PREPARATION AND STORAGE STABILITY OF PECTIN COATED BANANA CHIPS.

by

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

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Approval Letter

This *dissertation* entitled *Preparation and Storage Stability of Pectin Coated Banana Chips* presented by Dipendra Raj Pandey has been accepted as the partial fulfillment of the requirement for the B. Tech. degree in Food Technology.

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(Dipendra Raj Pandey)

Abstract

This work was carried out to prepare pectin coated banana chips and to evaluate its sensory and physiochemical properties and storage stability. The unripe malbogh banana (*Musa acuminata)* were collected from Morang and sunflower oil was collected from local market of Dharan. Proximate analysis of raw banana and physiochemical analysis of sunflower oil was carried out. Bananas were washed, peeled, sliced, blanched and treated with KMS. Then, it was dipped in pectin solution, drained, dried and fried in sunflower oil. The chips were drained, cooled, packed in PP packaging and stored. The banana chips were prepared by coating pectin at 0, 0.5, 1, 1.5, 2, and 2.5 % and named as sample A, B, C, D, E and F respectively. The samples were subjected to sensory evaluation (appearance, color, taste, texture and overall acceptance) by quality scoring method for consumer acceptability and the sensory data were analyzed by two-way ANOVA (no blocking) using Genstat and means were compared using LSD at 5 % level of significance.

The results shows that the pectin coating significantly improved the physicochemical attributes (fat, fibre, and carbohydrate) except moisture, protein and ash compared to non-coated sample. The proximate composition of raw banana in terms of moisture content, crude protein, crude fat, crude fibre, ash and carbohydrate were found to be 69.08, 1.15, 0.28, 0.51, 0.85 and 28.13 % respectively. The reduction of oil uptake was highest in 2.5 % pectin coated banana chips i.e., 30.22 %. From sensory evaluation, 1.5 % pectin coated banana chips was found to be significantly ($p \leq 0.05$) superior. The shelf life of this product was estimated in terms of moisture, acid value and peroxide value and the sample was fit for consumption till the last day of analysis (40 days). These findings enhance our knowledge to produce better fried banana chips with less oil absorption using pectin coating.

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List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of variance
AOAC	Association of Analytical Communities
AV	Acid Value
BOPP	Biaxially Oriented polypropylene
CMC	Carboxymethyl cellulose
DRI	Daily Recommended Index
DM	Dry Matter
FFA	Free fatty acid
HDPE	High Density Polyethylene
HMP	High Methoxyl Pectin
LSD	Least Significant Difference
KMS	Potassium metabisulphite
PP	Polypropylene
PV	Peroxide Value

Part I

Introduction

1.1 General introduction

The word ‘banana’ refers to the fruit of evergreen monocotyledonous, perennial, giant herb, exclusively subtropical belonging to the genus Musa from the family Musaceae. They are high energy fruit rich in carbohydrates and also good source of potassium, iron, phosphorous, vitamin C and B6 (Robinson and Galán Saúco, 2010). A lot of products obtained from the processing of Banana flesh are available in the market. These products have a wide diversity. Banana powder, banana flour, banana chips, banana biscuits, banana sauce, banana jam, banana juice, and banana pulp are most famous one counted (Ranjha *et al.*, 2022).

For banana chip production deep fat frying is a conventional method, basically it includes the immersion of banana slices in a vegetable oil at temperature of around 110-160°C that causes drying by means of frying. Deep-fat frying generally occurs at high temperatures under atmospheric pressure causing the absorption of a high amount of fat, which could be up to 50% of the total weight of the fried food (Sothornvit, 2011).

This high fat content of fried product has been related to obesity and coronary heart diseases. During deep-frying, the internal moisture of food is evaporated while oil is confined to the external surface. These processes are influenced by factors such as oil quality, frying conditions (temperature and time), and pre-frying treatments. The increase in the consumer’s interest for more healthy food products has led to the trend of reducing lipid uptake in fried-food products while maintaining acceptable organoleptic characteristics. Edible coatings prepared from food hydrocolloids, such as cellulose and derivatives, gums, alginate, whey protein, albumin or pectin have been studied for such purpose. The high-water absorption capacity and retention of the original food firmness of these coatings decrease the moisture loss by evaporation, reducing lipid uptake (Falguera *et al.*, 2011).

1.2 Statement of the problem

Nutrition and health awareness, concern leads consumers to choose reduced- or low-fat/-calorie foods. Oil content is often not necessary for product quality and is disadvantageous for both the food manufacturer (high operating cost) and the consumer. The specialty of the

fried products is their improved palatability and sterile and dry nature with a relatively longer shelf life. However, fried foods are becoming incompatible with the recent consumer trends towards healthier and low-fat food products. The increased health awareness of consumers has emphasized the need to limit oil consumption, calories originating from fat, and cholesterol (Bouchon and Pyle, 2004). Excess consumption of oil results in health problems such as coronary heart disease, cancer, diabetes, and hypertension (Saguy and Dana, 2003). Frying process involves high temperature and exposure to oxygen which causes other undesirable effects such as degradation of important nutritional compounds and the generation of toxic molecules in the fried product or in the frying oil (Fillion and Henry, 1998). The above-mentioned risks associated with frying have changes the market trends towards healthy, low fat snack food products. Therefore, this work was conducted to study the effect of pectin as edible coating on decreasing oil absorption in banana chips during deep-fat frying.

1.3 Objectives

1.3.1 General Objectives

The general objective of the dissertation work was to prepare pectin coated banana chips and to evaluate its storage stability.

1.3.2 Specific objectives

The specific objectives of this dissertation work were to:

1. To analyze the proximate composition of unripe banana and oil.
2. To study the effect of pectin coating on the oil uptake of banana chips.
3. To evaluate the sensory properties of pectin coated banana chips.
4. To analyze the pectin coated banana chips for its proximate composition.
5. To estimate acceptability period of the chips.

1.4 Significance of the study

Nowadays, consumers are concern about healthy diet. Interest in low fat products has recently increased. Fried foods contain high amount of fat, yet remain popular. Interest in low fat product has recently increased as excess fat consumption is considered to heighten

blood cholesterol, high blood pressure and coronary heart disease. Edible coating can reduce the excessive oil uptake due to their interesting thermo-gelling properties and at the same time they are invisible and have no negative influence on the sensory attributes of fried foodstuff. Even more, fried products will have low fat content with improved nutritional values, higher crispiness and better palatability (Kurek and Scetar, 2017). Pectin was shown to be the most effective coating for preparing low fat fried chips since it aids to reduce oil absorption in fried products as they are a good barrier to lipids, oxygen, and carbon dioxide during frying (Albert and Mittal, 2002).

This study specifically determines the effect of pectin coating concentration on the reduction of oil uptake in banana chips and the storage stability of the coated chips. Once the study is completed, it will be beneficial to the health of the consumer. Furthermore, the improved fried products can be produced.

1.5 Limitation of the study

The limitations of our study were:

1. Instrumental color and textural analysis were not carried out.
2. Only one packaging materials was used.
3. Shelf life was only studied for 40 days.

Part II

Literature review

2.1 Banana

Banana (*Musa* spp.) is a popular and widely consumed fruit worldwide. Bananas are monocotyledons and belong, to the family Musaceae. They are tree-like perennial herbs, two to nine meters tall, with an underground rhizome or corm, a pseudostem composed of leaf sheaths and a terminal crown of leaves through which an inflorescence emerges (Seymour, 1993). Being one of the oldest cultivated plants, bananas possess a high nutritional potential.

Banana is one of the fruits whose all parts could be preserved and processed (Shankar *et al.*, 2017). There are a number of products derived from the preservation and processing of banana flesh and non-flesh parts. Banana flesh can be processed to obtained different products like banana powder, banana flour, banana chips, banana biscuits, banana sauce, banana jam, banana juice, banana pulp, etc. (Ranjha *et al.*, 2022).

Banana peel can simply be dried and used as feed for draught animals (livestock). High quality feed could be obtained by banana peel because of its good nutrient contents. Pectin, starch, and polysaccharides can also be extracted from banana peel (Zhang *et al.*, 2008). Banana stem is rich in nutrients it can simply be dried and used as feed for animals. Being high in potassium it can be applied to soil as a fertilizer to increase potassium content and increase the organic content of soil. Banana stem can also be processed to make paper. Banana leaves possess a good fiber content, it can be processed to make fabrics, papers, and ropes (Zhang *et al.*, 2008).

