EFFECT OF INCORPORTION OF CARROT FLOUR ON THE QUALITY OF BISCUITS

by

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

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Approval Letter

This *dissertation* entitled *Effect of Incorporation Carrot Four on the Quality of Biscuits* presented by **Bhuwan Shahsankhar** has been accepted as the partial fulfillment of the requirement for **B. Tech. degree in Food Technology.**

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(Bhuwan Shahsankhar)

Abstract

This study was carried out to studied the effect of incorporating carrot flour into wheat flour biscuits with the aim of improving their nutritional quality and functional value. The main objective of this study was to develop biscuits by incorporating carrot flour at different substitution levels. The study also aimed to determine the proximate composition of the developed carrot flour biscuits and to analyze the chemical composition of the most preferred biscuit formulation. Fresh carrots were washed, peeled, sliced, and subjected to hot water blanching using 0.2% potassium metabisulphite with 1% tables salt followed by blanching at 95°C for 3 minutes. The blanched slices were cabinet dried at 50°C for 16 hours and ground into fine powder. Biscuit formulations were developed by incorporating carrot flour at different substitution levels (5%,10%,15%,20%). Standard analytical methods were used for chemical analysis, while sensory evaluation was conducted by a panel of semi-trained panelists.

The incorporation of carrot flour significantly improved the nutritional composition of the biscuits, particularly in terms of crude fiber, ash content, and β-carotene, while maintaining acceptable levels of other nutrients. Physical quality analysis showed that the diameter, thickness, and spread ratio of biscuits changed with the addition of carrot flour, showing its effect on dough behavior during baking. Sensory evaluation indicated that biscuits with 5% carrot flour were the most preferred for appearance, taste, texture, flavor, and overall acceptability. However, higher levels of carrot flour slightly reduced sensory scores due to stronger color and flavor. Statistical analysis using one-way ANOVA confirmed that the 5% carrot flour formulation was significantly superior ($p < 0.05$) among the tested samples. The study concluded that carrot flour can be successfully incorporated into biscuits up to a 5% level to enhance their nutritional and functional properties without adversely affecting consumer acceptance. Therefore, the use of carrot flour is strongly recommended for the food industry as a cost-effective and natural ingredient for the development of value-added, health-promoting biscuit products.

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List of Abbreviation

Abbreviation	Full form
ANOVA	Analysis of variation
AOAC	Association of Analytical Communities
Ca	Calcium
CCT	Central campus of technology
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
K	Potassium
KMS	Potassium, Metabisulphite
MC	Moisture content
Na	Sodium
NBC	Nepal Bureau of Standards
SMP	Skimmed milk powder
WF	Wheat flour

Part I

Introduction

1.1 General introduction

Biscuits are classified under the category of flour-based confectionery products. They are typically flat and crisp, with sweetness levels varying according to preference. Biscuits can be prepared from different types of dough, such as hard dough (e.g., crackers), hard sweet dough (e.g., rich tea), and short or soft dough (e.g., shortbread and shortcake) (Anggraeni and Handayani, 2017). Biscuits are ready to eat, convenient and inexpensive food products containing digestive and dietary principles of vital importance (Ahmad and Ahmed, 2014). Biscuits have gained popularity because of their low cost, good nutritional value, wide range of varieties, diverse flavors, easy accessibility, and extended shelf life (Sudha *et al.*, 2007). Baked products generally contain around 6–7% protein. Due to their extended shelf life, biscuits are considered suitable for nutritional enhancement in feeding programs (Agrawal *et al.*, 2017). In recent years, the consumption of biscuits has grown in many countries, as they are recognized as a significant source of nutrients (Mäkinen, 2014).

Biscuits are widely consumed across the world as they are convenient ready-to-eat products, cost-effective, nutritionally beneficial, available in numerous flavors, and possess an extended shelf life (Saadoudi *et al.*, 2024). Typically, biscuits offer several benefits, as they are convenient to consume at home or while traveling due to their availability in various packaging sizes that cater to individual preferences. In addition to being tasty, biscuits are energy-rich snacks that provide wholesome nutrition at an affordable price. Moreover, they generally have a longer shelf life compared to most other snack items. Therefore, biscuits play a significant role as a dietary supplement for both adults and children. Nowadays, they are no longer considered a luxury teatime treat but have become an essential part of the daily diet in an average Nepalese household (Rai, 2022)

Carrot (*Daucus carota L.*) is a highly nutritious root vegetable cultivated worldwide. It contains valuable phytonutrients, including phenolic compounds, polyacetylenes, and carotenoids, making it an important dietary component (Hansen *et al.*, 2003). The primary biological role of carotenoids is to serve as precursors for vitamin A in the human body (Nicolle *et al.*, 2003). Carotenoids found in carrots act as powerful antioxidants that help neutralize harmful free radicals. Research indicates that these compounds possess anti-mutagenic properties, which may contribute to lowering the risk of certain types of cancers

(Dias, 2012). Recent years have witnessed a growing acceptance of carrot and carrot-based products, largely due to their rich natural antioxidant content and the recognized anticancer properties of β-carotene, which serves as a vital precursor of vitamin A (Speizer *et al.*, 1999). Carrots are the primary source of β-carotene and also provide significant amounts of other fat-soluble antioxidants, including lutein and lycopene (Arscott and Tanumihardjo, 2010).

The color of carrots generally reflects both the type and amount of carotenoids present. For example, orange carrots mainly contain α- and β-carotenes, while red carrots are rich in lycopene, and yellow carrots predominantly contain lutein (Singh *et al.*, 2012). Carrots are also abundant in water-soluble phenolic antioxidants, which are recognized for their diverse health benefits, including anticancer, anti-atherogenic, anti-, and antimicrobial effects (Grassmann *et al.*, 2007; Sun *et al.*, 2009).

1.2 Statement of the problem

In the present era, foods are not only meant to satisfy hunger and supply essential nutrients but also to help prevent nutrition-related diseases while enhancing the physical and mental well-being of consumers. In this context, functional foods hold a significant and vital role (Hassan *et al.*, 2012). Biscuits rank among the most popular bakery items due to their low cost, ease of consumption, and extended shelf life. Nevertheless, the majority of commercially available biscuits are prepared using refined wheat flour, sugar, and fats, which lack essential nutrients like dietary fiber, vitamins, and minerals. Frequent intake of such biscuits may lead to nutritional deficiencies and elevate the risk of non-communicable diseases, including obesity and diabetes (SY, 2014).

Adding carrot flour to biscuits can improve their nutritional value and functional benefits. However, increasing the level of substitution may adversely influence sensory attributes, including flavor, texture, and visual appeal (Parveen *et al.*, 2017). While certain studies have explored the use of carrot pomace or composite flours, research specifically examining the inclusion of carrot flour in biscuits remains limited, particularly in terms of its effects on physicochemical, nutritional, and sensory properties. Hence, it is essential to evaluate the impact of varying levels of carrot flour substitution in biscuit formulations to determine the optimal amount that enhances nutritional quality without adversely affecting consumer acceptability (Adelekan and Gbadebo, 2019).

1.3 Objective of study

1.3.1 General objective

The general objective of this study is effect of incorporation of carrot flour on the quality of biscuits on nutritional content, physical properties, and sensory attributes.

1.3.2 Specific objective

The specific objectives are:

1. To production of carrot powder.
2. To determine the proximate composition of carrot flour incorporating biscuit.
3. To examine the chemical composition of the most preferred carrot flour biscuit formulation.
4. To study how adding carrot flour affects the color, taste, texture, smell, and overall acceptability of biscuits.

1.4 Significance of the work

In the field of functional food development, creating functional biscuits represents a contemporary scientific approach aimed at improving the health-promoting properties of foods without adversely affecting human well-being. Biscuits are one of the most commonly consumed snacks, but they are generally low in essential minerals and other nutrients due to their primary ingredients, such as refined flour and sugar. Carrot flour, obtained from dried and ground carrots, is abundant in β-carotene, dietary fiber, minerals, and antioxidants. Adding carrot flour to biscuits can improve their nutritional profile, offering a healthier snack option that may help prevent nutrient deficiencies and support overall well-being (Parveen *et al.*, 2017) .

This research is important as it investigated the use of carrot flour to enhance biscuits in terms of nutritional content, physical characteristics, and sensory appeal. The results can offer valuable insights to food producers, nutrition experts, and consumers interested in functional, nutrient-enriched bakery items. Moreover, it could promote the utilization of locally grown vegetables like carrots in value-added foods, contributing to both public health and sustainable agriculture.

1.5 Limitation of the work

1. Storage stability of the biscuits were not studied.

Part II

Literature review

2.1 Introduction to biscuit

Biscuits are an inexpensive processed food that provide both good taste and nutritional value at an affordable cost with easy accessibility. Compared to many other snack items, biscuits generally possess a longer shelf life, making them a suitable choice as a travel snack. They are no longer regarded merely as a luxury snack but have become a regular component of the daily diet in many Nepalese households. As a dry food with extended shelf stability, biscuits undergo minimal deterioration in comparison to other bakery products (Rai, 2022)

The term biscuit originates from the Latin word biscoctus and the Old French word bescoit (Stevenson and Waite, 2011),the word signifies “twice cooked,” referring to the traditional method in which the product was initially baked in a hot oven and then transferred to a cooler one to complete the drying process. Biscuits are widely consumed and regularly prepared food items that differ in size, shape, filling, and the type of recipe employed. Although their preparation is relatively simple, producing a standard product requires proper care, attention, and adequate knowledge of the process (Dahal, 2022). In general, the term biscuit is commonly used in European countries, whereas in the United States the term cookie is preferred. Biscuits and similar baked products have been prepared and consumed by humans for centuries(Connelly and Kokini, 2007).

Biscuits are considered ideal due to their nutrient content, pleasant taste, compact form, and convenience. They differ from other baked goods, such as bread and cakes, as they have lower moisture content, are relatively resistant to microbial spoilage, and possess a longer shelf life (Manley, 2011). Initially, biscuits were essentially dried rusks, valued as long-lasting food suitable for sea voyages. Early confectioners who worked with fat and sugar discovered that small pieces of dough baked in a hot oven and removed when lightly colored and structurally stable were not fully crisp. Returning them to a slightly cooler oven to complete the drying process enhanced both their texture and shelf life. Baking entirely in a cooler oven for a longer duration allowed for drying but produced less color and structural development. Originally, the term biscuit referred to dried pieces of bread, which were often sweetened and spiced. Other products resembling modern biscuits were also prepared but were typically referred to by cake-like names, such as shortcake and shortbread (Dahal, 2022)

Today, biscuits are predominantly produced in large-scale factories, which are extensive and technologically advanced. While forming, baking, and packaging are mostly continuous processes, the measurement of ingredients and dough mixing are generally carried out in batches (Parveen *et al.*, 2017). All flour-based confectionery products have evolved through human baking expertise, and considerable research has been devoted to understanding the science behind what occurs when flour is hydrated, combined with other ingredients, and baked. This scientific knowledge has been a key driving force in the advancement of the biscuit industry. Therefore, it can be stated that without science, innovation would not occur, and without innovation, competitiveness cannot be maintained (Dahal, 2022).

2.2 Classification of biscuits

Biscuits are typically categorized into hard dough and soft dough types based on the protein content of the flour used. For hard dough biscuits, the flour selected should have the lowest possible protein content, whereas for soft dough biscuits, flour with higher protein content is preferred(Manley, 2001). The soft dough category includes all sweet biscuits that share several common characteristics, while hard dough biscuits are typically divided into three groups: fermented dough, puffed dough, and semi-sweet dough (Whitely, 2012).

2.2.1 Soft dough biscuits

Soft dough biscuits are usually sweet, thin, and characterized by a smooth surface with more uniform and consistent dimensions compared to hard dough varieties. They typically contain higher levels of fat (25%–35%) and sugar (30%–45%) while maintaining a low moisture content. Due to the inherent properties of the dough, soft dough biscuits are relatively less versatile (Dahal, 2022).

