EFFECT OF BAMBOO SHOOT POWDER INCORPORATION ON BISCUIT QUALITY

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Approval Letter

This *dissertation* entitled *Effect of Bamboo Shoot Powder Incorporation on Biscuit Quality* presented by Prajwal Giri has been accepted as the partial fulfilment of the requirement for the B. Tech. degree in Food Technology.

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Abstract

The objective of this research was to study the effect of bamboo shoot powder on biscuit quality and to formulate bamboo shoot powder incorporated biscuit. Design of experiment was employed for formulating the recipe of biscuit. 5 formulations of biscuit containing 0, 5, 10, 15 and 20 parts of bamboo shoot powder were prepared. The prepared biscuits were subjected to sensory evaluation. The data obtained were statistically analysed using two way ANOVA (no blocking) at 5% level of significance. Bamboo shoot powder incorporated biscuit and control were subjected to analysis for proximate and minerals content.

From the mean sensory scores, 5 parts bamboo shoot powder incorporation was selected as the best formulation. At 5% level of significance, the control and optimized product were significantly different from each other. The protein, fiber and potassium increased from 5.63% to 7.13%, 0.89% to 1.54% and 112.00 mg/100 g to 152.52 mg/100 g respectively from control to optimized product. Moreover, the antioxidant activity determined by 2,2-Diphenyl-1-Picrylhydrazyl assay method was higher in optimized product (9.43%) than in control (5.03%). These findings show that bamboo shoot powder incorporated biscuits up to 5% are acceptable and are nutritionally enriched.

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List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of Variance
ACE	Angiotensisn Converting Enzyme
ACP	Acid Calcium Phosphate
BHA	Butylated Hydroxy Anisole
BHT	Butylated Hydroxy Toluene
CCT	Central Campus of Technology
DPPH	2,2-Diphenyl-1-Picrylhydrazyl
FAO	Food and Agriculture Organization
FCMP	Full Cream Milk Powder
GDL	Gluconodeltalactone
HCN	Hydrogen Cyanide
HDPE	High Density Polethylene
HIPS	High Impact Polystyrene
LDL	Low Density Lipoprotein
LDPE	Low Density Polyethylene
OPP	Oriented Polypropylene
PET	Polyethylene Terephthalate
PVC	Poly Vinyl Chloride
PVdC	Poly Vinylidene Chloride
SMS	Sodium Metabisulphite
TBHQ	Tertiarybutylhydroxyquinone
WHO	World Health Organisation

Part I

Introduction

1.1 General introduction

Biscuits are the most popular bakery items consumed nearly by all levels of society (Sudha *et al.*, 2007). Some of the reasons for such wide popularity are their ready to eat nature, affordable cost, good nutritional quality, availability in different tastes and longer shelf life (Ajila *et al.*, 2008). It is an important product in human diet and is also used as weaning food for infants and may be used as a nutrient supplement during emergency situation (Prodhan *et al.*, 2015). Biscuits have a cereal-flour base of at least 60% (Wrigley *et al.*, 2016). Refined wheat flour is commonly used for biscuit making owing to its high gluten content but is nutritionally very poor. Thus, there is a need to identify alternative flours which can substitute refined flour partially or completely in bakery products (Agrahar-Murugkar *et al.*, 2015). Biscuits have low moisture content, usually 1–5% (Caballero *et al.*, 2003). Not only long shelf-life of biscuits makes large scale production and distribution possible but also good eating quality makes biscuits more attractive for nutritional improvements (Prodhan *et al.*, 2015).

The evergreen bamboo plant consists of aerial stems known as culms, which arise from a network of rhizome system. An emerging young culm is known as bamboo shoot or juvenile shoot (Karanja, 2017). Bamboo shoots or bamboo sprouts are young stems that are harvested when they reach a height of 30 cm. They are tender, soft, crispy, generally ivory yellow in colour (Chauhan *et al.*, 2016). Most bamboo species produce edible shoots but less than 100 species are commonly grown or utilized for their shoots (Chongtham *et al*., 2011). For centuries, young edible bamboo shoots have remained one of the highly palatable dishes in delicacies. Fresh, fermented, and roasted tender bamboo shoots are considered culinary treats. They are consumed as vegetables, pickles, salads, and in various other forms in different countries (Singhal *et al*., 2013).

Bamboo shoot contains high amount of dietary fiber, vitamins, minerals, protein, and low amount of fat (Choudhury *et al.*, 2015). This low fat food is thus a low calorie food also, which can be adopted by the person on a crash diet for losing weight. It has high content of dietary fiber, which have functional properties such as weight reduction, prevention of constipation, bowel cancer and reduction of cholesterol level. Bamboo shoots are also good source of potassium. Potassium is a heart-healthy mineral (Rana, 2009). It also has Na, Mg, Ca, P, Fe as well as Cu, Co, Ni, Zn, Mn, Cd and Se. Bamboo Shoots contain 17 amino acids, 8 of which, are essential for the human body (Chongtham *et al.*, 2011). It contains arginine and tyrosine as the major amino acids that otherwise is a minor component in common fruits and vegetables. It also has lysine, which lacks in cereals, plays an important role in growth and development (Oinam *et al.*, 2016). It is also a good source of Vitamin E (α-Tocopherol), Vitamin C, Vitamin B_6, thiamin, riboflavin, and niacin (Choudhury *et al*., 2012b). In the 21st century, bamboo shoots are posed to go beyond nutritious and tasty vegetable to functional food and nutraceuticals due to presence of bioactive compounds such as dietary fibers, phenol and phytosterol (Rawat *et al*., 2015). However, bamboo shoots contain varying amount of cyanogen glycosides called taxiphyllin. The β-glycosidase which is released in disrupted bamboo shoot tissues acts on taxiphyllin to produce harmful hydrogen cyanide whose level should not exceed the toxic level in humans. The harmful hydrogen cyanide should be removed if shoots are to be used for human consumption (Nongdam and Tikendra, 2014). Reduction in cyanogen level can be achieved by several processing methods such as soaking, cooking (boiling, roasting), fermentation and drying (Rawat *et al*., 2015).

1.2 Statement of the problem

Bamboo shoots are seasonal, perishable, short lived and unpreserved (Choudhury *et al*., 2012a). Shelf life of freshly harvested bamboo shoots is 9 and 23 days in water and brine, respectively. They are becoming one of the preferred food products in the world, but there is hardly any organized bamboo shoot processing and marketing industry to serve this exceeding need. The preparation of various bamboo shoot-based food products is traditional, local, unorganized and based on the taste of the local people. There is no standardized process technology for preservation of the raw bamboo shoots into various food items in an organized manner. This calls for the development of appropriate technologies for preservation of bamboo shoots in various forms (Choudhury *et al*., 2012b).

Biscuits prepared from refined wheat flour is nutritionally poor. Wheat flour which is deficient in several nutrients including vitamins, minerals as well dietary fiber. Wheat flour also lacks essential amino acids such as lysine and tryptophan (Prodhan *et al.*, 2015). Thus use of nutritionally rich bamboo shoot can not only enrich biscuits, but also preserve bamboo shoot in a readily available form.

1.3 Objectives

1.3.1 General objective

The general objective of this dissertation work is to study the effect of incorporation of bamboo shoot powder on biscuits quality.

1.3.2 Specific objectives

- To prepare bamboo shoot powder incorporated biscuits.
- To optimize the concentration of bamboo shoot powder in biscuits.
- To compare proximate composition and mineral composition of control and optimized biscuit.
- To determine antioxidant activity of bamboo shoot powder, control and optimized product.

1.4 Significance of study

Bamboo shoot contains high amount of dietary fiber, vitamins, minerals, protein, antioxidants, and low amount of fat. The eight amino acids which are not synthesized in the body and regarded as essential amino acids are all found in bamboo shoots (Choudhury *et al.*, 2015). Bamboo shoots are rich in both phenols and phytosterols which have antioxidant properties (Chongtham *et al*., 2011). Modern research shows that the bamboo shoots have many health benefits, from cancer prevention and weight loss to lowering cholesterol level and improving appetite and digestion. It has low glycemic index therefore can be used by persons on sugar-restricted diets (Mustafa *et al*., 2016). Due to their health enhancing properties, bamboo shoots are now being considered as a health food or natural functional food (Oinam *et al.*, 2018).

Therefore, incorporation of wheat flour with bamboo shoot powder for making biscuits can improve the nutritional status of biscuits. It may be used for solving the problem of malnutrition in developing countries. Furthermore, incorporation of bamboo shoot powder in biscuits not only increase the food value of the biscuits, but also give a diversification in bakery products.

1.5 Limitations of study

- Shelf life study of the product was not carried out.
- Vitamins analysis of biscuits was not carried out.
- Texture analysis of product was not done.

Part II

Literature review

2.1 Biscuits

2.1.1 Introduction

The word biscuit is derived from either the Latin *bis coctus* or the Old French *bescoit*, meaning twice baked (Wrigley *et al.*, 2016). Its origins date back to Roman times, when certain foods needed to be completely dried so that they could be stored for long periods of time (Caballero *et al.*, 2016). The original process consisted of baking the biscuits in a hot oven and subsequently drying them in a cool oven. It is very rare to find this double baking technique in modern biscuit production (Wrigley *et al.*, 2016). The term ‘‘biscuit’’ is more common in the UK, Australia, and New Zealand, whereas the words ‘‘cookie’’ and ‘‘cracker’’ are more common in the USA (Caballero *et al.*, 2003).

In general, biscuits and cookies are small, flat, cereal-based, baked products containing shortening, sugar, and chemical leavening. While soft wheat is the most common, other cereal grains such as oats, rye, corn, and barley are sometimes utilized. Most biscuits and cookies have a low moisture content of less than 5%. They vary widely in size, shape, formulation, preparation method, and flavor. The texture varies from crisp and hard to soft and chewy. Some undergo secondary processing to create sandwiched, iced, coated, filled, and multiple other types of final products. Biscuits and cookies have a relatively low risk of microbial spoilage due to the high shortening, high sugar, and low water contents. They also do not stale like bread and other higher-moisture baked products. The most common cause of loss of eating quality is due to moisture migration. Moisture uptake by crisp, hard products causes them to become undesirably soft and soggy, while moisture loss from soft, chewy products renders them dry and hard. Biscuits and cookies are often broadly characterized based on their dough properties and then further distinguished by the technique used to shape and place the dough onto the oven band for baking (Caballero *et al.*, 2016).

The long shelf life, together with their high energy density, has made them popular with travelers and explorers over the years, and they still form a significant proportion of emergency food supplies. However, today, most of the products in this diverse category are considered to be a sweet snack or an accompaniment in savory-based meals. In few cases, the role that these products can play in delivering specific nutritional requirements through fortification has been recognized, and ranges of products that meet the needs of certain medical conditions have also been developed, for example, for diabetics and celiac sufferers (gluten-free) (Wrigley *et al.*, 2016). Biscuits have been suggested as a better use of composite flour than bread because of their ready-to-eat form, wide consumption, relatively long shelf-life and good eating quality (Yamsaengsung *et al*., 2012).

Biscuits can be grouped in many ways, based on their texture and hardness, their change in outline during shaping and baking, the extensibility or other characteristics of the dough, or the ways that the doughs are handled prior to biscuit formation. The differences in formulation, processing, and finished product attributes are all a function of the dough consistency or dough rheology. Certain key ingredients, such as flour, fat, and sugar largely determine the dough rheology and thus what type of forming equipment can be used to produce the biscuit. However, there are certain rheological requirements for all biscuits, namely the dough must be adequately cohesive for molding/ forming, without excessive stickiness, and the dough must have a short, cuttable texture (Caballero *et al.*, 2003).

2.1.2 Classification

Biscuits are broadly classified as being of hard dough or soft dough origin (Whiteley, 1971).

2.1.2.1 Hard dough

The hard dough group are savoury, unsweetened, or semi sweet, and include all types of crackers, puff dough biscuits, and the semi-sweet varieties. In addition to having a low sugar content, or none at all, the fat content rarely exceeds 22.0% of the flour content, except in the case of puff doughs (but even these have a very low fat content at the mixing stage) (Whitely, 1971).

The most common mixing method is a single-stage mix in which all of the ingredients are mixed together in one step. The gluten is developed during mixing in hard doughs. The formulation and developed gluten network result in tight, stiff dough that can be sheeted and then cut or stamped into shapes. One problem with hard doughs is that if the gluten is too strong and elastic, the dough has a tendency to tear during sheeting and the cut pieces shrink back and distort prior to entering the oven (Caballero *et al.*, 2016). Hard dough requires extensive mixing (work) with a resulting increase in dough temperature. They are similar to bread doughs, except that the sugar and fat contents modify their viscoelastic properties. Hard doughs are usually laminated and sheeted before cutting or stamping. During baking, the biscuits may continue to shrink in outline, but become thicker. This type of dough formulation may also be suited for rotary molded biscuits, due to its firm consistency (Caballero *et al.*, 2003). Hard dough biscuits fall naturally into three sections: fermented doughs, puff doughs, and the semi-sweet doughs (Whiteley, 1971).

2.1.2.1.1 Semisweet

Soft flours are used in the production of semi-sweet, hard dough biscuits, and frequently the flour is weakened by the addition of corn flour, arrowroot, or potato flour. The fat content is relatively low and rarely exceeds 22.0% of the flour weight. The sugar content is normally about 2.0% higher than the fat. The flavour is usually rather bland and is dependent upon milk, syrup, and vanillin, or other added background-type flavours (Whiteley, 1971)

As the fat content is relatively low and no fermentation is employed to modify the gluten, it might be expected that the resulting biscuits would be hard and tough. In actual fact they are inclined to be tender and brittle. This is achieved by the special mixing technique employed. The method of mixing is an all-in method, whereby the dissolved salt and aerating chemicals are added to the flour and remaining ingredients, and then mixed until the dough becomes developed as for a fermented dough. Mixing still continues, however, until the gluten becomes softened by the mechanical development and eventually loses its elasticity and is completely extensible. When this stage is reached, threads of dough can be peeled off, with no signs of springing back, but with in fact, a stretch like chewing gum. After mixing, the dough is allowed to stand for a period of approximately 1 h (Whiteley, 1971).

Biscuits are baked to low moisture contents, around 1.5-2.0%. Mixing time on a typical high speed mixer will be 20-25 min. The dough should reach 40-42°C. At this temperature it should be well kneaded and of correct consistency for machining. Higher dough temperatures result in unstable doughs. The dough may be laminated, but doughs made with SMS (sodium metabisulphite) are usually sheeted without lamination. Direct Gas Fired and Indirect Radiant ovens are both suitable for baking semi-sweet biscuits either as individual ovens or as a Direct Gas Fired / Indirect Radiant combination oven. Convection zones may be used in the middle and final zones of the oven for drying and coloring the biscuits (Davidson, 2017). Most semi-sweet biscuits are now produced from a warm dough with sodium metabisulphite used to modify the gluten chemically (Manley, 2011).

2.1.2.1.2 Puff dough biscuits

The flaky structure of puff biscuits offers an attractive alternative to those with more uniform internal structure. Puff biscuits are all made from doughs 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 separate to give a very flaky structure. The laminar structure of puff biscuits bears some similarities to cream crackers but the dough differs in that the fat is concentrated between the laminations and little is used to form the basic dough. The dough is not fermented and is invariably cold and underdeveloped. The methods for distributing the fat in the dough determine the type of mixers and laminators needed. The eating quality of puff biscuits is determined very largely by the nature of the fat used for laminating (Manley, 2011).

Puff biscuits may be used as unsweetened carriers for butter, cheese, jam, etc., or as shells for sweet or savoury cream sandwiches. In essence they are a type of cracker biscuit. Where used as ‘sweet’ biscuits, it is usual to garnish the surface prior to baking with sugar. During baking this sugar will melt and form a glossy, lightly browned surface which on cooling is hard. Fresh cheese is often used as the flavour material (Manley, 2011).

For the production of puff doughs, very strong flour is normally used, as the dough must have a good gluten structure to withstand considerable handling in the form of lapping. The dough generally consists only of flour, water, and salt, mixed to a very stiff dough. The salt content is usually from 2.0-3.0% of the flour content, depending upon the quantity of salt contained in the fat used for layering. Additional ingredients may include fat up to 5.0% of the flour content, and malt extract for flavor (Whiteley, 1971).

2.1.2.1.3 Fermented dough biscuits

Fermentation of a dough made from flour is known as 'panary fermentation', and is brought about by the action of enzymes present in the yeast and flour, and to a minor extent by acid bacteria present in the flour. The main action is a breakdown of carbohydrates into carbon dioxide and ethyl alcohol. This breakdown is the result of teamwork between a number of flour and yeast enzymes (Whiteley, 1971).

In the production of fermented doughs, flours with a fairly high gluten content (10-12%) and strong in nature are used. A strong gluten network is necessary to form structure in the doughs and to withstand the amount of handling in the form of sheeting and lapping which these types of doughs usually undergo. The results of fermentation should be a softening and mellowing effect on the gluten, rendering it extensible and suitable for machining, and the production of flavour. The improvement of flavour is marked and depends upon the production of alcohol, acids, esters, aldehydes, and other trace by-products during fermentation (Whiteley, 1971)

The texture, appearance, and eating qualities of the baked goods should be considerably enhanced by correct fermentation. The longer the fermentation process, the greater the flavour development, and to withstand the increase in softening, the flour must be stronger and have higher gluten content. Over-fermentation occurs when excessive acids are formed and the gluten becomes over-softened even to being corroded and broken down. The dough will be difficult if not almost impossible to handle, and will smell very strongly of acid, vinegary even (Whiteley, 1971). Soda crackers and cream crackers are examples of fermented dough biscuits whereas savoury crackers are less commonly fermented (Manley, 2011).

2.1.2.2 Soft dough

The soft dough group includes all the sweet biscuits, whether they are plain biscuits, shells, or flow type such as gingernuts. Soft or weak wheat is used in the production of flour suitable for the manufacturer of sweet biscuits. The flour should have gluten content in the 7.0-9.0% range, but in certain cases it may be necessary to weaken the flour with corn flour, or boost the structure-forming gluten content by the addition of a proportion of strong flour. An average quality sweet biscuit has a fat content of approximately 30.0% of the flour content, rising to 35.0% for rich biscuits such as shortcake, and even as high as

45.0% for shortbread. The average quality sweet biscuit will have a combined sugar solids content slightly higher than the fat content, being approximately equal at the 35.0% level, and the sugar content remaining at 35.0%, or even falling to 30.0%, as the fat content increases. At the other end of the scale, as the fat content falls towards 20.0%, the sugar solids content may increase to 45.0% (Whiteley, 1971).

Soft doughs do not have a formed gluten structure, because of their high levels of shortening and sugar, and are generally mealy or sandy in texture. They are usually formed by compressing into dies (rotary molded) or by extruding and cutting, but some types can be sheeted, then cut. Dough pieces formed from soft doughs tend to retain their shape until baking, but then they spread or flow, becoming thinner (Caballero *et al.*, 2003).

2.1.3 Types of biscuits

2.1.3.1 Crackers

Crackers are regarded by some as being savory cookies, while others consider them to be unsweetened, salty, crisp biscuits. Crackers are typically consumed as a snack or as a bread substitute. In general, crackers contain low shortening, low sugar, and low moisture. Their low moisture content makes them resistant to microbial spoilage and gives them a long shelf life. Depending on the type, the leavening is by yeast or chemical leavening. Some types are also leavened by steam during baking. Crackers are made from hard doughs that are laminated. Laminated doughs are thin sheets of dough, which are alternately layered with shortening. Puffing occurs between the layers, producing a light, crisp product (Caballero *et al.*, 2016).