2.1.1 Historical Background

Banana has been a significant factor in the development of human civilization. The fruits of the genus Musa go by more than 100 common names all throughout the world. The name Musa was coined by Linnaeus and is comparable to a number of Arabic phrases for the fruit. However, the name may possibly be related to Antonius Musa, a Roman physician who lived in the first century B.C. Honoring the Greek deities, "Muses" is another explanation for the name. The term "banana" was adopted in the New World to describe the fruit's peel (Morton, 1987).

Banana that is a significant tropical fruit is one of the oldest fruits that humans are aware of. The banana was initially cultivated in south-east Asia's hot, tropical climates (Bahadur *et al.*, 2020). Sanskrit literature such as the "Ramayana," Kautilya's "Arthashastra," and the Tamil classic "Shilappadikaram" all make explicit mention to banana (Mohandas and Ravishankar, 2016). Bananas are thought to have originated in Southeast Asia, specifically in the Philippines, Malaysia, Indonesia, and Papua New Guinea and cultivation started at around 8000 to 5000 BCE (Ploetz *et al.*, 2007). Bananas were introduced to new locations over a period of thousands of years when people migrated and traded across the Pacific Islands. Around the 5th century, bananas found their way to Africa via trade and migration. Bananas were discovered by European explorers on their voyages to the Caribbean and Central America. Bananas were introduced to the Americas by the Portuguese and Spanish in the 15th and 16th centuries. Commercial banana growing began in the 19th century in nations such as Honduras, Costa Rica, and Panama. Transportation advancements, particularly the construction of railroads and, subsequently, the Panama Canal, allowed the shipping of bananas to North America (Gowen, 2012; Simmonds, 1962). The Cavendish subgroup of bananas, which gained popularity in the mid-20th century, dominates the modern banana industry (Seah and Nair, 2004).

2.1.2 Production in Nepal

Banana is a high-value agricultural product and a major fruit in Nepal in terms of the potential growing area, production, and domestic consumption. The total productive area of banana plantations in 2012/2013 was 11,864 hactars, with a total production of about 182,005 tonnes. Although there is great potential for banana production in Nepal, there are few commercial banana plantations and current productivity is low. According to the Ministry of Agriculture, the average productivity is 13.2 tonnes per hectare, with maximum yields reaching up to 20 tonnes per hectare (Sangraula, 2018). Chitwan district is regarded as the primary hub for banana production, followed by Saptari, Jhapa, Morang, and Rupandehi districts (Pant *et al.*, 2023). 300-500 cultivars of banana are growing in more than 100 countries, mainly in Brazil, India, and Philippines with an annual production of approximately 114 million metric tons of bananas are produced annually worldwide from 5.6 million hectares of land (Ruwali *et al.*, 2022).

2.1.3 Taxonomy

Musaceae is the family that includes bananas (Musa sp.). There are more than 1000 varieties of banana produced and consumed in the world, among which three common species of Musa (*Musa cavendishii*, *Musa paradisiaca*, and *Musa sapientum*) are widely grown. *M. cavendishii*, known as dessert banana, is sweeter and less starchy than *M. paradisiaca*, while *M. sapientum*, known as true banana, is usually eaten raw when fully mature (Mohapatra *et al.*, 2010). *Musa acuminata* and *Musa balbisiana* are the two species of wild bananas. These two species are the sources of almost all edible parthenocarpic bananas today. *Musa paradisiaca* is the name given to the resulting hybrid of *Musa acuminata* and *Musa balbisiana* (Valmayor et al., 2000).

Kingdom: Plantae

Subkingdom: Tracheobionta

Division: Magnoliophyta

Class: Liliopsida

Order: Zingiberales

Family: Musaceae

Genus: Musa

2.1.4 Morphology

Bananas and plantains are large herbaceous plants which can confer the aspect of a tree as shown in Figure. 2.1. One wild species (*Musa ingens*) can reach 16 m tall, although most commercial types grow to between 2 m and 5 m. The main trunk is a pseudostem formed by the concentric assembly of the leaf sheaths (modified petioles), which is crowned by a rosette of very large oblong to elliptic leaves. The leaf blade (up to 2 m^2) normally is transversely split (by wind) between parallel veins, which assists cooling and photosynthesis. Leaves are produced successively until the single inflorescence is cast, and are present in variable number (10 to 20 under healthy conditions) depending on the variety, the climate and cultivation practices. Each leaf takes 7-14 days to emerge. The true stem is a subterranean

organ (corm) which extends upwards at the core of the pseudostem until culminating in the inflorescence which emerges from the top. The meristem of the true stem produces all other parts of the plant. The many main roots emerging from the rootstock are rather straight, adventitious cords (2-10 mm in diameter) that extend up to 2-3 (-5) m outwards, from which (with a density of 8 to 10 per cm of cord root) branch lateral roots (0.3-4 mm in diam) that extend up to 1 m, and from which tertiary rootlets extend for several cm. Under usual commercial growing conditions, most of the root system is within the first 60-100 cm radius from the plant and reaches to 20-40 cm in depth (though roots have been found to 150-180 cm deep in exceptional soils) (OECD, 2009).

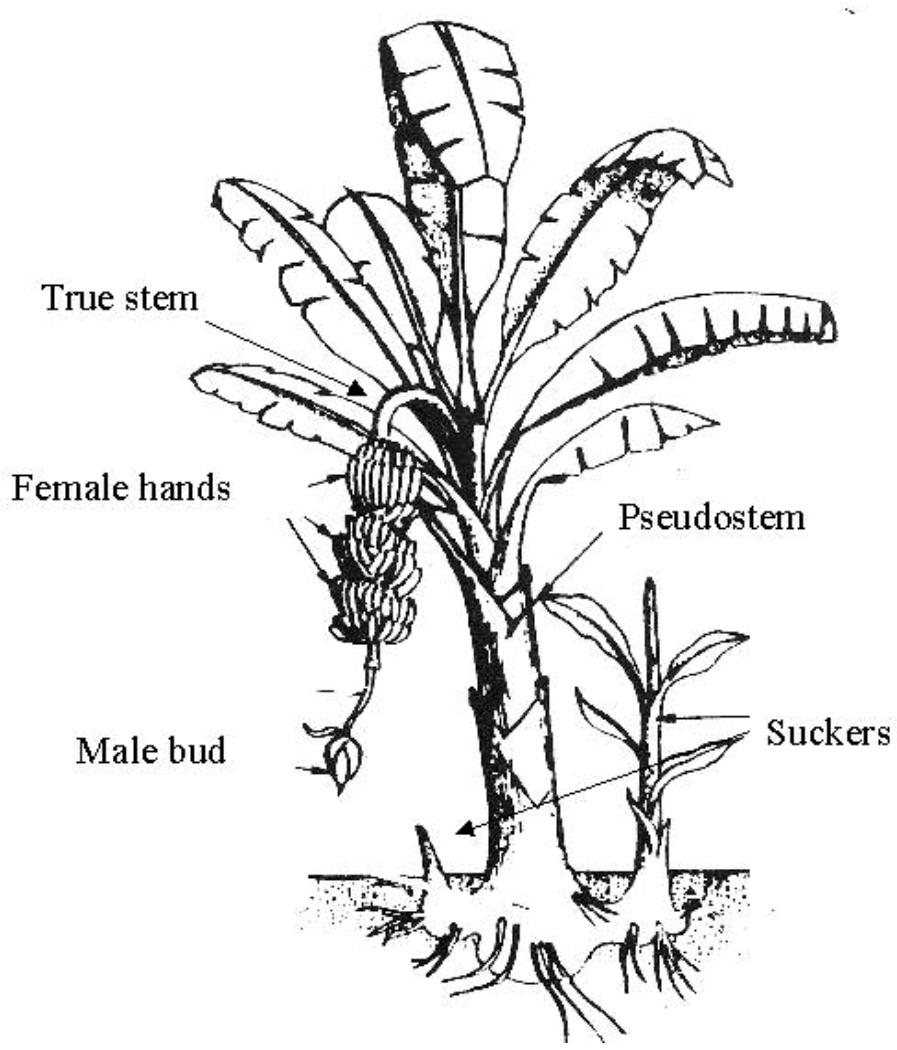


Fig. 2.1 Schematic representation of a cultivated banana plant

Source: OECD (2009)

2.1.5 Nutritional composition of banana

All the parts of this plants have nutritional and medicinal importance (Kumar *et al.*, 2017). The fruit is a good source of carbohydrates, dietary fiber, vitamins, and minerals (USDA, 2019). The nutritional composition of raw banana is shown in Table 2.1.

