties of the fibre matrix and affect the hydration properties as well (Dhingra *et al.*, 2012). Different drying conditions may also cause a difference in food quality. If the drying time is too long or the drying temperature is too high, the quality of the food including nutritional values, colour, taste etc. will be negatively affected. Thus, appropriate drying conditions should be chosen during food preservation. In this section, the principle of drying, drying curve, factors that will affect drying rate as well as effect of drying conditions will be presented.

2.6.6 Carbohydrates

Carbohydrates, the main source of the human diet, represent the primary energy source, contributing to nearly 55-70% of the total energy consumption (Osorio *et al.*, 2002). Their nutritional energy value amounts to 17 kJ/g. The function of carbohydrates in food includes sweetening, gel or paste-forming action, thickening agents and stabilizers.

Moreover, the carbohydrates are precursors for aroma and colouring substances in the food industry, especially in thermal processing (Belitz *et al.*, 2009). For instance, the Maillard reaction and caramelization both require carbohydrate as reagents. The non-digestible carbohydrates, such as the non-starch polysaccharides acting as bulk materials, are of importance to balanced daily nutrition. Food sources such as cereals, fruits, vegetables and legumes are all rich in carbohydrates.

2.6.6.1 Potential health benefits of carbohydrates

It has been stated in recent decades that some types of carbohydrates, especially non-digestible carbohydrate has some benefits on the chronic diseases. According to World Health Organization (WHO), chronic diseases, such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes, are by far the leading causes of mortality in the world, representing 63% of all deaths. Non-digestible carbohydrate, such as resistant starch and dietary fibre may be the constituents that could protect human beings from these modern diseases. Dietary fibre has been shown to have numerous benefits, which are not easily disputed like improving intestinal function, cholesterol reduction and increasing microbial biomass. Other benefits of fibre and resistant starch include weight reduction, satiety, regulating glucose and insulin responses, improvement as well as modification of micro biota composition, inflammatory markers such as C-reactive protein, interleukin 6 and tumor necrosis factor alpha in obesity and diabetes (Cui and Roberts, 2009). Long-term intake of the non-digestible carbohydrate could decrease the risk of some chronic disease, such as diabetes mellitus, obesity, coronary heart disease (CHD) and hyperlipidemia. The physiological effects of carbohydrates as well as their relationship to some diseases are as follows:

a) Hyperlipidemia

Hyperlipidemia means abnormally high levels of any or all lipids and/ or lipoproteins in the blood, which may be physiological increase after meal.

b) Diabetes mellitus

Diabetes mellitus is a metabolic disorder involving impaired glucose homeostasis due to either failure of secretion of the hormone insulin (insulin-dependent or type I diabetes) or impaired responses of tissues to insulin (non-insulin-dependent or type II diabetes). If untreated, the blood concentration of glucose rises to abnormally high levels (hyperglycaemia) after a meal and glucose is excreted in the urine (glucosuria). Prolonged hyperglycaemia may damage nerves, blood vessels, and kidneys, and lead to development of cataracts, so effective control of blood glucose levels is important (Bender, 2009).

c) Glycemic index (GI)

GI is the measurement of an individual's glucose response to a known quantity of available carbohydrate from a test food, in comparison to that person's glycemic response from a standard food, usually glucose or white bread. Low GI is believed to indicate a corresponding low glucose and insulin response (Cui and Roberts, 2009).

d) Coronary heart disease (CHD)

Coronary heart disease is the major cause of death in most western countries. Healthy eating for CHD prevention is a hot issue in the latest decade. High consumption of dietary fibre, especially soluble fibre is believed to have inverse association with risk of coronary heart disease. Mechanisms of non-digestible carbohydrates reducing the risk of CHD improve blood lipid profiles by lowering blood pressure and improving insulin sensitivity and fibrinolytic activity (Pereira *et al.*, 2004).

2.6.7 Effect of drying on the carbohydrate digestibility

Foods contain a range of chemically distinct carbohydrate components, which have varied gastrointestinal and metabolic properties (Englyst *et al.*, 2007). The bioavailability of food carbohydrates is the most important nutritional property, since it describes the utilization and biological effect of dietary carbohydrates. In recent decades, the traditional belief that carbohydrates such as starch are completely digested although slowly digestible, have been overthrown. It is believed that the digestibility of carbohydrates determines the place and form in which carbohydrates are absorbed. Different kinds of carbohydrates have different nutritional benefits to humans. Although rapid digestion and absorption of carbohydrates has benefits for some aspects of sports nutrition, this is not commonly considered desirable as the elevated glycemic response after a meal relates to several chronic diseases, especially with diabetes or with features of metabolic syndrome (Englyst *et al.*, 2007).

Slowly digested and absorbed carbohydrate sources, such as some of the oligosaccharides and SDS, may reduce postprandial glucose surges as well as the risk of coronary heart disease and diabetes incidence. Carbohydrates that escape digestion in the small intestine and poorly metabolized like resistant starch, some of the oligosaccharides and dietary fibre will enter the colon and the fermentable carbohydrates will be salvaged as short-chain fatty acids in the colon and meanwhile may stimulate colonic microflora like bifidobacteria, which are beneficial to health (Wong and Jenkins, 2007). The non-digestible carbohydrates can reduce the risk of cardiovascular disease, diabetes, obesity, hyperlipidaemia and hypertension (Scheppach *et al.*, 2001).

2.6.8 Effect of drying on the physicochemical properties

Crystallinity index (CI), water holding (WHC), swelling and solubility capacities of dried banana pseudostem suggest some possibilities about the use of banana pseudostem powder as ingredients in food products. For example, high WHC implies that the powder can be used as functional ingredients to avoid syneresis and modify the viscosity and texture of some formulated foods (Grigelmo *et al.*, 1999). Moreover, the study of the physicochemical properties of the banana pseudostem can reflect its health benefits. For instance, high viscosity and solubility is able to increase faecal bulking and reduce intestinal transit time, which may improve intestinal peristalsis (Gupta and Premavalli, 2011).

2.7 Technology involved during biscuit making

Technology is the factor which enables easy doing of something by significantly reducing the labour, time, expenditure and increasing the quality. Technology is always beneficial until it is under control. Hence the skill to handle the available technology is the fore most need during an operation. Not only the technology controller or his department is responsible with the machinery control but with the total control from ingredient purchase to sales (Rao *et al.*, 1991). The technology of biscuit production is shown in Fig. 2.1.

Preparation of ingredients

↓ (Weighing, recipe calculation and Fermentation of dough in case of Fermented biscuits)

Creaming

↓ (Performing is done for hard Dough and fermented dough Biscuits)

Laying the dough

↓

Dough forming

↓ (Moulding in case of soft dough Biscuit, sheeting for other types)

Baking (Temp. 176°C to 204°C for 4 to 6 min)

↓

Cooling (for 6 to 7 min)

↓

Wrapping and packaging

↓

Labelling and storage (RH 40-59% at room temperature)

Fig. 2.1 Flow sheet of manufacturing process of biscuit

Source: Smith (1972)

2.7.1 Dough mixing

Mixing is the major step during biscuit making. Properly mixed dough has a great influence in the final quality of the product. Mixing of the dough can be done in various ways as per requirement. Mixing in industries is carried out by use of electrical mixers, most commonly used mixers are two speed mixers. In top speed, the creaming up time is 3-5 min in two speed mixer types, while the flour should be mixed for 10 min on slow speed (Whitely, 1971).

In the context of biscuit dough, biscuit sandwich creams and batters, the “mixing” converse a number of distinct operations. It includes:

a. The blending of ingredients to form a uniform mass.
b. The dispersion of a solid in a liquid, or liquid in liquid.
c. The solution of a solid in a liquid.
d. The kneading of mass to impart development of glutrn from flour proteins which have been hydrated at earlier stage of the mixing.
e. Build-up of temperature as a result of work imparted.
f. Aeration of a mass to give a lower density.

One or more of these actions is required in the formulation of dough for the very many types of products that are called biscuits (Manley, 1998).