The higher gluten network development should be avoided which can be achieved by

- Weak flour
- Lower moisture content
- Short mixing time
- Less aerating agents

2.2.2 Hard dough biscuit

Hard dough biscuits usually contain relatively low levels of fat (10%–20%) and sugar (10%–18%). Their dough consistency is maintained by higher water content combined with reduced fat levels, which promotes the formation of an extensive gluten structure. Prolonged mixing further develops the gluten, while the mechanical action of the mixer stretches and aligns the gluten strands, reducing much of their elasticity. The amount of water required depends on the strength of the flour used and can reach up to 20% of the flour weight (Poudel, 2019). Further according to the variance in composition of one or more parameters hard dough biscuits can be further divided into:

2.2.2.1 Semi sweet biscuits

For this type of biscuit, the flour used should be as weak as possible. The relatively high water content, combined with low levels of sugar and fat, promotes the development of an extensive gluten network and structure. To reduce flour strength, many formulations incorporate cornstarch or arrowroot up to about 10% of the flour weight. In addition, prolonged mixing followed by the addition of sodium metabisulfite is employed to prevent excessive gluten development. Rapid cooling must be avoided, as these biscuits are highly prone to checking (Manley and Clark, 2011).

2.2.2.2 Fermented dough biscuits

This category of biscuits primarily includes two types: cream crackers and soda (salt) crackers. While both rely on fermentation as their fundamental method of production, they differ in composition and manufacturing processes. Research indicates that the production of soda crackers is fairly standardized, whereas cream crackers exhibit greater variations in processing methods. Common ingredients include medium-strength flour with a protein content of about 9.0–9.5%, shortening (approximately 12% for cream crackers and 14% for soda crackers), small amounts of sugar mainly serving as yeast food, salt at levels of 2%–3%, and malt, which supports rapid fermentation through its diastase-activating effect (Manley, 2001).

2.2.2.3 Puff dough biscuits

This type of hard dough biscuit is leavened by incorporating layers of fat between the dough sheets. For effective layering, the dough and fat should have similar flow properties, and care must be taken to prevent the fat from blending into the homogeneous dough phase, as this would reduce dough elasticity and impair product quality. In practice, the dough is mixed for about 15 minutes and then allowed to rest for 30 minutes. Subsequently, approximately 60% of the puff dough margarine is applied during sheeting, while the remaining fat is added after the sheet has been left to rest for 15 minutes (Rai, 2022).

2.3 Types of biscuits

2.3.1 Cream crackers

These biscuits are prepared using a simple formulation of flour, fat, and salt, with fermentation carried out using yeast. Before cutting and baking, the dough undergoes lamination. The final product is characterized by a flaky texture and the presence of distinct blisters (Dahal, 2022)

2.3.2 Soda crackers

Soda crackers are typically square in shape, measuring about 50 × 50 mm with a thickness of 4 mm. They are produced using scrapless cutters, which results in white edges that break after baking. The fermentation process generally involves two stages: an initial sponge fermentation lasting about 18 hours, followed by a dough stage that ferments for approximately 4 hours. After baking, the product exhibits an alkaline reaction, which is the origin of the name soda crackers (Dahal, 2022).

2.3.3 Savory crackers

These products are often salted, flavored, and sprayed with fat after baking. Since they are produced in a wide variety of shapes and sizes, they are generally classified as savory snacks (Dahal, 2022)

2.3.4 Water biscuits and matzos

Water biscuits are prepared using a straightforward recipe consisting of flour, fat, salt, and water in the ratio of 100:6.5:1:29. After mixing, the dough remains undeveloped and crumbly, often forming small balls. Matzos, a traditional Jewish product, are made using a similar approach, with a recipe ratio of approximately 100 parts flour to 38 parts water (Dahal, 2022)

2.3.5 Puff biscuits

Puff biscuits are produced from puffed dough in which the fat is unevenly distributed. During lamination, the fat creates gaps between the dough layers, and during baking, these layers separate to form a characteristic flaky texture. The dough is neither fermented nor fully developed and is always kept cold. Since puff biscuits are typically consumed cold, the fat used must not leave a waxy aftertaste (Dahal, 2022)

2.3.6 Short dough biscuits

These biscuits are prepared from a cohesive dough that has minimal extensibility and elasticity, without forming gluten strands from the wheat flour. The texture of the baked product primarily results from starch gelatinization and the behavior of supercooled sugar, rather than from a protein or starch network (Dahal, 2022)

Carrots flour is usually incorporated into a rich, cohesive dough rather than a pourable batter or laminated dough. The biscuits are baked, not fermented, and their texture mainly depends on starch gelatinization and sugar crystallization, which is characteristic of short dough biscuits.

2.3.7 Deposited soft dough and sponge drop biscuits

Short dough, which is sufficiently soft to be pourable, is classified as soft dough. These biscuits are typically rich in fat or are made using egg whites that are whipped into a stable foam (Dahal, 2022).

2.3.8 Wafers

Wafer biscuits are made from a batter that is baked between pairs of heated metal plates. Most wafer biscuits are produced as large, flat sheets. The wafer sheet is typically prepared from a simple batter containing little or no sugar, resulting in a tasteless product with a smooth surface and a very open, porous internal structure (Dahal, 2022).

2.3.9 Miscellaneous biscuits-like products

This category also encompasses products such as crispbreads, pizza bases, and sausage rusks (Dahal, 2022)

2.4 Chemical composition of biscuits

The chemical composition of biscuits varies among different types due to differences in raw materials, preparation methods, intended use, and other factors. The primary distinctions among major biscuit types hard dough, soft dough, and fermented dough are summarized in Table 2.1.

Table 2.1 Chemical composition of biscuits

Type	Protein %	Fat %	Total sugar %	Other carbohydrate %	Moisture %	Salt and chemical %
Soft dough	6.00	20.80	25.88	44.73	1.25	1.35
Hard dough	7.18	12.26	19.15	59.40	0.90	0.56
Fermented dough	7.20	15.00	7.20	67.00	1.25	2.10

Source : Kyte, (2006)

2.5 Raw materials for biscuits making

The common raw materials used in biscuit production include wheat flour, water, emulsifiers, sugar, and salt. In addition to these, industries also incorporate a variety of other ingredients depending on the desired quality and sensory characteristics of the final product. Raw materials are generally classified into major and minor ingredients. Major ingredients are those used in bulk quantities and are essential for biscuit production, such as flour, water, sugar, and fat. On the other hand, minor ingredients such as salt, skimmed milk powder (SMP), ammonium bicarbonate, sodium bicarbonate, coloring agents, flavoring agents, emulsifiers, fortifying agents, and improvers are used in smaller amounts and are not mandatory for all types of biscuits. These minor ingredients primarily contribute to enhancing the taste, texture, flavor, and overall aesthetic appeal of the product, which is why they are often referred to as product improvers. Each of these ingredients plays a vital role in producing biscuits that are more palatable and satisfactory. These raw materials are available in different physical forms, including solids, liquids, and pastes (Rai, 2022).

2.5.1 Major ingredients

2.5.1.1 Flour

Flour serves as the fundamental raw material in biscuit production, contributing the major bulk of the final product (Whitely, 2012). The flour utilized in the production of biscuits and crackers differs in terms of strength and baking propertie (Rai, 2022). Wheat is the only grain that naturally produces flour suitable for making low-density baked products (Lamsal, 2018). Soy flour is incorporated into biscuit dough for its emulsifying properties and its relatively high protein content (Whitely, 2012).

a. **Wheat flour**

Wheat, botanically classified as Triticum vulgare, is the primary source of flour used in biscuit production. The flour is derived from the endosperm and ground to a particle size fine enough to pass through a flour sieve, typically 100 mesh per linear inch (Lamsal, 2018). Wheat flour is distinct from other cereal flours because, when combined with the right proportion of water, it forms an elastic mass. This characteristic is attributed to the presence of insoluble proteins collectively known as gluten. The gluten-forming proteins, glutenin and gliadin, account for approximately 75–80% of the total protein content in wheat flour (Poudel, 2019). Glutenin provides firmness and structural strength to the product, while gliadin acts as the binding component, contributing to the soft and sticky nature of gluten. Gliadin is soluble in 70% alcohol and can be extracted from flour, whereas glutenin is soluble in both alcohol and water (Gorinstein *et al.*, 2002).

Gluten is elastic, cohesive, and rubbery, helping to bind the various ingredients in the dough. It has the ability to retain gases released during fermentation and baking, and it sets in the oven to create a firm, porous, and open structure essential characteristics for biscuits and crackers. Consequently, gluten serves as the primary framework, providing structural support to the entire baked product (Rai, 2022). For biscuit production, wheat flour should be obtained by milling cleaned hard or soft wheat, or a combination of both. Flour strength is generally determined by its protein content, with weak flour being defined as having a low percentage of protein. This protein is primarily gluten, which forms a dough that becomes highly extensible under stress but does not fully return to its original shape when the stress is removed. Additionally, less stress is needed to break a piece of dough made from weak flour compared to dough made from strong flour under the same conditions (Manley, 2001).

Proteins in strong flour consist of long chains with few cross-links, whereas proteins in weak flour are shorter and form many bonds. In biscuit production, weak, easily extensible soft wheat flour is preferred due to its superior handling and textural properties (Kim and

Kim, 1999). In addition to its natural properties, the strength of flour can be modified through various treatments. For example, treatment with sulfur dioxide reduces flour strength, while blending heat-treated flour with untreated flour is reported to enhance its strength. According to Kent and Amos (1983), flour improvers can influence the nature and behavior of gluten, enabling it to perform during fermentation similarly to gluten from stronger flour. Ideal flour for biscuit making should be free-flowing, dry to the touch, creamy in color, and free from visible bran particles. It should also possess a characteristic flavor and be free from musty or rancid off-tastes (Lamsal, 2018). The characteristics as required in flour is given in Table 2.2.

Table 2.2 Requirements for the flour characteristics

S No.	Characteristics	Requirements
1	Moisture Content	13.0% Max
2	Gluten content on dry basis	7.5 % Min
3	Total ash on dry basis	0.5%max
4	Acid insoluble ash on dry basis	0.05% max
5	Protein (N*7.5) on dry basis	9.0%
6	Alcohol acidity as H2SO4 in 90%alcohol	0.1%
7	Water absorption	55%
8	Sedimentation value	22%
9	Uric acid(mg/100gm)	10%max
10	Granularity	To satisfy the taste

Source: Bhardwaj *et al.*, (2017)

2.5.1.2 Fat or shorting

Fat is a key ingredient in biscuit production. Its shortening function is essential, as without it, the baked product would form a solid mass held tightly together by gluten strands (Schober *et al.*, 2003). Since fat is insoluble in water, it prevents excessive cohesion of gluten strands during mixing. An important characteristic of a shortening is its ability to remain plastic over a wide range of temperatures, which is essential for its effective use in biscuit production (Manley, 2001). The primary function of fat or shortening during mixing is to prevent the gluten-forming proteins from coming into direct contact with water, as its hydrophobic nature coats and insulates these proteins. This results in a dough that is less tough while still allowing the desired level of gluten development. Consequently, baked products made with shortening have a softer, crispier texture and a melt-in-the-mouth quality (Poudel, 2019). During mixing, fat also aids in the entrapment and retention of air, which is crucial for achieving a desirable texture. Additionally, it lubricates the gluten molecules, helping to distribute them evenly during sheeting and preventing their clumping. Fat further contributes significantly to the softness, texture, palatability, and shelf life of the final product (Poudel, 2019).

In the early days of biscuit production, animal lard was commonly used; however, it has now been largely replaced by hydrogenated vegetable oils. Oils naturally contain unsaturated fatty acid chains, which have double bonds that are relatively weak, making them susceptible to oxidative rancidity. During hydrogenation, hydrogen atoms are added to replace these double bonds, converting the liquid unsaturated fatty acids into stable, solid saturated fatty acids (Manley, 2001). Hydrogenated vegetable fats offer several advantages over the animal lards previously used. To achieve the best quality biscuits, the hydrogenated vegetable oil selected should exhibit specific (Dahal, 2022).

The hydrogenated vegetable fat used in biscuit production should meet the following criteria:

1. It should have a clean white to creamy color.
2. After being kept at 50°C for 24 hours and filtered, its color should remain comparable to a control sample.
3. The fat should have a smooth, uniform texture, without any oil separation or large crystals.
4. It should possess a neutral, clean odor and taste.

5. The fat should exhibit a wide plastic range suitable for specific production techniques and the final product.
6. Its crystalline structure must remain stable during mixing and after baking.
7. The fat should have an adequate shelf life even without added antioxidants, with an acid value not exceeding 0.5 mg KOH/g and a peroxide value below 10 meq/kg.
8. It should be produced from oil blends that prevent the occurrence of fat bloom during biscuit storage.