Table 2.1 Nutritional composition per 100 g of raw banana

Nutrients	**Amount (per 100g)**
Moistutre	74.9 g
Calorie	89 kcal
Protein	1.09 g
Total fat	0.33 g
Ash	0.82 g
Carbohydrate (by difference)	22.8 g
Dietary fiber	2.6 g
Calcium	5 mg
Iron	0.26 mg
Magnesium	27 mg
Phosphorous	22 mg
Potassium	358 mg
Vitamin C	8.7 mg

Source: USDA. (2018)

Bananas help the body to retain calcium, phosphorus, and nitrogen, as these all help to retain healthy tissues (Kumar *et al.*, 2017). Banana is a good supplementary staple food. Banana provides 89 KCal of energy per 100 g, 1.09g of protein that serves 2% of daily recommended

intake (DRI). Bananas have high fiber content. A medium size banana provides about 2.6 g of fiber and water-soluble fiber shares one third of this amount i.e., one medium size banana provides 1 g of soluble fiber. A normal size banana provides about 22.8 g of carbohydrates serving 12% of daily recommended intake (DRI). Bananas also serve as very powerful antioxidant, being rich in Vitamin C.

It has been reported that bananas also contain various bioactive compounds such as phenolic compounds, carotenoids, and phytosterols, which possess potential health-promoting properties (Singh et al., 2016). Bananas are also an excellent source of vitamins, including:

i. A - aids in healthy teeth, bones, soft tissue, and more
ii. B6 - aids the body's immune system, promotes brain health, heart health, and more
iii. C - aids in healing, growth of tissue, ligaments, and more
iv. D - helps the body to absorb calcium (Kumar *et al.*, 2017).

2.2 Banana Chips

It is the snack product prepared from unripe, firm, mature banana fruits. It is consumed after frying the slices of banana like potato and is analogue to potato chips. Banana chips are popular snack food in India and certain parts of European countries and they are more expensive than other common snacks. They are kept in sealed can or tin and are stored at room temperature (29-32ºC). Antioxidants are incorporated to keep the product from becoming rancid and so thereby increasing shelf life few hours to several months (Gautam, 2010).

Fried banana chips are reported to keep well for 2-3 months. A product with a pale yellow color is obtained when a stainless steel knife cuts slices; the slices are dipped in acidulated water, washed water and dried in sun or in a home dryer at 140-150ºF after exposure to SO_2 fumes for an hour (Gautam, 2010).

2.2.1 History and Origin of Banana Chips

Banana chips are a popular snack food that is enjoyed globally. They are made by slicing bananas into thin round shapes, frying them in hot oil until they turn crispy, and seasoning them with salt, sugar, or other flavorings. Banana chips have been in existence for many

years, and their origin can be traced back to India and the Philippines (Seyedabadi et al., 2017). In India, banana chips are known as "balekayi chips," which means plantain chips. They are a common snack food in South India and are often served with tea or coffee. In the Philippines, banana chips are called "saging chips" and are a popular snack food, especially in the southern part of the country.

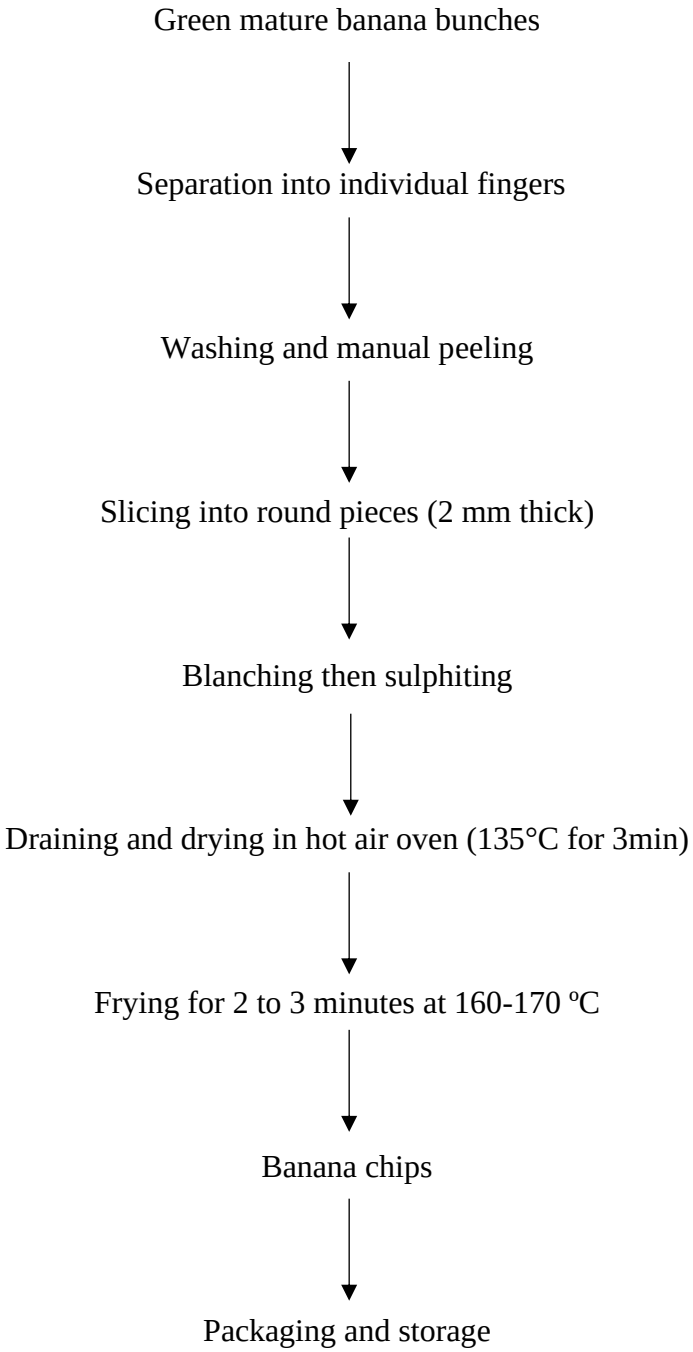
Bananas are usually consumed in its fresh ripe form. But banana in its ripe form has a very little shelf life ranging from days to weeks. The ripe bananas also cause troubles while storage and transport. A lot of loss in term of income may be observed as the product degenerates. To increase income and to avoid the loss from degeneration, bananas are processed into different products with wide diversifications. Banana is one of the fruits whose all parts could be preserved and processed. There are a number of products derived from the preservation and processing of banana flesh and non-flesh parts. These products have a wide diversity. Banana powder, banana flour, banana chips, banana biscuits, banana sauce, banana jam, banana juice, and banana pulp are most famous one counted (Ranjha *et al.*, 2022)

Banana can be consumed raw, steamed or boiled. One of the methods to process banana is to make banana chips. Banana chips are processed using deep-fried or dried slices of bananas (Aida *et al.*, 2016). Usually, the chips are produced from under ripe bananas, of which slices are deep-fried in oil. The frying process causes a number of physicochemical changes such as water loss, oil uptake, crust formation, starch gelatinization, and color changes (Mir-Bel *et al.*, 2012).

2.2.2 Production of banana chips

The production of banana chips is widespread activity in many banana-growing countries. The chips are either fried in oil or dried (Anurag and Chauhan, 2018). The process of making banana chips involves several steps, including selecting the right type of banana, slicing them thinly and uniformly, pre-treating the slices to prevent browning, frying them in oil, and seasoning them with salt or other flavor.