There are two basic methods of mixing the dough but each may have several variations designed to achieve the best result under the particular circumstances prevailing and depending upon the type of equipment used.

a. Creaming up method

This method of mixing up of dough mixing includes two steps, during first step the sugar and fat are blended together to fine dissolution after that other ingredients like milk powder, water, invert syrup, lecithin, color, essence, salt are mixed up for around 3-5 min to form a homogeneous cream. Now the flour along with the aerating agents is mixed up with the cream and mixed at slow speed in the mixing machine for around 10 min. If other type of flour are to incorporated than care must be taken that they must be pre-mixed into the shortenings and the water before adding the other ingredients if the true attribute of thus added flour is to be achieved (Smith, 1972).

This type of mixing method holds the water in a more or less stable state so that it is prevented from making a wide spread attack on the flour to form any significantly higher amount of gluten network. Mostly short cake rotary and wire cut doughs are mixed by this method, in order to control flow and volume during baking. A significant factor in such mixings is the amount of water used (Whitely, 1971).

b. All in one method

As the name suggests, all the ingredients are mixed together and fed in the mixing machine. This method is straight forward where all the ingredients along with major part of water is fed into the mixing machine which some part of water is used to dissolve the aerating chemicals, flavours, colours and salt which is alter on mixed with the dough and is mixed until a satisfactory dough is produced. This type of mixing method is widely applied with hard, semi-sweet dough. Due to the relatively higher water content in these doughs it results in very satisfactory gluten production and formation.

In fermented dough an important step apart from the above described methods is used which is known as punch back or knock back. This helps to break down the pockets formed by the carbon dioxide during fermentation. The accumulated carbon dioxide might otherwise be poisonous for the yeast cells (Smith, 1972).

2.7.2 Laying the dough

Lay time refers to the halt of the dough between mixing and machining. Lay time for various products is variable. Lay time for fermented dough is highly necessary and is long while in case of sulphated dough, it is avoided. A minimum of 15 minutes of lay off time should be given to the dough for the achievement of good surface gloss, color, and weight. It also makes the dough easily machinable (Smith, 1972).

2.7.3 Forming and performing

The shaping or forming of the dough into various shapes and to the required thickness before baking is one of the major steps in biscuit making. In case of hard dough and fermented dough forming is done by using sheeters and laminators, which reduces the thickness of the dough to convert it into a thin sheet. Occluded air is eliminated from the dough. It also helps in proper spread of fat, salts which helps in producing a product with short eating and layered appearance. Soft dough is directly fed into moulding or embossment disc which cuts them into required size, shape and appearance (Shrestha, 1995).

2.7.4 Baking

Baking is the major step of biscuit production without which the product loses its eating quality. During baking, the product is cooked, flavour and colour is developed and the raw dough is converted into an edible snack named biscuit. The main objective of baking is to remove the moisture present in the dough pieces by gradual heating. The dough contains more than 25% moisture, a part of which is bound water present in the flour and other ingredients while other part is the free water added externally for dough making and easy machinability (Bloksma, 1990).Every baking process depends upon the heat transfer from a hot source to the product being baked. Method of heat transfer during baking is mainly by three methods namely, conduction, convection and radiation. During baking a major part of heat transfer to the dough pieces is by radiation while the heat transfer by convection is very low as long as the air velocity in the tunnel is not higher than 5 feet per second, after which the heat transfer by convection tends to be higher. Apart from these three modes of heat transfer, high frequency heating is also used which has a higher rate of moisture removal (Smith, 1972).

Every oven used till date consists of four basic parts:

a) A heat source
b) A base (sole or hearth), capable of being heated, on which the dough piece is placed.
c) A cover over the base, making up a chamber in which to retain the heat.
d) A closable opening through which the dough piece can be put into and taken from the baking chamber.

During baking the dough undergoes gradual changes physically as well as chemically. Physical changes include:

a) Formation of a film crust on the dough.
b) Melting of the fat in the dough.
c) Gas release and volume expansion.
d) Conversion of water into steam.
e) Escape of carbon dioxide, other gases and steam.

Chemical changes include:

a) Gas formation
b) Starch gelatinization
c) Protein changes
d) Caramelisation of sugar
e) Dextrinization

Temperature in the baking oven has different effect on the raw dough which is shown in Table 2.8.

Table 2.8 Temperature related changes in biscuit during baking

Temperature (°C)	Changes occurred
32-37	Top crust skin formation (evaporation of surface moisture).
32-48	Evolution of CO_2 within crumb (less solubility of CO_2).
32-65	Increase in volume due to CO_2
32-99	Gas expansion (CO_2 and steam).
51-99	Starch gelatinisation (biscuit structure).
76-88	Evaporation of alcohol, yeast action ceases.
76-121	Evaporation of alcohol, yeast action ceases.
76-121	Coagulation of protein (irreversible).
188-204	Dextrinization (surface gloss)

Source: Mukhopadhyay (1990)

During baking it is necessary to have more steam in the oven than that derived from the moisture from the dough and the combustion of the fuel. Introducing steam into the baking chamber, either immediately at the entry of the dough pieces or at a point very early in their passage through the oven, helps to create a shiny crust formation, prevention of cracked crusts, increased volume and to some degree agitation of the oven atmosphere. The need of steam injection can be removed by using fast moving fans recirculating air at speeds of 2000 cu ft per min. The dampers present at the ovens play a vital role in releasing the high positive pressure within the oven created due to high heat evaporation, similarly if high moisture cookies or biscuits are desired than the dampers at the last zone must be closed (Smith, 1972).

2.7.5 Cooling

Cooling is one of the most important part of biscuit production. As biscuits emerge from the oven they are very hot nearly at a range of 99-101°C, very soft and moist. Therefore cooling of the biscuit prior to packaging must be done to maintain the proper structure of the biscuits. Immediately after the biscuits are released from the oven they possess a very high moisture content which signifies that the flour starch is still in some form of gelatinous paste and the dextrin still in partial solution. Similarly the sugar as well as fat will also be in its liquid form, protein although firmer than other ingredients is also pliable. Hence, almost all ingredients are in unset state. Cooling helps in consequent loss of moisture and slowly sugars start to crystallise out and the dextrin grow tougher, then only the biscuit grow tougher and set. Cooling should be gradual and slow (Bloksma, 1990).

Checking is the most common defect which occurs in the biscuits after they are prepared and not noticeable during processing. Checking refers to the hair like structure which might refer to weakening of the structure and breakage might occur after 24 hrs of packaging. Hard, semi-sweet biscuits are prone to checking rather than rotary moulded soft types which is due to its low fat and low sugar content leading to higher gluten development. As gluten has higher affinity towards water, it will extract it from the gelatinised starch present in the hot biscuit and so cause stresses to be set up. This problem is supposed to be further aided by rapid shrinkage of the biscuit due to rapid cooling. Hence, checking can be reduced or eliminated if the baking is slow and the cooling is gradual rather than rapid (Manley, 1983).

2.7.6 Packaging and storage

Biscuits are low moisture content food. Their mandatory standards state them to be of low moisture content, mainly below 6%. The relative humidity of freshly baked biscuit is very low so in order to prevent rapid uptake of moisture from the atmosphere, the biscuits must be packed in a water vapour resistant material. Uptake of moisture by biscuit make them prone to microbial attack similarly open access to the atmosphere make them prone to oxidative rancidity as fat is a major ingredient used during biscuit making(Paine and Paine, 1983).

Packaging materials are those materials which contain the product within them providing necessary conditions and protection to the product inside to keep them safe and consumable over a long period of time. In case of biscuit a good packaging material must be:

a) Resistant to water vapour.
b) Non- tainting material with good grease resistance.
c) Should be strong enough to protect against any possible mechanical injury.
d) Should be opaque.
e) Easily printable.

Packaging in case of biscuits must be close up together in order to provide a mutual reinforcing effect which prevents them from breakage. Packaging of biscuits at commercial level is generally done in triple laminates consisting of polyethylene, aluminium foil and paper (Paine and Paine, 1983). The characteristics of the packaging materials are described in Table 2.9.

Table 2.9 Some characteristics of packaging materials.

Component	Properties
LDPE	Moisture and vapour barrier, heat sealing medium
Paper	Stiffness, low cost, opacity, printable.
Aluminium foil	Opacity, good water vapour and gas barrier.
Oriented polyethylene terepthalate	Gas barrier, strength, grease resistant.
PVC	Transparency, rigidity, gas barrier
Polypropylene	Easy sealing, resistance to oil, grease.
HDPE	Stiff, smooth, resistant to chemicals, moisture, gas, harder than LDPE.