2.5.1.3 Sweeting agents

Sugar is another key ingredient in biscuit production. It is typically derived from sugarcane, which contains 16–22% sucrose, or from sugar beet, which contains 8–9% sucrose. Various forms of sugar—such as crystalline, powdered, liquid, brown, or soft sugar—are used depending on the specific product requirements. Among these, powdered sugar is the most commonly used in biscuit making due to its high solubility, which enhances perceived sweetness. Additionally, the size of sugar crystals influences the sweetness, shortness, and spreadability of the biscuits (Whitely, 2012).

The choice of sugar crystal size depends on the type of biscuit being produced. Medium-fine powdered sugar, with or without very fine granules, is ideal for rotary moulded doughs, while coarser sugar can be used in hard, semi-sweet doughs due to higher water content, longer mixing times, and elevated dough temperatures. Coarser sugar often produces fissured or cracked tops, which is desirable for crunchy or ginger biscuits. Additionally, other types of sugar, such as lactose from milk and brown sugar, are used to enhance both color and flavor in the final product.

Another form of sugar used in biscuit production is invert sugar syrup, or simply invert syrup. Because it has a lower caramelization temperature than sucrose, it produces a browner crust more quickly, which is desirable in many products. If the crust becomes too dark, part of the invert syrup can be replaced with glucose syrup. Studies have also shown that using invert syrup can reduce baking time. Additionally, it helps prevent cracking in biscuits and aids in moisture retention. Overall, sugar in any form contributes to sweetness, tenderness, volume maintenance, crust color development, flavor enhancement, moisture retention, and proper spreading of the biscuit (Manley, 2001).

2.5.2 Minor ingredients

2.5.2.1 Emulsifying agent

Emulsifying agents are surface-active compounds that promote the formation and stabilization of emulsions during biscuit production. They facilitate proper mixing of the lipid and aqueous phases and help maintain a desirable product texture. The emulsifying property arises from the presence of both hydrophobic and lipophilic groups within the same molecule. Biscuit recipes vary from high-fat to low-fat formulations, with corresponding differences in water content. In low-fat recipes, challenges often relate to gluten development and dough machinability, whereas in high-fat recipes, the focus is on optimizing fat functionality to achieve the desired texture, control dough stickiness, and manage spread during baking (Dahal, 2022).

The most commonly used emulsifiers in biscuit production include lecithin, eggs, and mono- and diglycerides. During the creaming stage, where fat and sugar are mixed with all or part of the water, lecithin acts as an emulsifier, producing a smooth and homogeneous mixture. Additionally, lecithin can serve as an antioxidant, further enhancing product stability (Manley, 2001).

2.5.2.2 leaving agent

Leavening agents are substances that cause dough to rise, creating a porous and open texture in the final product. Chemical leaveners, such as ammonium bicarbonate and sodium bicarbonate, are commonly used, while yeast serves as a biological leavener. Mechanical leavening can also be achieved by incorporating air into the dough through agitation. Gas production can occur through chemical reactions, typically between ammonium or sodium bicarbonates and acidulants. When considering the most widely used leavening agent, baking powder, it should meet certain essential properties:

The baking powder used as a leavening agent should have the following characteristics:

1. High gas-generating capacity, producing the maximum volume of gas with minimal product weight.
2. Properly balanced ingredients to ensure that taste and appearance of the biscuits are not adversely affected.
3. Safe, non-toxic ingredients and residues.
4. Controlled reaction rate, allowing predictable and manageable leavening during baking.

5. Good shelf stability, maintaining effectiveness under various and extreme storage conditions over a reasonable period.
6. Cost-effectiveness, providing economical use in production.

Source: Manley, (2001)

The chemical reactions that occur when chemical leaveners interact with acidulants can be represented as follows:

$NH_4HCO_3 \xrightarrow{\text{Heat}} NH_3 + CO_2 + H_20$

Ammonium bicarbonate Ammonium Carbon dioxide Water

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

Ammonium carbonate Ammonia Carbon dioxide Water

The chemical equation for the reaction of soda and commonly used acidulant are as below:

$NaHCO_3 + HX \rightarrow Na\ X + CO_2 + H_2O$

Sodium bicarbonate acid Carbon dioxide water

$NaHCO_3 + C_4H_5O_6K \rightarrow C_4H_4O_6NAK + CO_2 + H_2O$

Soda Cream of tartar Sod. Pot. Tartrate

Sodium bicarbonate and ammonium bicarbonate react with acidic constituents present in the dough. An excessive amount of ammonium bicarbonate can increase the alkalinity of the dough, which may alter the protein structure. Similarly, an overuse of sodium bicarbonate can negatively influence the crumb and crust color, often resulting in a soapy or unpleasant taste, unless neutralized by acidic compounds (Riaz *et al.*, 2020).

2.5.2.3 Milk and milk solid

Milk and milk solids are valuable ingredients in biscuit production. Beyond enhancing the nutritional content, they help retain flavors in the product. Milk is commonly used in the form of skimmed milk powder (SMP) or full cream milk due to its higher stability and ease of storage. The inclusion of milk solids improves crust bloom and color, as well as the tenderness and texture of biscuits, without affecting symmetry or crumb color. This coloration is largely attributed to lactose, which remains unfermented in the dough. Lactose participates in the formation of melanoidins—the primary crust coloring compounds—through a reaction between sugars and amino acids from proteins under heat, a reaction that likely occurs in all baked biscuit doughs (Manley, 2001).

A stronger milk flavor in biscuits can be achieved by using condensed milk. Among milk products, butter is the most effective for enhancing flavor; however, for economic reasons, it has largely been replaced by butter-flavored additives. Other dairy products occasionally used in biscuit production include cheese, whey, and buttermilk (Rai, 2022).

2.5.2.4 Salt (sodium chloride)

In biscuit production, salt is not primarily used to increase saltiness, except in certain savory biscuits. Its main function is to enhance natural or added flavors. Salt can also reduce the sourness of acids and enhance the perceived sweetness of sugars (Davidson, 2023). In fermented doughs, salt contributes to gluten development and acts as a fermentation rate controller. Slightly under-aged flours can achieve good gluten development by using a slightly higher amount of salt. The salt used should be free from magnesium and calcium chlorides, as these minerals can promote rancidity. A concentration of 1.0–1.5% of the flour weight is considered optimal, while levels above 2.5% may result in an unpleasant or even nauseating taste (Dahal, 2022).

2.5.2.5 Water

Water is a crucial ingredient in biscuit production, and its quality significantly influences the final product. Dissolved minerals and organic matter in water can affect the flavor, color, and physical characteristics of the baked biscuits(Manley, 2001). The water used in biscuit production should be potable and free from any noticeable odor. While water hardness generally has little effect, demineralization is recommended if mineral content is excessively high, as it can negatively impact the color of the final product (Arora *et al.*, 2007).

2.5.2.7 Anti-oxidants

Antioxidants function as inhibitors, slowing or preventing the onset of oxidative rancidity. Since biscuits are rich in nutrients and fat, they are particularly susceptible to oxidation, making the use of antioxidants essential for extending shelf life. Both naturally occurring substances and synthetic chemicals with antioxidant properties can be incorporated during biscuit production. It is important to add antioxidants at the early stages of biscuit making, as they cannot eliminate rancidity that has already begun (Manley, 2001).

The most commonly used antioxidants in biscuit production include BHA (Butylated Hydroxy Anisole), BHT (Butylated Hydroxy Toluene), PG (Propyl Gallate), and NGA (Nordihydro Guaiaretic Acid). Typically, antioxidants are added along with shortenings during mixing. An effective antioxidant should meet the following criteria:

1. Non-toxic
2. Minimal or no impact on the color, flavor, or odor of the fat or final product.
3. Easily incorporated, being soluble in fats and oils.
4. Effective at low concentrations.
5. Stable at baking or frying temperatures.
6. Resistant to heat, even in alkaline environments such as biscuit doughs.

In addition to these major and minor ingredients, conditioning agents like sodium metabisulfite and potassium metabisulfite are used. Special fortifying agents, including proteins, vitamins, fruits, nuts, and chocolates, can also be added to enhance the nutritional and sensory qualities of biscuits (Manley, 2001).

2.6 General specific of biscuits as published by Nepal Bureau of Standards

Biscuits should be properly baked, crisp, and uniform in both texture and appearance. They must be free from rancid flavors, fungal contamination, off-odors, and insect infestation. In the case of filled biscuits, a variety of fillings such as jam, jellies, marshmallow, cream, caramel, figs, or raisins may be used. Biscuits can also be coated with caramel, cocoa, or chocolate to enhance their sensory appeal. The use of antioxidants and permitted preservatives is allowed, provided the maximum permissible levels are not exceeded. The general specifications for biscuits, as described by the Nepal Bureau of Standards (NBS), are presented in Table 2.6.

Table 2.3 General specification of biscuits

S N.	Characteristics	Requirements
1	moisture	6.00% max
2	Acid insoluble ash (on dry basic)	0.05% max
3	Acidity of extract fat (as oleic acid)	1.00% max

Source: Dahal, (2022)

2.7 Nutritive value of biscuits

Biscuits are ready-to-eat products and serve as a good source of nutrients, as they contain carbohydrates, fats, proteins, minerals, and vitamins. Proteins contribute to growth and tissue repair, while carbohydrates and fats provide heat and energy. Similarly, minerals are essential for bone growth, and vitamins are responsible for normal metabolic activities and maintaining overall vitality of the body. The nutritive value of biscuits is presented in Table 2.4

Table 2.4 Nutritive value of hard dough biscuits (value per 100g)

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

Source : Kesavan and Iyer, (2014)

2.8 Technology involve in biscuit making

Technology is the factor that enables efficient performance of tasks by significantly reducing labor, time, and expenditure, while simultaneously improving quality. Technology remains beneficial as long as it is kept under proper control. Hence, the foremost requirement in any operation is the skill to effectively handle the available technology. Responsibility does not lie solely with the machinery operator or the technical department, but extends to the overall process control from the procurement of raw ingredients to the final sales of the product (Kyte, 2006). The overall technology of biscuit production is illustrated in Fig. 2.1.

Preparation of ingredients

(weighing, recipe calculation fermentation of dough in case of fermented biscuits)

↓

Creaming and mixing

(performing is done for hard dough and fermentation dough biscuits)

↓

Laying the dough

↓

Dough forming

(moulding in case of soft dough biscuits, sheeting for other types)

↓

Baking (Temperature 150 C to 250°C for 6to 7 min)

↓

Cooling (for 6 to 7 min)

↓

Wrapping and packaging

↓

Labelling and storage (RH 40 to 50 % at temperature of 23 to 27°C)

Fig. 2.1 Flow sheet of manufacturing process biscuit

Source : Manley, (2001)

2.8.1 Dough mixing

Mixing is one of the most critical steps in biscuit making, as the quality of dough mixing has a direct impact on the final product characteristics. A properly mixed dough ensures uniform distribution of ingredients, optimal gluten development, and desired dough consistency. Depending on the product type, mixing can be carried out in different ways. In industrial production, dough mixing is usually performed with electrically operated mixers, most commonly two-speed mixers. At high speed, the creaming stage generally requires 3–5 minutes, whereas flour incorporation and dough development at low speed may take up to 10 minutes (Whitely, 2012).

In the preparation of biscuit dough, sandwich creams, and batters, the process of "mixing" involves several specific operations. These include:

a. Combining the ingredients to produce a homogeneous mixture.
b. Dispersing a solid into a liquid, or one liquid into another.
c. Dissolving solid components into a liquid medium.
d. Kneading the mass to allow the development of gluten from hydrated flour proteins.
e. Increasing the temperature as a result of mechanical work during mixing.
f. Incorporating air into the mass to reduce density.

Depending on the formulation, one or more of these functions are essential for developing dough suitable for the wide variety of biscuit types (Dahal, 2022).

There are essentially two primary methods for dough mixing, each of which can have several modifications. These variations are applied to obtain the most desirable results, depending on the specific conditions and the type of equipment employed.

2.8.1.1 Creaming up method

This method of dough preparation is carried out in two stages. In the initial stage, sugar and fat are thoroughly blended until fine dissolution is achieved. Subsequently, additional ingredients such as milk powder, water, invert syrup, lecithin, color, essence, and salt are incorporated and mixed for approximately 3–5 minutes to obtain a uniform cream. In the next step, flour along with aerating agents is added to the cream mixture and blended at low speed for about 10 minutes. When other types of flour are to be included, it is essential to pre-mix them with the shortening and water prior to adding the remaining ingredients, in order to preserve their functional properties (Manley, 2001).