General process for preparation of banana chips is shown in Figure. 2.2



Source: Gautam (2010)

Fig. 2.2 Preparation of banana chips

The results obtained from different study indicates that fried banana chips were found to be better quality and acceptability. Baked banana chips were lower in quality and had weak acceptability compared with fried banana chips (Elmoneim *et al.*, 2014). But fried foods usually contain a significant amount of saturated and unsaturated fats, in some cases up to 1/3 of the total product mass. This high fat content has been related to obesity and coronary heart diseases. High oil uptake in fried food is a cause of concern and people are getting health conscious day by day (Arslan *et al.*, 2018).

2.2.2.1 Selection of raw material

It is essential to use under-ripe green bananas as these have the correct texture for drying and frying. Ripe and over ripe bananas and plantains should not be used, as the texture is too soft to make the chips. The process suitability of raw materials is a function of botanical properties like geometric, functional or sensory quality etc., hence careful selection is necessary for the efficient mechanized process and good product. Mature unripe and firm banana as best for banana chips. Generally, *M. paradisica* is used (Gautam, 2010).

2.2.2.2 Washing

Thorough washing of banana is necessary to remove any adhering, dust, dirt, and foreign matter and to reduce microbial loads that ultimately help saving machine damage and maintain clean. The graded fruits and vegetables are washed with water in different ways, such as soaking or agitating in water, spray etc. Agitation of the washing water is affected by compressed air. Spray washing is, however, the most efficient method (Giridhari *et al.*, 1986).

2.2.2.3 Grading and sorting

Grading considers factors like size, shape, color, density and defects. Not only it helps to maintain the quality but also facilitates in mechanization of different operations, consequently increasing the performance and finished product yield (Gautam, 2010). Bananas can be graded either manually or by using different types of mechanical equipment.

2.2.2.4 Peeling

Bananas can be peeled and cut by hand with the help of special stainless-steel knives.The peeling of unripe bananas and plantains is facilitated by immersing the fruit in hot water at 93ºC for 3 minutes (Sanchez and Mercado, 1978).

2.2.2.5 Slicing

After peeling slicing is done by stainless steel knife, mechanical slicer (Hobart slicer) in varying thickness. Thickness of banana slices between 1/32″- 2/ 32″ (Bai and Rao, 1969).

2.2.2.6 Blanching

In banana dehydration, blanching serves not only to inactivates the enzyme and prevent to retard development of undesirable odors and colors but also to partially cook tissue and render the cell membrane more permeable to moisture transfer. Blanching improves the flavor and loosens the skin of the fruits. Blanching is done in boiling water for a short period ranging from 2-5 minutes. It helps to clean the product and eliminate the microorganisms. Blanching removes undesirable acid and astringent taste (Giridhari *et al.*, 1986).

2.2.2.7 Sulphiting

In the preparation of banana slices, sulphiting is normally applied immediately after peeling and blanching of banana. Sulphiting is performed by dipping for varying period on varying amount of potassium metabisulphite (KMS). Generally, 15 minutes to 1 hour and 0.1% to 0.5% KMS is used (Gautam, 2010). This treatment retards the development of enzymatic browning and promotes the storage life of banana products and also protects the Vitamin C loss (Sanchez and Mercado, 1978).

2.2.2.8 Drying

After the pretreatments like blanching and sulphiting, all the pieces were drained and dried in a hot air oven at 135 ºC for 3 min to reduce the surface moisture (Singthong *et al.*, 2009) The oven dryer commonly used in food industry for predrying effectively reduces moisture content and exhibited improvement in the crispiness and decrease in oil uptake of chips (Lumanlan *et al.*, 2020).

2.2.2.9 Frying

Frying is simply a method of cooking, and involves the transfer of heat into food, with frying oil as a heat transfer medium. It is distinctive cooking process because the oil itself becomes the part of the finished food. In choosing oil for snacks, three main aspects need to be considered, viz. the commercial, the marketing and the technical. Commercially used liquid oils are groundnut, soybean, sunflower, palm oil, etc. (Shah, 1993).

Typically, ripe plantains are peeled, cut into slices or split lengthwise and fried in palm oil or groundnut oil (Patak, 2004). Banana Slices are also fried in hydrogenated fat or coconut oil at 160ºC, hydrogenated oil (Purico) at 190-200ºC. Adeva *et al.* (1968) investigated the optimum temperature for frying banana chips and concluded that a frying time of 1-2 minutes is optimum at 120-190ºC from color, texture and flavor point of view.

2.2.2.10 Packaging of banana chips

Usually, dehydrated banana chips are in BOPP, polypropylene (PP), cellophane, polyethylene, laminated aluminum foil, tin or can. They have good moisture barrier and heat sealable property so that the products can be protected from microbial, chemical deteriorations. After drying and frying, banana chips are stored in HDPE bags, which in turn are kept in sealed tin. According to Adeva *et al.* (1968), products are packed in polyethylene bags and stored in big tightly covered can at room temperature (29-32ºC).

2.2.3 Nutritional Composition of banana chips

Banana chips is rich in fiber which promote digestive health and prevents constipation. Ample amounts of fiber can also reduce the risk of having hearth disease and diabetes. Banana chips are good source of potassium, which promotes muscle function and eases digestion. For working out people, banana chips must be go-to snack to reduce muscle strain. Also, banana chips are rich in vitamins, especially vitamin C which strengthens the immune system and guard the body against infection (Gaushoul, 2022). The nutritional composition of banana chips per 100 g is shown in the Table 2.2.

Table 2.2 Nutritional composition per 100 g of banana chips

Nutrients	Amount (per 100g)
Moisture	4.3 g
Calorie	519 kcal
Protein	2.3 g
Total fat	33.6 g
Total ash	1.4 g
Carbohydrate (by difference)	58.4 g
Dietary fiber	7.7 g
Total sugar	35.3 g
Calcium	18 mg
Iron	1.25 mg
Magnesium	76 mg
Phosphorous	56 mg
Potassium	536 mg
Vitamin C	6.3 mg

Source: USDA. (2019)

While banana chips have some nutritional benefits, they also have some risks. Banana chips are high in calories which can lead to weight gain if consumed in excess. Banana chips contain high fat and sugar content. Consuming a diet high in saturated fats from processed foods is linked to a greater risk of chronic illness such as heart disease (Gaushoul, 2022).

2.2.4 Shelf life of Banana Chips

The term shelf life is generally understood to be the duration of that period, between packaging a product and using it, for which the quality of the product remains acceptable to the product user. (Matz, 2012).

The main causes of spoilage in banana chips are moisture absorption, rancidity, breakage and environmental factors such as oxygen, temperature, light and relative humidity during handling. The problem of moisture absorption is more serious than that of oxygen and hence the packaging container should have a high degree of resistance to gas and water vapor transmission (Manikantan *et al.*, 2014). Sunlight has a very strong accelerating effect on the rancidity development. On the other hand, normal fluctuations in environmental temperatures do not have strong influence on the rate of oxidation (Quast and Karel, 1972).

2.3 Oil used in frying

The mostly used oil for frying are soybean oil and sunflower oil.

2.3.1 Soybean oil

The soybean (*Glycine max*) is a legume native to East Asia, widely grown for its edible bean. Soyabean is used in many ways, like for food preparation like kinema or tofu or used as oils. Soybean is one of the dominant oilseeds used in the world, because of its favorable agronomic characteristics, high-quality protein, and valuable edible oil. They are used for cooking, frying, spreads, and shortening (Gunstone, 2011).

Soybean oil is recovered by solvent extraction or mechanical pressing. Crude oil contains primarily neutral lipids including tri-, di-, and mono-acylglycerols, free fatty acids, and phospholipids. It also contains a minor amount of phytosterols, tocopherols, and hydrocarbons. Trace metals are also found in soybean oil in concentration of ppm which reduces during refining (Gunstone, 2011). Refined, bleached, and deodorized (RBD) soybean oil is used for commercial frying, which were hydrogenated to increase stability during commercial frying and storage of fried food. However, nonhydrogenated oils are now popular alternatives to hydrogenated oils as reducing the amount of linolenic acid significantly increases the oxidative stability of soybean oils (Warner, 2008). Table 2.2 shows the fatty acid composition for the oil.