Source: Robertson (2013)

2.8 Sensory perception of biscuits

Before launching the biscuit in the market, a panel of experts evaluate the overall acceptability of the final product which is known as sensory perception or evaluation. Many basis of evaluation include appearance, crispiness, crumb color, flavour and finally the overall acceptability. The evaluation is marked on the score cards which is later on discussed in order to find out the best product. Consumer research, case history research is also some of the factors that need to be included which drawing conclusions from the analysis (Smith, 1972).

2.9 General specifications of biscuits as published by NBS

Biscuit should be properly baked, crisp and uniform in texture and appearance. They should not possess rancid flavour, fungal infection, off odour and any insect infestation. For filled biscuits any of the fillers like jam, jellies, marshmallow, cream, caramel, figs, raisins etc can be used. The biscuits may be coated with caramel, cocoa or chocolates. Use of antioxidant as well as permitted preservative can be done not exceeding the maximum dosages. The general specifications of biscuits as described by Nepal Bureau of Standards (NBS) is given in Table 2.10.

Table 2.10 General specification for biscuits

S. No	Characteristics	Requirements
1	Moisture	6.00% max
2	Acid insoluble ash (on dry basis)	0.05% max
3	Acidity of extracted fat (as oleic acid)	1.00% max

Source: NBS (2040)

2.10 Nutritive value of biscuits

Biscuit is a ready to eat good source of nutrient as it contains carbohydrates, fats, proteins, minerals and vitamins. Proteins are nutrients for growth and repair of tissues while carbohydrate and fat provide heat and energy. Similarly minerals provide nutrient for bone growth. Vitamins are responsible for normal metabolic activities and maintaining normal vitality of the body. Nutritive value of biscuit is given in Table 2.11.

Table 2.11 Nutritive value of biscuit (values per 100 g)

Weight per serving in gram	100 g
Calories (kcal)	480
Protein (g)	5.2
Fat (g)	20.2
Carbohydrate (g)	71.0
Calcium (g)	0.04
Phosphorous (g)	0.16
Iron (mg)	1.8
Vitamin A value (I. U)	-
Thiamine (mg)	0.03
Riboflavin (mg)	0.04
Nicotinic acid (mg)	0.8

Source: Swaminathan (1991)

2.11 Shelf life of biscuits

Moisture and oxidative rancidity of the biscuit are the main factors responsible for the shelf life reduction of the biscuit in terms of palatability. Sunlight causes loss of crust colour. Although moisture proof and opaque packaging are used the deterioration of crust colour and onset of rancidity is likely to occur at any time which might be due to the atmospheric oxygen present inside the packet. Normally packed and stored biscuits are prone to rancidity and color fading in about 60 days while biscuits stored in sealed jars and dark cupboards at 70-75°F were safe till 12 months (Smith, 1972).

Mainly increase in moisture content, onset of fat deterioration or increase in peroxide value and sometimes maillard reaction is considered responsible for off-flavour. Natural antioxidants if present in the raw materials might help in preventing oxidation. Banana pseudostem is a source of natural anti-oxidants like lutein, selenium, etc. Incorporation of banana pseudostem powder in the biscuit might help in preventing oxidative rancidity of the final product.

Part III

Materials and methods

3.1 Raw material

3.1.1 Wheat flour

Wheat flour named 'Fortune maida' produced by Nutri Food Pvt. Ltd., Sonapur, Sunsari, Nepal was used for biscuit making. The maida was purchased from local market of Dharan.

3.1.2 Banana pseudostem (*Musa acuminata*)

A common variety of fresh banana pseudostem after harvesting fruit, *Musa acuminata* were obtained from Central Campus of Technology, Dharan-14, Hattisar.

3.1.3 Butter

Vegetable ghee named 'Delicious fat spread' manufactured by Kaira District Co-operative milk producer's Union Ltd., Anand, India was used as shortening agent.

3.1.4 Sugar and Salt

Sugar in the form of pulverized sugar and iodized common salt were used. Sugar and salt were bought from local market of Dharan.

3.1.5 Skim milk powder

Skim milk powdered of Britannia India Limited, India was used.

3.1.6 Baking powder

Baking powder named as 'Weikfied baking powder double action' manufactured and packed by Weikfied food Pvt. Ltd., Pune, India was used.

3.1.7 Packaging material

High density polyethylene of 50 μ (micron) was used for the packaging of the product.

3.2 Chemicals required

The required chemicals were obtained from C.C.T. lab

- Acetone
- NaOH
- Sulphuric acid
- Boric acid
- Petroleum ether
- Phenolphthalein indicator
- Methylorange indicator
- Hydrochloric Acid
- Mixed indicator solution
- Boric acid
- Digestion mixture
- Distillled water
- Potassium Metabisulfite (KMS)

3.3 Apparatus required

The required apparatus were obtained from C.C.T. lab.

- Burette
- Conical flask
- Measuring cylinder
- Beaker
- Microprocessor flame photometer
- Pipette
- Cabinet dryer
- Thermometer
- Weighing balance
- Vernier calliper
- Screw gauge
- Hot air oven
- Soxhlet assembly
- Desiccator
- Heating arrragement
- Buchner filter assembly
- Suction pump
- Crucible
- Whatman filter paper
- Muffle furnance
- Silica crucible
- Petridish
- Kjeldahl digestion and distillation set

3.4 Method of experiment

3.4.1 Methodology

Design Expert v7.1.5 software was used to create the recipe. Rotatable central composite design was used to formulate the recipe. The independent variable for the experiment is concentration of banana pseudostem powder used to make biscuit.

3.4.2 Formulation of recipe

The recipe formulation for the banana pseudostem incorporated biscuit was carried out as given in Table 3.1.

Table 3.1 Recipe formulation for biscuit

Ingredient	A	B	C	D	E
Wheat flour	100	97.5	95	92.5	90
Banana pseudostem powder	0	2.5	5	7.5	10
Sugar	40	40	40	40	40
Fat	35	35	35	35	35
SMP	6	6	6	6	6
Baking powder	2.22	2.22	2.22	2.22	2.22
Salt	0.3	0.3	0.3	0.3	0.3

The biscuit was made as per the recipe formulation done and coded name A, B, C, D and E were given to each recipe. Composite biscuit were of soft dough type method as in Fig. 3.2.

3.5 Preparation of banana pseudostem powder

The banana pseudostem was first cleaned to remove the outer sheath. After removing the outer sheath, the inside found central core was washed and sliced using a stainless steel knife. The slices were then soaked in a solution of 0.2% concentration of potassium meta bisulphate (KMS) for 10 min in order to control browning. They were then dried in a cabinet dryer at 60°C temperature for 48 h, from an initial moisture content of 90% to final moisture content of 6% (wb) (Ambrose and Naik, 2016). The dried samples were powdered in a laboratory pulveriser to a fineness that 90% of the powder passed through 400 micron sieve. The flour obtained was packed in Aluminium foil pouches, sealed and stored at ambient condition. The process for preparing banana pseudostem powder is shown in Fig. 3.1.

Banana pseudostem

↓

Removal of outer sheath

↓

Washing

↓

Slicing (4-6 mm)

↓

Soaking in 0.2 % KMS for 10 min

↓

Cabinet drying 60°C for 48 h

↓

Pulverising (400 µ)

↓

Banana central core flour

Fig. 3.1 Process of making banana pseudostem powder

Source: Ambrose and Naik (2016)

3.6 Determination of threshold of banana pseudostem powder

The independent variable of the experiment is banana pseudostem powder. The determination of threshold for banana pseudostem powder is carried out by the help of trial experiment. The result of the experiment concluded that above 10%, the biscuit was not acceptable. Therefore, the threshold for banana pseudostem powder is set between 1 and 10%.

3.7 Preparation of banana pseudostem incorporated biscuit

Fat and sugar powder were firstly creamed. Salt was dissolved in water and added to the prepared cream mixture. As creaming process was continued, composite flour and baking powder were added and stirred well together. The full prepared dough was sheeted 5-6 mm thick and was cut to form required circle shape. The formed biscuit were baked at 200°C for 15 min. After cooling to about 35°C, the biscuits were packed in HDPE packages. The process for preparing banana psedostem incorporated biscuit is shown in Fig. 3.2.