This mixing method helps maintain water in a relatively stable state, preventing it from excessively interacting with the flour and forming an extensive gluten network. It is primarily used for shortcake, rotary, and wire-cut doughs to control flow and volume during baking. A critical factor in this method is the precise amount of water incorporated (Whitely, 2012).

2.8.1.2 All in one method

As the name implies, in this method all ingredients are combined and fed directly into the mixing machine. This straightforward approach involves adding all ingredients along with the majority of water, while a portion of water is reserved to dissolve aerating agents, flavors, colors, and salt, which are then incorporated into the dough. Mixing continues until a uniform and satisfactory dough is obtained. This method is commonly used for hard and semi-sweet doughs, where the relatively higher water content promotes effective gluten development and formation.

In the case of fermented dough, an additional step known as punch back or knock back is employed. This process helps to release the carbon dioxide pockets formed during fermentation, preventing the accumulation of gas that could otherwise inhibit yeast activity (Manley, 2001)

2.8.2 Laying the dough

Lay time refers to the period between dough mixing and machining. The duration of lay time varies depending on the type of product. For fermented dough, lay time is essential and typically longer, whereas it is usually avoided in sulphited dough. A minimum lay-off period of 15 minutes is recommended to achieve desirable surface gloss, color, and weight, while also improving the machinability of the dough (Manley, 2001).

2.8.3 Forming and performing

Shaping or forming the dough into the desired shapes and thickness prior to baking is a crucial step in biscuit production. For hard and fermented doughs, shaping is achieved using sheeters and laminators, which reduce the dough to thin sheets. This process helps eliminate trapped air and ensures uniform distribution of fat and salt, contributing to a product with a layered structure and a tender texture. In contrast, soft dough is directly fed into molding or embossing machines, which cut it into the required size, shape, and appearance (Rai, 2022).

2.8.4 Baking

Baking is a critical step in biscuit production, as it directly affects the quality and edibility of the final product. During baking, the dough is cooked, flavors and color are developed, and the raw dough is transformed into the finished biscuit. The primary purpose of baking is to remove the moisture from the dough gradually. Biscuit dough typically contains more than 25% moisture, part of which is bound water present in the flour and other ingredients, while the remainder is free water added to facilitate dough formation and ease of machinability (Komlenić *et al.*, 2012).

The baking process relies on the transfer of heat from a hot source to the product being baked. Heat is primarily transferred through three mechanisms: conduction, convection, and radiation. In biscuit baking, the majority of heat reaches the dough pieces through radiation, while convection plays a minor role as long as the air velocity in the baking tunnel remains below 5 feet per second. When air velocity exceeds this threshold, convection contributes more significantly to heat transfer. In addition to these traditional methods, high-frequency heating can also be employed, offering a faster rate of moisture removal from the product (Manley, 2001)

All ovens used in biscuit production consist of four fundamental components:

a. A heat source to provide the necessary thermal energy.
b. A base (sole or hearth) that can be heated, on which the dough pieces are placed.
c. A cover over the base, forming a chamber to retain and circulate heat.
d. A closable opening through which the dough pieces can be inserted and removed from the baking chamber.

During baking, the dough undergoes gradual physical and chemical transformations, which are essential for developing the texture, color, and flavor of the final biscuit (Manley, 2001)

The physical changes that occur during baking include:

a) Formation of a thin crust on the surface of the dough.
b) Melting and redistribution of fat within the dough.
c) Expansion of the dough as gases are released.
d) Transformation of water into steam.
e) Escape of carbon dioxide, other gases, and steam from the dough matrix.

The chemical changes occurring during baking include:

a) Formation of gases within the dough.
b) Starch gelatinization, leading to structural setting.
c) Protein transformations, which contribute to texture and structure.
d) Caramelization of sugars, resulting in color and flavor development.
e) Dextrinization, enhancing browning and crispness of the biscuit.

The temperature within the baking oven has varying effects on the raw dough, which are summarized in Table 2.5.

Table 2.5 Temperature related changes in biscuits during baking

Temperature (220^0C-230^0C)	Changes occurred
32-37	Top crust skin formation (evaporation of surface moisture)
32-48	Evolution of CO_2 with crumb (less solubility of CO_2)
32-65	Increase in volume due to CO_2
32-99	Gas expansion (CO_2 and steam)
51-99	Starch gelatinization (Biscuit structure)
76-88	Evaporation of alcohol, yeast action ceases
76-88	Coagulation of protein (irreversible)
176-204	Caramelization (Combustion of sugar like maltose, fructose and glucose)
188-204	Dextrinization (surface gloss)

Source: Poudel, (2019)

During baking, it is essential to maintain a higher level of steam in the oven than that generated from the dough moisture and fuel combustion. Steam can be introduced into the baking chamber either at the entry point of the dough or early in its passage through the oven. This practice promotes the formation of a glossy crust, prevents cracking, increases product volume, and helps to slightly agitate the oven atmosphere. Alternatively, the need for steam injection can be minimized by using high-speed fans that recirculate air at approximately 2000 cubic feet per minute. Oven dampers play a critical role in releasing the high positive pressure generated by rapid heat evaporation. Additionally, to achieve biscuits or cookies with higher moisture content, the dampers in the final zone of the oven should be kept closed (Manley, 2001)

2.8.5 Cooling

Cooling is a critical step in biscuit production. As biscuits exit the oven, they are extremely hot, typically ranging from 99 to 101°C, and remain soft and moist. Proper cooling prior to packaging is essential to preserve the structure and texture of the biscuits. Immediately after baking, the biscuits contain a high moisture content, indicating that the flour starch is still partially gelatinized, and the dextrin remains partially in solution. Likewise, sugar and fat are still in liquid form, and although the protein is firmer than the other components, it remains pliable. Essentially, most ingredients are in an unset state at this stage. Gradual cooling allows moisture to be slowly lost, sugars to crystallize, and dextrin to firm up, resulting in biscuits that achieve the desired toughness and stability. Therefore, cooling should be slow and controlled to ensure proper setting of the final product (Komlenić *et al.*, 2012).

Checking is one of the most common defects observed in biscuits after production, often not noticeable during processing. It is characterized by fine hairline cracks on the surface, indicating a weakening of the structure, which may lead to breakage within 24 hours of packaging. Hard and semi-sweet biscuits are more susceptible to checking compared to rotary- moulded soft types, primarily due to their lower fat and sugar content, which results in increased gluten development. Gluten, having a strong affinity for water, draws moisture from the gelatinized starch in the hot biscuits, creating internal stresses. This issue is further aggravated by rapid shrinkage caused by fast cooling. Therefore, checking can be minimized or prevented by employing slow baking and gradual cooling processes (Dahal, 2022) .

2.8.6 Packaging

Biscuits are considered low-moisture foods, with mandatory standards requiring their moisture content to remain below 6%. Since freshly baked biscuits have very low relative humidity, they must be packaged in water vapor–resistant materials to prevent rapid moisture absorption from the environment. Moisture uptake can make the biscuits susceptible to microbial contamination, while exposure to air can lead to oxidative rancidity, as fat is a key ingredient in biscuit production (Paine and Paine, 2012).

Packaging materials are used to enclose the product, providing the necessary protection to maintain its quality and safety over extended periods.

For biscuits, an ideal packaging material should:

a) Be resistant to water vapor.

b) Be non-tainting and offer good grease resistance.
c) Be strong enough to prevent mechanical damage.
d) Be opaque.
e) Allow for easy printing.

Biscuits should be packaged closely together to provide mutual support, reducing the risk of breakage. At the commercial level, biscuits are typically packaged using triple-layer laminates, which consist of polyethylene, aluminum foil, and paper. The specific characteristics of biscuit packaging materials are summarized in Table 2.6.

Table 2.6 Some characteristics of packaging materials

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

Source: Robertson, (2005)

2.9 Sensory perception of biscuits

Before a biscuit product is introduced to the market, it undergoes sensory evaluation by a panel of experts to determine its overall acceptability. The key attributes assessed include appearance, crispiness, crumb color, flavor, and overall sensory appeal. The evaluation process is usually carried out using scorecards, and the results are analyzed to identify the most suitable product. In addition to expert evaluation, consumer research and case history studies are also important considerations when drawing final conclusions from the analysis (Manley, 2001)

2.10 General specification of biscuits as published by (DFTQC)

A well-baked biscuit should exhibit a crisp texture and uniform appearance. It must be free from undesirable attributes such as off-flavor, mold growth, unpleasant odor, or insect contamination. Various fillers like jam, jelly, cream, caramel, marshmallow, figs, and raisins can be incorporated to produce filled biscuits, while coatings such as chocolate, cocoa, or caramel may also be applied to enhance appeal. The addition of antioxidants and approved preservatives is acceptable, provided their concentrations remain within the permissible limits. The general quality standards for biscuits as prescribed by the Department of Food Technology and Quality Control (DFTQC) are presented in Table 2.7.

Table 2.7 General specification of biscuits according to DFTQC

S No	Characteristics	Requirement
1	Moisture	6.00%max
2	Acid insoluble ash (on dry basis)	0.1%max
3	Acidity of extracted fat (as oleic acid)	2.00%max

Source: DFTQC (2075)

2.11 Nutritive value of biscuits

Biscuits are a rich source of nutrients, as they contain a combination of carbohydrates, fats, proteins, minerals, and vitamins. Carbohydrates and fats function primarily as sources of energy and heat for the body, while proteins are essential for the growth, maintenance, and repair of body tissues. Likewise, minerals and vitamins play vital roles in bone development and in supporting various physiological processes necessary for overall health. The nutritional composition of biscuits is presented in Table 2.8.

Table 2.8 Nutritive value of biscuits (values per 100 g)

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

Source: Youssef, (2015)

2.12 Shelf life of biscuits

The major factors contributing to the reduction of biscuit shelf life and overall palatability are moisture absorption and oxidative rancidity. Exposure to sunlight can lead to fading of the crust color, affecting the product's appearance. Even when moisture-resistant and opaque packaging materials are used, deterioration of color and the onset of rancidity may still occur due to the presence of residual oxygen within the package. Generally, biscuits stored under normal packaging conditions tend to develop rancidity and color loss within 60 days (Manley, 2001).

The development of off-flavors in biscuits is generally associated with factors such as increased moisture content, fat oxidation, a rise in peroxide value, and Maillard reactions occurring during storage. The presence of natural antioxidants in the raw ingredients can help slow down or prevent oxidation. Banana blossom, for instance, contains several natural antioxidants including quercetin, catechin, phenols, saponins, and tannins, which can contribute to maintaining product quality. Incorporating banana blossom flour into biscuit formulations may therefore assist in reducing oxidative rancidity and preserving the flavor and freshness of the final product (Thaweesang, 2019) .

2.13 Carrots

2.13.1 Introduction

Carrot (*Daucus carota L.)* is one of the most important members of the Apiaceae family and is cultivated globally as a root vegetable. Historically, carrots were initially valued for their medicinal properties before gradually becoming a common food crop. Historical documents from Europe show that carrot cultivation began before the tenth century. Carrot roots can appear in a variety of colors, including white, yellow, orange, red, purple, and deep violet. The earliest cultivated types were yellow and purple. The now widely consumed orange varieties were developed in Central Europe during the 15th and 16th centuries, and their popularity increased rapidly once their high provitamin A content became known (Simon, 2000).

Carrots contain two major groups of antioxidant pigments—carotenoids and anthocyanins. The variation among carrot cultivars is mainly attributed to the type and concentration of these pigments. Carotenoids are responsible for the yellow, orange, and red coloration in most yellow and orange-fleshed varieties. The commonly consumed orange carrot is particularly rich in α-carotene and β-carotene, both of which serve as important sources of provitamin A. In yellow carrots, the dominant pigment is lutein, a compound known for its protective role in preventing macular degeneration (Singh and Devi, 2015)

2.13.2 Taxonomy of carrot

Carrot is a flowering plant that belongs to the Kingdom Plantae and is classified under the Division Magnoliophyta, which includes all angiosperms. It falls within the Class Magnoliopsida, commonly known as dicotyledonous plants due to the presence of two seed leaves. The plant is further placed under the Order Apiales and the Family Apiaceae, a family known for aromatic and edible plants. Carrot is classified under the Genus Daucus, and its botanical name is Daucus carota L(Ikram *et al.*, 2024).