2.3.2 Sunflower oil

Sunflower (*Helianthus annuus L.*) belongs to the family Compositae. They are composed of triacylglycerols (98–99%) and small proportion of phospholipids. Unsaponifiable matter present contains tocopherols, sterols and waxes along with other substances. Fatty acid composition of sunflower oil is given in Table 2.3. Due to its relatively good oxidative stability, refined sunflower oil has been used both for domestic and industrial uses. However, the oxidative stability of vegetable oil depends not only on the amount of natural antioxidants remaining in the oil after refining, but also depends on the added antioxidants and quality parameters of the refining process (Gunstone, 2011).

In countries where sunflower oil is common edible oil, it is used as salad dressing, cooking and frying oil. Sunflower oil rarely reaches the critical value of polar compounds during continuous frying processes but results are bad for discontinuous uses. When stored in dark, soybean oil has a higher oxidative stability than regular sunflower oil, despite soybean oil content of linolenic acid. However, when stored in the light, oxidative stability of sunflower oil is higher than that of soybean oil (Gunstone, 2011). The DFTQC Nepal Standard of Sunflower oil shown in the Table 2.3.

Table 2.3 DFTQC Nepal Standard of Sunflower oil

Parameters	Value
Acid value (mg of KOH/g of oil)	< 4
Peroxide value (meqv O_2/kg of oil)	< 10
Iodine value	110-143

Source:(DFTQC, 2023)

2.4 Mechanism of oil uptake during deep frying and cooling

Oil uptake is a complex process which involves numerous physical, chemical and structural transformations during frying. The surface phenomenon is an equilibrium between adhesion and drainage with the most significant part of the fat absorption is at the end of the frying period (Ufheil and Escher, 1996). During cooling, the competition between oil outflow and

the suction within the crust results in higher fat content in potato chips (Moreno *et al.*, 2010). For example, the crust of the french fries contains about six times as much oil as the inner part (Aguilera and Gloria, 1997), while Keller *et al.* (1986) showed that the frying oil remained on the porous surface region of the french fries. This was further confirmed with the electron scanning microscope that oil was mainly located in the surface of potatoes (Lisinska and Golubowska, 2005).

Deep fat frying is a conventional frying method for chips production, basically it includes the immersion of banana slices in a vegetable oil at temperature of around 110-160°C that causes drying by means of frying. The high temperature causes an evaporation of the water, which moves away from food and through the surrounding oil. Oil is absorbed by food, replacing some of lost water (Suyatma *et al.*, 2015).

During deep frying, the water loss led to moisture evaporation expands the capillary pores resulting in oil adhering on the surface of the food. Limited oil is absorbed during this process, while the steam is escaping when food is immersed in the hot oil. However, after food is removed from the deep fryer, the oil penetrates the microstructure by vacuum forces created by evaporative cooling. Indeed, the oil absorption is slower during frying period, however, most oil fill-up the porous crust during the cooling time (Lumanlan *et al.*, 2020). According to Garmakhany *et al.* (2008), about 20% oil uptake takes place during deep frying and about 80% during cooling. They stated that the rapid release of water vapour limits oil absorption into the porous crust developed during deep frying, and more oil was absorbed during cooling.

2.5 Factors affecting oil uptake

Factors affecting the oil uptake during deep frying contribute to the fat content. The factors affecting oil uptake are:

2.5.1 Porosity

The rapid and continuous water evaporation during deep frying resulted in structural changes such as, surface dehydration and development of porous structure (Baumann and Escher, 1995) have attributed to the improvement of the crispy and crunchy texture of the potato chips, consequently resulting in increase in fat content. For example, the development of the

crust in French fries was found nearly six times more porous than the core indicating its capacity for oil absorption (Lumanlan *et al.*, 2020).

During deep frying, the moisture is converted into steam and escapes through the microstructure, damages the cells and expands the pores forming tunnels of capillaries. The vigorous release of water vapour, creating a barrier, could prevent oil migration into the porous crust and limits oil absorption during frying. Nevertheless, after the food was removed from the hot oil, a condensation of water vapour in the porous crust creates a 'vacuum effect' absorbing more oil (Lumanlan *et al.*, 2020).

2.5.2 Surface area and roughness

The dimension and structural properties influencing the oil uptake during deep frying are not linked to the volume, but to the permeability and the surface area of the product, and the increase in fat content are due to most oil adhered on the food surface (Lumanlan *et al.*, 2020). More recently, Ghaderi *et al.* (2018) showed that simulated potato strips with increasing surface area to volume ratio of potato strips affect the moisture and oil content. For example, increasing the thickness of potato slices from 0.8 to 1.2 mm resulted in a significant increase in fat content due to thicker food requiring longer frying time (Lumanlan *et al.*, 2020). On the other hand, Moreno *et al.* (2010) found that mixing 10% methyl cellulose with 90% potato flakes decreased the surface roughness and reduced the fat content after deep frying. Baumann and Escher (1995) pointed out that surface coarseness facilitates oil absorption and adhesion. Therefore, using sharper blades for cutting will have a smooth surface and could result in lower oil uptake during deep frying.

2.5.3 Frying time and temperature

Frying time and temperature are the most important parameters influencing chemical and physical transformation such as water loss, fat content and final product quality. Ghaderi *et al.* (2018) confirmed that increasing the temperature from 150 to 190 °C decreased the fat content by up to 35% by using a 3- D mathematical model to simulate a domestic deep fryer. Also, Krokida *et al.* (2000) stated that increasing the frying temperature and time decreases moisture content and an increase in oil content. They explained that food with lower thickness may contain more oil due to the water loss and oil uptake getting more intense at higher temperature with shorter frying time. Lower temperature (e.g., 150 °C) requiring

longer frying time results in higher oil uptake, and higher temperature (e.g., 180 °C) leading to the rapid development of harder crust in shorter time results in lower oil uptake (Baumann and Escher, 1995). It was concluded that the development of crust where most oil is deposited is associated with frying time and temperature (Lumanlan *et al.*, 2020).

2.5.4 Degraded oil

Extended frying time and higher temperature leading to autoxidation, thermal oxidation and polymerization are associated with oil degradation. A recent study shows that the degraded oil with higher oil viscosity can affect amount of oil uptake during deep frying and cooling period. Also, the unsaturated fatty acids showed an increase in free radicals and decreased in oleic and linoleic acid resulting in oil degradation with increasing frying time (Lumanlan *et al.*, 2020). Pinthus and Sam (1994) found that oil exposed to 10 h frying at 170 °C resulted in higher fat content in the final product compared to frying in fresh oil.

2.6 Methods to reduce oil uptake

Producing a high-quality fried food low in fat content at a considerable cost has been an interest by many researchers. Also, reducing the excessive oil content in fried food could reduce the increasing rate of obesity and related diseases that affects the health and well-being of consumers. The methods to reduce oil uptake are described below:

2.6.1 Moisture reduction after pre-drying

During deep frying, oil replaces the water that was evaporated. While reducing the food moisture before deep frying was found to effectively reduced the oil uptake during deep frying (Lumanlan *et al.*, 2020). Recently, Dehghannya and Abedpour (2018) investigated the ultrasound osmotic dehydration in reducing potato strips moisture before deep frying and found a significant influence in moisture loss and decreasing fat content. However, the cost to process low-fat chips using the method developed by the researchers is not economical for commercial production. Alternatively, the oven dryer commonly used in food industry for predrying effectively reduces moisture content and exhibited improvement in the crispiness and decrease in oil uptake of potato chips (Lumanlan *et al.*, 2020). In addition, (Kumar *et al.*, 2017) reported that reducing moisture content of taro slices after oven drying

resulted in a significant moisture loss and reduced oil uptake while enhancing texture, color and taste.

2.6.2 Effects of hydrocolloids

Food gums also known as hydrocolloids are commonly used in food industries as natural ingredients due to functional properties and health benefits. Food gums that have been applied interchangeably as food coating or incorporated to the chip's formulation showed a promising fat reduction and moisture retention during deep frying. However, the reduction in fat content is more dominant in fried foods (Lumanlan *et al.*, 2020). Recently, Ajo (2017) reported that the application of edible coating with xanthan gum reduced oil absorption by up to 57% and improved overall product quality such as flavor, taste and crispiness. Also, Al-Asmar *et al.* (2018) demonstrated a reduction in Maillard reaction that could decrease carcinogenic risk from fried foods with hydrocolloid coating due to the increase in water retention during frying.