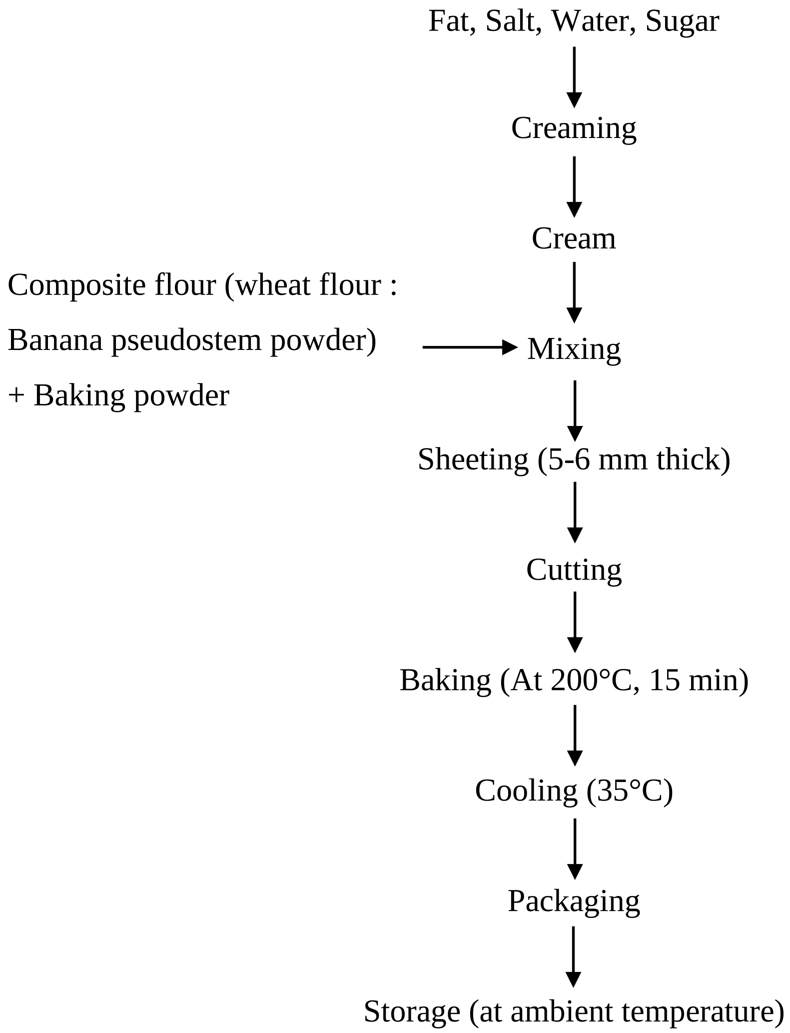

Fig. 3.2 Flow chart for the preparation of banana pseduostem incorporated biscuit

Source: Smith (1972)

3.8 Analysis of raw materials and product

3.8.1 Physical parameter analysis

3.8.1.1 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.

3.8.1.2 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)

3.8.1.3 Density

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

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

3.8.2 Physicochemical analysis

3.8.2.1 Moisture content

Moisture content of the sample was determined by heating in an oven at 100 ± 5°C to get constant weight (Ranganna, 2012).

3.8.2.2 Crude fat

Crude fat content of the samples was determined by solvent extraction method using Soxhlet apparatus and solvent petroleum ether Ranganna (2012).

3.8.2.3 Crude protein

Crude protein content of the samples was determined indirectly by measuring total nitrogen content by micro Kjeldahl method. Factor 6.25 was used to convert the nitrogen content to crude protein as per KC and Rai (2007).

3.8.2.4 Crude fibre

Crude fibre content of the samples was determined by the method given by Ranganna (2012).

3.8.2.5 Total ash

Total ash content of the samples was determined by following the method given by Ranganna (2012) using muffle furnace.

3.8.2.6 Carbohydrate

The carbohydrate content of the sample was determined by difference method.
Carbohydrate (%) = 100-(protein + fat + ash + crude fibre)

3.9 Potassium content

The potassium content of the sample was determined by flame photometer as per KC and Rai (2007). Biscuit ash solution is atomized in an oxy-hydrogen or oxyacetylene flame. The flame excites atoms of potassium causing them to emit radiations of specific wavelengths. The amount of radiation emitted is measured by the emission flame photometer (768 nm). Under standard conditions, the amount of emission is proportional to the concentration of potassium in the sample solution.

3.10 Sodium content

The sodium content of the sample was determined by flame photometer same as potassium as per KC and Rai (2007).

3.11 Calcium content

The calcium content of the sample was determined by flame photometer same as potassium content as per KC and Rai (2007).

3.12 Sensory analysis

The sensory analysis for overall quality was carried out withten semi-trained panelists which consisted of teachers and students of Central Campus of Technology. The parameters for sensory evaluation were texture, crispiness, color, taste, flavour and overall acceptability. Sensory evaluation was performed according to the 9- Point Hedonic Scale as in appendix A.

3.13 Statistical analysis

The obtained data was analyzed statistically by Genstat Discovery Edition 3, for Analysis of Variance (ANOVA) at 5% level of significance. The data obtained from proximate analysis and sensory evaluations were subjected to one and two way Analysis of Variance.

3.14 Packaging and storage of the biscuit

High density polyethylene bag was used for the packaging of the biscuits and was stored at ambient temperature.

3.15 Determination of shelf life

Shelf life of the product was determined by acid value, peroxide value of the extracted fat and moisture content of the biscuit. The analysis was carried out once a month basis.

Part IV

Results and discussion

This work was carried out for the preparation of different biscuit formulation with varying proportion of banana pseudostem powder with wheat flour. As biscuit is a product widely flavoured and consumed by general population, banana pseudostem incorporated biscuit as a functional food was chosen as a vehicle to drive the functional ingredients in this study. At first, the major raw materials were subjected for proximate analysis.

4.1 Proximate composition

Wheat flour and banana pseudostem powder were analysed for proximate components whereas SMP was analysed for fat and solid not fat (SNF). The results of analysis of wheat flour and banana pseudostem powder in dry basis are tabulated in Table 4.1 and that of SMP in Table 4.2.

Table 4.1 Proximate composition of wheat flour and banana pseudostem powder

Proximate Composition (db)	Wheat flour*	Pseudostem powder*
Moisture content (%)	12.35±0.25	6.2±0.15
Crude protein (%)	10.2±0.12	3.6±0.01
Crude fat (%)	1.55±0.02	1.8±0.02
Crude fibre (%)	0.61±0.01	13.3±0.03
Total ash (%)	0.57±1.23	12.3±0.01
Carbohydrate (%)	87.11±0.45	62.8±0.25
Gluten content (%)	8.1±0.25	-
Calcium (mg/100g)	34±0.15	318±0.03
Potassium (mg/100g)	126±0.35	680±0.20
Sodium (mg/100g)	2±0.01	104±0.01

*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 Kent and Amos (1983). The moisture content of the banana pseudostem powder was found to be 6.2%. The value obtained was lower than those reported in literature that determined the moisture content of banana pseudostem by using the same oven drying method. Both Aziz *et al.* (2011) and Bhaskar *et al.*(2011) reported higher moisture contents in dried banana pseudostem (8.82% and 15.1%). The reasons for this difference could be attributed to species, size of banana pseudostem pieces and drying conditions (temperature, relative humidity and time).

The protein content was found to be 3.6% in banana pseudostem powder. The obtained result was similar to the results obtained by Aziz *et al.* (2011). However, compared to wheat flour, which was 10.2%, the protein content in banana pseudostem is low. It implies that dried banana pseudostem flour has a potential to make low gluten food, such as cake. The fat content of banana pseudostem flour was found to be 1.8%. The obtain result was slightly higher than those reported by Aziz *et al.* (2011) and Bhaskar *et al.* (2011)

Pseudostem contains a lot of minerals, confirmed by its higher ash content as 12.30 g/100g. The ash content of pseudostem powder in the present study (12.30%) is higher than ash contents of wheat flour (0.57%) and barley flour (3.6%) which is similar to the results obtained by Aziz *et al.* (2011) who also found that the ash content of pseudostem powder is higher than that of the ash contents of wheat flour and barley flour. This might be due to differences in the nature of different crops. Ho *et al.* (2012) and Aziz *et al.* (2011) reported lower ash contents, which were 6.75% and 10.08%. Higher ash content indicates higher mineral contents.