Table 2.9 Systematic position of Daucus carota L.

Kingdom -Plantae

Division -Magnoliophyta

Class - Magnoliopsida(dicotyledonous)

Order -Apiales

Family - Apiaceae

Genus -Daucus L.

Species -Daucus carota L.

2.13.3 Carrot production of Nepal of 2014

In Nepal, a growing number of farmers have shifted from traditional crops such as maize and millet to carrot cultivation due to its higher economic returns and increasing market demand. Commonly used carrot varieties include Sigma, New Kuroda, Early Nantes, and Nepa Dream hybrids. According to the latest data from the Ministry of Agricultural Development, Nepal produces approximately 31,405 tons of carrots annually across 2,685 hectares of farmland. Among the regions, the Central Region leads in production with 12,330 tons, representing about 39 percent of the total output, followed by the Eastern Region with 10,000 tons (32 percent) and the Western Region with 5,100 tons (16 percent) of the national production (Bhattarai *et al.*, 2017).

Table 2.10 Carrot production of Nepal 2014

Region	Production(tones)	Area (Ha.)
Eastern Region	10,087	1,115
Central Region	12,337	854
Western Region	5,102	291
Mid Western Region	2,589	331
Far western Region	1,291	96
Nepal	31,406	2,687

Source: Bhattarai *et al.*, (2017)

2.14 Chemical composition of carrots

Table 2.11 Chemical composition of carrots

Parameter	Value
Moisture	86%
Carbohydrate	10.06%
Protein	0.9%
Crude fat	0.2%

Crude fiber	1.2%
Total ash	1.1%
Calcium	80 mg/100g
Potassium	108 mg/100g
B-Carotenoids	9.77 mg/100g

Source : Longvah *et al.*, (2017)

2.15 Phytonutrients

Phytonutrients are plant-derived compounds, mainly secondary metabolites, that contribute to health promotion. The role of antioxidant compounds in maintaining health and preventing conditions such as coronary heart disease and cancer has attracted growing attention from researchers, food producers, and consumers, as the trend increasingly favors functional foods with targeted health benefits. In vitro studies have suggested that phytonutrients, including carotenoids and phenolic compounds, may significantly protect biological systems against oxidative stress, alongside vitamins. Carrots are an important source of phytonutrients such as phenolics, polyacetylenes, and carotenoids. They are particularly rich in β-carotene, ascorbic acid, and tocopherols, earning them the classification of a vitamin-rich food. Given their diverse bioactive compounds, carrots are recognized as a functional food with notable health-promoting properties (Sharma *et al.*, 2012).

2.15.1 Carotenoids

Carotenoids in foods are important not only as natural pigments but also for their diverse biological functions. These compounds are found within cells and are involved in regulating gene expression and influencing cell activation. Their biological roles are independent of pro-vitamin A activity and are largely attributed to their antioxidant properties, which help deactivate free radicals and quench singlet oxygen. Carotenoids are generally categorized into carotenes and xanthophylls, both of which impart appealing red or yellow hues and enhance overall food quality. Structurally, carotenoids may be acyclic or possess one or two rings of five or six carbon atoms at either end of the molecule (Carle and Schiber, 2001).

Carotenoids are essential micronutrients that play a vital role in human health. In the edible portion of carrot roots, total carotenoid content varies between 6,000 and 54,800 µg per 100 g. Their primary physiological role is serving as precursors to vitamin A. Over the past decade, carotenoids, particularly β-carotene, have gained significant attention due to their potential protective effects against certain types of cancer. In humans, α- and β-carotene exhibit 50% and 100% of provitamin A activity, respectively, with a single molecule of β-carotene capable of producing two molecules of retinol (Nicolle *et al.*, 2003).

Carotenoids are associated with strengthening the immune system and reducing the risk of degenerative conditions, including cancer, cardiovascular diseases, age-related macular degeneration, and cataracts. Additionally, carotenoids have been recognized as potential agents in the prevention of Alzheimer's disease (Press, 2002).

The high levels of antioxidant carotenoids, particularly β-carotene, are likely responsible for the medicinal and biological benefits of carrots. Carrots are reported to exhibit diuretic and nitrogen-balancing effects and aid in the elimination of uric acid. Various animal studies and epidemiological research have shown that carotenoids can inhibit carcinogenesis in mice and rats and may provide anticarcinogenic effects in humans. Within biological systems, β-carotene acts as a free radical scavenger and singlet oxygen quencher, offering antimutagenic, chemo preventive, photoprotective, and immune-enhancing properties (Srinivasan, 2005)

2.15.2 Phenolics

Phenolic compounds, also known as polyphenols, have garnered significant interest due to their physiological roles, including antioxidant, antimutagenic, and antitumor activities. They are recognized for their potential in neutralizing harmful free radicals that can damage both the human body and food systems. Although phenolics do not contribute directly to nutrition, their antioxidant capacity makes them important for human health. These compounds are widespread in plants and are primarily synthesized from phenylalanine through the phenylpropanoid pathway. In carrots, phenolics are distributed throughout the root, with the highest concentrations found in the periderm. The two main categories of phenolic compounds are hydroxycinnamic acids and para-hydroxybenzoic acids (Nagai *et al.*, 2003).

(Zhang and Hamauzu, 2004) investigated the phenolic compounds in carrots, focusing on their antioxidant properties and distribution across different tissues. They reported that hydroxycinnamic acids and their derivatives were the primary phenolic compounds present, with chlorogenic acid being the most abundant, accounting for 42.2–61.8% of the total phenolics in various carrot tissues. The concentration of phenolics followed the order: peel > phloem > xylem. Although the peel constitutes only about 11% of the carrot's fresh weight, it contributed approximately 54.1% of the total phenolics, while the phloem contributed 39.5% and the xylem only 6.4%. Antioxidant and free radical scavenging activities mirrored this distribution, being highest in the peel and lowest in the xylem. These results indicate that phenolic compounds, particularly hydroxycinnamic derivatives like chlorogenic acid and dicaffeoylquinic acids, play a significant role in the antioxidant potential of carrots. Phenolic compounds in carrots vary among tissues, with the highest concentration found in the peel, followed by the phloem and then the xylem.

Although the peel constitutes only about 11% of the fresh carrot weight, it contributes approximately 54.1% of the total phenolics, while the phloem contributes 39.5% and the xylem just 6.4%. The antioxidant and radical scavenging activity of carrot tissues follows the same trend as phenolic content, highlighting the significant role of phenolics, particularly hydroxycinnamic derivatives like chlorogenic acid and dicaffeoylquinic acids, in antioxidant properties. The peel, often discarded during processing, could therefore be utilized for value-added products due to its high phenolic content and antioxidant potential. Oviasogie et al. (2009) reported that the total phenolic content in carrots was measured at 26.6 ± 1.70 µg/g. The total phenolic content in violet carrot juice has been reported to be 772 ± 119 mg/L (Karakaya, 2001).

2.15.3 Dietary fiber

Dietary fiber is a type of complex carbohydrate present in the structural parts of plants that cannot be digested or absorbed by the human body, and therefore contributes no calories. Despite this, consuming a fiber-rich diet provides numerous health benefits, such as preventing constipation, regulating blood glucose levels, protecting against cardiovascular diseases, lowering elevated cholesterol, and reducing the risk of certain cancers. Fibers are categorized as either insoluble or soluble based on their solubility. Insoluble fibers mainly include cell wall components like cellulose, hemicellulose, and lignin, while soluble fibers consist of non-cellulosic polysaccharides such as pectin, gums, and mucilage (Yoon *et al.*, 2005).

According to (Lineback, 1999), the cell wall of carrot consists of pectin, including galacturonans, rhamnogalacturonans, arabinans, galactans, and arabinogalactans-1; cellulose in the form of β-4, D-glucan; lignin, comprising trans-coniferyl alcohol, trans-sinapyl alcohol, and trans-p-coumaryl alcohol; and hemicellulose, which includes xylans, glucuronoxylans, β-D-glucans, and xyloglucans. Carrots are rich in dietary fiber, which plays a significant role in human health. Diets containing high amounts of fiber have been linked to the prevention, management, and reduction of certain diseases, including diverticular disease and coronary heart disease (Villanueva-Suarez *et al.*, 2003). (Nawirska and Kwaśniewska, 2005) reported the composition of dietary fiber in fresh carrots on a dry weight basis as follows: pectin at 7.41%, hemicellulose at 9.14%, cellulose at 80.94%, and lignin at 2.48%. Dietary fibers are valued not only for their nutritional benefits but also for their functional and technological properties, which make them useful as ingredients in food products (Schieber *et al.*, 2001).

2.16 Health benefits of carrots

Research indicates that increased consumption of fruits and vegetables high in antioxidants, like carrots, may lower the risk of cancer and cardiovascular diseases. In addition, carrots are a good source of vitamins, minerals, and dietary fiber, contributing to overall health benefits (Ware, 2017).

2.17 Risks

Excessive intake of vitamin A can be toxic to humans. While it may cause a mild orange discoloration of the skin, this is not harmful. Vitamin A overdose is unlikely through diet alone, but it can occur with high supplement use. Individuals taking vitamin A–based medications, such as isotretinoin (Roaccutane) for acne or acitretin for psoriasis, should limit carrot consumption to avoid hypervitaminosis A. Anyone beginning a new medication should consult their doctor regarding dietary adjustments (Ware, 2017).

Part III

Materials and methods

3.1 Materials

3.1.1 Raw material

For the preparation of biscuits, 'Gyan chakki atta' wheat flour, manufactured by Vikas Food Pvt. Ltd. Parvatipur ,Kohalpur,,Nepal, was utilized. The wheat flour, carrot, sugar and table salt were purchased from the local market of Dharan, Sunsari, Nepal. Kamdhenu Ghee was bought from local market of Dharan manufacture by Kamdhenu Dairy Development Cooperative Ltd. was used.

3.1.2 Packaging material

High-density polyethylene films were used for packaging the product.

3.2 Chemical, apparatus and equipment

The necessary chemicals, apparatus and equipment were obtained from the laboratory of Central Campus of Technology, and their details are provided in Appendix B.

3.4 Method

3.4.1 Formulation of recipe

The formulation of the biscuit recipe incorporating carrot flour was carried out as presented in Table 3.1.

Table 3.1 Recipe formulation of biscuits

Ingredient	A	B	C	D	E
Wheat flour(parts)	100	95	90	85	80
Carrot flour(parts)	0	5	10	15	20
Sugar(g)	25	25	25	25	25
Fat(g)	30	30	30	30	30
Baking powder(g)	1	1	1	1	1
Salt(g)	0.3	0.3	0.3	0.3	0.3
Water(ml)	35	35	35	35	35

The biscuits were prepared according to the formulated recipes, with each batch assigned a coded name: A, B, C, D and E. The biscuits were made using the soft dough method, as illustrated in Fig. 3.1.

3.5 Preparation of carrots flour

Carrot powder was prepared following the procedure described by (Okezie *et al.*, 2024). Fresh carrot roots were thoroughly washed with clean water, peeled, and sliced into thin pieces. These slices were blanched for 3 minutes in hot water containing sodium metabisulphite to prevent enzymatic browning and discoloration. After blanching, the slices were cooled in open air and subsequently dried in a hot-air dryer at 50°C for 12 hours. The dried carrot slices were then finely ground into powder and stored in black polythene bags until further use.

Carrots

↓

Washing and peeling

↓

Cutting into 0.3 cm cubes

↓

Blanching (92^0C for 3min)
(containing 0.2% potassium metabisulphite and 1% table salt)

↓

Dehydration (50^0C for 12h)

↓

Grinding of cubes

↓

Sieving of powder (60 mesh size)

↓

Carrot flour

Fig 3.1: Flow chart of preparation of carrot flour

Source: Okezie *et al.*, (2024)

3.6 Preparation of carrots flour incorporated biscuits

The biscuit samples were prepared using the creaming method. The formulation included 100 g of flour blend, 30 g of fat, 25 g of sugar, 1 g of baking powder, and 35 ml of water. Biscuits were produced from various combinations of refined wheat flour and carrot flour in ratios of 100:0, 95:5, 90:10, 85:15, and 80:20, with the 100% refined wheat flour serving as the control sample. The dough was manually mixed, sheeted, and rolled to a uniform thickness of approximately 5–6 mm. It was then cut into the desired shapes using a biscuit mold. The shaped dough pieces were arranged on perforated trays and baked in an oven at 190°C for 25 minutes. After baking, the biscuits were allowed to cool to room temperature and were stored in airtight containers until further analysis.