2.1.3.1.1 Soda crackers

Soda crackers have been popular in the United States for over 150 years. They are typically 4 mm thick and 50×50 mm square. The shortening content is 8–10% (Wrigley *et al.*, 2016). They are made using a sponge and dough process. First, a sponge containing strong hard wheat flour, yeast, water, and an inoculum (also called a buffer or old sponge) is prepared and given a long fermentation time of 16–24 h. This long fermentation is critical to develop the proper flavor and texture in the final crackers (Caballero *et al.*, 2016).

After the sponge fermentation is complete, weak soft wheat flour, shortening, salt, and sodium bicarbonate (baking soda) are added and mixed into a fully developed dough. The dough is then allowed to ferment for an additional 4–6 h after which additional sodium bicarbonate is added to raise the dough pH into the 7–8 range. The raise in pH stops the action of the native protease, so the gluten is not too degraded, which would result in a dough that is too weak to be sheeted and to maintain the distinctive layers. The yeast also becomes active again and dominates fermentation at the higher pH to produce more flavor compounds and strengthen the dough to help produce the correct texture. Additionally, the sodium bicarbonate gives the crackers their characteristic taste and is the reason they are also known as soda crackers (Caballero *et al.*, 2016).

Once the dough is mature, it is sheeted to about 4 mm and then laminated 6–8 times. The cracker is cut by making lines of perforations and baked as a whole sheet, a process that minimizes the amount of waste dough. A feature of soda crackers is the nine-hole docking pattern on each cracker, set out in a 3×3 grid pattern. After baking, the sheet of crackers is split along the perforation lines (Wrigley *et al.*, 2016).The crackers are baked on mesh bands in tunnel ovens that are 100 m long at very high temperatures of 250–300°C in a very short time of 2.5–3 min (Caballero *et al.*, 2016). Each biscuit weighs about 3–3.5 g and the moisture content is about 2.5% (Manley, 2011).

2.1.3.1.2 Cream crackers

They are usually relatively large and rectangular (about 65 × 75 mm) and have a pale bake with darker coloured blisters on both top and bottom surfaces. The blisters should not be too pronounced but their presence gives a very uneven surface. Internally cream crackers have an obviously flaky structure which should be as even as possible throughout (Manley, 2011). They are slightly thicker than soda crackers. Unlike soda crackers, they are usually produced as individual units (Wrigley *et al.*, 2016).

While, traditionally, the long sponge and dough fermentation process was used for manufacturing cream crackers, modern techniques involve a single-stage mixing and fermentation process, which takes from 4 to 16 h. As with soda crackers, cream crackers are sheeted and laminated. A feature of cream crackers is the laminating ‘dust,’ consisting of flour, shortening, and salt, that is applied between the layers of dough. This causes the laminations to lift apart during baking, giving an extra flaky structure. Cream crackers have a final moisture content of 3–4%, which is quite high for a cracker, and along with the increased fat content, the cracker is relatively soft, will not crumble, and should 'melt in the mouth.'(Wrigley *et al.*, 2016).

Compared with soda crackers, the cream cracker sponge contains much less flour and half the level of yeast. An inoculum is not added into the cream cracker sponge, so the pH of the sponge does not drop appreciably from its original value of around 6. After the sponge fermentation is complete, weak soft wheat flour, shortening, salt, and sodium bicarbonate are added. The level of sodium bicarbonate is significantly lower than the levels used in soda crackers. The majority of the flour is added in the dough stage rather than into the sponge. In cream cracker production, the sponge is fermented for 12–16 h, and the dough is fermented for an additional 1–3 h. in single stage process, the formula typically contains a blend of 50% strong flour and 50% weak flour, shortening, yeast, salt, sugar, sodium bicarbonate, and water; with higher level of yeast and fermentation time of about 4 to 16 h (Caballero *et al.*, 2016).

2.1.3.1.3 Snack crackers

Snack crackers are also known as savory crackers, cocktail crackers, or cheese crackers (Caballero *et al.*, 2016). They have two distinguishing characteristics. The first is that the cracker is sprayed with hot oil as it leaves the oven, and the second is that a topping is applied to the crackers to add flavor (Wrigley *et al.*, 2016). Snack crackers contain more sugar and more shortening than soda and cream crackers (Caballero *et al.*, 2016). They are usually chemically leavened, but some snack crackers are made from fermented doughs (Wrigley *et al*., 2016).

Because snack crackers do not have the long fermentation to mature the dough, proteolytic enzymes or sulfites are used to relax the doughs so that the crackers do not deform during sheeting and cutting. Snack crackers come in a wide range of shapes and sizes but are often round and have docking holes to allow an even lift during baking. Only snack crackers produced by fermentation are laminated. Toppings are generally applied before baking and include herb, cheese, salt, chicken, and smoke flavors. Sometimes, the crackers are decorated with small seeds, such as poppy, sesame, or celery. Snack crackers have a dense texture and are quite soft. The hot oil spray improves the mouth feel and gives an attractive appearance to the finished product (Wrigley *et al.*, 2016). Snack crackers are prepared using a single-stage mixing process in which all of the ingredients are mixed together at once to make dough, which then may or may not be rested. The dough is then sheeted, laminated, cut, docked, and baked (Caballero *et al.*, 2016).

2.1.3.2 Wafer

The term 'wafer' usually refers to a thin crisp type of biscuit. Wafers, unlike other biscuits, are produced from a very fluid batter which is baked between heavy hot plates to produce thin sheets. Wafer offers a unique textural eating experience (Manley, 2011). Most wafers bake in hot metal moulds and are available in sheets, hollow figures, wafer cones or with different intricate shapes. Flute wafers (wafer sticks) bake on hot metal drums (Tiefenbacher, 2017). The ice cream cone is the most familiar member of the wafer product group (Wrigley *et al*., 2004).

The baking of wafer sheets is performed in ''tongs,'' i.e., pairs of cast-iron metal plates with a hinge and latch on opposite sides. Baking plate sizes up to 350×730 mm are available. The precisely machined baking plates carry reedings or other engravings. We call the resulting wafers ''flat'' wafer sheets, with an overall thickness of no more than 2-5 mm. But such baking plates can also carry special figures (nuts, sticks, hemispheres, fancy shapes) up to a depth of ~20 mm, thus yielding the so-called ''hollow'' wafer sheets Wafer baking ovens frequently have 32-104 pairs of plates, continuously circulating on a chain. They are mostly gas, sometimes electrically heated and operate at mold temperatures between 160°C and 190°C. The overall baking times are between 1.5 and 2.5 min, depending on the wafer thickness and baking temperature (Wrigley *et al.*, 2004).

Wafers sold in biscuit markets are usually formed as large flat sheets which are rigid as they come from the oven and these are subsequently sandwiched with cream or caramel before cutting with saws or wires. They may be chocolate enrobed or included in moulded chocolate (Manley, 2011). Wafers are cereal-based low-fat products made of wheat flour, sometimes with addition of other flours or starches. There are two main types of wafer: low or no sugar wafer and high sugar wafer (containing more than 10% sugar) (Wrigley *et al.*, 2004). The crispness of wafers is a result of the low residual moisture after baking, typically in the range of 1–2%. The starch-protein matrix is in the glassy state. Wafers are quite hygroscopic and require high moisture barrier packaging. The crisp texture is lost at about 6–7% moisture content. (Tiefenbacher, 2017).

2.1.3.3 Matzos and water biscuits

Matzos are made from flour and water only. The Matzo recipe is about 100 parts of flour to about 38 parts of water. This mixture is gently rolled together in a mixer to form a crumbly 'dough'. There is little or no dough development. The sheeter presses the mix together to form a sheet which, after reduction, is simply laminated with 2–6 layers. After further gauging, the sheet becomes clear and strong. This sheet is heavily dockered and cut. It is then baked for a very short time in a very hot oven. Baking times of around one minute at 400°C are not unusual. Matzos are a Jewish product (Manley, 2011).

Water biscuit are a slightly more variable group than matzos. There are some that are very similar to matzos with 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. There may then be a conditioning period before sheeting when some form of proteolytic activity mellows the gluten to make it a little more extensible. The sheet is then laminated (without any inclusions between the layers), gauged and cut before being baked in a very hot oven. Water biscuits are usually round and may be as large as 70 mm in diameter All water biscuits (strangely they are not referred to as crackers), like matzos, have strongly blistered surfaces. All water biscuits are fairly hard and crisp with bland flavour (Manley, 2011).

2.1.3.4 Deposited soft dough and sponge drop biscuits

Short doughs which are soft enough to be just pourable are conveniently referred to as soft doughs. Pieces are formed by extrusion in a similar way, and often in the same machine as wire cut and rout biscuits, but nozzles rather than die holes are used to channel the dough. The dough is pressed out, either continuously or intermittently, onto the oven band which may be raised up and then dropped if discrete deposits are required. As the band drops the dough piece breaks away from the nozzle. The biscuits produced in this way are usually rich in fat or based on egg whites whipped to a stable foam, the dough must be very short to allow it to break away easily as it is pulled away from the nozzle. The nozzles through which the dough is extruded are usually indented to give a pattern and relief to the deposits. Also by rotating the nozzles, swirls, circles and other attractive shapes can be produced (Manley, 2011).

Sponge products with jam (or jelly) such as Jaffa Cakes and Sponge Boats are on a borderline between cakes and biscuits. The 'dough' is a more or less fatless sponge mixture based on fresh egg, and jam is added to the drop either before (Sponge Boats) or after (Jaffa Cakes) baking. These sponge cakes have about 8% moisture content. The 'dough' is an aerated batter which is pumped to a sparge pipe depositor. Batter is released from the pipe onto the oven band or into baking trays according to a set routine and at the end of each deposit the holes are shut off to prevent drips (Manley, 2011).

2.1.3.5 Miscellaneous biscuit like products

These includes crisp bread, yeastless sausage rusk, cereals bars, pizza bases, pretzels, dog biscuits, etc (Manley, 2011).

2.1.4 Ingredients

2.1.4.1 Flour

Flour is the basic raw material of biscuit production (Whiteley, 1971).

a) Wheat flour

Wheat is a temperate crop (Dignity *et al*., 2018). Wheat flour is the principal component of nearly all biscuits. It does contribute strongly to the baked texture, hardness and shape of biscuits. The nature of these effects differs for different biscuits related to the enrichment with fat and sugar and to the way in which the dough has been mixed. The principal property of flour of interest to biscuit makers is the quantity and quality of protein and thus of the gluten that is formed when the flour is mixed with water. Most biscuits can be made from flour that has a low quantity of protein and gluten that is weak and extensible. Thus, flour with a protein level of less than 9.0% is best and levels of more than 9.5% often create processing problems. The exceptions are fermented cracker doughs and puff doughs where a medium strength of flour is needed, with protein values of 10.5% or more. If the ash content of white flour is too high, the function of the gluten during baking is impaired and the biscuit may look grey. To a certain extent, the quality of the gluten can be adjusted by additives and processing techniques (Manley, 2011).

For most biscuit applications, 'straight run' flour, that is a complete set of flour fractions, is blended. As biscuits are baked to low moisture levels, it can be assumed that less water in dough will save energy during baking. However, the effects are different for developed doughs, such as for hard sweet biscuits, and short doughs. Finer flour for hard doughs tends to give biscuits with a higher density and less development during baking, whereas finer flour for short doughs gives biscuits with lower density, more development during baking and less spread on the oven band. The mean particle size for most biscuit flours is around 50 µm with less than 10% more than 130 µm. Much importance is attached to the flour protein level, though the quality of the gluten that this protein gives in a dough is probably of more importance for biscuits (Manley, 2011).

Wheat flour contains proteins including gliadin and glutenin. In the presence of water, these proteins combine to form gluten. As the dough is mixed the protein molecules form long strands of gluten, which have strength and elasticity. The gluten forms an elastic web, which gives the dough strength and allows it to be machined into a thin sheet for crackers and hard sweet biscuits. The gluten web is also important in trapping air and gas bubbles formed by yeast fermentation and by leavening agents such as sodium bicarbonate (soda) or ammonium bicarbonate (vol). This leavening process, combined with the laminating of the dough, gives the characteristic open, flaky texture of crackers during baking (Davidson, 2016).

The protein level of soft wheat is usually lower, producing a less resistant, more extensible dough. Flour should contain no more than about 14% moisture. Biscuit flour is typically left unbleached and unchlorinated (Caballero *et al.*, 2003).

b) Maize

When maize is milled in the more or less traditional way like wheat, yellowish flour is produced but more significantly a semolina-sized powder or ‘grit’ can be obtained. Although the protein content is around 9% on a 13% moisture basis, this protein does not form gluten. The flour is not commonly used in baked products. As the flour has a yellow colour, blends with wheat flour do impart a rich appearance to baked goods suggesting the inclusion of egg. By a process of wet milling, the maize starch is separated from the protein and oil germ components of the grain and after drying very fine flour which is almost pure starch is obtained. This is known as cornflour in Europe and cornstarch in America. Cornstarch may be used as a minor ingredient in hard sweet biscuit recipes to improve the surface sheen of the biscuits. It also makes the texture somewhat more delicate. Also, with the increasing protein content of biscuit flours giving tougher, less extensible gluten, cornstarch may sometimes be useful to ‘dilute’ the biscuit flour. This helps to make the dough less tough and easier to sheet. Up to 10 or 15% of the flour can be replaced with cornstarch (Manley, 2011).

c) Oats

The plant is *Avena sativa*. There are two important forms in which oats are used in baked products. Oatmeal (sometimes known as groats) which is a branny flour, and oat flakes which are also known as rolled oats. Oatmeal is often milled between stones and the separation of bran and endosperm is never as complete as in wheat flour production. Oat flakes are relatively large and thick particles made by rolling knibbed pieces of the grain. Oat flakes are produced from cut pieces (knibs) of cleaned grain which are graded to ensure an even sized production of flakes in the following rolling process. Oatmeal biscuits are dense and short, rather friable, biscuits with a distinctive but not unpleasant flavour. They are usually made by mixing oatmeal with roughly its own weight of wheat flour and then processing as for short dough biscuits. Oat flakes are very attractive in wire cut biscuits. Here again, the dough is short (Manley, 2011).

d) Rye

This cereal, *Secale cereale*, is the only other commercially available cereal whose protein forms a gluten in dough. It finds a major use in the manufacture of crispbreads. Rye flour crispbreads have established an important position in slimming diets and this is because the pentosans gelatinise and swell in the stomach, giving a feeling of satisfaction and the hydrolysis of the polysaccharides is slow, so the blood sugar level rises slowly, but is maintained for 5 or 6 h, thereby controlling the appetite (Manley, 2011).

e) Rice

The flavour of rice flour is very bland. It is not commonly used in biscuits (except for rice crackers in Japan) but if used as a minor substitute for wheat flour it gives a softer texture and will reduce the rise during baking (Manley, 2011).

f) Barley

Malt flour is produced from the dried unroasted germinated grains. This has an extremely high amylase activity and may be used to boost this property in flour for fermented doughs

(Manley, 2011). In fermented doughs, malt products act as yeast food, modify gluten, and improve flavor (Whiteley, 1971).

g) Soya flour

This, *Glycine max*, is a plant grown principally as an oil-producing crop but the protein-rich meal remaining after oil extraction is an important and valuable food raw material. The main function of soya flour, when used in doughs, is as an emulsifying agent, owing to the presence of lecithin. This emulsifying action helps to produce a more homogeneous dough, which in turn should assist in biscuit-piece formation and sheeting. Its inclusion in doughs will result in an increase of biscuit colour and bloom (Whitely, 1971). Soy flour is also a major source of high protein for dietary biscuit. The balance of amino acids is more suited to human nutrition than that found in cereal proteins. The latter are short of lysine and soya protein is especially high in this (Manley, 2011).

h) Arrowroot

Another tropical plant, a herbaceous perennial, *Maranta arundinacea*, has swollen roots from which the starch is extracted. This was used in a particular variety of British semi-sweet biscuits to weaken the flour and give an improved smoothness to the palate. The combination of a world crop failure in the 1960s and the availability of cheaper starches with almost identical properties has effectively precluded its use in biscuits now (Manley, 2011).

2.1.4.2 Fat

Fat in a biscuit can be denoted in several ways: it can be seen on the label as butter, animal fat (although this is less common now), vegetable fat or vegetable oil (including the named types such as palm oil, sunflower oil, etc). It may also be presented in a generic form such as ‘shortening’ which is a term used to describe one of the functions of fat in biscuits which is to ‘shorten’ the dough that is, to give it that typical ‘melt in the mouth’, crumbly texture which is characteristic of biscuits (Manley, 2011). Recipes with high fat contents require little water for producing a cohesive dough and produce soft, short doughs. During mixing, the fat coats the flour particles and this inhibits hydration and interrupts the formation of the gluten. Fats also tend to inhibit the leavening action of the carbon dioxide diffusion in the dough during baking, and this produces a softer, finer texture (Davidson, 2016). Shortening also aids dough aeration during the creaming step. The overall effect improves palatability, extends shelf-life, improves flavor and, of course, adds caloric energy (Caballero *et al.*, 2003).

2.1.4.3 Sweetening agents

White and brown sucrose, glucose, glucose syrup, golden syrup, invert sugar syrup, and highfructose corn syrup are all used in as sweetening agents (Wrigley *et al.*, 2016). Also malt syrup, malt extract, maple syrup, honey, etc are also used (Whiteley, 1971).

The sugar crystals which have a coating of syrup are known as raw sugar or brown sugar. The colour of the syrup varies so the brown sugar may be golden brown or quite dark. Brown sugars are extensively used in baking for the distinctive flavour they give (Manley, 2011). Golden syrup is made by the refiner from low grade sugars and uncrystallised syrups. It is a mixture of sucrose and invert sugar in solution with a small proportion of gums, acid, and mineral salts. Glucose is a clear, thick, viscous fluid, only about half as sweet as sucrose. Glucose is readily fermented by yeast. During baking it readily caramelises, giving a good colour to the face of the biscuit, and it also assists in soft dough formation. Malt extract is very poor as a sweetening agent, but consists of approximately 50% malt sugar (maltose), the rest being water, dextrins, and a small proportion of protein. Its main use is for flavour, but can also be used in fermented doughs to assist gluten modification and as a yeast food. Whereas malt extract is generally prepared from malted barley, malt syrup is produced from barley and maize starch and is consequently sweeter. It is used for flavour and as a yeast food (Whiteley, 1971).

Maple syrup is obtained from the sap of certain maple trees. The sap contains about 3% sucrose and has a distinctive flavour. This sap is concentrated to about 70–75% sucrose. Maple syrup is used primarily as a flavouring ingredient and is relatively expensive (Manley, 2011).

Sugars affect product dimensions, color, hardness, structure, surface finish, and sweetness. At low levels, the sugar goes into solution during heating and forms a glass-like structure when cooled. This results in an open texture when no gluten has been developed. The hard-eating properties of crunch biscuits are due to their high sugar content. Sugar inhibits gluten development by competing with the flour for the recipe water. In short-dough biscuits, which have high sugar and low recipe water levels, some of the sugar dissolves in the water to form a saturated sugar solution, leaving no free water to hydrate the flour protein to form gluten (Wrigley *et al.*, 2016).

Many biscuit manufacturers mill crystalline sugar to change the particle size distribution. When a crunchy, coarse-eating product is desirable, a proportion of granulated sugar is added. Particle size affects the rate of solution of sucrose during mixing and in short-dough biscuits affects biscuit dimensions and texture. Larger-particle-sized sugar produces doughs that flow less during baking, meaning that the biscuits produced are shorter, wider, and thicker. Large sugar particles increase in biscuit hardness (Wrigley *et al.*, 2016).