The combined effects of surface tension, hydrophilicity, thermal gelation and film-forming properties of food gums have effectively reduced oil uptake in some fried foods such as sev and potato products. Hydrocolloids at high concentration contribute to the thickening and viscosity of the coating solution. However, food gums added to dry ingredients require more water due to high water-binding capacities to form soft dough. As a result, it decreases hardness and increases stickiness during extrusion of sev (Lumanlan *et al.*, 2020).

Hydrocolloid's ability to lower the surface tension of water in the food affects the oil uptake with the addition of hydrocolloid coating. When heated at above 60 °C, the protective layer prevents the transfer of moisture and oil. Food without the coating shows more oil and moisture exchange. More water was retained during deep frying with coating and could result in less crispiness of the final product. The effects of thermo gelling leading to a stronger coating reducing the pore size resulted in lower fat content of the final product (Lumanlan *et al.*, 2020).

2.6.3 Vacuum frying

Vacuum frying is known for enabling to fry at a low temperature and produce high product quality fried fruits by retaining the food color and nutrient content. Also, vacuum frying potato chips reduced the fat content by 13% (Lumanlan *et al.*, 2020).

2.6.4 Air frying

Air frying compared to deep frying of potatoes shows 70% less fat content, less fat oxidation and better nutritional quality. The relatively new alternative in frying food was found to use 30 g of cooking oil for every kilogram of potato slices as compared to litres of oil required in conventional deep frying (Lumanlan *et al.*, 2020)

Overall, the economic cost saving of using less oil in both recent technologies is attracting more food industries while meeting the increasing demand for high quality, low-fat food. However, the expensive equipment and higher initial investment could lead to an increase in the cost of fried foods (Lumanlan *et al.*, 2020).

2.7 Oil content of Chips

For the chip processing the oil content of chips is very important factor, because the oil is one of the main raw material for chip and is costly. So, the high oil content firstly increases the cost of production and secondly it becomes greasy or oily and hence less desirable to consumers. On the other hand, its storage stability also decreases. Therefore, it is important to study the various factors which affecting oil content of chips (Shah, 1993) which are described below:

i. Specific gravity or dry matter content of bananas.
ii. Partial drying of slices of raw tubers in air before frying.
iii. Leaching raw slices with hot water, hot sodium chloride solution or other chemical.
iv. Thickness of slices
v. Type of fat
vi. Temperature of fat during frying and
vii. Length of frying time.

2.8 Edible coating

Edible coating or films are biopolymers that are hugely being investigated for the packaging and preservation of food. Edible coatings can be defined as a thin layer of edible and environmentally friendly materials that could be consumed and provide a barrier to gases, microbes and moisture to food products. Application of these films is simple, eco-friendly, highly safe and low priced which makes it promising for preserving food products. These films prevent moisture loss, aroma loss or water uptake by the food material or even penetration of oxygen which produces a good storability condition for these food products, Edible coating enhance the texture and improves the product appearance and prolong the shelf life by creating semi-permeable barriers (Oduro, 2021).

In order to reduce the fat uptake in the chips, edible coating effectiveness has been studied to coat the chips. Coating deep-fried food with edible coating causes the formation of a protective layer on the surface which can help to diminish the oil uptake in the fried food. These coating materials can be thin and invisible or thick like batter. The application of the coating is a promising route to reduce the fat uptake in the fried food product. Concerning fat uptake, properties of coating solution are aimed at reducing moisture loss and/or modification of the surface structure form upon frying. There are several ways to coat food product, such as dipping, spraying and brushing. Dipping is the most common method used to apply coatings on food materials especially when the coating solution is highly vicious, and the food materials will be dipped into coating solution for 5 to 30 s. Researchers have stated that the moisture of frying food product can be reduced up to 40% of the total product weight. Different coating materials like gelatin, gellan gum, methyl cellulose, pectin, soy protein isolates have help in reducing the oil uptake in the fried food compared to uncoated fried food (Latif *et al.*, 2020).

2.9 Some Edible Coatings for reducing fat uptake

An edible coating is defined as a thin layer of edible material, generally not exceeding 0.3 mm, applied to the food surface in addition to or as a substitution for natural protective coatings. Hydrocolloids are mainly used for frying applications due to good gelling attributes. Polysaccharides (cellulose derivate, corn starch, carrageenan, pectin, gums) and proteins (egg white, gelatin, sodium caseinate, soy protein, wheat gluten, whey protein) can

be used as base components, alone or in a mixture (Kurek and Scetar, 2017). Some of the commonly used coatings are:

2.9.1 Carboxymethyl cellulose (CMC)

CMC is derived from cellulose which possess good film forming properties and are suitable for edible coatings. Influence of CMC coating and its combination with other polymers on the quantity of the oil uptake and on the sensory attributes of potato (chips or French fries) is well reported in the scientific literatures. CMC coatings are shown to be efficient in reducing the oil uptake by 21.2% without influencing the sensory properties (21.2% and 50.4% for 1% w/v and 10% w/v coating, respectively). Moisture loss during frying decreased, and hence the oil uptake of potato products was reduced. Coating with CMC (1% w/v) and pectin (1% w/v) mixture led to a higher decrease (70%) in fat content of fried potato strips due to the synergistic effect of both hydrocolloids. Interaction between protein and starch (amylose and amylopectin) is shown to be important for the quality and for the texture of the final product. Hence, pectin and CMC can react with the elements in the cell wall (calcium) of potato and lead to a harder texture which requires a higher cutting force (Kurek and Scetar, 2017).

2.9.2 Pectin

Pectin is a white, amorphous and colloidal carbohydrate of high molecular weight occurring in ripe fruits, especially in apples, currants, *etc.*, and used in fruit jellies, pharmaceuticals and cosmetics for its thickening and emulsifying properties and ability to solidify to a gel. (Valdés *et al.*, 2015). Pectin extracted from different plant sources, usually from food processing waste by-products, can be used in making edible films and coatings, either alone or in combination with other compatible polymeric components forming composite film/coating matrices. Alginate and pectin are widely used in food systems to stabilize and to modify the rheology of food. The most useful property is gelation, which is formed by intermolecular association with polyvalent cations. Several types of food hydrocolloids as edible coatings have been investigated to reduce oil absorption in fried products since they are a good barrier to lipids, oxygen, and carbon dioxide during frying (Albert and Mittal, 2002).

Pectin treated chips had better organoleptic attributes and crunchiness than CMC treated samples and reduced acrylamide content (around 33%). In addition, higher reduction of acrylamide in fried chips up to 91.9% was achieved due to a synergic effect of pectin and blanching treatments (Kurek and Scetar, 2017).

2.9.3 Starch

Starch is easily available, inexpensive natural polymer. It is a mixture of the predominantly amylose and the highly branched, high molecular weight amylopectin. Amylose is a better film forming component due to its linear nature. So, coating can be made from any type of starch that contains amylose. The starch edible coating at different levels (from 1% to 5% w/v) reduced fat absorption of potato pellet chips (up to 27%). Starch coatings at different levels also improved sensory attributes of potato chips (Kurek and Scetar, 2017).

2.9.4 Guar Gum

Guar gum, a galactomannan obtained from the Indian cluster bean (*Cyamopsis tetragonoloba* (L.) Taub), is water soluble polysaccharide. Gum based coatings can enhance the barrier properties of fried potato chips by lowering the formation of pores and cracks in the fried food. When the polymer concentration is increased, more coating solution remains on the sample, so likewise coating pick-up percentage increases (Kurek and Scetar, 2017).

2.9.5 Xanthan Gum

Xanthan Gum is widely used in the food industry, mainly due to the good film forming properties such as a highly viscous character even at low concentrations and it has high water binding capacity. Comparing with the cellulose derivatives, xanthan gum had a lower impact on decreasing the oil uptake in French fries (Kurek and Scetar, 2017). When coating banana slices, xanthan attributed to the reduction of the oil uptake by 17.2%, without influencing neither crispiness, color, flavor nor overall quality. This was a good indication of its suitability for use and of consumer's acceptability (Sothornvit, 2011).

Some examples of application of edible coatings for reducing the oil uptake in different foodstuffs are given in Table 2.4.