Weighing of ingredients

↓

Mixing (5min)

↓

Dough kneading(3min)

↓

Sheeting and cutting (5-6mm)

↓

Baking (190^{0}C ,25 min)

↓

Cooling

↓

Packaging

Fig 3.2: Preparation of carrots flour incorporated biscuits

3.7 Packaging and storage of biscuits

High-density polyethylene (HDPE) zip-lock bags were used for packaging the biscuits, which were then stored at ambient temperature (25^{0}C-27^{0}C).

3.8 Analytical procedure

3.8.1 Spread ratio

The spread ratio of the biscuits was calculated using the formula recommended by AOAC (2005).

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

Where diameter was measured in mm by Vernier caliper and thickness was measure in mm by screw gauge.

The spread ratio is an important quality parameter of biscuits because it correlates with texture, visual appeal, and consumer acceptance described by Bharti *et al.*, (2017).

3.8.2 Volume

The volume of the biscuits was calculated by multiplying the biscuit's area by its thickness, following the guidelines of AOAC (2005).

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

Where t = Average thickness of biscuits (mm)

d = Diameter of biscuits (mm)

3.8.3 Density

The density of the biscuits was determined by dividing their mass by their volume, according to AOAC (2005).

$$\text{Density(g/cm}^2\text{)} = \frac{Mass(g)}{Volume(cm^3)}$$

3.8.2 Physicochemical analysis

3.8.2.1 Moisture content

The moisture content of the samples was determined by drying them in an oven at 103 ± 2°C until a constant weight was achieved described by Rai and Kc, (2007).

3.8.2.2 Crude fat

The crude fat content of the samples was determined using the solvent extraction method with a Soxhlet apparatus, employing petroleum ether as the extracting solvent, as described by Rai and Kc, (2007).

3.8.2.3 Crude protein

The crude protein content of the samples was determined indirectly by assessing the total nitrogen content using the micro Kjeldahl method. A conversion factor of 6.25 was applied to convert the nitrogen content into crude protein described by Dangal *et al.*, (2021).

3.8.2.4 Crude fiber

The crude fiber content of the samples was determined following the method described by Rai and Kc, (2007).

3.8.2.5 Total ash

The total ash content of the samples was determined using a muffle furnace, following the method described by Rai and Kc, (2007).

3.8.2.6 Carbohydrate

The carbohydrate content of the samples was calculated using the difference method.

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

3.9 Sensory evaluation

The sensory evaluation of the biscuits was conducted using twelve semi-trained panelists, comprising teachers and students from the Central Campus of Technology. The assessment parameters included texture, crispiness, color, taste, flavor, and overall acceptability. Sensory analysis was performed following the 9-point Hedonic Scale, as presented in Appendix A.

3.10 Statical method

All analyses were performed in triplicate. Statistical computations were carried out using Microsoft Office Excel 2013. The data obtained from the experiment were analyzed for significance using Analysis of Variance (ANOVA) through the statistical software Genstat Discovery Edition 3. Mean values were compared using Fisher's protected Least Significant Difference (LSD) at a 5% level of significance.

Part IV

Result and Discussion

Wheat flour and carrot flour were collected and blended with other ingredients to prepare biscuits containing 0%, 5%, 10%, 15%, and 20% levels of carrot flour substitution. Proximate composition analysis was conducted for both the flours and the prepared biscuits. In addition, the physical properties of carrot flour were examined. Sensory evaluation was used to identify the most acceptable product among the five formulations, and the detailed nutritional composition of the best-performing sample was further analyzed.

4.1 Proximate composition

The proximate composition of wheat flour and carrot flour is presented in Table 4.1.

Table 4.1 Chemical composition of wheat flour, carrots flour

Parameters	Wheat flour	Carrots flour
Moisture content (%)	12.23±0.25	7.76±0.24
Crude protein (db, %)	11.16±0.09	9.34±0.14
Crude fat (db, %)	1.58±0.02	3.00±0.16
Crude fiber (db, %)	0.25±0.02	21.36±0.38
Total ash (db, %)	0.54±1.22	6.68±0.25
Carbohydrate (db, %)	74.23±0.51	51.86±0.04
Calcium(mg/100g)	38.78±0.17	313.65±0.87
Potassium(mg/100g)	144.86±0.49	243.36±3.62
Gluten content(mg/100g)	9.36±0.25	ND
B-carotenoids (mg/100g)	ND	19.58±0.02

*The value are the means of three determination ± standard deviation

ND= Not determined

The moisture content of wheat flour was recorded as 12.23%, which is consistent with the typical range reported for commercial wheat flour by Kent and Evers, (1994). In contrast, carrot flour showed a moisture content of 7.76%, which was lower than values previously documented. For instance, Giang *et al.*, (2024) reported a moisture level of 8.32% in carrot flour. Such differences may be due to variations in carrot varieties and processing conditions, particularly drying temperature and duration.

The protein content of carrot flour was found to be 9.62%, which is slightly higher than the value reported by Giang *et al.*,(2024). However, compared to wheat flour, which contains

11.16% protein, carrot flour presents a lower protein level. This suggests that carrot flour could be suitable for the formulation of gluten-free bakery products such as cakes. The fat content of carrot flour was measured at 2.67%, which is also marginally higher than the value reported by Giang *et al.*, (2024).

Carrot flour exhibited a relatively high ash content of 7.17 g/100 g, reflecting its richness in minerals. This value is substantially higher than the ash content of wheat flour (0.65%) and also exceeds the findings of Giang *et al.*, (2024). According to Wang *et al.*, (2022), elevated ash content indicates a higher mineral concentration. The calcium content of carrot flour was recorded as 313.65 mg/100 g, closely aligning with the value reported by Madukwe and Eme, (2012), who observed 287.21 mg/100 g. Similarly, the potassium content was found to be 243.36 mg/100 g, slightly differing from the 221.5 mg/100 g reported by Madukwe and Eme, (2012).

The gluten content of wheat flour was measured at 9.36%, while carrot flour showed no detectable gluten, which supports the reported by De Kock and Magano, (2020). Additionally, the β-carotene content of carrot flour was 19.58 mg/100 g, slightly higher than the 18.05 mg/100 g reported by Yusuf *et al.*, (2021).

4.2 Influence of carrot flour on physical parameters of biscuits

The increase in the level of carrot flour substitution influenced the physical properties of the biscuits, including thickness, diameter, spread ratio, weight, volume, and density, as illustrated in Table 4.3. The findings indicated that as the proportion of carrot flour substitution increased, both the diameter and thickness of the biscuits improved. The sample containing 20% carrot flour exhibited the highest diameter and thickness values, measuring 61.94 mm and 5.94 mm, respectively. These results are consistent with the observations of Hussain et al. (2006), who reported a gradual increase in the diameter and thickness of cookies with higher levels of flour substitution.

Moreover, the results for the spread ratio of biscuits showed a decline from 11.12 to 10.56 as the level of carrot flour increased. A consistent reduction in the spread ratio was observed with higher substitution levels of carrot flour. These findings align with those of (Ganorkar and Jain, 2014), who suggested that the decrease in spread ratio might be due to the higher dietary fiber and protein content associated with the increased amount of substituted flour. Dietary fiber and protein possess strong water-binding capacities, and with higher water absorption, a greater amount of sugar dissolves during dough mixing, influencing the spread behavior of the biscuits.

Table 4.2 Physical parameters of carrot flour incorporated biscuits

Sample	Thickness (mm)	Diameter (mm)	Spread ratio	Weight (g)	Volume (cm^3)	Density (g/cm^3)
A	5.55±0.2	60.64±0.1	11.12±0.15	13.10±0.2	15.64±0.1	0.838±0.15
B	5.62±0.1	60.93±0.1	11.06±0.1	13.24±0.2	16.10±0.15	0.822±0.1
C	5.76±0.2	61.24±0.1	10.74±0.15	13.41±0.3	16.67±0.2	0.804±0.25
D	5.85±0.1	61.46±0.3	10.68±0.2	13.29±0.3	17.05±0.1	0.780±0.15
E	5.94±0.1	61.94±0.1	10.56±0.1	13.37±0.3	17.39±0.1	0.769±0.25

*Values represent the mean of three determinations ± standard deviation. The figures shown in parentheses indicate the corresponding standard deviations.

4.3 Effect of incorporation of carrots flour on biscuits

Biscuits prepared with varying levels of carrot flour incorporation were evaluated for sensory characteristics. The evaluation was carried out using a nine-point hedonic rating scale, where 1 represented the lowest and 9 the highest score. Ten semi-trained panelists were selected to assess the samples based on different quality attributes, including appearance, taste, color, flavor, texture, and overall acceptability. Panelists recorded their perceptions on score sheets, and the data obtained were statistically analyzed to determine the most acceptable product.

4.3.1 Color

The mean sensory scores for color were 6.5, 6.7, 6.8, 6., and 6.3 for samples A, B, C, D, and E, respectively. The mean sensory scores for color of carrot flour incorporated biscuits are presented in Figure 4.1

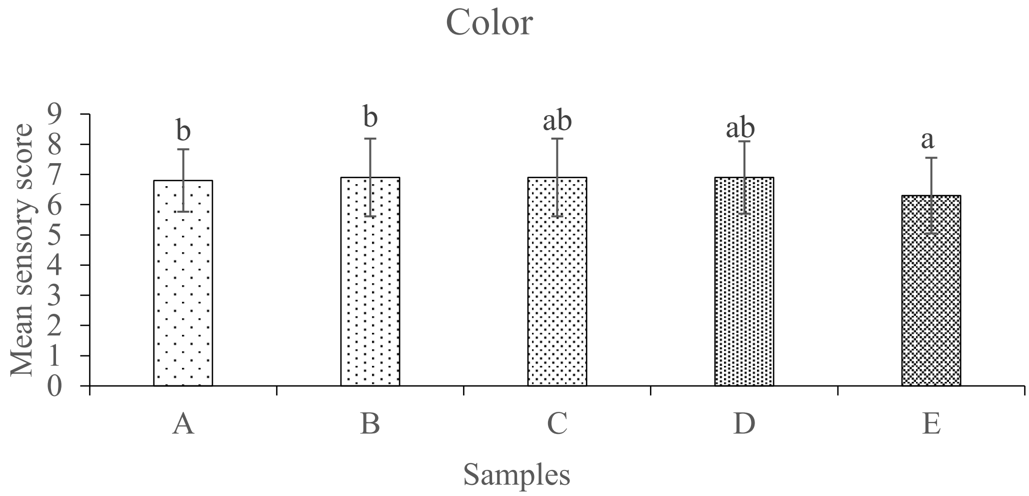

Fig 4.1 Mean sensory score for color of carrot biscuits

At a 5% level of significance, values on top of the bars with similar superscripts do not differ significantly. The vertical error bars represent the standard deviation (± SD) of scores given by ten semi-trained panelists.

Among the five formulations, Sample C obtained the highest mean sensory score (6.8), while Sample E recorded the lowest (6.3). Statistical analysis revealed that incorporation of carrot flour had a significant ($p < 0.05$) effect on the color of biscuits. Samples A and B were not significantly different from each other, while samples D and E showed a slight decline in color acceptability with increasing levels of carrot flour.

The enhancement of color at lower substitution levels (up to 6%) may be attributed to the natural orange pigment (β-carotene) present in carrot flour, which imparts a pleasant golden-brown hue upon baking. This improvement in color intensity enhances the visual appeal of biscuits and increases consumer preference. However, at higher substitution levels, the darker shade produced by excessive pigmentation and caramelization during baking may have reduced color acceptability.

Similar observations were reported by Mahdi and Shakir, (2025), who found that vegetable-based flours rich in carotenoids improved the appearance of bakery products at moderate levels of incorporation, while excessive addition led to undesirable color darkening. Sudha *et al.*, (2007) also highlighted that incorporation of fiber-rich ingredients affects Maillard browning, influencing the final color of biscuits.

Thus, incorporation of carrot flour up to 5–6% is optimal for producing biscuits with appealing color and uniform surface appearance. Beyond this level, the product tends to develop a slightly darker tone, possibly due to increased sugar–protein reactions and pigment concentration during baking.