The calcium content in banana pseudostem powder was found to be 318 mg/100g, which varies from the calcium content as calculated by Ho *et al.* (2012), which was 1335.3 mg/100g. The potassium content in banana pseudostem powder was found to be 680 mg/100g. However, the result obtained differ from those reported by Ho *et al.* (2012), which was 944.12 mg/100 g. The potassium content in banana pseudostem powder was found to be 104 mg/100 g. However, the result obtained differ from those reported by Ho *et al.* (2012), which was 444.1 mg/100 g. The reason for this may be due to the difference in the maturity of banana pseudostem samples collected. Ca concentration increased with age (Ho *et al.*, 2012). Potassium accumulates in the stalk before efflorescence. Its concentration in the pseudostem decreases during the fruiting phase, because the bananas require substantial amounts for fruit development (Ho *et al.*, 2012). At the maturation stage, the calcium concentrations increase due to competition with other cations, especially potassium (Ho *et al.*, 2012). Banana pseudostem could be a good source of potassium.

The crude fibre of the banana pseudostem powder was found to be 13.3% (db) which are comparatively greater than that of wheat flour 0.61% (db).

Table 4.2 Anlaysis of SMP

Component	SMP (% wb)
Fat	0
SNF	94 $\pm$0.25

* The values in the table are the mean of the triplicates $\pm$ standard deviation

4.2 Influence of pseudostem powder on physical parameters of biscuits

Physical characteristics of biscuits such as thickness, diameter, spread ratio, weight, volume and density were affected by the substitution increment of the level of pseudostem powder which is presented in Table 4.3. The results indicated that diameter and thickness of biscuit were slightly increased with increasing substitution percentage of pseudostem flour. 10 parts pseudostem flour incorporated biscuit revealed the maximum diameter and thickness (62.14 and 6.56 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 9.85 to 9.47. It is clear that as the pseudostem powder 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 and protein percentage with increasing level of pseudostem flour because dietary fibre and protein has more water binding power. Also, when more water is present, more sugar is dissolved during dough mixing (Ganorkar and Jain, 2014).

Table 4.3 Physical parameters of banana pseudostem incorporated biscuits

Samples	Thickness (mm)	Diameter (mm)	Spread ratio	Weight (g)	Volume (cm^3)	Density (g/cm^3)
A	6.12±0.1	60.30±0.2	9.85±0.15	14.09±0.2	17.48±01	0.806±0.15
B	6.18±0.2	60.78±0.1	9.83±0.15	13.92±0.3	17.92±0.2	0.776±0.25
C	6.29±0.3	61.30±0.1	9.74±0.2	13.58±0.2	18.55±0.1	0.731±0.15
D	6.42±0.1	61.96±0.1	9.65±0.1	13.14±0.3	19.34±0.2	0.679±0.26
E	6.56±0.2	62.14±0.1	9.47±0.15	12.86±0.2	19.88±0.1	0.646±0.15

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

4.3 Sensory analysis of banana pseudostem incorporated biscuit

Statistical analysis of the sensory scores was obtained from 10 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 texture, crispiness, color taste flavour and overall acceptability of banana pseudostem powder incorporated biscuit.

4.3.1 Texture

The mean sensory score for texture of sample B was found to be 7.7 which was the highest score of all the biscuit formulations. Statistical analysis showed that the partial substitution of wheat flour with banana pseudostem flour had significant effect ($p<0.05$) on the texture. Sample B got highest score which was not significantly different with the sample A while it was found from samples C, D and E. Fig. 4.1 represents the mean sensory scores for texture of banana pseudostem incorporated biscuit.

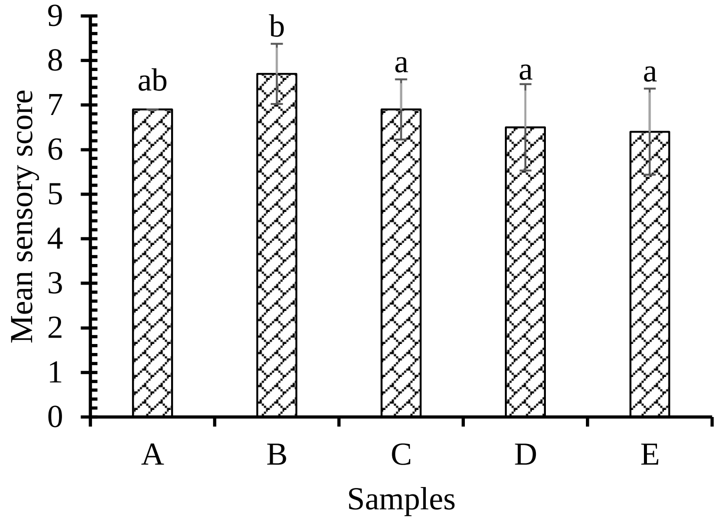

Fig. 4.1 Mean sensory scores for texture of biscuit pseudostem biscuit

The probable cause of highest score for the texture of sample B may be the amount of fibre present in the formulation because of all the formulations product B had the optimum fibre incorporated in it. The result is in accordance with Sudha *et al.* (2007) who found similar result with the addition of fibre in biscuit. Samples D and E were found to have the lowest mean score due to the least gluten development as higher amount of pseudostem flour is used which is gluten less affecting the formation of gluten development in wheat flour. As proportion of pseudostem flour increases texture score decreased which may be due to tougher texture and cracks on the crust. Sample B 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).

4.3.2 Crispness

Statistical analysis showed that partial substitution of wheat flour with pseudostem flour had significant effect ($p<0.05$) on the crispiness. The sample A was significantly different to other samples but similar to other sample B. The sample A got highest score while E rank lowest score because incorporation of high level of pseudostem flour depresses the water holding capacity. Fig. 4.2 represents the mean sensory scores for crispness of banana pseudostem incorporated biscuit.

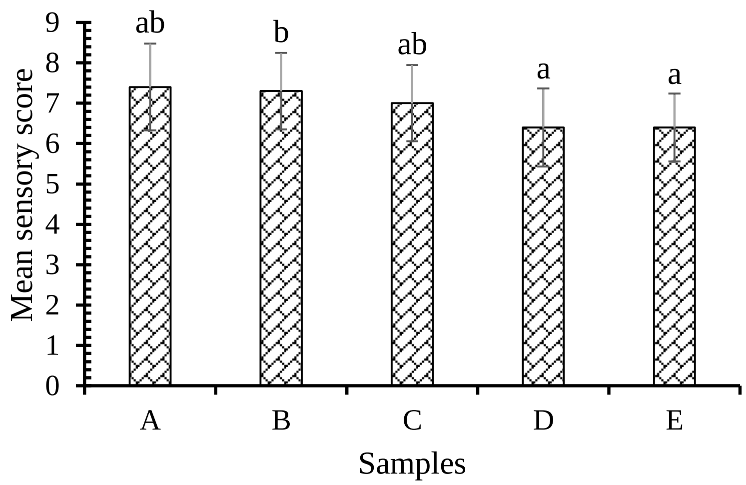

Fig. 4.2 Mean sensory scores for crispness of banana pseudostem biscuit

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).

4.3.3 Colour

The mean sensory score for colour of sample B was found to be 7 and was heighest 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 pseudostem flour has no significant effect ($p<0.05$) on the color. Fig. 4.3 represents the mean sensory scores for taste of banana pseudostem incorporated biscuit.