Table 2.4 Application of edible coatings for reducing oil uptake in deep fat fried products

Coating	Concentration	Reduction in oil uptake (%)	Food
CMC	1	21.2	Potato
	0.5	30.3	Potato
	1	54	Potato strips
Corn starch	1,2,3,4,5	44.3	Potato pellet chips
K carrageenan - konjac blend	1,2	54	Cereal products
Okra	1	45	Potato chips
Okra + carrageenan	1	45	Potato chips
Pectin	4	17	Cereal products
	0.5,1	47 – 63	Potato slices
Pectin (sunflower head pectin)	1	30	Potato chips
Guar gum	1	51.8	Potato chips
	1.5	25.2	Banana chips
Xanthan	1	24.8	Potato
	1,5	17	Banana chips

Source: Kurek and Scetar (2017)

2.10 Pectin coating during deep fat frying

Innovative frying technologies and pre-treatment methods, such as air frying, electric field frying, and hot-air pre-drying, positively affect oil reduction, but, regrettably, are time-consuming and energy-intensive. Compared with these methods, using an edible coating to inhibit the oil uptake in fried food has the advantages of being low-cost, wide sources of

materials, convenient operation, and so on. Nowadays, some natural polysaccharide coatings such as pectin, and guar gum have been used to inhibit oil absorption in fried food, reducing the chips' oil content by 31.0 % and 26.9 %, respectively. Polysaccharide coatings reduce water loss and change the surface structure by forming barrier coatings on the food surface(Li *et al.*, 2023).

Pectin is a high-molecular-weight water-soluble polysaccharide, mainly composed of (1 → 4) linked α-d-galacturonic acid esterified units, which confer structure to the primary cell walls of plants and fruits (Plesoianu and Nour, 2022). Pectin has a higher standard barrier to oxygen, aroma preservation, oil barrier and good mechanical properties, it is recently proposed in food industries as edible coating even though it is not effective against moisture transfer through films by their hydrophilic nature. Other than that, pectin also used as a pre-frying treatment to reduce the oil absorption in deep fat fried products and the use as a pre-dried treatment to improve the retention of nutrients and quality characteristic of dehydrated food (Latif *et al.*, 2020).

The most recent trends in the field of pectin coating applications include the shelf-life extension of fresh-cut highly perishable food, the application of pectin coatings as pre-frying treatment to reduce the oil consumption in deep-fat fried products and the use as pre-dried treatments to improve the retention of nutrients and quality characteristics of dehydrated and lyophilized food (Valdés *et al.*, 2015). A high oil content in fried products shortens the shelf life of the product and causes a decrease in product acceptability to consumers. The oil absorption problem associated with fried products might be reduced by using hydrocolloids as edible coatings (Lazaridou *et al.*, 2020).

The advantages of hydrocolloids coating on chips are:

- Reduces oil uptake during frying.
- Increases the texture and overall acceptability of chips.
- Lowers the chance of fat rancidity and hence increase shelf life of chips.
- Using pectin-based edible coating could reduce 33.0% of acrylamide (carcinogenic compound) content in the fat fried products (Suyatma *et al.*, 2015).

PART III

Materials and method

3.1 Materials

The materials collected for the preparation of pectin coated banana chips were as follows:

3.1.1 Banana

Raw bananas *Musa acuminata* (*Var. Malbhog*) were obtained Inaruwa Banana farming, Sunsari.

3.1.2 Oil

Sunflower oil was procured from the market. Marketed by the trade name Celo Refined Sunflower Oil by Bagmati Oil Industries, Katahari-4, Morang.

3.1.3 Pectin

High methoxyl pectin (HMP) of 150±5 USA SAG grade having 66-69 % degree of esterification was collected from the laboratory of Central Campus of Technology.

3.1.4 Equipment and chemicals

Equipment and chemicals required were utilized from Central Campus of Technology laboratory which are given in Appendix D.1 and D.2.

3.2 Method

3.2.1 Experimental procedure

3.2.1.1 Preparation of banana chips

The flow chart for the preparation of pectin coated banana chips is shown in Figure 3.1.

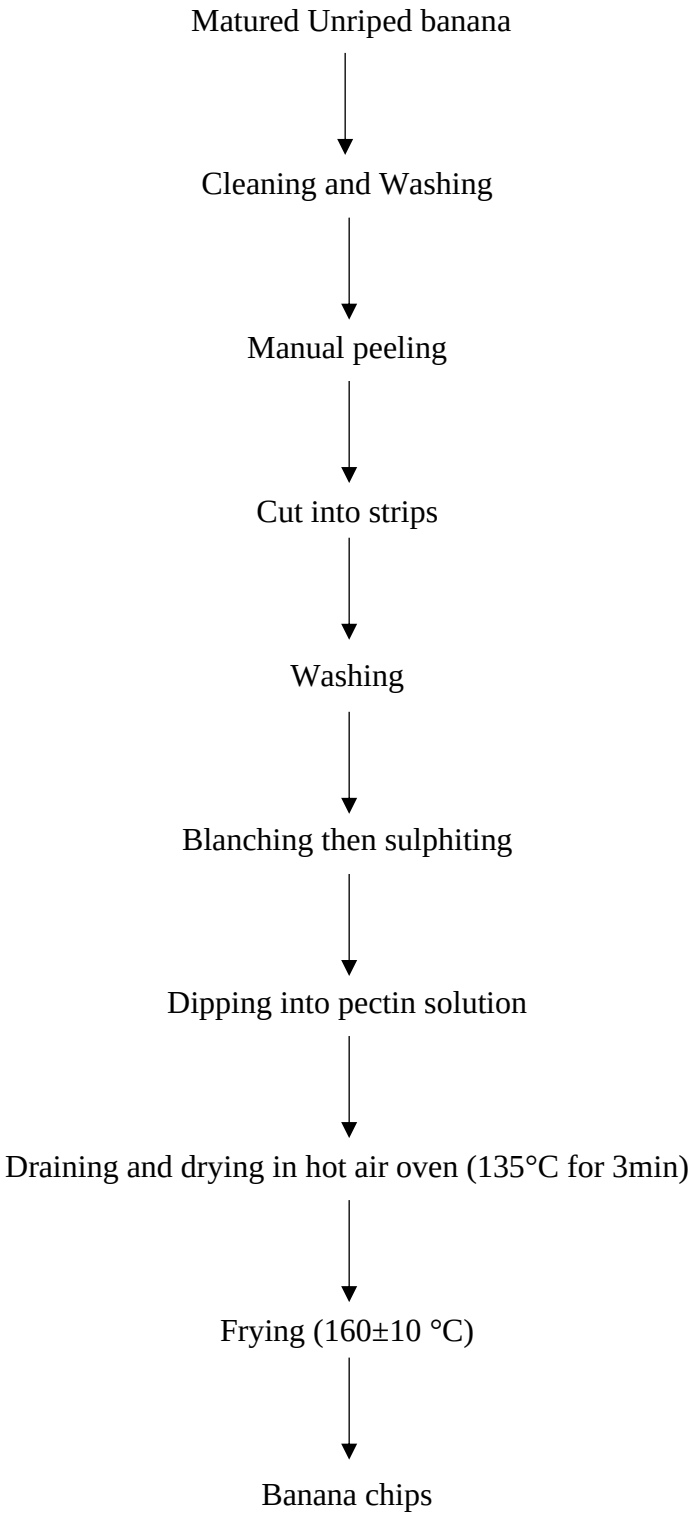


Fig 3.1 Preparation of pectin coated banana chips

Source:(Singthong *et al.*, 2009)

Unripe bananas were washed peeled and cut into strips of thickness 1.3 mm. After that, hot water blanching was done at 100°C for 3 minutes drained and cooled and sulphiting was performed by dipping banana slices on potassium metabisulphite (KMS) solution (0.2 % in 1 litre of distilled water) containing 0.05% citric acid at room temperature for 10 minutes. Then, it was dip in the pectin solution of different concentration (0.5, 1, 1.5, 2 and 2.5 %) at 27±3°C for 2 minutes which were previously prepared (dissolved using hot distilled water). The slices were drained and then dried in hot air oven at (135°C for 3min). Then, the banana slices were fried in sunflower oil at 160±10 °C for 2 min 41 seconds. The obtained pectin coated banana chips were drained, cooled, packed in Polypropylene (PP) packaging and stored.