Large sugar particles, which have not dissolved during mixing, melt to form a glass on the surface during the early stages of baking. As the dough expands, the glass cracks, resulting in the typical cracked surface appearance. Sugar contributes to color via Maillard browning reactions, which require the presence of both reducing sugars and amino acids. Sucrose is not a reducing sugar but is partially hydrolyzed to glucose and fructose (reducing sugars) during baking. Some of the compounds produced by Maillard reactions contribute to biscuit flavor. Brown sugars contribute to biscuit flavor and color both via Maillard reactions and due to small quantities of aromatic compounds from the molasses (Wrigley *et al.*, 2016). Dissolved sugar tends to inhibit starch gelatinisation and gluten formation and creates a biscuit with a more tender texture. Undissolved sugar crystals give a crunchy, crisp texture (Davidson, 2016). Texture is a very important characteristic which makes a significant contribution to the overall acceptance of food products (Kulthe *et al.*, 2017).

2.1.4.4 Leavening agents

Leavening agents are a group of predominantly inorganic salts which, when added to dough either singly or in combination, react to produce gases which form the nuclei for the textural development within a biscuit during baking. Most of these chemicals leave residues in the dough which affect the final pH and maybe the flavour (Manley, 2011). Leavening (raising) agents decrease biscuit bulk density to give a softer-eating product. The extent to which bulk density is affected depends on the type of biscuit. For instance, raising agents account for about 50% of the increase in thickness of semisweet but only

10% of that for short-dough biscuits; the remainder of the increase is due to steam generated by the dough water during baking (Wrigley *et al.*, 2016).

a) Ammonium bicarbonate (vol)

This leavening agent decomposes completely when heated, producing carbon dioxide, ammonia and water. The reaction is rapid at around 60°C, and therefore the expansion of the dough takes place during the initial stages of baking (Davidson, 2016). A major advantage of using Vol is that there are no solid residues at the end of baking. Vol has low solubility so it should always be added to the dough in water to avoid small pimples from undissolved salts forming on the biscuit surface (Wrigley *et al.*, 2016). Excess can completely break down the structure of the biscuit, and it is important that the ammonia gas is eventually released from the biscuit because of its very strong pungent flavour and odour (Whiteley, 1971).

b) Sodium bicarbonate (baking soda)

In the presence of moisture, soda will react with any acidic materials to liberate carbon dioxide gas, decomposing to the appropriate sodium salt and water. In the absence of an acidulant when heated, the bicarbonate will liberate some of its carbon dioxide and remain as sodium carbonate (Manley, 2011).

Sodium carbonate is known also as common washing soda, and as such has an unpleasant flavour and can react with fats (particularly if developing rancidity) to cause soapy tastes. Sodium carbonate has a marked softening action on gluten, causing spread, and it also darkens the crumb. In biscuit making it is the usual practice to use an acid ingredient to react with part of the sodium bicarbonate, but it is rarely the practice to neutralise the alkali completely. In this way there is a considerable yield of carbon dioxide for aeration, as well as a smaller quantity of sodium carbonate being left to soften the gluten and permit the biscuit to spread a little. The flavour and discoloration will be minimised to such an extent as to be unnoticeable (Whitely, 1971).

An excess of sodium bicarbonate will give biscuits an alkaline reaction and a yellowish crumb and surface colouration with an accompanying unpleasant taste (this taste is known as soda bite). These high pH values, sometimes in excess of pH 8, give flavours liked by some. Normally, in all but a few special types of biscuits, the aim is for a biscuit pH of 7.0

± 0.5 and this is achieved by the use of an appropriate amount of sodium bicarbonate (Manley, 2011).

2.1.4.5 Acidulants and acids

Baking powder is a mixture of sodium bicarbonate and either an acid such as citric or tartaric acid or a salt that dissociates to give an acidic reaction in solution. The purpose of this combination of chemicals is to produce bubbles of carbon dioxide gas either before baking or, more particularly, as the dough piece warms up in the oven. The original acidulants for baking were soured milk (lactic acid) and cream of tartar (potassium acid tartrate). The technology has developed to use other compounds which are cheaper or less readily reactive so that the carbon dioxide is liberated at stages during the baking rather than in the mixer (Manley, 2011).

Most of the common acidulants are phosphate salts which have the disadvantage of leaving phosphate residues with a flavour that is not particularly desirable. Establishing the correct balance between the acidulant and soda depends on the recipe and is normally a matter of some trial and error controlled by flavour or measurement of the biscuit pH. Acid calcium phosphate (ACP) used to be the most common acid salt used for biscuits but because of the slower action of sodium acid pyrophosphate (SAPP), this has now more or less replaced ACP. Gluconodeltalactone (GDL) is not an acid but when dissolved in water it slowly changes to gluconic acid which then reacts with sodium bicarbonate to liberate carbon dioxide. It has the advantage that there is no aftertaste (Manley, 2011).

2.1.4.6 Milk and milk products

The protein and reducing sugar (lactose) contents of milk products contribute strongly to the Maillard reaction which gives golden brown surface colouration to biscuits during baking. Milk may also give slightly more tenderness to the eating quality of the biscuit but it is only used in small quantities due to the effect on the surface colouration. Fresh milk is now rarely used in biscuit manufacture because of its short storage life, the tendency for the cream to separate and its large bulk (it has about 87% water). It is usual to use the dried products, either full cream milk powder (FCMP) or skimmed milk powder (SMP) because of ease of handling, good storage life and low moisture content (Manley, 2011)

a) Full cream milk powder (FCMP)

This material is usually derived from whole fresh milk by a process of evaporation under vacuum followed by roller or, more commonly, spray drying. Full cream milk is now rarely used in biscuit manufacture due to its high cost and the limited storage life (up to six months) which is determined by rancidity development in the fat (Manley, 2011).

b) Skimmed milk powder (SMP)

When fat is separated from fresh milk for cream or butter manufacture, a white fluid, rich in lactose and proteins, remains. This is known as skimmed milk and may be concentrated and dried in a similar manner to full cream milk powder. The flavour is strong and this powder is used in many ways during the manufacture of biscuits. The lactose is a reducing dissacharide which is only about 16% as sweet as sucrose but combines with proteins by the Maillard reaction at the biscuit surface during baking to give attractive reddish brown hues. Skimmed milk powder has therefore found widespread use as a minor dough ingredient both to give subtle flavour and textural improvements and to aid surface colourings. It is a rather expensive ingredient for these roles and the use of cheaper sources of reducing sugars (whey powder, glucose and invert syrups, and maltodextrin powders) have tended to replace it (Manley, 2011).

c) Cheese

There are many different types of cheese but only the strongest flavour types are used for biscuits. Mature Cheddar and Parmesan cheeses are those most commonly used in baking. They are expensive. In the fresh form there may be some incorporation problems of cheese in dough, so the dried, powdered cheeses are preferred even though they tend to have lost some flavour. Cheese is one of the most acceptable and satisfactory basic savoury flavours for biscuits. This is because the flavour loss and change during baking is relatively small. It is, however, important to obtain the maximum effect of the flavour derived from cheese by paying attention to the salt, monosodium glutamate (a flavour enhancer) and acidity levels (pH). The pH should always be slightly acid (6.5–6.7) best achieved with lactic acid additions. Cheese is rich in fat and protein which have shortening effects on doughs making it more difficult to maintain a good cracker structure (Manley, 2011).

d) Whey powder

When milk turns sour, the lactic acid that is developed coagulates the protein matter (casein) to form curds. In cheese making, the curds are separated from the liquid phase which is known as whey. Whey is available in powder form and can be used as an inferior substitute for skimmed-milk powder. It is approximately 70.0% lactose, the remainder being moisture, protein, mineral salts, and a small proportion of fat (Whitely, 1971).

2.1.4.7 Egg and egg products

Eggs are highly nutritious, and therefore enrich any recipe in which they are included. Because of their albumen content they assist in structure formation, both in dough form and when baked. Eggs also appear to have beneficial effects on the crispness, the texture, and the eating qualities of biscuits. They also enhance the biscuit colour and flavour, and help to prevent wafers sticking to the plates and biscuits sticking to the oven band. The yolk is rich in lecithin, which is valuable for its emulsifying properties in doughs (Whiteley, 1971).

Due to the difficulties of cracking and subsequent handling of the egg, it is unusual to use whole eggs in biscuit manufacture. Whole egg material is, therefore, purchased either frozen or as a spray dried powder. It is very easy to denature the egg proteins with heat so reconstituted dried whole egg powder will not have the same foaming properties as fresh or carefully thawed frozen egg (Manley, 2011).

2.1.4.8 Yeast

Yeast is capable of breaking down sucrose and maltose into monosaccharides, and glucose and fructose into alcohol and carbon dioxide. When compressed yeast is added to a dough, the correct conditions for life and reproduction are available; the yeast feeds upon the sugars and produces carbon dioxide, which in turn aerates the dough. However, in biscuit production fermentation is .mainly used to bring about gluten modification and flavour development; the aeration that is achieved is of very minor importance, as the time between the dough passing through the last gauge roller until it reaches the oven is insufficient for any measurable amount of aeration (Whiteley, 1971).

2.1.4.9 Enzymes

Protease acts on the inner peptide linkages of gluten proteins (Manley, 2011). Proteases are important in crackers (low sugar). They are often added to modify the gluten framework. The effect of a protease is to make the dough less elastic, so that shrinkage does not occur during sheeting and cutting. Proteases may occasionally be used in cookie production. A dough containing gluten that is too strong will decrease biscuit spread, so proteases can improve the spread ratio (Caballero *et al.*, 2003). Hemicellulase is sometimes used in cracker doughs where, by the partial breakdown of the pentosans in the flour, the dough is softened and less water is needed to make the dough. Less water means that less has to be removed in baking. In low-fat or high-fiber biscuits more water has to be used to replace the softening action of fat. This tends to give a tough dough because more gluten is developed. By using hemicellulase, less water is needed for the dough so the toughening is reduced to the advantage of biscuit structure (Manley, 2011).

2.1.4.10 Emulsifiers

Fats in biscuits reduce the hardness by interrupting the gluten structure in the dough. By using small amounts of emulsifier the fat phase is spread more uniformly over the hydrophilic ingredients such as flour, sugar, etc., in the dough. The fat phase is thus more effective if it tends to be in films or very small droplets rather than globules. Lecithin, derived principally from soya bean, has been in common usage in biscuits. It is usually dissolved in the fat before addition to the recipe. It aids the dispersion of the fat in semi-sweet doughs and improves the emulsification during cream up in short doughs. Other emulsifiers are mono/diglycerides, acid derivatives of monoglycerides, stearoyl lactylates, etc. (Manley, 2011).

2.1.4.11 Antioxidants

Antioxidants may be useful to extend the storage life of fats, before use in biscuits, and to extend the shelf life of biscuit products. The most commonly used antioxidants in biscuit manufacturing are BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene), propyl gallate and TBHQ (tertiarybutylhydroquinione). They are thought to work by preventing the formation of free radicals that initiate and propagate autooxidation (Manley, 2011).

2.1.4.12 Salt

Salt improves flavor and is particularly important in sweet biscuits (typical level about 1% on flour weight). It can be used in the dough of all biscuit types and dusted onto fat sprayed crackers (Wrigley *et al.*, 2016).

2.1.4.13 Other ingredients

Dried fruits such as currants, sultanas, raisins, figs, dates; glace cherries, are used in biscuits. Nuts such as coconut, walnut, almonds, groundnuts, hazel nuts, cashew nuts, etc are also used. Spices such as ginger, cloves, cinnamon, pepper, coriander, cardamom, celery seeds etc are used as flavourings (Whitely, 1971). Monosodium glutamate, yeast extracts, etc are used as flavor enhancers. Cocoa and chocolate, colorings, artificial sweeteners are also used (Manley, 2011).

2.1.5 Technology of biscuit making

2.1.5.1 Mixing

The primary purpose of mixing is to bring about a complete and uniform dispersion of ingredients to form a homogeneous dough within a decided time period. In the case of biscuits, mixing mainly involves blending, dispersing, dissolving a solid ingredient into a liquid medium like shortening or water, kneading, developing of dough, and discharging of dough into trolleys or on conveyor belts for further processing (Caballero *et al.*, 2016). Kneading is the name given to the rolling, deformation and stretching of dough rather than a cutting action, which results in the formation of gluten. The formation of gluten is known as dough development (Manley, 2011).

The mixing time usually ranges from 15 to 25 min and depends on factors like flour characteristics, formulation and temperature of dough during mixing (Caballero *et al.*, 2016). The dough characteristics change with time after mixing and often they become stiffer. Where doughs have a significant gluten network, the tendency is to rest them before processing (commonly 10–40 min) to enable easier processing and limit potentially adverse impacts on biscuit shape (Wrigley *et al.*, 2016). The temperature of short doughs is not allowed to rise above 82°F (28°C) so the fat is not significantly melted and the lower temperature also helps resist the formation of flour gluten. In case of hard dough, the correct final temperature varies from dough to dough, but would be somewhere in the range 95-113°F (35-45°C) (Townsend, 1990).

The main types of mixing process are as follow: (a) All-in, where all of the ingredients are added to the mixer at the start. This is best for doughs with some gluten development. If used for short doughs, extra water is needed to achieve a standard consistency. (b) Two-stage, usually called creaming, where all of the ingredients apart from flour and materials such as nuts are mixed to a cream, and then the flour is added and mixing continued to form the dough. (c) Multistage, where the flour may be added in more than one portion. If used, nuts, fruits, or chocolate chips are added in a third stage by blending them in on slow speed (Wrigley *et al.*, 2016).

2.1.5.2 Forming

The forming process is specific for every product and can be generally classified into three types: (1) sheeting, laminating, gauging, and cutting; (2) rotary molding; and (3) extrusion of dough through dies. Dough with a fully developed gluten network is generally sheeted and strong, inextensible dough is laminated. Rotary molding is applicable to dough with less developed gluten, and the soft dough is generally extruded (Caballero *et al.*, 2016).

1) Sheeting, gauging, laminating and cutting

This method involves the production of a thick sheet of dough, evenly reducing the thickness of the sheet, cutting out the desired shapes, and returning the scrap dough to be reincorporated either in the mixer or early in the sheeting process. This method is used for the production of crackers, semisweet biscuits, and selected soft doughs. After mixing, the dough is fed into a hopper, below which lie the sheeting rollers. There are typically three rollers below the hopper arranged in a triangular fashion. The purpose of this sheeting unit is to compact the mass from dough hopper uniformly and provide a sheet of even thickness having the width of the processing line. The relatively thick dough slab from the sheeter then passes through a series of reduction or gauge rollers. These are smooth steel rollers used to reduce the dough sheet to the thickness that is desired before cutting of the finished dough piece. The gauge rollers occur in pairs mounted vertically. On most process lines, there are two or three pairs of gauge rollers (Caballero *et al.*, 2003).

Some doughs, such as those of saltines and cream crackers, are laminated before cutting (Caballero *et al.*, 2003). Laminating is done for several reasons: (1) it helps to repair the sheet that was formed using a simple pair of rolls; (2) uniform stress distribution can be achieved by turning the folded dough through 90˚ (3) consecutive and repetitive cycles of rolling and folding cause more working of dough and develop a delicate structure in baked products; and (4) flaky structure can be obtained in products by spreading fat between two layers (Caballero *et al.*, 2016). The lamination occurs by lapping the dough back upon itself in the process direction. At the lapper, the take-away conveyor lies at a 90° angle relative to the line delivering the dough. The number of layers is controlled by the relative rate of the lapper and take-away conveyor. The lapped dough then passes through several more sets of gauging rollers to bring the dough sheet to the desired thickness prior to cutting (Caballero *et al.*, 2003).

The repeated working of the dough in one direction results in the accumulation of stress. If the dough were cut at this point, the resulting pieces would shrink to relieve the stress, and misshapen or distorted products would result. Therefore, it is normal to relax the dough after reduction and before cutting (Caballero *et al.*, 2003). It is desirable to relax the dough more often in puff or other laminated types to facilitate shrinkage (Caballero *et al.*, 2016). The relaxation is accomplished by transferring the dough to a conveyor, still moving in the same direction, but at a slower speed. Flutes are formed on the relaxing web. After the relaxing web, the sheet is again straightened by increasing the speed of the conveyor carrying the sheet to the cutter (Caballero *et al.*, 2016).

Once the dough has been relaxed, it passes on to the cutting operation. Two different types of cutting methods exist: reciprocating cutters and rotary cutters. Reciprocating cutters consist of heavy block cutters that stamp out one or more pieces at a time (Caballero *et al.*, 2003). For maintaining a perfect size and shape, it is necessary that the dough sheet travels at constant speed under the cutter, which drops over the dough sheet, moves along with the dough, and comes to the original position before (Caballero *et al.*, 2016). The cutter head may have a dual action, whereby the cutter drops first, followed by a docking head or an embossing plate (Caballero *et al.*, 2003). Reciprocating cutters are rarely used nowadays (Manley, 2011)

The Rotary cutters are of two types, those that employ two rolls, one immediately after the other, and those with only one roll. In case of two roll types the dough sheet, on a cutting web, is pinched between engraved rolls (mounted in series) and a rubber-coated anvil roll(s). The first roll dockers the dough, prints any surface pattern or type and thereby pins the dough onto the cutting web. The second roll is engraved with only the outline of the biscuit and cuts out the piece leaving a network of scrap. A single-roll rotary cutter achieves both dockering, pinning and outline cutting with only one roll. In many cases this works well and there is a saving in capital equipment, but there is a strong tendency to lift the dough piece from the cutting web because the pinning down facility is not independent of the cutting pressure (Manley, 2011). Scrap can be reused either by mixing it with a fresh batch of dough in the sheeter with the help of the 'scrap return,' or it is added in the horizontal mixer while kneading a new batch (Caballero *et al.*, 2016).

2) Rotary moulding

A rotary moulder is a machine commonly in use for producing biscuit dough pieces from short doughs (Manley, 2011). Three rollers are placed in a triangular arrangement below a dough hopper. A roller, called the forcing or feed roller, has deep grooves designed to pull dough down from the hopper. The dough is forced into the cavities of the engraved roller by the forcing roller (Caballero *et al.*, 2003). The engraved roller forms the dough pieces, and the molds are made of plastic or bronze (Caballero *et al.*, 2016). A scraper blade is mounted against the engraved roller to remove any excess dough and return it to the hopper via the forcing roller. Beneath the engraved roller is a rubber-covered extraction roller that serves to drive the take-away belt. The extraction roller applies pressure to the engraved roller via the belt, causing the dough to adhere preferentially to the conveyor belt. Dough pieces are dropped from the take-away belt into pans or directly on to the baking belt (Caballero *et al.*, 2003).

The rotary molding process is suitable only for dry, crumbly doughs. This process offers advantages over sheeting and cutting in that there is no scrap to recycle, and there are very low labor requirements to run the process (Caballero *et al.*, 2003).

3) Extrusion

Extrusion is one of the simplest ways of making dough pieces and is done by forcing soft short dough through orifices by means of a pump or rollers. Batter like dough is easy to extrude rather than mold or sheet. Extrusion is of great advantage while handling sticky dough and dough containing coarse particles such as nuts, flakes, or chocolate chips

(Caballero *et al.*, 2016). Extruded short dough products fall into two categories: wire cut and bar-press (also known as rout press) (Caballero *et al.*, 2016) Both systems are very similar in design. A hopper is placed over a system of two or three rollers that force dough into a pressure chamber. The rollers may run continuously or intermittently to force dough out of the pressure chamber at the die (Caballero *et al.*, 2003).