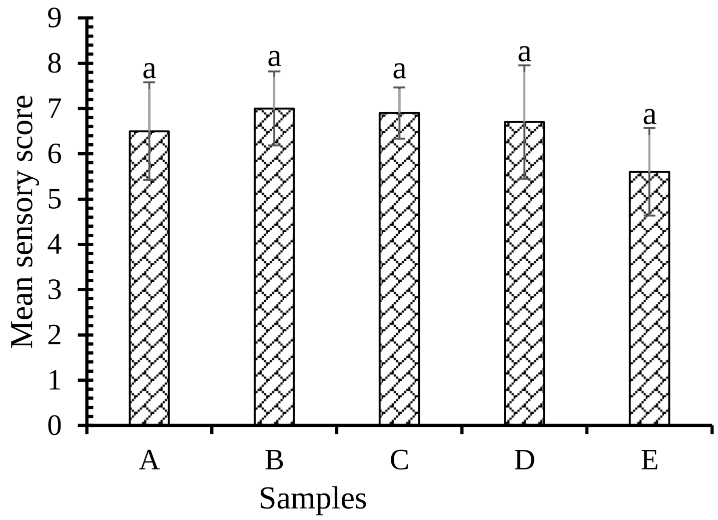

Fig. 4.3 Mean sensory scores for colour of banana pseudostem biscuit

The effect of heigher amount of incorporation of the pseudostem flour may be the cause of dark brown color. The result is in accordance with Masoodi and Bashir (2012) who found that the colour of the fortified biscuits attained more dark colour as the supplementation was increased. However, the texture was slightly decreased with supplementation but described no undesirable change.

4.3.4 Taste

Statistical analysis showed that the partial substitution of wheat flour with pseudostem flour had significant effect ($p<0.05$) on the taste. Sample A and B was found to be scoring highest in taste as compared to other samples with incorporation of pseudostem flour. However, it is found to be not different from sample C. Sample E is the lowest scoring formulations of all which indicates that heigher amount of pseudostem powder in the formulations could lower the score and acceptability of the product. Fig. 4.4 represents the mean sensory scores for taste of banana pseudostem incorporated biscuit.

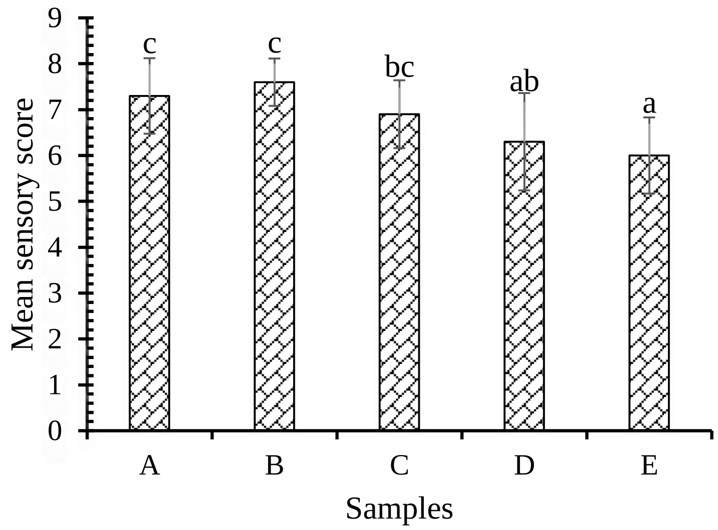

Fig. 4.4 Mean sensory scores for taste of banana pseudostem biscuit

4.3.5 Flavour

The mean sensory score for flavour of sample B was 7.5 and was the highest score scored among the different formulations. The lowest mean sensory score was of sample C. Samples A, C, D and E were not significantly different in flavour. Fig. 4.5 represents the mean sensory scores for flavour of banana pseudostem incorporated biscuit.

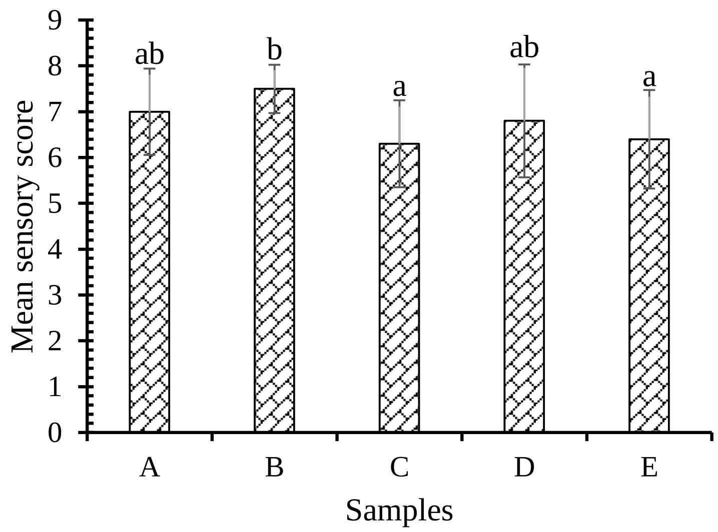

Fig. 4.5 Mean sensory scores for flavour of banana pseudostem biscuit

The biscuit with the higher amount of pseudostem powder such as samples C, D and E had low score which could indicate that due to the more amount of total phenolic and flavonoid content in pseudostem flour it results banana flavor. The flavor of sample B was found to be of balanced flavor giving as a whole of blended flavor which was preferrable to other product formulations.

4.3.6 Overall acceptability

Sample B scored highest in overall acceptability of the sensory conducted among the panellists, which might be due to good texture as adequate amount of gluten formation was possible in such composition. Sample B, C and D was found to be not significantly different from the control sample A but sample E was significantly different from sample A. Fig. 4.6 represents the mean sensory scores for flavour of banana pseudostem incorporated biscuit.

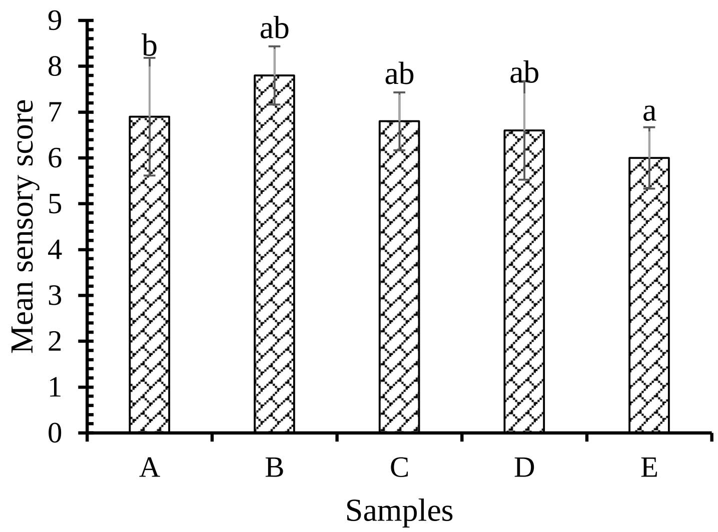

Fig. 4.6 Mean sensory scores for overall acceptability of banana pseudostem biscuits

Statistical analysis from the experimental data showed that the partial substitution of pseudostem flour in samples showed significant difference ($p<0.05$) in overall acceptability of samples. Sample E showed lowest score in overall acceptability which could be as a result of highest amount of Pseudostem flour incorporated in it. Similarly, not too much amount of pseudostem flour, but adequate enough to provide good flavour, better swelling power and solubility capacity might have provided good mouth feel in sample B.

4.4 Proximate composition of 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 4.4.

Table 4.4 Composition of banana pseudostem incorporated biscuit

Proximte composition (db)	Product A (Wheat biscuit)	Product B (Pseudostem Biscuit)
Moisture content (%)	2.62±0.18	2.54±0.15
Crude protein (%)	6.7±0.12	5.8±0.19
Crude fat (%)	16.26±0.25	18.6±0.19
Crude fibre (%)	1.1±0.01	1.7±0.02
Total ash (%)	2±0.02	5±0.08
Carbohydrate (%)	71.32±0.31	66.36±0.25
Calcium (mg/100gm)	52.3±0.13	57.7±0.21
Potassium (mg/100gm)	210.4±0.30	274.2±0.35
Sodium (mg/100gm)	28.6±0.18	95.9±0.23

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

The composition of banana pseudostem incorporated biscuit is shown in Table 4.4. The ash content of biscuits increased in banana pseudostem incorporated biscuit. The increase in ash content may be due to the high mineral content i.e. calcium, potassium and sodium. The moisture content ranged from 2.62% in wheat biscuit to 2.54% in banana pseudostem incorporated biscuit. The decrease in moisture content may be due to the decrease in protein content. Mustafa *et al.* (1986) reported an decrease in moisture content of bakery products with decrease in protein content. The fat content of BPIB was higher than wheat flour biscuits. This was probably due to the oil retention ability of pseudostem flour during baking process (Ganorkar and Jain, 2014). Higher oil retention improves the mouth feel and retains the flavor of the biscuits. Banana pseudostemis also found to be one of the richest sources of crude fibre. Therefore, Banana pseudostem incorporated biscuit showed an increase in the fibre content. The protein content of biscuits ranged from 5.8% in banana pseudostem incorporated biscuit to 6.7% in wheat biscuit. The biscuits showed an increase in ash content when banana pseudostem powder concentration was increased which might be due to the use of low protein soft wheat flour.