4.3.2 Texture

The mean sensory scores for texture were recorded as 7.4, 6.3, 6.1, 6.0, and 5.8 for samples A, B, C, D, and E, respectively. The mean sensory scores for texture of carrot flour incorporated biscuits are illustrated in Figure 4.2

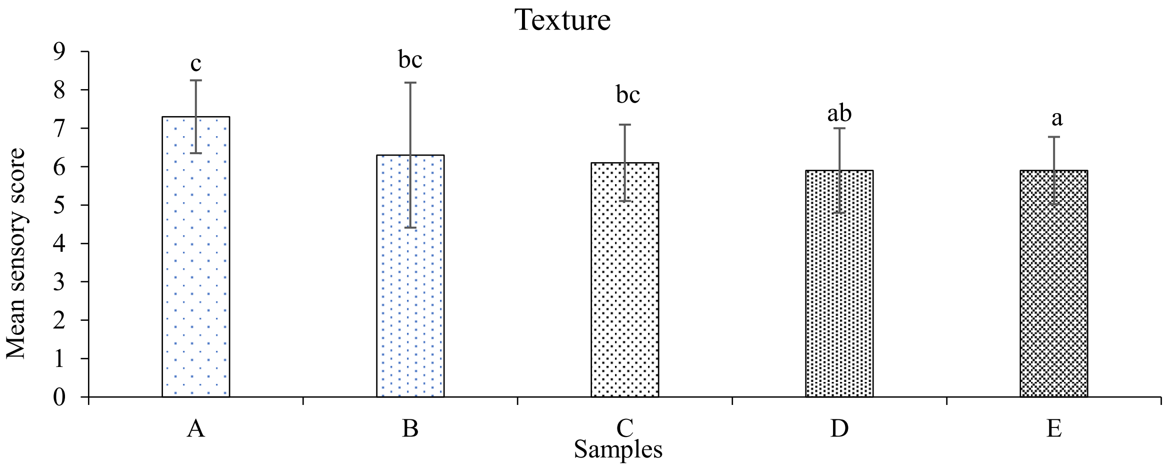

Fig 4.2 Mean sensory score for texture of carrot biscuits

At a 5% level of significance, values displayed on top of the bars with similar superscripts do not differ significantly. The vertical error bars indicate the standard deviation (± SD) of the scores assigned by ten semi-trained panelists.

Among the different formulations, Sample A (control) exhibited the highest mean sensory score (7.4), while Sample E obtained the lowest (5.8). Statistical analysis revealed a significant ($p < 0.05$) effect of carrot flour substitution on the texture of biscuits. Samples B and C did not differ significantly from each other, whereas samples D and E demonstrated a noticeable decline in textural quality.

The reduction in texture score with higher levels of carrot flour incorporation could be attributed to the increased fiber content and the reduced gluten network in the dough. Carrot flour lacks gluten-forming proteins; hence, its higher inclusion may have interrupted the viscoelastic properties of wheat gluten, leading to a denser and slightly harder texture Sudha *et al.*, (2007). The increased fiber absorbs more water, reducing dough extensibility and producing biscuits with a firmer and less crisp texture.

Similar findings were observed by Mahdi and Shakir, (2025) , who reported that partial replacement of wheat flour with vegetable-based flours, such as carrot or beetroot powder, affected the gluten structure and subsequently altered the biscuit's textural attributes. The control sample (A) maintained a desirable crispness and uniform surface, which contributed to its higher acceptability score.

As the substitution level increased beyond 5%, the biscuits exhibited a more compact and less flaky texture. This may be due to insufficient gluten development and increased brittleness resulting from the high fiber and moisture-binding capacity of carrot flour. Texture is a critical quality parameter in bakery products since it strongly influences consumer preference and product acceptability Ahmed *et al.*, (2020).

Thus, the results indicate that incorporating carrot flour up to 5% maintains an acceptable texture comparable to the control, while higher levels adversely affect the crispness and bite of the biscuits.

4.3.3 Appearance

The mean sensory scores for appearance of biscuit formulations A, B, C, D, and E were 6.8, 7.0, 6.9, 6.7, and 6.6, respectively. The mean sensory scores for the appearance of carrot flour incorporated biscuits are presented in Figure 4.5.

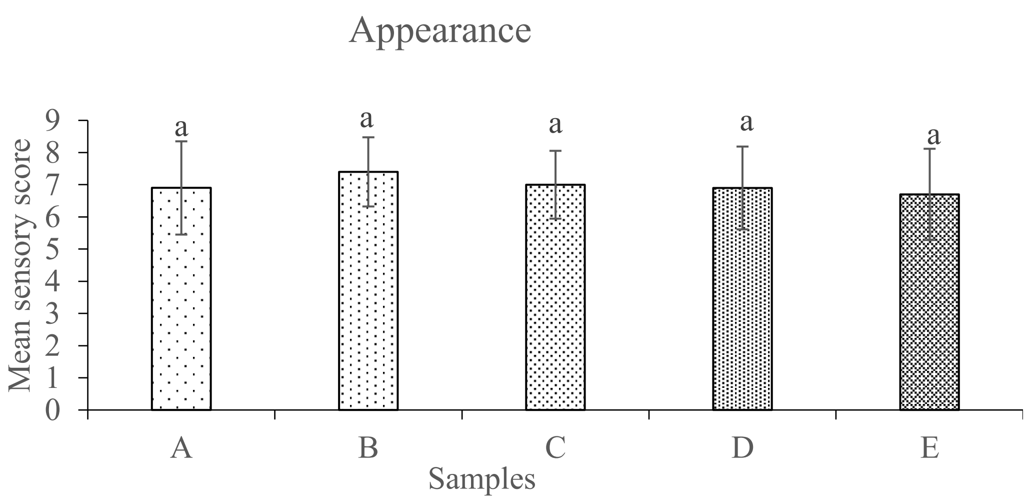

Fig 4.3 Mean sensory score for appearance of carrot biscuits

At the 5% level of significance, values on the bars with identical superscripts were not significantly different, indicating that the inclusion of carrot flour had no adverse effect on the visual appeal of the biscuits. The vertical error bars in the figure represent the standard deviation of scores assigned by ten semi-trained panelists.

Among all the formulations, Sample B received the highest score (7.0), suggesting that a moderate substitution of carrot flour provided an attractive appearance with a pleasant golden-brown color. As the proportion of carrot flour increased, a slight dullness in color and surface texture was observed, which might be attributed to the natural pigments and fiber content in carrot flour that affect browning during baking.

These findings are consistent with the observations of Sudha *et al.*, (2007), who reported that the addition of vegetable-based flours can influence surface color and texture due to variations in sugar and pigment content. Overall, the results indicate that incorporating carrot flour up to 15% can maintain the desirable appearance of biscuits without affecting consumer acceptance.

4.3.4 Taste

The mean sensory scores for taste of biscuit formulations A, B, C, D, and E were 7.1, 7.4, 7.0, 6.3, and 6.2, respectively. The mean sensory scores for taste of the carrot flour incorporated biscuits are shown in Figure 4.6

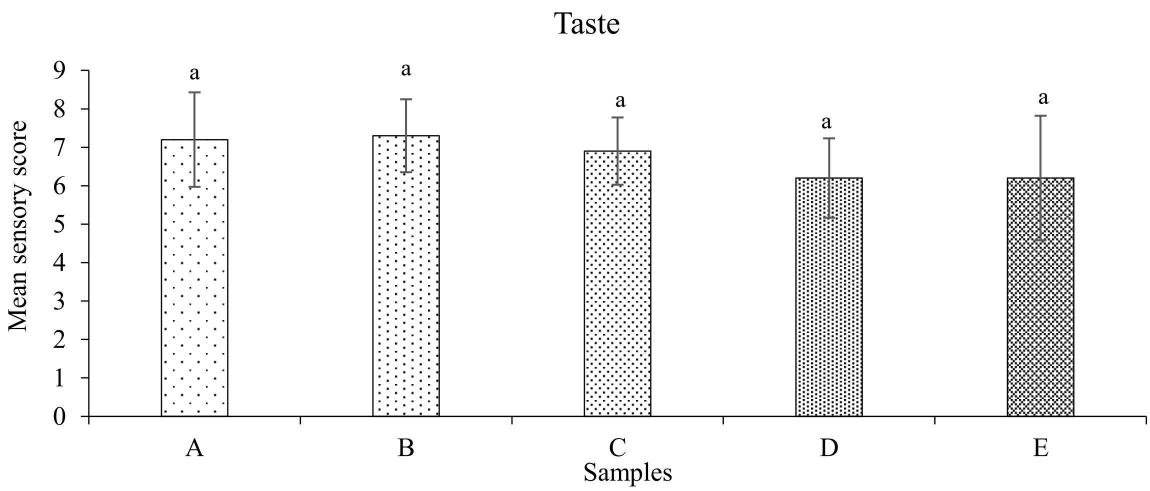

Fig. 4.4 Mean sensory score for taste of carrot biscuits

At the 5% level of significance, values on the bars with identical superscripts were not significantly different, indicating that the substitution of carrot flour did not adversely affect the taste of the biscuits. The vertical error bars represent the standard deviation of the sensory scores provided by ten semi-trained panelists.

Among the formulations, Sample B received the highest mean taste score (7.4), followed closely by Samples A and C, suggesting that moderate levels of carrot flour maintained a desirable flavor balance. The slightly lower scores for Samples D and E may be due to the stronger carrot flavor and natural earthy notes that become more pronounced at higher incorporation levels, which some panelists found less appealing.

The findings are in accordance with Proestos and Komaitis, (2006), who reported that higher substitution levels of vegetable-based flours can alter the sensory profile of baked goods due to the presence of natural pigments and compounds that influence flavor perception. Overall, the results demonstrate that incorporating up to 15% carrot flour into biscuit formulations can enhance nutritional quality without significantly compromising taste acceptability.

4.3.5 Overall acceptance

The mean sensory scores for overall acceptability of biscuit samples A, B, C, D, and E are presented in Figure 4.5

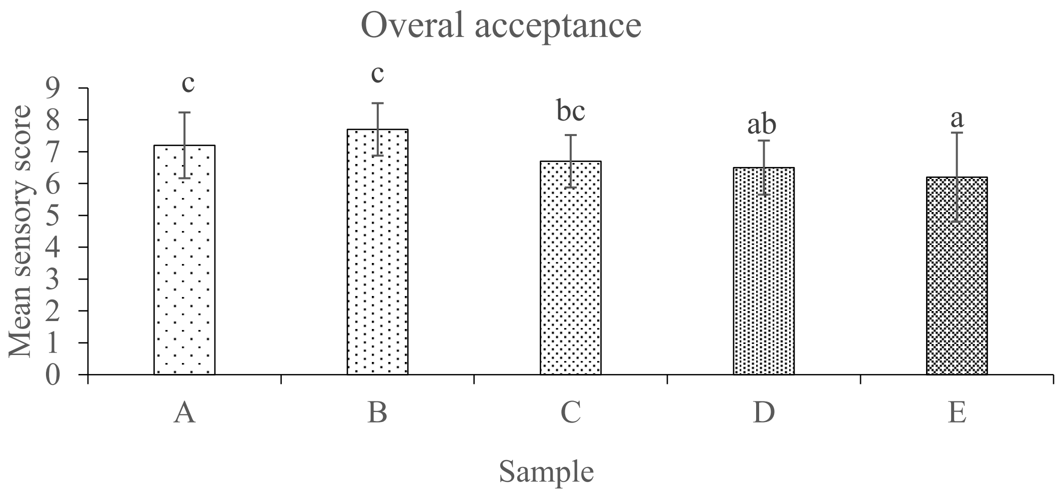

Fig 4.5 Mean sensory score for overall acceptance of carrot biscuits

Figure 4.5 presents the mean sensory scores for overall acceptability of biscuit samples A, B, C, D, and E. The error bars illustrate the standard deviation of evaluations provided by ten semi-trained panelists. Mean values sharing the same superscript letters are statistically similar at the 5% significance level ($p < 0.05$), indicating no significant difference among those samples.

Among all the formulations, Samples A and B received the highest overall acceptability scores, suggesting that these biscuits were most preferred by the panelists. Statistical analysis showed that substituting wheat flour with carrot flour had a significant effect ($p < 0.05$) on overall acceptability. Samples A and B were not significantly different from each other but were rated significantly higher than Samples C, D, and E.