For wire-cut cookies, the dough is extruded through a row of dies, and a wire or blade mounted on a frame moves through the dough just below the die nozzle outlet. The cut dough pieces then drop into a conveyor band for transport to the oven (Caballero *et al.*, 2003) The extruding nozzle used is the diameter or shape of the dough piece required. The top surface of the product is formed by the cutting wire so it is not possible to impose any design on the biscuit (Wrigley *et al.*, 2016).

The bar-press or rout-press production process is similar to the wire cut procedure except that the base of the dough chamber contains a die plate with nozzles (Caballero *et al.*, 2016). The dough is extruded continuously as a ribbon (Wrigley *et al.*, 2016). The nozzles are shaped to form a design. Some nozzles can rotate while the dough is extruding to produce twists, swirls, or other fancy designs (Caballero *et al.*, 2016). The ribbons are usually guillotined into short lengths before baking, but, alternatively, some form of cutter may be used on the oven band after baking (Manley, 2011).

2.1.5.3 Baking

Baking is the most important manufacturing process, and the final product quality and shelf life rely on the effectiveness of the oven to bake the product (Caballero *et al.*, 2016). To make biscuits palatable, baking is essential, and is achieved by transferring heat from a heat source to the biscuit (Whiteley, 1971). There are three main changes which we will see as all biscuits are baked. They are the development of the biscuit structure and texture, the reduction in the moisture content and the development of the colour (Davidson, 2016). Baking profile varies with type of biscuit and depends on the formulation and the desired textural product characteristics. Baking time varies from 3 to 12 min and depends on the product. Temperature also varies from 140 to 240°C, varies from zone to zone, and is product specific (Caballero *et al.*, 2016).

2.1.5.3.1 Oven

A traveling or band oven is extensively used for industrial baking processes, whereas small bakeries rely on simple ovens or static ovens, which usually have a heated box with a door and different trays and can be heated by means of electricity, gas, or wood. The traveling or band oven is a tunnel that is enclosed, is insulated, and bears different sections/zones. Oven length ranges from 30 to 150 m, with an average length of about 60 m and a band width of 1–2 m. The oven consists usually of 3–7 zones with different temperature and air profiles, which are controlled separately as for the baking profile of the product. In a continuous oven, temperature and heat transfer conditions can be controlled throughout the oven during the baking process. Industrial ovens usually run on fuels such as petroleum gas, oil, or electricity, which heat the atmosphere around the product either directly or indirectly via heat exchangers (Caballero *et al*., 2016).

The band or trays serve as the baking surface inside the oven. The selection of the oven band is product specific as it affects the quality of the finished product by altering the heat transfer at the bottom of the product itself. The band can be a continuous sheet of steel, which may or may not be perforated and is also available in the form of a wired mesh type. The speed of the band usually decides the baking time of the product (Caballero *et al.*, 2016).

The formation of the structure and texture of the biscuit will occur in the first half of the oven, the reduction of moisture mainly in the middle and the development of color in the final third of the oven (Davidson, 2016). Most biscuits are now baked in travelling ovens but many small manufacturers bake on trays placed in a static oven (Manley, 2011). Ovens for industrial baking purpose are classified into direct fired, indirect fired, and hybrids (Caballero *et al.*, 2016).

2.1.5.3.2 Changes during baking

There are three main changes which we will see as all biscuits are baked. They are the development of the biscuit structure and texture, the reduction in the moisture content and the development of the colour (Davidson, 2016).

1. Development of structure

Development of the internal structure of a biscuit takes place mainly in the first quarter or third of the baking period. The changes are all temperature related and involve several aspects of the recipe and the form of the dough piece. Bubbles of gas and water vapour are formed which expand and result in a large reduction in the density of the dough. It is the open porous structure that gives a biscuit a pleasant eating texture. The development of the structure is often known as oven spring. The conditions for giving maximum spring, which are sustained through the remainder of the bake, are imperfectly understood but the changes to the dough piece that are involved include:

a) heating the starch and proteins to levels where swelling, gelatinisation, denaturation and setting occur
b) liberation of gases from leavening chemicals
c) expansion of these bubbles of gases as a result of increasing temperature which also increases the water vapour pressure within them as well as rupture and coalescence of some of these bubbles
d) loss of moisture from the product surface by evaporation followed by migration of moisture to the surface and continued loss to the oven atmosphere
e) increase of sugar solution concentration as the temperature rises
f) reduction in consistency of sugar solutions and fat with temperature rise.

Starch gelatinisation occurs in the temperature range 52–99°C and the change is somewhat time dependent. Proteins are denatured and coagulated above about 70°C. Gas is liberated from chemical leavening agents at a significant rate from about 65°C. It can also be seen that the volume increase due to water vapour accelerates very rapidly above 70°C. Fats used in baking melt completely well below any of these temperatures. It will be seen that as the different parts of the dough piece reach about 65°C expansion and loss of flexibility are converging forces. Too much expansion and the structure ruptures, too little expansion and a dense close structure forms (Manley, 2011).

2. Reduction in moisture

Ideally, moisture loss should occur after the structure has set but obviously this is impossible to achieve throughout the dough piece. Moisture can only be lost from the dough piece surface so migration to the surface by capillary action and diffusion must occur. Both of these phenomena are accelerated by temperature gradients so a rapid heating of the whole product to 100°C is required during this stage of baking. If the surface is heated too much, and it dries too rapidly (as will occur if there is much air movement in the oven), colour changes occur prematurely and it is thereafter difficult to dry the biscuit enough without excessive surface colouration (Manley, 2011).

Loss of moisture from surface occur principally at 100°C for pure water, but at higher temperatures (up to 130°C) when the water is held in solution, for example, in a sugar solution. At temperatures over 100°C, the application of heat will always result in moisture loss from the surface of the dough pieces, even in an oven atmosphere which is saturated with water vapour. This loss of moisture from the dough piece is dependent on the temperature, the method of heat transfer and the humidity of the oven (Davidson, 2016).

The moisture gradient across a dough piece increases during drying and as the biscuit structure dries the starch/protein structure shrinks. While hot the biscuit is flexible enough to withstand these shrinkage stresses, but a phenomenon known as 'checking' may occur if a large moisture gradient remains after the biscuit leaves the oven. As the biscuit cools moisture equilibrates (moving from the wetter areas to drier) and the shrinkage stresses so developed may cause cracks to form. This is called checking. The best way to prevent checking is to ensure that the total moisture content of the biscuit is low so that any gradients will be small (Manley, 2011).

3. Color changes

Although there is a change to a yellow-brownish hue during baking, the term colour here is used to imply merely a darkening, reduction in reflectance, of the biscuit surface (Manley, 2011). After the moisture has been mainly evaporated from the dough pieces, the temperature of the surface rises quickly and the colour will change from around 150°C. There are three processes which contribute to the browning of the biscuits. Caramelisation is a non enzymatic browning reaction, which is caused by the breakdown of sugars at high temperatures. The caramelisation of different sugars occurs at different temperatures: fructose at 110°C, glucose 160°C and sucrose at 160°C. Caramelisation results in both colour and flavour development. A second browning process, dextrinisation, is the breaking down of starch molecules by heating. This produces pyrodextrins which are brown in colour and have a distinctive flavour. Dextrinisation of the starch occurs at temperatures of 100–200°C (Davidson, 2016).

The third browning process is known as the Maillard reaction. This is a complex chemistry in which many compounds are formed at high temperatures by the reaction of reducing sugars and amino acids (Davidson, 2016). The Maillard reaction, non-enzymic browning, involves the interaction of reducing sugars with proteins to produce attractive reddish-brown hues. This occurs around 150–160°C and will happen only in a moist situation. It is not possible to reheat baked biscuits to increase significantly the surface colour due to the Maillard reaction (Manley, 2011).

In order to get these high surface temperatures while the dough piece is relatively moist, it can be seen that radiant heat rather than convected heat is likely to be important. At even higher temperatures the biscuit structure chars or burns (Manley, 2011).

An excess of alkali, usually resulting from too much sodium bicarbonate in the recipe, will cause a general yellowish colour throughout the biscuit structure and this will be unattractive in products where there is no other colouration present (Manley, 2011).

As drying continues, the colouration due to the changes already described will develop in the thinner or more exposed areas of the biscuit. This change is accompanied by the development of a bitterness of flavour. A condition known as 'perishing' will occur if this continues throughout the biscuit structure. Perished biscuits are bitter and unpleasant (Manley, 2011).

2.1.5.4 Cooling

Freshly baked products leaving the oven must be cooled before packaging or secondary processing. The product leaving the oven has a temperature of about 100°C. Cooling is important because warm biscuits or cookies might not able to withstand the packaging process if too soft, and also the packaging material may shrink and the product quality may deteriorate due to condensation of water vapor inside the packed product. In the industrial production, the cooling process starts at the oven exit: the biscuits are transferred from the oven band to an open conveyor using a doctor's knife. The length of the cooling conveyor varies from 1.5 to 2 times the length of the oven (Caballero *et al.*, 2016). The products cool naturally in the ambient factory atmosphere. In a few cases, it is necessary to provide forced air to aid the cooling process (Caballero *et al*., 2003). Usually the product is cooled up to 40–45°C, and those who require secondary processing like cream filling are cooled to 18–26°C (Caballero *et al.*, 2016).

2.1.5.5 Secondary processing

Typical secondary processing involves the deposition of cream, jam, or marshmallow on the biscuit or the enrobing with chocolate or coating with icing, which gives the product a different appearance, texture, and taste. Cream sandwiching is a process in which two or three biscuits are sandwiched with cream filling between them. The filling generally contains sweet cream with 30–40% fat and 60–70% sugar with added color and flavor (Caballero *et al.*, 2016).

2.1.5.6 Packaging

Biscuits require immediate protection as they are highly hygroscopic in nature and tend to gain moisture from the atmosphere, which leads to spoilage (Caballero *et al.*, 2016). Biscuits are typically very fragile and lose much of their appeal if broken. Biscuits are very susceptible to the pick-up of strong odours and even small traces can spoil their flavour. Oxidation of fats results in rancidity and this is greatly promoted by light, particularly ultraviolet light. The packaging materials can retard the effects of chemical change by excluding (or reducing) the intensity of light and by excluding oxygen (Manley, 2011).

The overall biscuit packaging involves primary, secondary, and tertiary packaging that have different functions and requirements. The primary package is generally in the form of flow wraps, slugs, sachets, displays, tubes, and shrink wrappings (Caballero *et al.*, 2016).

Packaging material used to pack biscuits is oriented polypropylene (OPP), either as plain or, more commonly, coextruded oriented polypropylene film or acrylic-coated on both sides. Plain oriented polypropylene films are economical but generally require a heat seal coating to improve sealability. Coextruded oriented polypropylene films provide superior seal strength. If a superior O_2 barrier is required, then acrylic-coated oriented polypropylene is used, and one side is sometimes coated with poly vinylidine chloride (PVdC) copolymer rather than acrylic. In addition, acrylic and polyvinylidine chloride copolymer-coated OPP films provide a superior flavor and aroma barrier compared with that of uncoated oriented polypropylene (Robertson, 1993)

Mechanical protection is generally provided either by placing the product in a protective rigid container such as a paperboard carton of appropriate caliper or by packing the product tightly together, the choice depending on a number of factors. If the product is particularly moisture sensitive, the carton will need to be overwrapped with a film which can provide a good barrier to water vapor. A further option is to place the biscuits inside a tray (typically made from thermoformed poly vinyl chloride (PVC) or high impact polystyrene (HIPS) but now more commonly polyethylene terephthalate (PET) and then overwrap the tray with a film that provides suitable protection from water vapor and O_2 (Robertson, 1993)

2.1.5.7 Storage

Conditions of temperature and humidity are very important in biscuit stores. High or fluctuating temperatures may cause fat migration, fat bloom, chocolate and rancidity problems. High humidities or dampness will reduce the strength of the cardboard cases and increase the rate of moisture transmission through wrapping films. Thus, all parts of biscuit stores should be dry and cool. Good insulation of walls and ceilings combined, if necessary, with air conditioning and air circulation will reduce the chance of local high or fluctuating temperatures. Cases should not be stored on floors or touching walls. Dampness problems are considerably reduced if air circulation is good and gaps left at floor/wall junctions will help in prevention of rodent and insect infestations (Manley, 2011).

2.2 Bamboo

2.2.1 Introduction

Bamboo is botanically a grass belonging to perennial evergreen plants in the family of *Poaceae,* and have a large diversity in growth habitat and geographical distribution in the world (Karanja, 2017). Bamboos comprise the subfamily *Bambusoideae*, one of 12 subfamilies currently recognized within the grass family (*Poaceae*) (Clark *et al.*, 2015). There have been approximately 1100–1500 different species of bamboo which have been identified and classed into a range of over 115 genera species across the globe (Akinlabi *et al.*, 2017).

2.2.2 Growth characteristics and distribution

Bamboo grasses grow naturally in areas that receive an annual rainfall ranging from 1200 to 4000 mm, with average annual temperature ranging from 8 to 36°C. They also grow well in different types of soils ranging from rich alluvium to hard lateritic soil, loamy soils and sandy soils. Bamboo is one of the fastest-growing plants on the planet, with reported higher rates of growth in tropical and subtropical climate regions compared to timber (wood). Bamboo grows very fast, but mostly the species type also has a significant influence. All bamboo matures quickly and might have 40–50 stems in one clump, which adds 10–20 culms yearly as compared to wood which does not add a single shoot. Bamboo can attain its maximum height within four to six months with 15–18 cm (5–6 in.) daily increments. The fast growth characteristic of bamboo gives it an added advantage for its utilisation as it is a high-yield renewable resource, cheap and abundant across the globe for multiple industrial applications (Akinlabi *et al.*, 2017). Culms take 2 to 6 years to mature depending upon species (Sangeetha *et al.*, 2015). The bamboo's lifespan is not very long only about 20 years (Shukla *et al.*, 2012)

The occupancy of bamboo plants in an ecological area includes temperate deciduous forests, coniferous forest, lowland tropical forests, mountainous forests,(moist) wetter forests, grasslands, and many other regions. They are mostly distributed across the tropics and subtropics zones through natural occurrence, as well as cultivation on farmlands (Akinlabi *et al*., 2017). Bamboos are native to all continents except Antarctica and Europe (Clark *et al.*, 2015). Nearly, 300 species are found in China, 237 in Japan, 136 in India, 90 in Burma, 55 in Philippines, 50 in Thailand, 44 in Malaysia, 33 in Bangladesh, 30 in Nepal and 30 in Srilanka (Choudhury *et al*., 2012a). China is the major bamboo producing country followed by India (Bal *et al.*, 2012).

2.2.3 Morphology

Bamboo is divided into two major portions, the rhizomes and the culms. The underground part of the culm (stem) is known as the rhizome and mostly sympodial or to a much lesser degree, monopodial. The rhizomes store the nutrients for growth and also secure the bamboo plant in the ground for its sustenance. The culm part is the upper portion of the bamboo grass that contains most of the woody material. The rhizomes consist of buds which develop into shoots that emerge from the ground to form a clump of culms. The culm of a bamboo is cylindrical and subdivided into sections by diaphragms or nodes. The culm of a bamboo by nature is hollow but has a thick wall which makes it ideal for the production of structural components. The bamboo culm is hollow with a diameter ranging from 0.25 to 12 in. (0.64–30.48 cm) and with a height from one foot to 120 feet. However, bamboo does not have any bark but has a hard, smooth outer skin due to the presence of silica. The branch systems, sheath, foliage leaves, and flowers complement the culm of the bamboo (Akinlabi *et al*., 2017).

Bamboo has a natural composite material of cellulose fibers immersed in a lignin matrix. It has a higher tensile strength, strength-to-weight ratio, and specific load-bearing capacity compared to mild steel. However, less energy is required for its processing (Akinlabi *et al.*, 2017).

2.2.4 Uses

Bamboo is one of the oldest structural material used by humans. For many centuries, bamboo culms have been used for constructing all kinds of structures and structural components, such as houses, boards, roof trusses, wall cladding, pillars, tools, furniture, flooring, ceilings, walls, windows, doors, fences, rafters, etc. It can also be used for soil stabilisation, rehabilitation of degraded land, food, medicine and as fuel (Akinlabi *et al.*, 2017).

2.3 Bamboo shoot

2.3.1 Introduction

The evergreen bamboo plant consists of aerial stems known as culms, which arise from a network of rhizome system. An emerging young culm is known as bamboo shoot or juvenile shoot and contains short vertical nodes and internodes tightly clasped with overlapping sheaths that have to be removed to extract the edible part (Karanja, 2017). The sheaths covering the shoots are black, brown, yellow or purple, in some species covered with tiny hairs (Choudhury *et al*., 2012a). If not harvested, bamboo shoot will grow into a tall bamboo plant within three to four months (Singhal *et al.*, 2013).

Bamboo shoots or bamboo sprouts are young stems that are harvested when they reach a height of 30 cm. They are tender, soft, crispy, generally ivory yellow in colour. The underlying white part that is revealed, once the culm sheath is peeled off , turns yellowish when cooked (Chauhan *et al.*, 2016). They are tapering at one end and weigh almost to a pound. The shooting period of bamboo varies from species; their size and weight depending on location, depth and nutrition of the soil, watering and drainage conditions, temperature, pH and soil fertility. Broadly, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub tropical varieties are clumpers, which shoot in the late summer and fall (Choudhury *et al.*, 2012a). Young shoots of both running and clump-forming bamboos are used for edible purposes (Singhal *et al.*, 2013). When a newly harvested bamboo shoot is peeled, it gives a strong smell and bitter taste. The bitter taste in bamboo shoots is due to the presence of cyanogenic glycoside taxiphyllin, which is toxic in nature. All species of bamboo shoots available in the world are not edible (Choudhury *et al.*, 2012b).

Bamboo shoots are low in fats and cholesterol, but high in potassium, carbohydrates and dietary fibers. Many nutritious and active materials such as vitamins, minerals and amino acids as well as antioxidants such as phenols, steroids and flavones are present in bamboo shoots (Choudhury *et al*., 2012a). Thus bamboo shoots have many health benefits. They are important in reducing cholesterol, fighting cancer, protecting heart, healing wound, controlling weight, treating stomach disorders, etc. (Padhan, 2015). It also helps in digestion, improving appetite and has anti-inflammatory and anti microbial properties (Chongtham *et al.*, 2011).

Bamboo shoots form traditional delicacy of many countries such as China, India, Nepal, New Zealand, US, Japan, Korea, Thailand, Indonesia, Malaysia, Bhutan and Australia. Bamboo shoots are eaten as fresh, dried, canned and fermented forms (Choudhury *et al*., 2012a). Different types of preparations such as bamboo shoot curry, chutney, *chukh, pulau*, bamboo candy, fried shoot, bamboo canned juice, bamboo beer, etc are made from bamboo shoots (Chauhan *et al.*, 2016). Bamboo fiber is now common ingredient in breakfast cereals, fruit juices, frozen deserts, bakery products, meat products, sauces, shredded cheeses, pastas, snacks and many other food products (Padhan, 2015). The list of commercially important edible species of bamboo consumed in various countries is shown in Table 2.1.

Table 2.1 List of commercially important edible bamboos consumed in various countries.