The high ash content in the wheat banana pseudostem supplemented food would be of nutritional importance in most developing countries like Nepal. BPIB contains a lot of minerals, confirmed by its higher ash content. The higher level of minerals in BPIB is also demonstrated by higher level of calcium (57.7 mg/100 g), potassium (274.2 mg/100 g) and sodium (95.9 mg/100 g) (Aziz *et al.*, 2011).

4.5 Shelf life evaluation of the biscuit

The shelf life of the biscuit was studied for 3 months with triplicate samples. The product was packed in high density polyethylene bags and stored in ambient temperature. The acid value, peroxide value of the extract fat and the moisture content of the product was evaluated from the date of manufacture upto 3 months.

4.5.1 Change in acid value

In general, acid value is the indication of free fatty acid content in the product. The increment in the fatty acid of the product was found increased with storage time and also depends on packaging material.

The acid value of the product was observed to be 0.20 at initial which reached 0.24, 0.28, 0.33 within 30, 60 and 90 days respectively but the acid value is below the unacceptability level of maximum 0.5 mg KOH/mg of oil as described by Hood and Jood (2005) till the last date of analysis. The rate of increase in AV shows a gradual increase which suggest that it will be self-preserved till 6 months as described by Smith (1972). The change in acid value of the product is shown in Fig. 4.7.

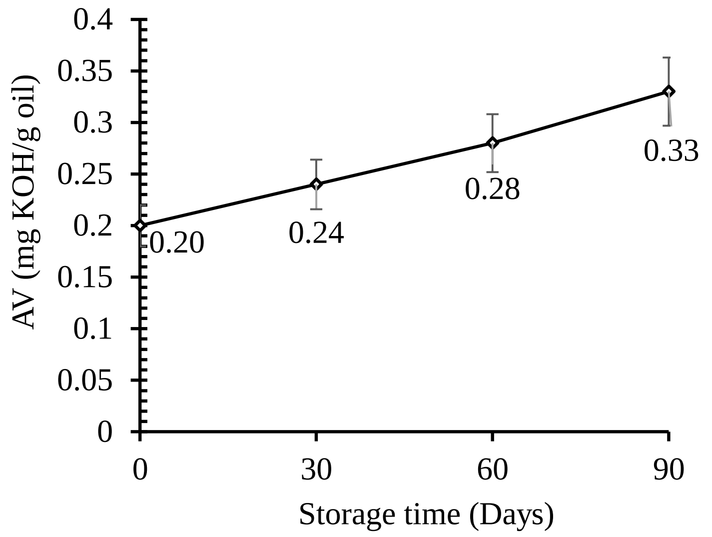

Fig. 4.7 Change in acid value during storage

4.5.2 Change in peroxide value

Peroxide value is a sensitive indicator of early stages of oxidative deterioration of fats and oils. Peroxide value provides a means of predicting the risk of the development of flavour rancidity. The peroxide value of the product was observed to be 5.81 at initial which reached 6.20, 6.68 and 7.25 within 30, 60 and 90 days respectively but the PV obtained was far below the unacceptable level of maximum 10 meqv peroxide/kg fat as described by Hooda and Jood (2005) till the last date of analysis. The change in peroxide value of the product is shown in Fig. 4.8.

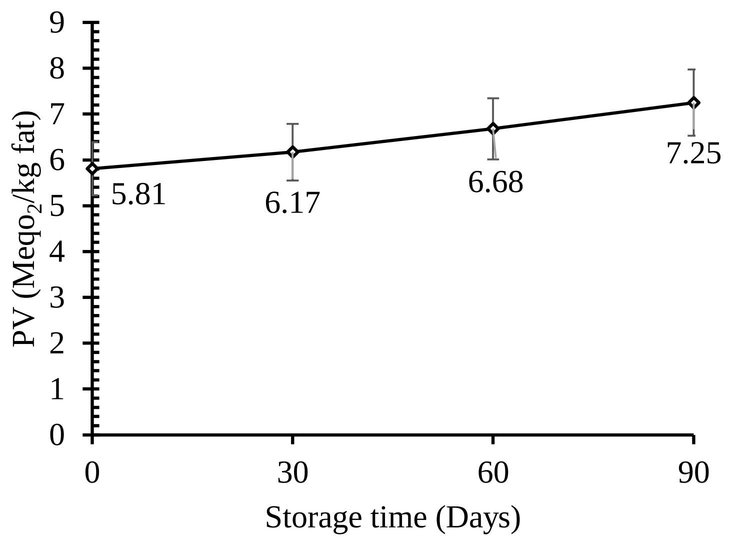

Fig. 4.8 Change in peroxide value during storage

4.5.3 Change in moisture content

The moisture content of the product was observed to be 2.54 at initial which reached 2.76, 3.18 and 3.72 within 30, 60 and 90 days respectively but the value was far below the acceptable level of maximum 6%. Hence, the biscuit could be considered safe for consumption till date. The change in moisture content of the product is shown Fig. 4.9.

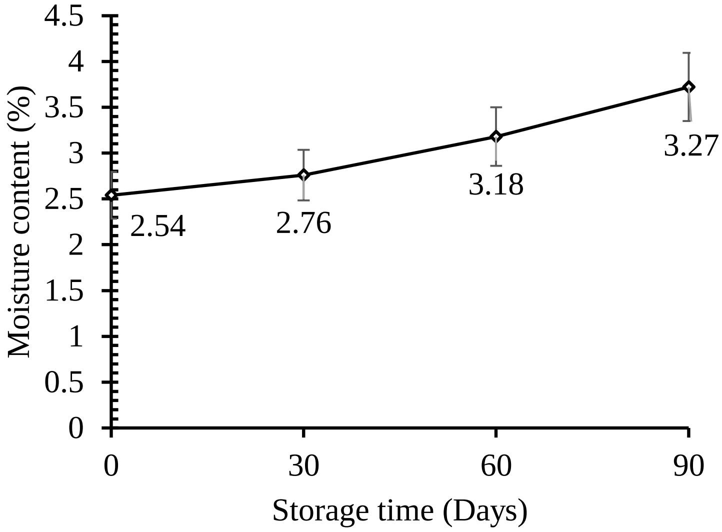

Fig. 4.9 Change in moisture content during storage

Hence, the shelf life of the product was evaluated and all the parameters determining the shelf stability of biscuit were found to be within the standard limit. The rate of increase in AV, PV and moisture content signified that the product would be safe for consumption till standard best before time of six months. Packaging in laminate packets would have further increased the stability of the biscuit.

4.5.4 Shelf life of the product

The probable shelf life of the biscuit was projected by studying the observed increase pattern of the values. The rate of increase in AV was calculated to be 0.0014 mg KOH/ g oil per day for 90 days. The obtained AV was within the acceptable limit. Similarly, the rate of increase in the PV was calculated to be 0.016 meq peroxide/kg fat per day for 90 days. The obtained AV was within the acceptable limit. The moisture content was observed to be increasing with a rate of 0.0131% per day. This rate of increase in the moisture content will take 264 days to cross the unacceptable value of the moisture content which is 6%.

4.6 Cost of the banana pseudostem incorporated biscuit

The total cost associated with the best product was calculated and the cost of banana pseudostem incorporated biscuit per 100 g was NRs. 14.7 including overhead cost and profit of 10%. From the cost calculation given in appendix D, it can be seen that due to the low cost of banana pseudostem to prepare pseudostem powder, the cost of biscuit has been decreased.

Part IV

Conclusion and recommendations

5.1 Conclusions

On the basis of research, following conclusions can be drawn:

1. The banana pseudostem powder can be incorporated upto 2.5 parts with wheat flour, with no adverse effect on sensory quality of biscuits.
2. The nutritional quality of the biscuit seemed to be enhanced in the case of fibre and mineral content.
3. Production cost of the prepared banana pseudostem incorporated biscuit was reasonable, within the reach of general population so its commercialization could be done.