A gradual decline in acceptability was observed with increasing levels of carrot flour substitution. This reduction in preference for Samples C, D, and E could be attributed to changes in color, texture, and flavor caused by higher incorporation of carrot flour. Increased amounts of carrot flour may result in a slightly firmer texture, darker coloration, and stronger carrot notes, which may not be as appealing to all panelists. Conversely, moderate substitution levels in Samples A and B enhanced the product's sensory properties by providing an attractive appearance and a mild sweetness, contributing to greater consumer acceptance.

Overall, these findings indicate that moderate incorporation of carrot flour can improve the sensory quality of biscuits, whereas higher substitution levels may negatively affect consumer preference. This observation aligns with previous studies reporting that vegetable flour addition at optimal levels enhances baked product acceptability, while excessive substitution can lead to undesirable sensory changes (Hussain *et al.*, 2006; Sudha *et al.*, 2007).

4.4 Chemical composition between best and control biscuits

Proximate analysis was conducted for the superior product (sample B), identified based on sensory evaluation, and the control sample (sample A). The obtained results are presented in Table 4.3.

Table 4.3 Composition of the product

Parameters	Control biscuits	Best biscuits
Moisture (%)	3.62±0.16	3.24±0.23
Crude Protein (db, %)	8.10±0.14	6.56±0.14
Crude Fat (db, %)	17.62±0.12	19.55±0.24
Crude Fiber (db, %)	0.23±0.01	0.65±0.01
Total ash (db, %)	1.71±0.05	3.67±0.06
Carbohydrate (db, %)	68.72±0.34	66.33±0.26
Calcium(mg/100gm)	58.33±0.14	67.94±0.16
Potassium(mg/100gm)	210.2±0.36	263.37±0.32
B-Carotenoids(mg/100gm)		3.04±0.01

*The values represent the mean of three determinations ± standard deviation, with the figures in parentheses indicating the corresponding standard deviations.

Table 4.3 presents the formulation of biscuits enriched with carrot flour. The ash content of the carrot-enriched biscuits showed an increase, which may be attributed to the higher levels of minerals, such as calcium and potassium. The moisture content varied from 2.82% in the control wheat biscuits to 3.24% in the carrot-enriched biscuits. The decrease in moisture content may be associated with a reduction in protein levels. Mustafa *et al.*, (1986) observed that a reduction in protein content led to lower moisture levels in bakery products. The fat content of biscuits containing carrot flour (CIB) was higher compared to those made with only wheat flour, likely due to the ability of carrot flour to retain oil during baking Ganorkar and Jain, (2014). Increased oil retention enhances both the texture and flavor of the biscuits. Carrot is considered a rich source of crude fiber, which led to an increase in fiber content in the carrot-enriched biscuits. The protein content of the biscuits varied from 5.90% in the carrot-added biscuits to 7.62% in the wheat-only biscuits. With higher levels of carrot flour incorporation, the ash content of the biscuits also increased, likely due to the use of low-protein soft wheat flour.

The elevated ash content in biscuits enriched with carrot flour is nutritionally valuable, especially in underdeveloped countries such as Nepal. The incorporation of carrot flour enhances the mineral content of the biscuits, which is reflected in their higher ash values. This increase in minerals is further evidenced by higher levels of calcium (65.45 mg/100 g) and potassium (253.60 mg/100 g) Aziz *et al.*,(2011). Moreover, carrot flour biscuits provide a notable amount of β-carotene (2.93 mg/100 g).

4.5 Cost of the carrot flour incorporated biscuit

The overall cost associated with the best biscuit (Sample B) was determined, and the cost of carrot flour incorporated biscuits per 100 g was NRs 34.68, including overhead costs and a 10% profit. Calculation is shown in the appendix E.

Part V

Conclusion and recommendation

5.1 Conclusion

Based on the findings of this research, the following conclusions were drawn:

1. Carrot flour can be incorporated into wheat flour up to a level of 5% without causing any negative impact on the sensory attributes of the biscuits.
2. The nutritional profile of the biscuit (best sample) was enhanced, particularly in terms of fiber, mineral content, and β-carotene levels.
3. Chemical analysis showed a significant increase in dietary fiber, ash (mineral content), and β-carotene in biscuits containing carrot flour compared to the control sample.
4. Physical characteristics such as shape, surface appearance, color, and texture remained acceptable at the optimum level of carrot flour incorporation.
5. The production cost of biscuits containing carrot flour was economical and affordable for the general public, indicating strong potential for commercial production.
6. Cost calculation showed 100g of carrot incorporated biscuit cost NRs. 34.68.

5.2 Recommendation

The study can be further extended in the future based on the following recommendations:

1. As biscuits containing 5% carrot flour demonstrated the best sensory characteristics, future formulations should adopt this level to achieve optimal consumer acceptability.
2. Carrot flour can also be used to prepare other products such as cookies, bread, and muffins.

Part VI

Summary

The study entitled "Effect of Incorporation of Carrot Flour on the Quality of Biscuits" was conducted to develop nutritionally enriched and low-cost biscuits by partially substituting wheat flour with carrot flour. Carrot (Daucus carota) is rich in dietary fiber, minerals, and β-carotene, making it a valuable functional ingredient for improving the nutritional profile of bakery products.

Different formulations of biscuits were prepared by incorporating carrot flour at varying levels while keeping other ingredients such as fat, sugar, salt, SMP, and baking powder constant. The prepared biscuits were evaluated for proximate composition and sensory attributes such as color, flavor, texture, taste, and overall acceptability.

The results indicated that the incorporation of carrot flour significantly influenced both nutritional composition and sensory quality of biscuits. The optimized sample containing 5% carrot flour (CF:WF = 5:95) recorded the highest sensory score and was most preferred by the panelists. The proximate analysis of the optimized biscuit showed moisture content of 3.24%, crude protein 6.56%, crude fat 19.55%, crude fiber 1.70%, total ash 3.67%, and carbohydrate 65.28%. The addition of carrot flour also enhanced the β-carotene content 3.04 %, improving the nutritional and functional value of the product. The cost analysis revealed that the production cost of carrot flour incorporated biscuits was reasonable and affordable for general consumers, indicating good commercial potential.

Hence, the study concludes that partial replacement of wheat flour with up to 5% carrot flour produces biscuits with superior sensory quality and improved nutritional value, offering a practical approach to promote the utilization of underused agricultural resources like carrots in value-added food products.

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Appendices

Appendix A

Sensory evaluation score sheet of biscuits

Date:

Panelist Name:

Name of the products: Carrot flour incorporated biscuits

Dear panelist, you are provided with 6 samples of carrot flour incorporated biscuit with one control and rest are of varying carrot flour content. Please test the following sample of biscuits and check how much you prefer for each of the samples. Give the points for your degree of preferences for each samples as shown below:

Sample	Appearance	Taste	Color	Texture	Overall acceptance
A					
B					
C					
D					
E					

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

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

Any Comments: ………………………………………………………………………………

…………………………………………………………………………

Signature

Appendix B

One-Way ANOVA Results for Sensory Analysis

Table B.1 ANOVA for color

	Sum of squares	df	Mean Square	F	Sig.
Between Group	12.920	4	3.23.	6.403	.000
Within Group	22.700	45	.504		
Total		35.620	49		

Table B.2 ANOVA for texture

	Sum of squares	df	Mean square	F	Sig.
Between Group	19.680	4	4.920	9.840	0.000
Within Group	22.500	45	.500		
Total	42.180	49			

Table B.3 ANOVA for appearance

	Sum of Squares	df	Mean Squares	F	Sig.
Between Group	5.00	4	1.250	2.885	0.33
Within Group	19.500	45	.433		
Total	24.500	49			

Table B.4 ANOVA for taste

	Sum of Square	df	Mean Square	F	Sig.
Between Group	4.880	4	1.220	2.590	.049
Within Group	21.200	45	.471		
Total	26.080	49			

Table B.5 ANOVA for overall acceptance

	Sun of squares	df	Mean Square	F	Sig..
Between Group	19.880	4	4.970	11.468	.000
Within Group	19.500	45	.433		
Total	39.380	49			

Appendices C

Table F.1 t-test (two product assuming unequal variance) for moisture content control product (product A) with best (product B)

	Product A	Product B
Mean	3.82	3.68
Variance	0.0256	0.529
Observations	3	3
Hypothesized mean difference	0	
df	4	
t Stat	0.865474	
P(T<=t) one tail	0.2178	
t Critical one-tail	2.131847	
P(T<=t) two tail	0.4356	
t Critical two tail	2.776445	

Table F.2 t-test (two product assuming unequal variance) for protein of the control product (product A) with best (product B)

	Product A	Product B
Mean	7.93	6.13
Variance	0.0196	0.0196
Observations	3	3
Hypothesized mean difference	0	
df	4	
t Stat	15.74672	
P(T<=t) two tail	4.75E-05	
t Critical two-tail	2.131847	
P(T<=t) two tail	9.5E-05	
t Critical two tail		

Table F.3 t-test (two product assuming unequal variance) for fat of the control product (product A) with best (product B)

	Product A	Product B
Mean	17.58	18.81
Variance	0.0144	0.576
Observations	3	3
Hypothesized mean difference	0	
df	3	
tStat	-7.93962	
P(T<=t) two tail	0.002083	
t Critical two-tail	2.353363	
P(T<=t) two tail	0.004167	
t Critical two tail	3.182446	

Table F.4 t-test (two product assuming unequal variance) for crude fiber of the control product (product A) with best (product B)

	Product A	Product B
Mean	1.44	4.726667
Variance	0.0025	0.049233
Observations	3	3
Hypothesized mean difference	0	
df	2	
t Stat	-25.0283	
P(T<=t) two tail	0.000796	
t Critical two-tail	2.919986	
P(T<=t) two tail	0.001593	
t Critical two tail	4.302653	

Table F.5 t-test (two product assuming unequal variance) for total ash control product (product A) with best (product B)

	Product A	Product B
Mean	1.44	4.72667
Variance	0.0025	0.049233
Observations	3	3
Hypothesized mean difference	0	
df	2	
t Stat	-25.0283	
P(T<=t) two tail	0.000796	
T Critical two-tail	0.919986	
P(T<=t) two tail	0.001593	
t Critical two tail	4.302653	

Table F.4 t-test (two product assuming unequal variance) for carbohydrate control product (product A) with best (product B)

	Product A	Product B
Mean	73.45	70.9
Variance	0.1156	0.3241
Observations	3	3
Hypothesized mean difference	0	
df	3	
t Stat	6.660741	
P(T<=t) two tail	0.003449	
T Critical two-tail	2.353363	
P(T<=t) two tail	0.006898	
t Critical two tail	3.182446	

Appendix D

Apparatus Required

1. Grinder
2. Heating arrangement
3. Thermometer
4. Digital electronic balance
5. Beaker
6. Volumetric flask
7. Measuring cylinder
8. Conical flask, funnel, test tube
9. Soxhlet assembly
10. Stuffer
11. Petri plate
12. Hot air oven
13. Filter paper
14. Centrifuge
15. Kjeldahl apparatus
16. Digestion flask

Chemical Required

1. Petroleum ether
2. Sulphuric acid
3. Potassium sulphate
4. Sodium hydroxide
5. Boric acid
6. Ethanol
7. Acetic acid
8. Distilled water
9. Folin-Ciocalteuphenol reagent
10. Phenolphthalein

Appendix E

Table E.1 Cost calculation of the product

Particulars	Cost (NRs/kg)	Weight in a lot(g)	Cost (NRs)
Wheat flour	120	85	10.2
Carrot flour	80	15	1.2
Sugar	85	30	2.5
Fat	400	20	30
SMP	480	4	1.92
Salt	25	0.3	0.0075
Baking powder	125	1	0.125
Raw material cost			45.95
Processing and labor cost (10% of raw material cost)			4.60
Profit (10%)			5.05
Grand total cost			55.60
Average weight of CIB (g)		13.44	
Total no. of CIB formed		12	
Total weight of CIB(g)		160.3	
Total cost of CIB (NRs/100g)			34.68

Photo gallery

Plate1: Slice of carrots

Plate 2: Drying chamber

Plate 3: Dry carrot

Plate 4: Preparation for baking of biscuit

Photo gallery

Plate 5: Lab analysis

Plate 6: Sample for sensory analysis

Plate 7: Sensory evaluation of carrot flour incorporated biscuit