Country	Species consumed
Australia	*Bambusa oldhamii, Dendrocalamus asper, Dendrocalamus brandisii, Dendrocalamus latiflorus, Bambusa arnhemica, Gigantochloa atter, Phyllostachys pubescens, Phyllostachys heterocycla var. pubescens*
Bhutan	*Dendrocalamus giganteus, Dendrocalamus hamiltonii var. edulis, Dendrocalamus hookeri, Dendrocalamus sikkimensis*
China	*Bambusa oldhamii, Dendrocalamus asper, Dendrocalamus brandisii, Dendrocalamus latiflorus, Phyllostachys praecox, Phyllostachys iridescens, Phyllostachys nuda, Phyllostachys makinoi, Phyllostachys pubescens, Phyllostachys viridis, Pleioblastus amarus, Thyrsostachys siamensis.*
India	*Bambusa balcooa, Bambusa bambos, Bambusa kingiana, Bambusa nana, Bambusa nutans, Bambusa pallida, Bambusa polymorpha, Bambusa tulda, Bambusa vulgaris var. vulgaris, Chimonobambusa hookeriana, Dendrocalamus asper, Dendrocalams giganteus, Dendrocalamus hamiltonii, Dendrocalamus hookerii, Dendrocalamus longispathus, Dendrocalamus membranaceus, Dendrocalamus sikkimensis, Dendrocalamus strictus, Gigantochloa rostrata, Melocanna baccifera, Phyllostachys bambusoides, Schizostachyum capitatum, Teinostachyum wightii, Thyrsostachys siamensis, Thyrsostachys oliveri, Schizostachyum dullooa*
Japan	*Bambusa oldhamii, Dendrocalamus asper, Phyllostachys edulis, Phyllostachys bambusoides, Phyllostachys pubescens, Phyllostachys Mitis*
Korea	*Phyllostachy pubescens, Phyllostachys nigra, Phyllostachys heterocycla*
Nepal	*Dendrocalamus giganteus, Dendrocalamus hamiltonii, Dendrocalamus hookeri, Dendrocalamus sikkimensis*

Taiwan	*Bambusa edulis, Bambusa multiplex, Bambusa oldhamii, Bambusa pallida, Dendrocalamus asper, Dendrocalamus latiflorus, Phyllostachys makinoi, Phyllostachys pubescens and Thyrsostachys siamensis*
Thailand	*Bambusa edulis, Bambusa oldhamii, Bambusa pallida, Dendrocalamus asper, Dendrocalamus latiflorus, Thyrsostachys siamensis*
USA	*Phyllostachys dulcis, Phyllostachys edulis, Phyllostachys bambusoides, Phyllostachys pubescens, Phyllostachys nuda, Phyllostachys viridis*

Source: Chongtham *et al*. (2011)

2.3.2 Nutritional value of bamboo shoots

The nutrients content in bamboo shoots has been reported to be higher in the shoots than in leaves and stems, and is also found to vary between different parts of the shoots (Karanja, 2017). Bamboo shoots contain several nutritional components like protein, carbohydrates, fat, vitamins, minerals, etc. Bamboo shoot is rich in fiber and low in fat (Chongtham *et al*., 2011).

1. Protein

Bamboo shoots are rich in protein containing between 1.49 and 4.04 g (average 2.65 g) per 100 g of fresh bamboo shoots (Chongtham *et al.*, 2011). The wide variation in the protein content of bamboo shoots may be attributed to differences in species, growing site, climatic factors, and method (Singhal *et al.*, 2013). Shoots contain 17 amino acids, 8 of which, serine, methionine, isoleucine, leucine, phenyalanine, lysine, and histidine are essential for the human body (Chongtham *et al.*, 2011). Glutamic acid and lysine are the most abundant amino acids (Chauhan *et al.*, 2016).

The crude protein content has been found to decrease after boiling the shoots at increasing temperature. Cooking diminishes the biological value of proteins by destroying the essential amino acids (Singhal *et al*., 2013). The content has been also found to decrease in the 10-day-old shoots (2.17–2.60%) when compared with the freshly harvested juvenile shoots (3.10–3.71%) in five different species (Chongtham *et al*., 2007). A detailed study has revealed that canned shoots has the lowest protein content (1.93%) followed by fermented (2.57%), 10-days-old (2.6%), and juvenile shoots (3.11%) in the *Dendrocalamus giaganteus* species (Singhal *et al*., 2013).

2. Fat

Bamboo shoots are known for their low fat content. The fat content ranged from 0.3% to 3.97% in the fresh shoots, highest being in *Bambusa tulda* (Singhal *et al*., 2013). Its low content makes bamboo shoots an ideal candidate for providing healthy nutrition to people with diabetic and cardio thoracic diseases (Nongdam and Tikendra, 2014). Variation in the distribution of lipids between different sections of the shoot has been reported. The main fatty acids are palmitic, linoleic, and linolenic acids, but composition is remarkably different among different sections (Singhal *et al*., 2013). The major fatty acid is palmitic acid (Chauhan *et al*., 2016).

The fat content in the juvenile shoots ranged from 2.64 to 3.97%, but for the 10-day-old shoots, the content ranged from 8.2 to 13.84% in five different species (Chongtham *et al*., 2007). The level of fat was reduced in boiled and steamed bamboo shoots of *Phyllostachyspraecox* (Nongdam and Tikendra, 2014). Canned shoots were reported to contain the lowest content of crude fat, i.e., 0.25%, as compared to the raw shoots of different species (Singhal *et al*., 2013).

3. Carbohydrate

The carbohydrate content ranges from 2.0% to 9.94% in the raw form of bamboo shoots. The carbohydrate content has been reported to be 3.3%, 3.4%, 2.6%, and 2.9% in *Bambusa nutans*, *Bambusa vulgaris*, *Dendrocalamus strictus*, and *Dendrocalamus asper*, respectively (Singhal *et al*., 2013). Three main sugars have been identified in bamboo shoots namely, fructose, glucose and sucrose (Karanja, 2017). Sucrose is the most abundant sugar (Chauhan *et al*., 2016).

The carbohydrate content decreased upon storage ranging from 4.9–6.92% in the juvenile shoots to 4.46–2.3% in the 10-days-old shoot sample of five different species (Chongtham *et al.*, 2007). The content was found to increase after boiling ranging from 3.1% to 5.1%, which might be due to fibrous nature of bamboo (Singhal *et al.*, 2013). The carbohydrate content decreased when bamboo shoots from *Bambusa bamboos*, *Bambusa tulda*, *Dendrocalamus asper*, and *Bambusa strictus* were boiled in solution with different salt concentrations. The presence of salt in solution might have played a role in reducing the carbohydrate level in shoot by enhancing the hydrolysis of carbohydrate during boiling. Carbohydrate in fermented shoot (1.504 g/100 g fresh weight) was decreased when compared to carbohydrate content of fresh shoots of *Dendrocalamus giganteus* (5.103 g/100 g fresh weight) (Nongdam and Tikendra, 2014). The reducing sugar content decreased on boiling shoots and ranged from 0.01% to 0.59%. Prolonged heating under moist conditions degrades reducing sugars by browning reaction (Singhal *et al*., 2013).

5. Fiber

Dietary fiber comes from the portion of plants that is not digested by enzymes in the intestinal tract. Part of it, however, may be metabolized by bacteria in the lower gut (Obasi and Ifediba, 2018). Bamboo shoots are a rich source of dietary fiber. They have high amounts of fiber, ranging from 2.23 to 4.20 g/100 g fresh weight of shoot in some bamboo species (Chongtham *et al*., 2011). The apical and basal portions of *Dendrocalamus giganteus* shoots contained 0.96 and 0.97% crude fiber on fresh weight basis (Satya *et al.*, 2012).

The fiber content in the juvenile shoots ranged from 2.64% to 3.97% whereas for 10-days-old shoots the increase ranged from 8.2% to 13.84% in five different species (Chongtham *et al.*, 2007). In a study, it was evident that upon storage, the enhancement of the activity of the enzyme, phenylalanine ammonia lyase was closely correlated with the increase of crude fiber and lignin. The content also increased significantly after fermentation and canning (Satya *et al.*, 2012). The fiber content does not seem to change after boiling (Chongtham *et al.,* 2011). Table 2.2 shows nutrients content in freshly emerged juvenile shoots of some species.

Table 2.2 Macronutrients (g/100 g fresh weight), moisture, dietary fiber, and ash content in the freshly emerged juvenile shoots of some species.

Parameters	Species			
	Bambusa tulda	*Dendrocalamus hamiltonii*	*Dendrocalamus giganteus*	*Bambusa nutans*
Moisture	83.60±1.26	92.51±0.51	90.70±0.12	92.00±0.23
Protein	3.69±0.03	3.72±0.12	3.11±0.17	2.84±0.12
Fat	0.48±0.07	0.41±0.02	0.39±0.03	0.40±0.02
Dietary fiber	3.97±0.02	3.90±0.03	2.65±0.03	2.28±0.01
Ash	0.85±0.13	0.86±0.12	0.89±0.13	0.68±0.01
Carbohydrate	6.92±0.04	5.50±0.08	5.10±0.04	5.47±0.05

Source: Chongtham *et al*. (2011)

5. Minerals

Juvenile bamboo shoots have a high content of minerals such as K, P, Na, Mg, Ca, and Fe. The shoots are labeled as a heart protective vegetable because of its high content of K that helps to maintain normal blood pressure and a steady heart beat. The K content in bamboo shoots ranges from 232 to 576 mg/100 g fresh weight. Trace elements present in bamboo shoots include cadmium, cobalt, copper, nickel, manganese, selenium, and zinc (Chongtham *et al*., 2011). The potassium content in bamboo shoot varied from as low as 20 mg to as high as 1400 mg/100 g according to reports by different investigators .The calcium content ranged from 0.36 mg to 1900 mg/100 g shoots. Huge variation is observed in calcium content estimated by different investigators and among different species. Phosphorus showed values from 150 mg to 1000 mg/100 g. Sodium content ranged from 8.22 mg to 400 mg/100 g in different species as examined by different investigators. The iron content ranged from 0.1 mg to 3.37 mg/100 g in different species. Magnesium content ranged from 5.38 mg to 140 mg/100 g as examined by different investigators (Singhal *et al*., 2013).

The potassium content did not decrease significantly in five different species upon keeping except in *Dendrocalamus hamiltonii* where the content reduced to half in 10-dayold shoots. Potassium content examined in fresh or frozen bamboo shoots (533 mg/100 g) decreased to 450 mg/100 g on boiling for 5–10 min. The content further decreased to 300 mg/100 g when the shoots were soaked for 2 h and boiled at 50°C for 5–10 min. The change in calcium content upon keeping the shoots was examined and found that the calcium content decreased in 10-day-old shoots. Drastic reduction took place in *Dendrocalamus giganteus* from 6.80 to 1.48 mg/100 g shoots. The sodium content was found to decrease drastically, i.e., three to four fold in 10-day-old shoots as compared to the raw in all the five species tested. The magnesium content did not decrease significantly upon keeping, fermenting, and canning. Processed and dried shoots have shown to possess a very high phosphorous content, i.e., 1,049 mg/100 g. Significant reduction in the phosphorous content upon storage was not observed except in *Dendrocalamus asper* where the content decreased from 40.95 to 29.08 mg/100 g. A higher value of iron (22 mg/100 g) was reported in processed and dried shoots. The iron content was reduced in 10-day-old shoots in all the species (Satya *et al.*, 2012). Table 2.3 shows minerals and vitamins content of freshly emerged bamboo shoots of two species.

Table 2.3 Minerals (mg/100 g) and vitamins content (mg/100 g) of freshly emerged bamboo shoots

Minerals and vitamins	*Bambusa tulda*	*Dendrocalamus hamiltonii*
Potassium	408	416
Calcium	4.06	3
Sodium	12.96	9.32
Magnesium	8.68	6.09
Phosphorus	19.31	28.12
Iron	3.19	2.69
Zinc	0.72	0.70
Manganese	0.70	0.16
Copper	0.44	0.29
Selenium	0.4µg	0.8µg
Vitamin C	1.42	2.45
Vitamin E	0.61	0.71

Source: Chongtham *et al*. (2011)

6. Vitamins

The juvenile bamboo shoots are rich in vitamins (vitamin A, vitamin B1, vitamin B3, vitamin B6, vitamin C, vitamin E) (Chongtham *et al.*, 2018). The vitamin C content, as determined by Chongtham *et al.* (2011) in the fresh shoots of various bamboo species ranges from 1.00 mg to 4.80 mg/100 g, fresh weight.

One study has shown vitamin A (20 IU), B_1 (0.15 mg/100 g), B_2 (0.07 mg/100 g) and B_3 (0.60 mg/100 g). The content of nicotinic acid ranges from 3.87 mg to 14.92 mg/100 g in the four species of shoots, highest being in *Bambusa nutans*. The amount of pyridoxine in raw bamboo shoots ranged from 0.53 mg to 1.70 mg/100 g. The vitamin E content in juvenile shoots for *Bambusa bamboos*, *Bambusa tulda*, *Dendrocalamus asper, Dendrocalamus giganteus* and *Dendrocalamus hamiltonii* has been found to be 0.61, 0.61, 0.91, 0.69 and 0.71, respectively, but it decreased to 0.24, 0.24, 0.42, 0.24 and 0.31, respectively, in 10-day-old shoots (Satya *et al.*, 2012).

Juvenile shoots of *Bambusa bamboos*, *Bambusa tulda*, *Dendrocalamus asper*, *Dendrocalamus giganteus* and *Dendrocalamus hamiltonii* contained 1.90, 1.42, 3.2, 3.28 and 2.45 mg of vitamin C/100 g, respectively, as compared to 10-day-old shoots containing 1.31, 1.00, 2.12, 2.15 and1.79 mg/100 g shoots, respectively. Further reduction in the content was observed in the canned shoots (1.8%) of *Dendrocalamus giganteus* followed by fermented shoots (1.09%) (Satya *et al.*, 2012).

7. Calories

The calories in different species are in the range 14–27 Kcal/100 g of bamboo shoot. It has been noticed that calories provided by raw bamboo shoots are comparable to calories provided by any other vegetable (Singhal *et al*., 2013).

2.3.3 Antioxidants

1. Phytosterols

Sterols cannot be synthesized by humans and are absorbed from the diet in small but significant amounts. The level of total phytosterols in bamboo shoots ranges from 0.12% to 0.19% on a dry weight basis in different species of bamboos. Predominant sterols in bamboo shoots have been identified as β-sitosterol, campesterol, and stigmasterol, but some minor sterols (ergosterol, cholesterol, stigmastanol) have also been reported (Chongtham *et al*., 2011).

2. Phenols

Eight phenolic compounds, protocatechuic acid, p-Hydroxybenzoic acid, catechin, caffeic acid, chlorogenic acid, syringic acid, p-coumaric acid, and ferulic acid, have been found in bamboo shoots of *Phyllostachys pubescence* (Chongtham *et al*., 2018), the most important compounds being protocatechuic acid, p-Hydroxybenzoic acid, and syringic acid (Chongtham *et al*., 2011). The phenolic content of shoots of different bamboo speciesranges from 191.37 mg/100 g to 630.0 mg/100 g, fresh weight. When the shoots of fourbamboo species, *Bambusa nutans*, *Dendrocalamus giganteus*, *Dendrocalamus hamiltonii* and *Dendrocalamus latiflorus* were evaluated for their total phenolic content, results showed that *Dendrocalamus latiflorus* (612.24 mg/100 g, fresh weight) has highest phenolic content, followed by *Dendrocalamus hamiltonii* (586.36 mg/100 g, fresh weight), *Bambusa nutans* (489.83 mg/100 g, fresh weight), and *Dendrocalamus giganteus* (336.56 mg/100 g, fresh weight (Chongtham *et al.*, 2018).

3. Vitamin C

Vitamin C is known to have many biological functions, such as collagen formation, reduction of plasma cholesterol level, and enhancement of immune system. The vitamin C content, in the fresh shoots of various bamboo species ranges from 1.00 mg to 4.80 mg/100 g, fresh weight (Chongtham *et al.*, 2018).

4. Vitamin E

Vitamin E is the major lipid soluble antioxidant in the cell antioxidant defense system, and it can only be obtained from the diet. Fresh bamboo shoots are a good source of vitamin E and the content in various bamboo species ranges from 0.42% to 0.91%, (Chongtham *et al*., 2018).

5. Trace elements

Trace elements in bamboo shoots associated with antioxidant defense system, are selenium, zinc, copper, iron, and manganese. Very few bamboo species have been evaluated for selenium content in the shoots. Selenium content in shoots of two bamboo species namely, *Bambusa tulda* and *Dendrocalamus hamiltonii* have been found to be 0.8 µg/100g, fresh weight and0.4 µg/100g, fresh weight. Iron content in shoots of different bamboo species ranges from 10.3 µg, to 43.2 µg/g. Zinc, copper, and manganese content in *Phyllostachys* species ranges from 11.5 µg to 54.6 µg/g, 0.6 µg to 35.0 µg/g, and 11.5 µg to 176.7 µg/g, respectively (Chongtham *et al*., 2018).

2.3.4 Anti-nutrients in bamboo shoot

2.3.4.1 Cyanogenic glycosides

2.3.4.1.1 Introduction

Cyanogenic glycosides are phytotoxins which occur in at least 2000 plant species, of which a number of species are used as food in some areas of the world (Rana, 2009). Approximately 25 cyanogenic glycosides are identified and their content has been reported in various parts of food plants. Major ones are Linamarin in roots of cassava, amygdalin in seeds of apple, kernels of peach and apricot, Dhurrin in leaves of sorghum and triglochinin in leaves of giant taro. Cyanogenic glycoside is defined as glycoside of α-hydroxynitrile. They belong to a group of amino acid-derived secondary metabolites which are widely distributed in plants. The amount of cyanogenic glycoside in plants is usually referred to the level of releasable hydrogen cyanide (HCN). Plant synthesizes cyanogen glycosides as a defence mechanism against attack of herbivores, insects and pathogens. Additional roles of cyanogenic glycosides include improvement of plant plasticity, i.e., establishment, robustness and viability with response to environmental challenges (Rawat *et al.*, 2015).

2.3.4.1.2 Biosynthesis and enzymatic degradation

Cyanogenic glycosides are biosynthesized from closely related amino acid precursors such as tyrosine converted into dhurrin and taxiphyllin, phenylalanine into prunasin, valine into linamarin and isoleucine into lotaustralin. In intact cells, cyanogen glycosides are stored in vacuoles and protected from degrading enzyme. But, when the plant is disturbed, as caused by chewing herbivores or when cell integrity is destroyed by physical processes, such as by freezing or maceration, the two components come into contact and in this process; cyanogens glycoside is hydrolysed in two steps. First β-glucosidase enzyme converts the cyanogens into cyanohydrin which is further converted into aldehyde or ketone and hydrogen cyanide by hydroxynitrilelyase enzyme (Rawat *et al.*, 2015).

2.3.4.1.3 Cyanogenic glycosides in bamboo shoot

In bamboo the cyanogenic glycoside is taxiphyllin, which is structurally p-hydroxylated mandelonitrile tiglochinin. On hydrolysis, taxiphyllin yields glucose and hydroxybenzaldehyde cyanohydrins which further decomposes to hydroxybenzaldehyde and hydrogen cyanide. The cyanogenic glycosides is responsible for the acridity and sometimes peculiar smell in the shoots (Rawat *et al*., 2015). Unlike linamarin and lotaustralin which are the cyanogenic glycosides found in cassava plants, taxiphyllin in bamboo shoots is highly unstable and is easily decomposed when treated with boiling water (Nongdam *et al*., 2014).