5.2 Recommendations

The experiment can be further continued with the following recommendations:

1. Study on the incorporation of the different varieties of banana pseudostem can be carried out.
2. Study of various flavour incorporated banana pseudostem biscuits can be carried out.
3. Study of banana pseudostem incorporated multigrain biscuits can be carried out.

Part IV

Summary

Biscuits are the low cost, processed food which offers good taste along with nutritional value 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 banana pseudostem powder. Incorporation of wheat flour with banana pseudostem powder 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.

The stem of the banana plant, which is also called pseudostem, produces a single bunch of banana before dying and replaced by a new pseudostem. Due to this, the crop generates a large amount of residue. Banana pseudostems are crop waste, which cause economic loss and environment issues after harvest. However, pseudostems are rich in dietary fibre, mineral content and have health benefits. So preservation and utilization of banana pseudostem is very important. In this case banana pseudostem can be dried and converted into powder from which can be used for fortification in snaked products like biscuits, bread, cookies, etc.

The overall objective of this research was to utilize waste banana pseudostem in the development of a nutritious low cost biscuits for the nutritional benefit of poor people of Nepal and other developing countries. The product being low cost, nutritious, easily availability, longer shelf life and ready to eat instant characteristics, the research will be advantageous for the people of Nepal and other developing countries, particularly of school children age group and old people.

Response Surface Methodology was used for the formulation of recipe and for this, Design Expert v7.1.5 software was used. Five different biscuit formulations, namely A (100 parts wheat flour), B (2.50 parts pseudostem powder), C (5 parts pseudostem powder), D (7.50 parts pseudostem powder) and E (10 parts pseudostem powder) were

prepared by soft dough process. The other ingredient fat 35 parts, pulverized sugar 40 parts, salt 0.3 parts, SMP 6 parts and baking powder 2.22 parts were taken constant. The biscuit formulated was of soft dough type. The five different biscuits samples were prepared and subjected to sensory evaluation. The sensory analysis was carried out based on texture, crispiness, color, taste, flavour and overall acceptance. The data obtained were statistically analysed using two way ANOVA (no blocking) at 5% level of significance. Sample B (BP:WF :: 2.5:97.5) got the highest mean sensory score. The proximate analysis for moisture, crude protein, crude fat, crude fibre, and total ash and carbohydrate were found to be 6.2%, 3.6%, 1.8%, 13.3%, 12.3%, 62.8% and 2.54%, 5.85%, 18.6%, 1.7%, 5%, 66.37% of the banana pseudostem powder and the sample B respectively.

Further, BP and BPIB were subjected for calcium, potassium and sodium content evaluation. The calcium, potassium and sodium content in BP and BPIB was 34 mg/100 g, 126 mg/100 g, 2 mg/100 g and 57.7 mg/100 g, 274.2 mg/100 g 95.9 mg/100 g respectively. At 5% level of significance the two samples were significantly different from each other. Thus prepared biscuits were packed in HDPE and stored at ambient temperature. The product was further analysed for prediction of shelf life based on acid value, peroxide value and moisture content found to be 0.33 mg KOH/g oil, 7.25meq O_2/kg fat and 3.72% respectively at the end of 90 days which were all within the acceptable limits. These findings suggest that banana pseudostem flour can be successfully incorporated in refined wheat flour up to the concentration of 2.5 parts without any adverse effect on sensory attributes giving a nutritionally enriched product especially calcium, potassium, sodium content, ash, fibre and fat content with best acceptability. The cost of the final BPFB was found to be NRs.14.71 per 100 g including overhead cost and profit each of 10%.

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Appendices

Appendix A

Sensory evaluation score sheet for biscuit

Date:

Name of Panelist:

Name of the product: Banana Pseudostem Incorporated Biscuit (BPIB)

Dear panelist, you are provided 5 samples of Banana Pseudostem Incorporated Biscuit (BPIB) on each proportion with variation on pseudostem 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

Parmeters	Sample Code				
	A	B	C	D	E
Crispiness					
Color					
Taste					
Texture					
Flavor					
Overall acceptability					

Any Comments:

Signature:

Appendix B

ANOVA for physical analysis of samples

Table B.1.1 Two way ANOVA (No blocking) for Texture

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Parameters	4	10.7200	2.6800	2.93	0.034
Panelist	9	3.1200	0.3467	0.38	0.937
Residual	36	32.8800	0.9133		
Total	49	46.7200			

Table B.1.2 Two way ANOVA (No blocking) for crispiness

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Parameters	4	9.2000	2.3000	2.62	0.051
Panelist	9	9.7000	1.0778	1.23	0.309
Residual	36	31.6000	0.8778		
Total	49	50.5000			

Table B.1.3 Two way ANOVA (No blocking) for color

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Parameters	4	12.5200	3.1300	3.33	0.020
Panelist	9	8.0200	0.8911	0.95	0.498
Residual	36	33.8800	0.9611		
Total	49	54.4200			

Table B.1.4 Two way ANOVA (No blocking) for taste

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Parameters	4	17.8800	4.4700	7.02	<.001
Panelist	9	6.5800	0.7311	1.15	0.356
Residual	36	22.9200	0.6367		
Total	49	47.3800			

Table B.1.5 Two way ANOVA (No blocking) for flavor

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Parameters	4	9.4000	2.3500	2.84	0.038
Panelist	9	12.8000	1.4222	1.72	0.121
Residual	36	29.8000	0.8278		
Total	49	52.0000			

Table B.1.6 Two way ANOVA (No blocking) for overall accepatability

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Parameters	4	16.8800	4.2200	4.59	0.004
Panelist	9	3.3800	0.3756	0.41	0.922
Residual	36	33.1200	0.9200		
Total	49	53.3800			

Appendix C

Table C.1 Summary of ANOVA of sensory evaluation of banana pseudostem incorporated biscuit

Sample code	Texture	Crispiness	Color	Taste	Flavor	Overall
A	$7.0^{ab}\pm0$	$7.4^{ab}\pm1.07$	$6.5^{b}\pm1.08$	$7.3^{c}\pm0.82$	$7.0^{ab}\pm0.94$	$6.9^{b}\pm1.28$
B	$7.7^{b}\pm0.67$	$7.3^{b}\pm0.95$	$7.0^{b}\pm0.82$	$7.6^{c}\pm0.51$	$7.5^{b}\pm0.52$	$7.5^{ab}\pm0.63$
C	$6.7^{b}\pm0.67$	$7.0^{ab}\pm0.94$	$6.9^{bc}\pm0.56$	$6.9^{bc}\pm0.73$	$6.3^{a}\pm0.94$	$6.8^{ab}\pm0.63$
D	$6.1^{a}\pm0.97$	$6.4^{a}\pm0.96$	$6.7^{b}\pm1.25$	$6.3^{ab}\pm1.05$	$6.8^{ab}\pm1.23$	$6.6^{ab}\pm1.07$
E	$6.4^{a}\pm0.96$	$6.4^{a}\pm0.84$	$5.6^{b}\pm0.96$	$6.0^{a}\pm0.83$	$6.4^{a}\pm1.07$	$6.0^{a}\pm0.66$
LSD (5%)	0.867	0.850	0.880	0.724	0.825	0.870

Appendix D

Table D.1 Cost calculation of the product (BPIB)

Particulars	Cost (NRs/kg)	Weight in a lot (g)	Cost (NRs)
Wheat flour	38	97.5	3.705
Pseudostem flour	-	-	-
Sugar	65	40	2.6
Fat	310	35	10.85
SMP	480	6	2.88
Salt	20	0.3	0.006
Baking powder	125	2.22	0.277
Raw material cost			20.318
Processing and labor cost (10% of raw material cost)			2.032
Profit (10%)			2.235
Grand total Cost			24.585
Average weight of BPIB (g)		13.92	
Total no. of BPIB formed		12	
Total weight of BPIB (g)		167.04	
Total cost of BPIB (NRs/100g)			14.71

Photo Gallery

Plate 1 Harvesting of banana pseudostem

Plate 2 Slicing of banana pseudostem

Plate 3 Semi-trained panelist carrying out Sensory analysis