The cyanogen content varies in different species of bamboo as well as in different parts of plants. In bamboo it is the young juvenile shoots where maximum amount of cyanogenic content is found. It has been found that fresh shoots of some species like *Chimonobambusa callosa, Phyllostachys mannii, Melocanna baccifera* have very less content of cyanogenic glycoside ranged from 31.68- 285.12 mg/kg fresh weight which is below permissible limit of cyanogen i.e 500 mg/kg. The shoots of these species can be eaten raw without any processing treatments. In some other species like *Bambusa jaintia, Bambusa mizorameana, Bambusa bambos, Dendrocalamus membranaceus, Dendrocalamus calostachys, Dendrocalamus hamiltonii and Dendrocalamus sikkimensis*, the cyanogenic glycoside content ranged from 285.12 to 778.27 mg/kg of fresh shoots. The cyanogen content was observed to be more than 1000 mg/kg in number of the species like *Dendrocalamus longispathus, Thyrsostachys oliveri, Dendrocalamus flagellifer* (Rawat *et al*., 2015).

In a study worked out in the fresh shoots of 15 bamboo species, total cyanogen content varied from 300-2604 ppm (tip portion), 210-2243 ppm (middle portion) and 199-920 ppm (basal portion). Generally the tip portion contains comparatively higher amount of cyanogenic content than the middle and base portion of the young edible shoot. Cyanogenic content in the fresh shoot of bamboo also varies according to genotype, geographic location and age of shoot. Young shoots of bamboo growing at lower altitude were high in cyanogen content as compared to species growing on higher altitude. The age of harvesting of shoots was found to be related with cyanogen toxicity. In the newly emerging shoots cyanogens content has been reported to be minimum, while an increasing trend was seen with age or days of the harvested shoot (Rawat *et al.*, 2015).

2.3.4.1.4 Lethal dose, Recommended level and toxicity

In animals, the lethal doses of HCN (hydrogen cyanide) are generally reported to be between 0.66 and 15 mg/kg body weight for various species. The acute lethal dose of hydrogen cyanide for human beings is reported to be 0.5-3.5 mg/kg body weight.

Approximately 50-60 mg of free cyanide constitutes a lethal dose for an adult man (Anon., 2004). FAO/WHO Codex Alimantarius has defined a safe limit for human consumption, which is 10 mg HCN equivalent per kg dry weight (Singhal *et al.*, 2013)

Cyanide ingested by release from cyanogenic glycosides, either prior to or following consumption, follows the known cyanide metabolic pathway and toxicokinetics for humans and animals. In humans, cyanide is detoxified by the enzyme rhodanese, forming thiocyanate, which is excreted in the urine. This detoxification requires sulphur donors, which by different metabolic pathways are provided from dietary sulphur amino acids, cysteine and methionine (Anon., 2004). In humans, the symptoms of acute cyanide intoxication from inadequately prepared bamboo shoots can include: rapid respiration, drop in blood pressure, rapid pulse, dizziness, headache, stomach pains, vomiting, diarrhoea, mental confusion, twitching and convulsions. Death due to cyanide poisoning can occur when the cyanide limit exceeds the limit an individual is able to detoxify (Anon., 2004). Chronic sub-lethal dietary cyanide has reportedly caused some reproductive effects including lower birth rate, increased number of neonatal deaths, thyroid dysfunction, and behavioral defects. Chronic consumption can lead to hypothyroidism by inhibiting thyroid peroxidase activity (Singhal *et al.*, 2013). This effect is caused by thiocyanate, which is similar in size to the iodine molecule and interferes with uptake of iodine into the thyroid gland (Anon., 2004).

2.3.4.1.5 Removal of cynogenic glycosides

1. Soaking

Soaking is a simple traditional practice and is quite effective in eliminating cyanogens particularly in those species which have low content. The soaking of shoots can be for few hours as in case of *Chimonobambusa callosa* and *Phyllostachys mannii* which have very low cyanogen content in fresh shoots to long term treatment in closed containers or in running water in rivers and streams in those species which have very high content of cyanogen in the fresh shoots. The Khasi-Jaintia tribes of Meghalaya have a unique method of removing the antinutrients from the shoots of *Dendrocalamus hamiltonii* which has around 733 ppm cyanogenic glycoside in fresh shoots. The shoots are chopped in small chips and soaked in plain water for more than six months, after which the shoots lose all anti-nutrient elements and become palatable (Rawat *et al*., 2015).

Soaking bamboo slices overnight involves enzymatic hydrolysis of taxiphyllin by ß-glucosidase to yield glucose and 4- hydroxyl (R) mandelonitrile, which is further hydrolyzed to HCN (hydrogen cyanide) and benzaldehyde by the activity of hydroxynitrile lyase enzyme. Changing water several times before cooking or presoaking for a long time in water containing 2% salt may also help in further reduction of the cyanogenic glycoside (Singhal *et al*., 2013). The reduction in cyanogenic glycosides of shoots of *Dendrocalamus hamiltonii* and *Dendrocalamus giganteus* is reported to be around 49.52 and 63.61% respectively when soaked for 12 h in plain water and more than 80% when soaked for 24 h (Rawat *et al.*, 2015).

2. Boiling

Usually bamboo shoots are boiled for particular time before consumption. The boiling time is dependent on locality, traditional practices and the need for removal of bitterness of bamboo shoot (Badwaik *et al*., 2015). During boiling or cooking, cell walls rupture which permit leakage of cell content including antinutrients and toxic substance. Duration of boiling and amount of water used for boiling greatly affect the reduction of cyanogenic glycoside (Rawat *et al*., 2015). Traditionally, boiling bamboo shoot in an open vessel for three to four hours can reduce toxicity through the non enzymatic hydrolysis of taxiphyllin (Singhal *et al*., 2015).

Boiling of bamboo shoots in an open vessel at 98 - 102°C for 148 - 180 min can reduce the toxicity by 97%. Steaming can also reduce the HCN from shoots up to the permissible limit. Boiling for 10 min reduced cyanide content by 67.8% and 76.9 % for *Dendrocalams giganteus* and *Dendrocalamus hamiltonii*, respectively and further boiling for 20 min reduced cyanide by 87% (Rawat *et al*., 2015).

According to Pandey and Ojha (2014), boiling of *Bambusa bambos* for 15 min in 5% NaCl reduces cyanide content from 110 mg/kg to 20 mg/kg. Boiling of *Bambusa tulda* for 10 min in 1% NaCl decreases cyanide content from 160 mg/kg to 60 mg/kg. Similarly, boiling of *Dendrocalamus asper* for 10 min 5% NaCl reduces cyanide from 160 mg/kg to 20 mg/kg and boiling of *Dendrocalamus strictus* for 15 min in 1% NaCl reduces from 180 mg/kg to 30 mg/kg.

3. Drying

Drying methods such as sun, oven, freeze and superheated steam can be employed for the reduction of cyanogen. In bamboo shoots around 80% of cyanogen glycoside is reduced after vacuum freeze drying for 24 h at -50ºC temperature. Superheated steam drying at 120-160°C decomposes the taxiphyllin which causes bitterness in shoots. Oven drying after grating at 60ºC for 8 h leads to very high reduction of cyanogen content up to 95% of the initial cyanide content. Oven drying at 50°C removes around 81% of cyanogen glycoside within 24 h (Rawat *et al*., 2015).

4. Fermentation

To remove bitterness in the shoots *Adi* women of Arunachal Pradesh used to do semi-fermentation of shoots by covering the shoots with banana leaves and pressing under stones near water stream for 3 - 4 months (Rawat *et al*., 2015). Prolonged fermentation also reduces the taxiphyllin content by lowering the pH through microbial activity. In a study upon natural fermentation of shoots of *Dendrocalams giganteus* and *Bambusa Tulda*, as the pH drops, the lactic acid bacteria indirectly degrades taxiphyllin into HCN and other components by accumulating acid (Singhal *et al*., 2013). During fermentation, hydrogen cyanide which is easily soluble in water can be reduced by 99.96% (Rawat *et al*., 2015).

2.3.4.2 Tannins

Tannins are considered anti-nutritive because they are known to precipitate proteins from aqueous medium by inhibiting digestive enzymes and exhibiting anti-trypsin and anti-amylase properties, and thus rendering the proteins unavailable to the body. Tannins have been reported in the bamboo shoots of *Fargesiayunnanensis*. High tannin content in bamboo shoots is said to cause an offensive taste and therefore lowers the deliciousness of the shoots. Tannins are also known to chelate zinc and iron irreversibly and thus interfering with the absorption in the body (Karanja, 2017).

2.3.4.3 Oxalic acid

Some researchers have reported the presence of oxalates in bamboo shoots. It occurs as a free acid, as soluble salt of potassium and sodium, and as insoluble salts of calcium, magnesium and iron. Their presence in the food eaten therefore may reduce the mineral availability to the body. When oxalic acid binds with calcium, they form insoluble calcium oxalates that are precipitated and deposited in the kidney to form kidney stones, which may results to renal failure (Karanja, 2017).

2.3.5 Health benefits

1. Weight loss

Bamboo shoots are ideal for healthy weight loss as they are low in calories (Karanja, 2017). Dietary fibers have markedly increased volume after swelling and can cause satiety. Besides, the presence of dietary fiber affects the digestion and absorption of other food components and delays the feeling of hunger (Wang *et al.*, 2012).

2. Appetizer

The high cellulosic content of bamboo shoots stimulates appetite. Being crisp, crunchy, and tender with a sweet flavor, shoots have a unique and delicious taste that function as an appetizer (Padhan, 2015).

3. Controls cholesterol

Consumption of bamboo shoots is also helpful in decreasing LDL (low density lipoprotein) levels of cholesterol, with stable glucose levels. This is due to the fact that bamboo shoots contain negligible amounts of fat and very low calories (Padhan, 2015). Also, soluble dietary fiber is primarily responsible for decreased cholesterol absorption by several mechanisms including interference with micelle formation and influence with enzyme substrate interaction. Insoluble dietary fiber may assist in reducing cholesterol absorption by reducing transit time and total time available for absorption (Rana, 2009). Furthermore, phytosterols are ideal for dissolving harmful LDL (low density lipoprotein) cholesterol in the body (Padhan, 2015). Vitamin C also reduces the plasma cholesterol level (Chongtham *et al.*, 2018.).

4. Heart friendly

Phytosterols found in bamboo shoots are ideal for dissolving harmful LDL cholesterol in the body. This helps in easing out arteries for smooth supply of blood throughout the body (Padhan, 2015). The phytosterol of bamboo shoot inhibits the absorption of dietary cholesterol and cholesterol esterification in the intestinal mucosa that in turn protect cardiovascular activity (Vanitha *et al.*, 2017). Potassium protects human heart by maintaining normal blood pressure and stable heartbeat (Nongdam and Tikendra, 2014). Vitamin C as an antioxidant, reportedly, reduces the risk of arteriosclerosis. Vitamin E reduces the risk of coronary heart diseases by inhibiting low density lipoprotein (LDL) oxidation (Chongtham *et al*., 2018).

Bamboo shoots are known to have high content of phenols and phytosterols. They are used in Chinese traditional herbal medicine due to their antihypertension effect. Hypertension is major cause of cardiovascular disease which is one of world's leading causes of death each year. Angiotensisn converting enzyme (ACE) is an important factor causing hypertension and is considered as a key point in the prevention and therapy of hypertension. Methanol extracts of *Phyllostachys pubescens* shoots were reported to possess ACE inhibitory activity and were proven to have an antihypertensive effect on hypertensive rats (Chongtham and Bisht, 2015). Bamboo shoots have high amount of silica which is important in maintaining structural integrity, elasticity and permeability of the arteries thereby regulating the blood pressure. Silica may be also useful in reducing cholesterol and blood fat (Chongtham *et al.*, 2018).

5. Anticancer

Dietary fiber appears to play a contributing role in reducing colon cancer risk. The beneficial involvement of dietary fiber in colon cancer prevention includes increasing faecal bulk and thereby decreasing the concentration of carcinogens, co-carcinogens and decreasing transit time to minimize exposure of intestinal cells to these compounds (Rana, 2009). Phytosterol-rich diets help in reduction of colon, breast, and prostate cancer. (Nongdam *et al*., 2014).

6. Anti-inflammatory properties

Phenols have anti-inflammatory properties (Nongdam and Tikendra, 2014).

7. Antidiabetic

Soluble dietary fiber slows the release of glucose into the blood by increasing the viscosity of the intestinal contents. Soluble fiber also acts by adsorption to enzymes and substrate, which slows the rate of enzymatic digestion (Rana, 2009).

8. Helps in digestion

Various enzymes such as nuclease, deaminase, proteolytic enzymes, amylase, amigdalin splitting enzyme and silicon splitting enzyme are present in tender bamboo shoot. The juice of pressed bamboo shoot help in digestion of proteins (Vanitha *et al.*, 2017).

9. Antimicrobial activity

Due to the presence of lignins which are an important component of fiber, the shoots of the bamboo are reported to have antiviral and antibacterial activity. An idiosyncratic antifungal protein, dendrocin, is also isolated from shoots (Basumatary *et al.*, 2017).

10. Other benefits

Decoctions of tender shoots is also used for cleaning wounds and maggot infected sores, ulcers etc (Rana, 2009). For women's it is helpful in stimulating the menstrual cycle and induce labour pain during the last month of the pregnancy (Vanitha *et al*., 2017). Besides, the shoots of few bamboo species such as *Bambusa bambos* are used in treating thread worm, cough and diarrhea due to the presence of glucosides, betain, urease, cynogens, nuclease and cholin (Basumatary *et al.*, 2017). Germaclinium in shoots has been reported to carry anti-aging properties (Choudhury *et al*., 2012b).

2.3.6 Bamboo shoot as food

In many parts of the world, bamboo shoots form a part of the conventional cuisine and are consumed in various forms (Choudhury *et al*., 2012b).

1. Fresh bamboo shoot

People consume fresh bamboo shoots in various forms. Bamboo shoot can be eaten fresh after boiling. In Indonesia, bamboo shoots are eaten with thick coconut milk and spices, which are called *gulei rebung*; sometimes also mixed with other vegetables, called *sayur lade*. In Manipur, the fresh bamboo shoots are taken with dry fish. The edible bamboo species in Western Ghats of India are extensively used as snacks, fried food stuffs, and curries. *Tama,* a non-fermented bamboo shoot curry is very familiar among the people of Sikkim (Choudhury *et al*., 2012b). Steam ground pork with finely diced bamboo shoots sprinkled with soy sauce as a very popular dish in China. Vietnamese broth called *sup bunmang gd* is a noodle soup made with chicken and fresh bamboo shoots and taken as breakfast (Karanja, 2017). The bamboo shoot pieces after boiling are salted slightly for 8–10 minutes and consumed in Australia and New Zealand (Nongdam and Tikendra, 2014).

2. Canned bamboo shoots

High moisture content of bamboo shoots make them easily perishable giving space for the growth of undesirable micro-organisms like bacteria, molds and yeasts. Canning has been observed to be effective in abating rancidity and preventing the growth of micro-organisms in bamboo shoots. Canned bamboo shoots can be satisfactorily preserved and can be used frequently in various food items such as vegetables or pickle condiments (Choudhury *et al*., 2012b).

The processing technique to produce canned bamboo shoot involves crucial steps that must be followed in order to obtain good quality products. This involves boiling the sliced bamboo shoots in water for about 4 h or for 40 to 60 min at 120°C, cooling, and then storage in brine solution containing usually around 5% to 10% NaCl or more, depending on the species used, and 1% citric acid. Products so processed may be in cans or retort pouches. Cans contain processed fresh materials, while retort pouches contain processed salted or cured materials. Most tinplate canned products are used for cooking, and the pouch products are ready to eat. There are more than 80 companies manufacturing 49 products of canned shoots under various brand names in the world. China, Taiwan, and Thailand are the leading countries supplying canned bamboo products to the world market. The canned shoots find market in Singapore, Malaysia, Vietnam, United States, Canada, Europe, Australia, and New Zealand (Chongtham *et al*., 2011).

3. Fermented bamboo shoots

Traditionally, various fermented bamboo shoot products are consumed in the world. A traditional fermented bamboo shoot product of the eastern hills of Nepal and Bhutan is *mesu.* Use of *mesu* as a pickle and as a base in curries is a conventional dish among the Nepalese, Bhutias and the Lepchas of the Darjeeling hills and Sikkim. In Nepal, bamboo shoots are fermented with turmeric and oil, and cooked with potatoes to prepare an item called *alu tama* (Choudhury *et al*., 2012b).

Soibum, a fermented bamboo shoot, is an exceptional delicacy of the Meities of Manipur, eaten as pickle and curry mixed with fermented fish. Similar fermented bamboo shoot product called *naw-mai-dong* or *nor-mai-dorng* is consumed in Thailand. *Soidon* is another fermented bamboo shoot product in Manipur, prepared from the tip of matured bamboo shoots and consumed both as a curry and pickle. *Soijim* is another type of fermented bamboo shoot product developed by submerged fermentation in Manipur. *Iromba* is a fermented or boiled bamboo shoot taken with fish and other vegetables by Khasi tribes in Meghalaya. In central India, the young shoots are grated and fermented to prepare *kardi* or*amil*, a sour vegetable soup (Choudhury *et al*., 2012b).

4. Other uses as food

In Japan, bamboo shoot-based powder is used as an essence in cookies and various other food items. Japanese use bamboo powder in standard bread flour and also recommends a 3–8% addition of the powder to any food products. In China, bamboo juice produced by pressure-cooking, is used to make beverages and specific liquors (Bora *et al.*, 2015). Bamboo fiber is now common ingredient in breakfast cereals, fruit juices, frozen deserts, bakery products, meat products, sauces, shredded cheeses, pastas, snacks and many other food products (Padhan, 2015). Several value-added products such as candies, nuggets, buns, chips, etc have been prepared from bamboo shoots (Oinam *et al.*, 2016).

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 Bamboo Shoot

Bamboo shoots of *Bambusa tulda* was purchased from local market of Dharan.

3.1.3 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.

3.1.4 Skim milk powder

Skimmed milk powder named 'Skimmed milk pre-mixed powder' produced by Singhania industries, Shripur, Birgunj was used.

3.1.5 Vegetable ghee

Vegetable ghee named 'Superman'was used.

3.1.6 Baking powder

Baking powder named as 'Weikfield baking powder double action' containing sodium bicarbonate, sodium aluminium phosphate and corn flour was used. It was manufactured and packed by Weikfield food Pvt. Ltd., Pune, India.

3.1.7 Packaging material

High density polyethylene was used for the packaging of the product.

3.2 Method of experiment

3.2.1 Methodology

Design Expert 10 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 bamboo shoot powder used to make biscuit.

3.2.2 Formulation of recipe

The biscuit was made as per the recipe formulation done and coded name A, B, C, D and E were given to each recipe. Biscuits were of soft dough type method. The recipe formulation for the bamboo shoot powder 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	95	90	85	80
Bamboo shoot powder	0	5	10	15	20
Sugar	40	40	40	40	40
Fat	25	25	25	25	25
SMP	6	6	6	6	6
Baking powder	2.22	2.22	2.22	2.22	2.22
Salt	0.5	0.5	0.5	0.5	0.5

3.3 Preparation of bamboo shoot powder

The shoots were peeled and chopped into small pieces. The pieces of shoots were boiled for about 3 h at 100°C for removal of glycocyanide contents (Mustafa *et al.*, 2016). Then shoots were dried in cabinet dryer at 70°C until it reached equilibrium moisture content of about 5%. The dried pieces of shoots were ground, sieved and packed in polythene pouches (Choudhury *et al.*, 2015).

3.4 Preparation of bamboo shoot powder incorporated biscuit

Sugar was ground to powder consistency and creamed along with fat till a smooth paste was obtained. Skim milk powder was mixed with water and added in the paste slowly while whipping was continued. Salt and baking powder were added in paste little by little, and whipping was continued. Sieved flour and bamboo shoot powder were added in above mix with predetermined quantity and soft dough was prepared. Salt, SMP, baking powder, bamboo shoot powder and sieved flour were mixed properly and mixed with the paste. The dough was sheeted to thickness of about 5 mm and cut to form circular shape of diameter of about 5 cm. The moulded parts were kept in a greased pan and baked in oven for 20 min at 160°C. After baking the biscuits were cooled to room temperature and packed (Choudhury *et al.*, 2015). The process for preparing bamboo shoot powder biscuit is shown in Fig. 3.1

Fat+ground sugar

↓

Creaming

↓

Addition of SMP and water with whipping continued

↓

Addition of salt and baking powder little by little with whipping continued

↓

Addition of flour and bamboo shoot powder

↓

Mixing

↓

Dough

↓

Sheeting to thickness of about 5 mm

↓

Cutting to circular piece of about 5 cm

↓

Baking at 160°C for 20 min

↓

Cooling to room temperature

↓

Packing

Fig. 3.1 Process for preparing bamboo shoot powder incorporated biscuit

Source: Choudhury *et al*. (2015)

3.5 Analysis of raw material and product

3.5.1 Physical parameter analysis

3.5.1.1 Spread ratio

The spread ratio of the biscuit was determined by using the formula (Choudhury *et al*., 2015).

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

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

3.5.2 Chemical analysis

3.5.2.1 Moisture content

Moisture content of the sample was determined by heating in an oven at 103 ± 2°C to get constant weight as per KC and Rai (2007).

3.5.2.2 Crude fat

Crude fat content of the samples was determined by solvent extraction method using Soxhlet apparatus and solvent petroleum ether as per KC and Rai (2007).

3.5.2.3 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).

3.5.2.4 Crude fibre

Crude fibre content of the samples was determined by the method given by KC and Rai (2007).

3.5.2.5 Total ash

Total ash content of the samples was determined by following the method given by KC and Rai (2007) using muffle furnace.

3.5.2.6 Carbohydrate

The carbohydrate content of the sample was determined by difference method.

Carbohydrate (%) = 100-(protein + fat + ash + crude fibre)

3.5.2.7 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.

3.5.2.8 Sodium content

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

3.5.2.9 Calcium content

The calcium content was determined by flame photometer as per KC and Rai (2007).

3.5.2.10 Determination of antioxidant activity

Plant materials were extracted and antioxidant activity was determined Choudhury *et al*. (2015) with some modifications. 10 g of powdered plant materials were steeped in 80% methanol (100 ml) for 12 h at room temperature. They were then filtered through Whatman No. 41 filter paper. Finally, extracts were transferred to brown colored glass bottles, sealed by using bottle caps and stored at 4 ± 2°C until analysis. Different dilutions of the extracts were made using 80% methanol. Then 1 ml of the extract was mixed with 2 ml of 0.1 mM 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) solution. The absorbance was read at 517 nm after

30 min incubation in the dark. Finally, percentage scavenging activity was determined using following equation:

$$\% \text{ Scavenging activity} = \frac{Ac - As}{Ac} \times 100$$

Where Ac is the absorbance of control and As is the absorbance of test sample.

3.5.3 Sensory analysis

The sensory analysis for overall quality was carried out with ten semi-trained panelists. The parameters for sensory evaluation were texture, crispiness, color, flavour and overall acceptability. Sensory evaluation was performed according to the 9- Point Hedonic Scale as in appendix A.

3.5.4 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 sensory evaluations were subjected to two way analysis of variance. The data obtained from analysis of proximate constituents and minerals for control and optimized product were subjected to one way analysis of variance.

Part IV

Results and discussion

Wheat flour was mixed with 0, 5, 10, 15 and 20 parts bamboo shoot powder to make 5 formulations of biscuits and named as A, B, C, D and E respectively. Both wheat flour and bamboo shoot powder were subjected to proximate analysis and minerals analysis. Biscuits were analyzed for effect on physical parameters of biscuits with increase in bamboo shoot powder content.

4.1 Chemical composition of wheat flour and bamboo shoot powder

Wheat flour and bamboo shoot powder were analyzed for proximate components and minerals content. Table 4.1 shows the results of chemical composition of wheat flour and bamboo shoot powder in dry basis.

Table 4.1 Chemical composition of wheat flour and bamboo shoot powder

Parameters (db)	Wheat flour*	Bamboo shoot powder*
Moisture content (%)	12.45±0.31	5.06±0.55
Crude protein (%)	10.16±0.18	24.62±0.84
Crude fat (%)	1.26±0.10	3.73±0.12
Crude fibre (%)	0.62±0.05	17.20±0.26
Total ash (%)	0.43±0.08	5.07±0.42
Carbohydrate (%)	85.87±0.47	48.89±0.53
Potassium (mg/100 g)	117.75±3.19	268.44±9.16
Calcium (mg/100 g)	30.11±1.77	60.19±4.52
Sodium (mg/100 g)	2.97±0.47	8.50±1.33

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

The moisture content of wheat flour was found to be 12.45% which was in accordance with the result obtained by Prodhan *et al.* (2015). The moisture content in bamboo shoot powder was found to be 5.06%. The value obtained was lower than those obtained by Rana (2009) and Mustafa *et al.* (2016). The results for moisture content were 10.60% and

13.62% respectively. The difference could be due to different drying conditions (temperature and time).

The protein content of wheat flour was found to be 10.16% which is similar to result obtained by Prodhan *et al*. (2015). The protein content of bamboo shoot powder was significantly higher than in wheat flour (24.2%). The value obtained was close to that obtained by Mustafa *et al*. (2016) i.e. 19.32% whereas Rana (2009) obtained much lower value (16.53%). The difference in values could be due to use of different variety of bamboo.

The crude fiber content of wheat flour of wheat flour and bamboo shoot were found to be 0.62% and 17.20% respectively. This indicates that bamboo shoot powder is good source of crude fiber and can be incorporated to enhance nutritive value of various food products. Rana (2009) found crude fiber content of bamboo shoot powder to be 15.49% which is similar to the value obtained in this experiment. However, Mustafa *et al*. (2016) obtained higher value (24.44%). The fat content in bamboo shoot powder was found to be 3.73% which was slightly lower than that obtained by Choudhury *et al*. (2015) which was 4.41% and slightly higher than that obtained by Rana (2009) which was 2.08%.

The ash content of wheat flour and bamboo shoot powder were found to be 0.43 and 5.07% respectively. The significant increase in ash content is due to the presence of higher amount of minerals found in bamboo shoot than in wheat flour. Similar results were obtained by Mustafa *et al*. (2016) and Rana (2009). Potassium content in wheat flour and bamboo shoot powder were found to be 117.75 mg/100 g and 268.44 mg/100 g. This indicates that potassium content is much higher in bamboo shoot powder than in wheat flour. Rana (2009) found a bit higher amount of potassium in NaCl treated bamboo shoot powder (306.81 mg/100 g). Similarly, calcium content was found to be 60.19 mg/100 g and was higher than that in wheat flour (30.11 mg/ 100 g). Oinam *et al.* (2018) showed similar amount of Ca content in wheat flour (29.67 mg/100 g) but found higher amount of Ca content (116.33 mg/100 g) in fresh freeze-dried bamboo shoot powder. The sodium content in bamboo shoot powder was found to be 8.50 mg/100 g. Similar results were obtained by Rana (2009) and Oinam *et al.* (2018).

4.2 Influence of bamboo shoot powder on physical parameters of biscuits

The physical parameters such as diameter, thickness and spread ratio were affected by the increasing level of bamboo shoot powder in biscuits. It was seen that the percent expansion decreases with the increased level of bamboo shoot powder. The average diameter of biscuits decreased from 59.19 to 54.12 mm where as thickness was decreased from 5.81 to 5.48 and ultimately spread ratio was decreased from 10.18 to 9.87 from control to 20 % bamboo shoot powder incorporated biscuit. These results are in accordance with the findings of Choudhury *et al*. (2015) and Mustafa *et al*. (2016).

The decrease in spread factor may be due to the fact that gluten is decreased with increased level of replacement of wheat flour (Choudhury *et al.*, 2015). Increase in water absorbing fiber content retarded the spreading of biscuits thus reducing the diameter (Kulthe *et al.*, 2017). It has been noted that the spread factor of biscuits is affected by the competition of ingredients for the available water; flour or any other ingredient that absorbs water during dough mixing decreases (Yamsaengsung *et al.*, 2012). Therefore the reduced spread-ratios of bamboo shoot powder biscuits can be attributed to the presence of more water absorbing constituents like protein and fiber. These constituents form aggregates with available hydrophilic sites thus reducing free water in biscuit dough. Rapid partitioning of free water of these hydrophilic sites occurs during dough mixing and increases dough viscosity, thereby limiting biscuit spread (Agrahar-Murugkar *et al.*, 2015). Table 4.2 shows effect of bamboo shoot powder incorporation on physical parameters such as diameter, thickness and spread ratio of biscuits.

Table 4.2 Physical parameters of bamboo shoot powder incorporated biscuits.

Samples	Thickness (mm)	Diameter (mm)	Spread ratio
A	59.19±0.13	5.81±0.02	10.18±0.05
B	58.32±0.10	5.79±0.01	10.06±0.03
C	56.95±0.04	5.67±0.01	10.03±0.03
D	55.52±0.08	5.58±0.01	9.95±0.00
E	54.12±0.11	5.48±0.01	9.87±0.01

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

4.3 Sensory analysis of bamboo shoot powder 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 biscuit formulations. Sensory analysis was performed with the aid of different panelists evaluating texture, crispiness, color, flavor and overall acceptability of bamboo shoot powder incorporated biscuit.

4.3.1 Color

Fig. 4.1 represents the mean sensory scores for color of bamboo shoot powder incorporated biscuit.

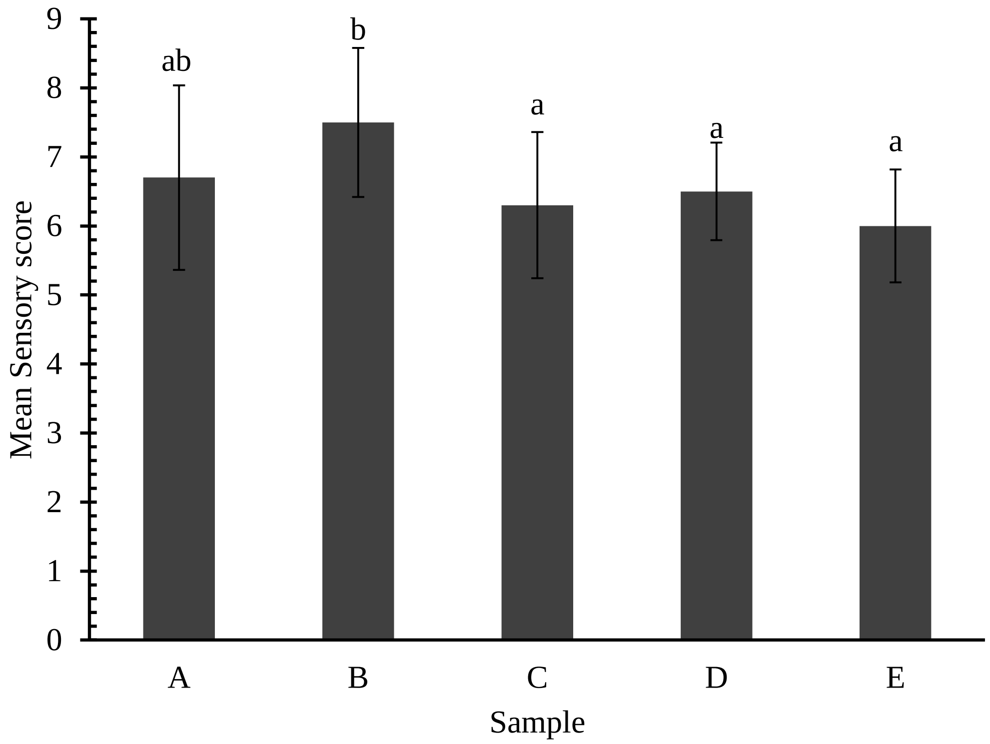

Fig. 4.1 Mean sensory scores for color of bamboo shoot powder incorporated biscuit

The mean sensory score for color of sample B was found to be 7.5 and was highest of all other biscuit formulations. The lowest score was 6 for sample E. Sample B was significantly different ($p<0.05$) from samples C, D and E and almost significantly different with sample A. Samples C, D and E were not significantly different with each other and they show some similarity to sample A.

The sample B got the highest score which may be due to the appropriate amount of bamboo shoot powder (5 parts) and grayish yellow color of bamboo shoot powder might have been attractive to panelists. The decrease in score with increase in bamboo shoot powder may be due to the increase in darkness of biscuits due to darker color of bamboo shoot powder. Similar results were obtained by Mustafa *et al*. (2016) who found highest score for biscuits containing 4% bamboo shoot powder and then decrease in score with increase in bamboo shoot powder content. However, Choudhury *et al*. (2015) showed highest score for control with gradual decrease in score with increase in bamboo shoot powder content.

4.3.2 Texture

Fig. 4.2 shows the mean sensory scores for texture of bamboo shoot powder incorporated biscuit.

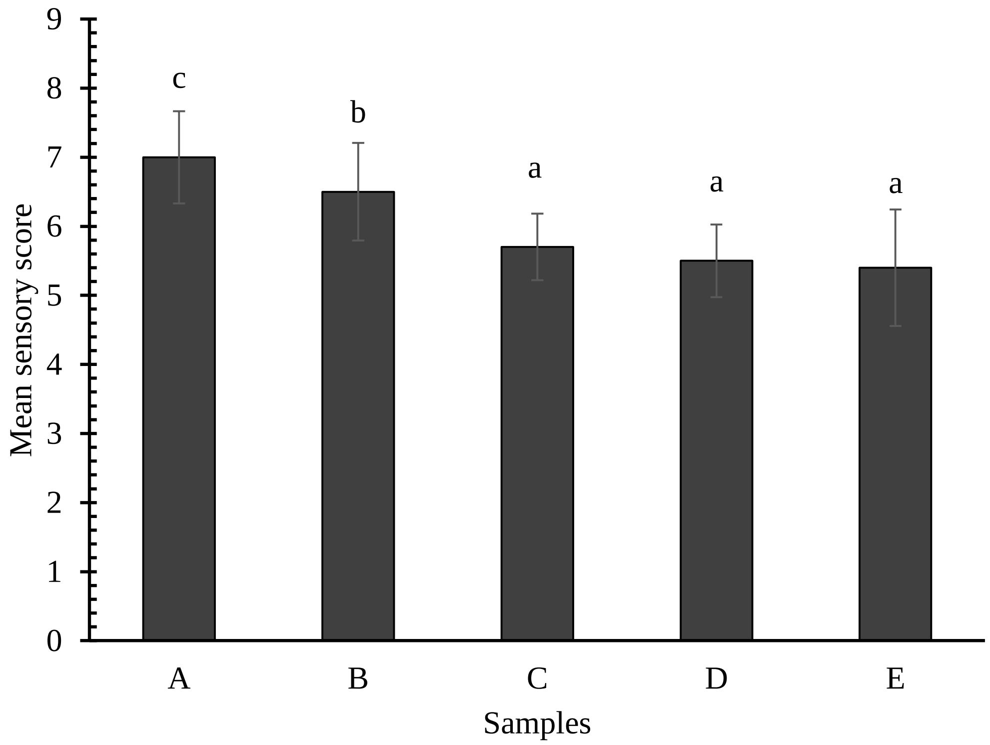

Fig. 4.2 Mean sensory scores for texture of bamboo shoot powder incorporated biscuit

The highest mean sensory score was found to be 7.0 for sample A with gradual decrease in score with increase in bamboo shoot powder content. Hence, sample E has lowest score of 5.4. Sample A was significantly different with samples B, C, D and E. Sample B was significantly different with samples A, C, D and E.

The comparatively higher score for control than bamboo shoot incorporated samples may be due to the presence of gluten in wheat flour, leading to formation of an elastic smooth dough that will likely result to biscuits with better texture (Obasi and Ifediba, 2018). The decrease in score with increase of bamboo shoot powder may be due to increase in fiber content resulting in coarse texture. The result obtained is in accordance with findings of Choudhury *et al*. (2015) who found the highest score for control with decreasing scores with increase in bamboo shoot powder content.

4.3.3 Crispness

Fig. 4.3 shows the mean sensory scores for crispness of bamboo shoot powder incorporated biscuit.

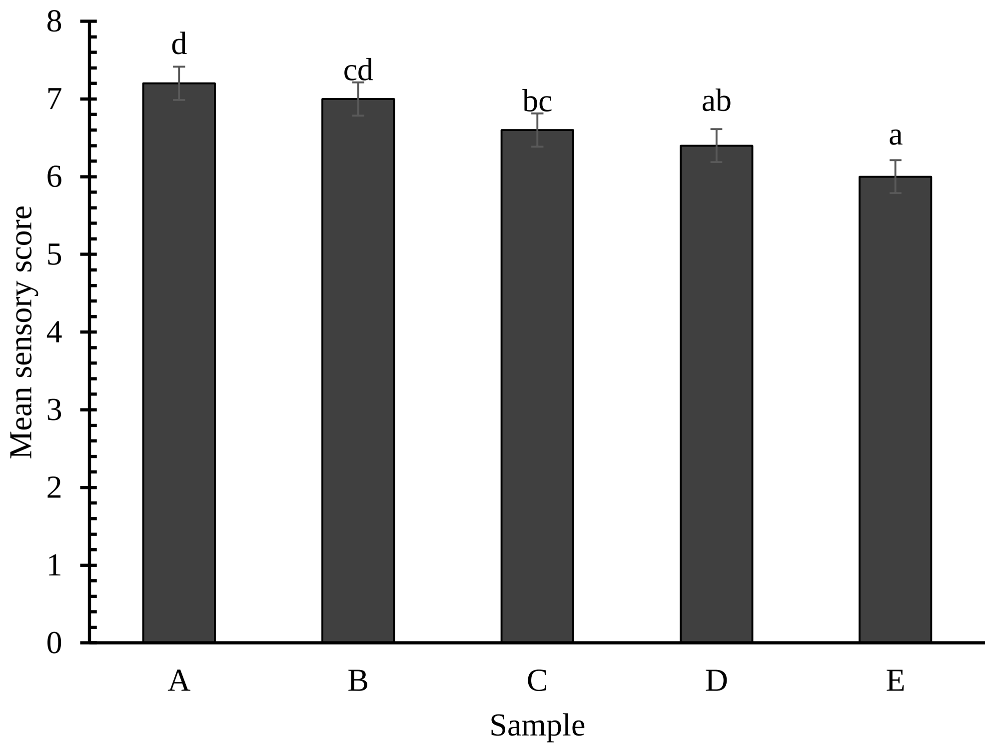

Fig. 4.3 Mean sensory scores for crispness of bamboo shoot powder incorporated biscuit

Sample A got highest score for crispness which was 7.2. The score decreased with increase in bamboo shoot powder content. Sample E has lowest score of 6. Sample A was significantly different with samples C, D and E but almost significantly different with sample B. However, sample B was significantly different with samples D and E; and almost significantly different with samples A and C.

The decrease in score with increase in bamboo shoot powder in biscuits may be due to increase in grittiness due to higher amount of fiber in bamboo shoot powder than wheat flour. However, result obtained by Mustafa *et al*. (2016) showed uneven pattern of scores with increase in bamboo shoot powder content.

4.3.4 Flavor

Fig. 4.4 shows the mean sensory scores for flavor of bamboo shoot powder incorporated biscuit.

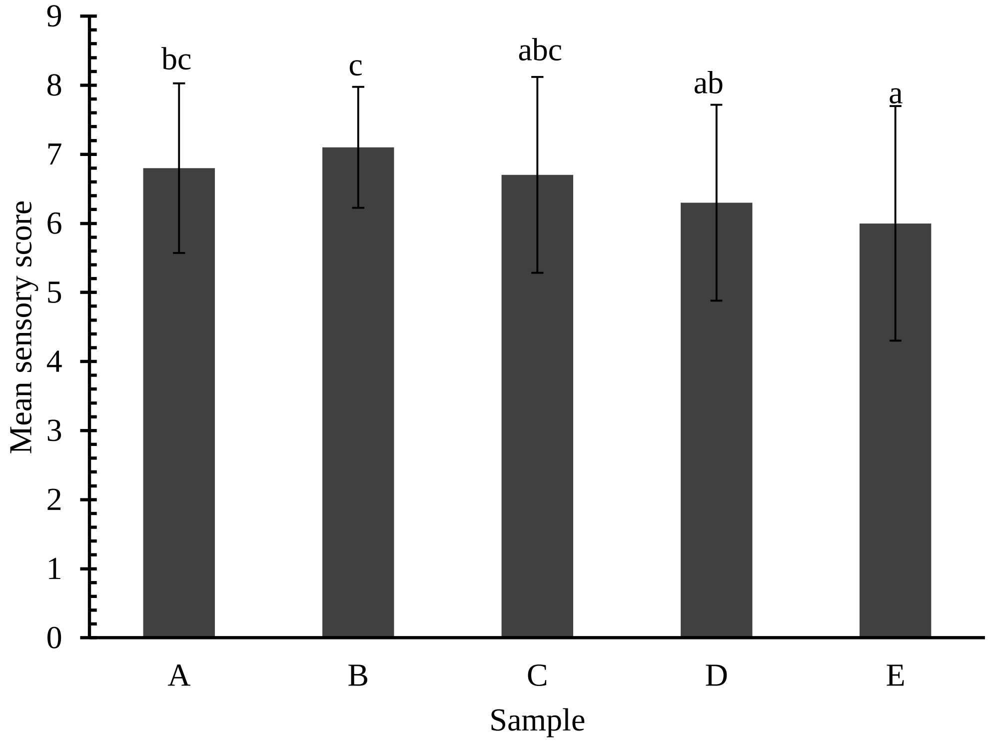

Fig. 4.4 Mean sensory scores for flavor of bamboo shoot powder incorporated biscuit

The highest mean sensory score for flavor was found to be 7.1 for sample B and lowest was 6 for sample E. The score gradually decreased with increase in bamboo shoot powder content. Sample B was significantly different ($p<0.05$) from samples D and E. It was almost significantly different with control and sample C. Sample A was only significantly different with E.

The highest score to sample B might be because of slight bitterness that is present in the bamboo shoots due to high polyphenol content (Choudhury *et al.*, 2015). Effect of slight bitterness might have been liked by panelists. The decrease in score with increase in bamboo shoot powder may be due to increase in bitterness. In result obtained by Choudhury *et al.* (2015) highest score was given to the control with decrease in score with increase in bamboo shoot powder content.

4.3.5 Overall acceptability

Fig. 4.5 shows the mean sensory scores for overall acceptability of bamboo shoot powder incorporated biscuit.

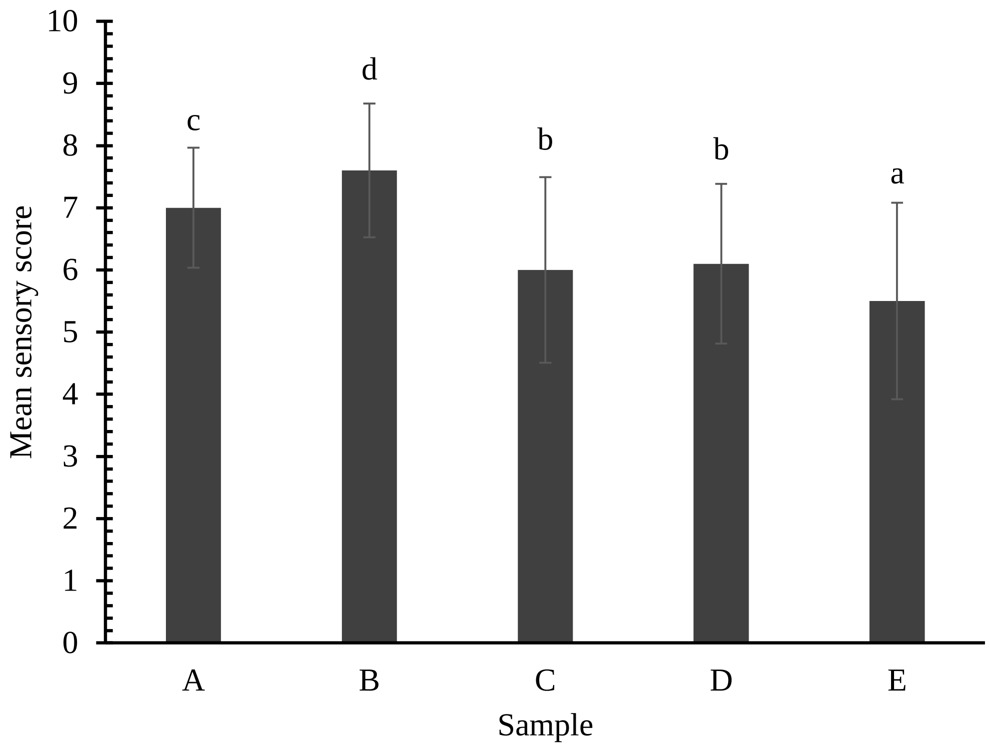

Fig. 4.5 Mean sensory scores for overall acceptability of bamboo shoot powder incorporated biscuit

The highest score for overall acceptability was 7.6 for sample B and lowest was 5.5 for sample E. Sample B was significantly different ($p<0.05$) with samples A, C, D and E.

Similarly, sample A was significantly different with B, C, D and E. Samples C and D were significantly different with A, B and E but not with each other.

The decrease in score with increase in bamboo shoot powder content may be due to darker color, increased bitterness, increased grittiness and increased residual branny mouth feel. Similar result was obtained by (Choudhury *et al.*, 2015) in which control had highest score with gradual decrease in score with increase in bamboo shoot powder content.

The result obtained from sensory analysis showed that product B has highest scores in case of color, flavor and overall acceptability. In case of color, sample B was significantly different with other samples except control. Furthermore, in case of texture and overall acceptability, sample B was significantly different with both control and other samples. Hence, sample B is the best product (optimized product).

4.4 Chemical composition of control and optimized biscuit

The chemical composition of the control and optimized product was determined by chemical analysis. Table 4.3 shows the chemical composition of control and optimized biscuit.

Table 4.3 Chemical composition of control and optimized biscuit

Parameters (db)	Control biscuit	Optimized Biscuit
Moisture content (%)	$2.21^{a} \pm 0.22$	$3.84^{b} \pm 0.26$
Crude protein (%)	$5.63^{a} \pm 0.21$	$7.13^{b} \pm 0.20$
Crude fat (%)	$17.65^{a} \pm 0.29$	$19.42^{b} \pm 0.19$
Crude fibre (%)	$0.89^{a} \pm 0.01$	$1.54^{b} \pm 0.03$
Total ash (%)	$1.27^{a} \pm 0.08$	$2.22^{b} \pm 0.52$
Carbohydrate (%)	$74.38^{a} \pm 0.42$	$69.42^{b} \pm 0.40$
Potassium (mg/100 g)	$112.00^{a} \pm 3.02$	$152.52^{b} \pm 2.11$
Calcium (mg/100 g)	$48.77^{a} \pm 6.45$	$61.66^{b} \pm 3.02$
Sodium (mg/100 g)	$31.83^{a} \pm 2.32$	$54.12^{b} \pm 2.91$

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

The moisture content increased from 2.21% in control to 3.84% in 5% level of substitution. The increase in moisture may be due to more water retaining capacity of the fibers as well as more amount of water required to prepare the biscuit dough having more amount of fiber (Ajila *et al*., 2008). There is increase in protein content from 5.63 to 7.13%. This is because of higher protein content of bamboo shoot powder than wheat flour. Similarly, there is increase in crude fiber from 0.89 to 1.54% because of higher fiber content of bamboo shoot powder. Crude fiber is known to aid the digestive system of human and presence of high crude fiber in bamboo shoot powder incorporated biscuits could attract good acceptability by many people (Rana, 2009).

The fat content has slightly increased from 17.65% to 19.42%. This is due to higher fat content of bamboo shoot powder than wheat flour. The increase total ash content from 1.27% to 2.22% is due to the higher amount of minerals in bamboo shoot powder than in wheat flour. Carbohydrate content reduced from 74.32% to 69.42%. The reduction in carbohydrates might be due to high protein, ash and fiber content of the biscuit. The reduction in carbohydrate could be of help in addressing the risk of sugar intake (Dignity *et al*., 2018). The result obtained by Choudhury *et al*. (2015) presented similar patterns in the cases of moisture, protein, crude fiber, fat and ash content. Rana (2009) also presented similar results in case of moisture, protein, carbohydrate, ash and crude fiber on analysis of 20% bamboo shoot powder incorporated biscuits. However, Rana (2009) found slight decrease in fat content.

There is increase in potassium content from 112.00 mg/100 g in control to 152.52 mg/100 g in optimized product. Potassium content has increased significantly. Similarly, there is increase in calcium content and sodium content. The increase in minerals content is because of higher minerals content in bamboo shoot powder than wheat flour. It is similar with result obtained by Rana (2009) with the exception for calcium content which showed slight decrease.

4.5 Antioxidant activity

Free radical scavenging activity was used to measure the antioxidant activity by using 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) assay method. Table 4.4 shows the antioxidant activity of control, optimized biscuit and bamboo shoot powder.

Table 4.4 Antioxidant activity of control, optimized biscuit and bamboo shoot powder.

Sample	Antioxidant activity (%)
Control	5.03 ±1.09
Optimized biscuit	9.43 ±1.89
Bamboo shoot powder	29.55±2.88

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

The antioxidant activity of control and optimized biscuit were found to be 5.03% and 9.43%. The increase in antioxidant activity is due to presence of higher amount of antioxidants in bamboo shoot powder biscuit. This result is in accordance with the result obtained by Choudhury *et al*. (2015). However, the antioxidant activity of bamboo shoot powder was found to be 29.55% which is lower than the value obtained by Choudhury *et al*. (2015) which was 72.36%. The decrease may be due to longer cooking of bamboo shoots in this research work. Badwaik *et al.* (2015) found that antioxidant activity of bamboo shoot decreases with increase in blanching time. Reports indicate that conventional cooking significantly decreases the polyphenol content in various vegetables (Ajila *et al*., 2008).

4.6 Cost of the bamboo shoot powder incorporated biscuit

The total cost of best biscuit per 100 g was NRs. 18.05 including overhead cost and profit of 10%. The cost calculation is given in Appendix D.

Part V

Conclusions and recommendations

5.1 Conclusions

On the basis of this research work, the following conclusions can be drawn,

1. Bamboo shoot powder could be incorporated up to 5% with wheat flour with no adverse effects on sensory quality of biscuits.
2. The nutritional quality of the biscuit was superior in case of protein, fiber and potassium content.
3. The antioxidant activity of biscuits also seemed to be enhanced by the incorporation of bamboo shoot powder.

5.2 Recommendations

The experiment can be further continued with the following recommendations:

1. Effect on the incorporations of bamboo shoot of different species could be carried out.
2. Study of bamboo shoot powder incorporated multi-grain biscuit can be done.

Part VI

Summary

Bamboo shoots are young stems that are harvested when they reach a height of 30 cm. They are seasonal and have low shelf life. But they are rich in dietary fiber, minerals and antioxidants and thus have numerous health benefits. So it is necessary to preserve and utilize bamboo shoot. In this case it is dried, powdered and used to enrich biscuits. Response Surface Methodology was used for the formulation of recipe and for this, Design Expert 10 software was used. Five different biscuit formulations, namely A (wheat flour: Bamboo shoot powder::100:0), B (wheat flour: bamboo shoot powder::95:5), C (wheat flour: bamboo shoot powder::90:10), D (wheat flour: bamboo shoot powder::85:15) and E (wheat flour: bamboo shoot powder::80:20) were prepared by soft dough process and subjected to sensory evaluation. The data obtained were statistically analysed using two way ANOVA (no blocking) at 5% level of significance. Product B was the best product. Both Product A and product B were subjected to analysis for proximate and minerals content. At 5% level of significance, the two samples were significantly different from each other.

In case of bamboo shoot powder the values for moisture, crude protein, crude fat, crude fiber, total ash and carbohydrate were found to be 5.06%, 24.62%, 3.73 %, 17.20%, 5.07% and 48.89% respectively. Similarly, for control the values for moisture, crude protein, crude fat, crude fiber, total ash and carbohydrate were 2.21%, 5.63%, 17.65%, 0.89%, 1.27%, 74.38% respectively whereas for the optimized product the values were 3.84%, 7.13%, 19.42%,1.54 %, 2.22% and 69.42% respectively. The potassium, calcium and sodium content were 268.44 mg/100 g, 60.19 mg/100 g and 8.50 mg/100 g for bamboo shoot powder; 112.00 mg/100 g, 48.77 mg/100 g and 31.83 mg/100 g for control 152.52 mg/100 g, 61.66 mg/100 g and 54.12 mg/100 g for optimized product respectively. Furthermore, the antioxidant activity of control, optimized biscuit and bamboo shoot powder were found to be 5.03/%, 9.43% and 29.55% respectively. These findings suggest that bamboo shoot powder can be incorporated in wheat flour up to the concentration of 5 parts without any adverse effect on sensory attributes giving a nutritionally enriched product having better antioxidant activity. The cost of the optimized biscuit was found to be NRs.18.05 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: Bamboo shoot powder Incorporated Biscuit

Dear panelist, you are provided with 5 samples of Bamboo shoot powder incorporated biscuit with variation on bamboo shoot powder 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 slightly – 6	Dislike moderately – 3
Like very much – 8	Neither like nor dislike – 5	Dislike very much – 2
Like moderately – 7	Dislike slightly – 4	Dislike extremely – 1

PARAMETERS	SAMPLE CODE				
	A	B	C	D	E
COLOR					
TEXTURE					
CRISPNESS					
FLAVOR					
OVERALL ACCEPTABILITY					

COMMENT:

Signature:

Appendix B

ANOVA for sensory analysis of samples

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

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	4	12.800	3.200	3.20	0.024
Panelist	9	11.200	1.244	1.24	0.300
Residual	36	36.000	1.000		
Total	49	60.000			

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

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	4	14.0800	3.5200	10.63	< .001
Panelist	9	12.5800	1.3978	4.22	< .001
Residual	36	11.9200	0.3311		
Total	49	38.5800			

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

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	4	15.4800	3.8700	9.60	< .001
Panelist	9	32.4800	3.6089	8.95	< .001
Residual	36	14.5200	0.4033		
Total	49	62.4800			

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

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	4	7.4800	1.8700	2.94	0.034
Panelist	9	59.7800	6.6422	10.43	< .001
Residual	36	22.9200	0.6367		
Total	49	90.1800			

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

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	4	17.880	4.470	3.97	0.009
Panelist	9	58.080	6.453	5.73	< .001
Residual	36	40.520	1.126		
Total	49	116.480			

Appendix C

Table C.1 Summary of ANOVA of sensory evaluation of bamboo shoot powder incorporated biscuit

Sample code	Color	Texture	Crispiness	Flavor	Overall acceptability
A	$6.7^{ab}\pm1.33$	$7.0^{c}\pm0.66$	$7.2^{d}\pm0.78$	$6.8^{bc}\pm1.22$	$7.0^{c}\pm0.96$
B	$7.5^{b}\pm1.08$	$6.5^{b}\pm0.70$	$7^{cd}\pm0.94$	$7.1^{c}\pm0.87$	$7.6^{d}\pm1.07$
C	$6.3^{a}\pm1.05$	$5.7^{a}\pm0.48$	$6.6^{bc}\pm1.17$	$6.7^{abc}\pm1.41$	$6.0^{b}\pm1.49$
D	$6.5^{a}\pm0.70$	$5.5^{a}\pm0.52$	$6.4^{ab}\pm1.19$	$6.3^{ab}\pm1.41$	$6.1^{b}\pm1.28$
E	$6.0^{a}\pm0.81$	$5.4^{a}\pm0.84$	$6.0^{a}\pm0.94$	$6.0^{a}\pm1.69$	$5.5^{a}\pm1.58$
LSD (5%)	0.907	0.5201	0.5760	0.724	0.912

Appendix D

ANOVA for proximate and mineral analysis of samples

Table D.1 One way ANOVA for moisture

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	4.02948	4.02948	67.05	0.001
Residual	4	0.24039	0.06010		
Total	5	4.26987			

Table D.2 One way ANOVA for protein

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	3.39002	3.39002	75.03	<.001
Residual	4	0.18073	0.04518		
Total	5	3.57075			

Table D.3 One way ANOVA for carbohydrate

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	36.8528	36.8528	210.25	<.001
Residual	4	0.7011	0.1753		
Total	5	37.5540			

Table D.4 One way ANOVA for fat

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	4.69935	4.69935	75.03	<.001
Residual	4	0.25053	0.06263		
Total	5	4.94988			

Table D.5 One way ANOVA for crude fiber

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	0.6402667	0.6402667	873.09	<.001
Residual	4	0.0029333	0.0007333		
Total	5	0.6432000			

Table D.6 One way ANOVA for ash

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	1.3728	1.3728	9.91	0.035
Residual	4	0.5543	0.1386		
Total	5	1.9271			

Table D.7 One way ANOVA for potassium

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	2462.806	2462.806	361.58	<.001
Residual	4	27.245	6.811		
Total	5	2490.050			

Table D.8 One way ANOVA for calcium

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	249.20	249.20	9.53	0.037
Residual	4	104.61	26.15		
Total	5	353.81			

Table D.9 One way ANOVA for sodium

Source of variation	d.f.	s.s	m.s.	v.r.	F pr.
Sample	1	744.932	744.932	107.14	<.001
Residual	4	27.813	6.953		
Total	5	772.745			

Appendix E

Table E.1 Cost calculation of the optimized biscuit

Particulars	Cost (NRs/kg)	Weight in a lot (g)	Cost (NRs)
Wheat flour	72.5	95	6.88
Bamboo shoot	80	5	0.4
Sugar	65	40	2.6
Fat	140	25	3.5
SMP	320	6	1.92
Salt	25	0.5	0.0125
Baking powder	600	2.22	1.33
Raw material cost			16.64
Processing and labor cost (10% of raw material cost)			1.66
Profit (10%)			1.83
Grand total Cost			20.13
Average wt. of optimized biscuit (g)			18.58
Total no. of optimized biscuits			6
Total weight of optimized biscuits (g)			111.48
Total cost of optimized biscuits (NRs/100g)			18.05

Color plates

Plate 1: Dried bamboo shoot

Plate 2: Bamboo shoot powder

Plate 3: Best biscuits

Plate 4: Semi-trained panelists carrying out sensory analysis