3.2.1.2 Formulation of Sample

The addition of pectin on banana chips was determined by hit and trial method. Firstly, pectin coated banana chips were prepared by with the pectin concentration varied from 0 to 5 %. The increase in pectin level results in the increment in the hardness of the chips. So, pectin coated banana chips were prepared by varying the pectin concentration from 0 to 2.5 %. Banana chips from pectin content 0, 0.5, 1, 1.5, 2 and 2.5 % were coded as Sample A, B, C, D, E and F respectively. These samples were subjected to sensory evaluation in terms of texture, appearance, color, taste and overall acceptability and the scores obtained were subjected to statistical analysis and best chips in terms of sensory score in comparison to control was taken. The best sample and control were subjected to physicochemical analysis and shelf-life evaluation.

3.2.2 Analytical procedure

3.2.2.1 Chemical analysis of raw materials and product

3.2.2.1.1 Crude fat

Fat content of banana and banana chips was determined by Soxhlet apparatus as described in AOAC (2005).

3.2.2.1.2 Crude fiber

Crude fiber of banana and banana chips was determined by the method given by Ranganna (1986).

3.2.2.1.3 Crude protein

Protein content of banana and banana chips was determined by kjeldahl method as given in KC and Rai (2007).

3.2.2.1.4 Total ash

Ash content of banana and banana chips was determined as described in Ranganna (1986).

3.2.2.1.5 Moisture

Moisture content of raw material and product was determined as per the methods described by AOAC (2005).

3.2.2.1.6 Carbohydrate

Total carbohydrate was calculated by difference, that is the percentage of moisture, ash, protein, and fat was subtracted from 100 % (Pearson, 1976).

% carbohydrate = 100 – (moisture + protein + crude fat + crude fiber + ash)

3.2.2.1.7 Acid value

Acid value of oil was analyzed according to AOAC (2005).

3.2.2.1.8 Peroxide value

Peroxide value of oil was analyzed according to AOAC (2005).

3.2.2.1.9 Iodine value

Iodine value of oil was analyzed according to AOAC (2005).

3.2.2.1.10 Reduction of fat uptake due to coating

The reduction of fat uptake in banana chips due to pectin coating on different concentrations are calculated by the formula followed by Garmakhany *et al.* (2008) in their study.

$$\text{Reduction of fat uptake due to coating} = \frac{\text{Fat uptake(noncoated)} - \text{fat uptake(coated)}}{\text{fat uptake (noncoated)}}$$

3.2.2.2 Storage stability of banana chips

3.2.2.2.1 Moisture content:

According to AOAC (2005), the ground chip was weighed and placed petri-disc and fixed weight was noted. It was then dried in hot air oven at 105 ± 2 ºC for 1 h to constant weight. Disc with dried sample was firstly cooled in desiccators to room temperature and then weighted and again dried, cooled and weighed until constant weight was achieved. Then the moisture content was calculated by using following equation.

$$\%\ \text{Moisture content} = \frac{\text{loss in weight}}{\text{Weight of sample}} \times 100\%$$

3.2.2.2.2 Determination of peroxide value (PV):

By AOAC (2005), oil was extracted from the chips, solvent were removed and cooled. Fixed weight of oil (about 5gm) was taken in Iodine flask. 35 ml of solvent mixture (i.e., acetic acid glacial and chloroform 3:2 v/v) was added and flask was swirled until the sample dissolved (approx.1 min). 1 ml of saturated potassium iodide (KI) was added by 1ml pipette and 30 ml of distilled water and 1ml of freshly prepared starch solution were added, then the mixture was titrated with 0.1N Sodium thiosulphate ($Na_2S_2O_3$) solution with constant and vigorous shaking, until blue color was completely disappeared.

The peroxide value is calculated using the following equation.

$$\text{PV (meqv O2/kg of oil)} = \frac{\text{N} \times (\text{Vs} - \text{VB}) \times 1000}{\text{Weight of sample (g)}}$$

Where, N= normality of sodium thiosulphate,

Vs= sod-thiosulphate consumed by sample (ml) and

V_B = sod-thiosulphate consumed by blank (ml)

3.2.2.2.3 Determination of Acid value

The acid value was determined by AOAC (2005). 3 gm oil was accurately weighed in 250 ml conical flask. About 50 ml previously neutralized ethanol (95 %) was added and warm to about 70 ºC and a drop or two drop of phenolphthalein indicator (1 %, alcoholic) was added

and titrated with 0.1N sodium hydroxide solution shaking vigorously. The end point was indicated by a pink color persisting at least 30 seconds.

The acid value was calculated using the following equation

$$\text{Acid value}(\text{mg of KOH/g of oil}) = \frac{\text{ml of alkali} \times \text{N of alkali} \times 56.1}{\text{weight of sample (g)}}$$

Where, N= Strength of sodium hydroxide solution

3.2.3 Sensory evaluation

Sensory evaluation was carried out using 9-point hedonic scale described by Ranganna (1986). Sensory panelists were semi trained panelists from Central Campus of Technology, Dharan. The parameters for sensory evaluation were: texture, appearance, color, taste and overall acceptability. The specimen of the evaluation of card is shown in Appendix A.

3.2.4 Statistical analysis

ANOVA (Analysis of variance) was used to analyze the data from the sensory evaluation. The Genstat release 12.1 software program developed by VSN International Ltd. was used to analyze the significant differences between them using LSD at the 5 % level of significance, and Microsoft Excel 19 was used to perform a t-Test. The results of the chemical analysis of the best and control chips were statistically analyzed using the t-Test.

Part IV

Results and discussions

The pectin coated banana chips was prepared at Central Campus of Technology, Dharan, in a laboratory for the present study. The pectin coated banana chips were prepared by coating 0, 0.5, 1, 1.5, 2 and 2.5 % pectin on banana. Unripe bananas were washed peeled and cut into strips of thickness 1.3 mm. After that, sulphiting was performed by dipping banana slices on potassium metabisulphite (KMS) solution. Then, it was dip in the pectin solution at 27±3°C for 2 minutes. The slices were drained and then dried in hot air oven at (135°C for 3min). The coated banana chips were then fried in sunflower oil at 160±10 °C for 2 min 41 seconds.

4.1 Proximate composition of raw banana

The proximate composition of raw banana collected from Dharan is presented in Table 4.1

Table 4.1 Chemical composition of raw banana (dry basis)

Parameters	Values
Moisture (%, wb)	69.08±0.377
Crude protein (%, db)	1.15±0.0221
Crude fat (%, db)	0.28±0.06
Ash (%, db)	0.85±0.091
Crude fiber (%, db)	0.51±0.11
Carbohydrates (by difference)	28.13±0.25

*Values in the table are arithmetic mean of triplicate samples. Figure in the parentheses indicates standard deviation.

The proximate analysis of the raw banana for various parameters like moisture content (%), crude protein (%), crude fat (%), crude fibre (%), ash (%) and carbohydrate (%) (in dry basis except moisture content) were found to be 69.08 %, 1.15 %, 0.28 %, 0.51 %, 0.85 % and 28.13 % respectively as given in Table 4.1. DFTQC. (2012) reported respective

proximate values to be 70.1 %, 1.2 %, 0.3 %, 0.4 %, 0.8 %, and 27.2 % respectively. Similarly, the respective proximate values reported by USDA. (2018) were 74.9 %, 1.09 %, 0.33 %, 2.6 %, 0.82 % and 22.8 % respectively. Our data was in the range as given by DFTQC. (2012) and USDA. (2018). The moisture and protein content was lower than the value reported by DFTQC. (2012). The lower concentration of the protein in banana might be due to the loss of nitrogenous material during the digestion of sample. This might have reduced the final protein content. The crude fat content was lower than the value reported by DFTQC. (2012) and USDA. (2018). The fiber content and ash content was in similar to the value given by DFTQC. (2012). The high fibre content in banana made it more desirable for making chips, as it provided more structural stability and integrity to the end product (Paramasivam *et al.*, 2022). The carbohydrate content was higher than the value reported by USDA. (2018).

Similarly, the moisture content (%), crude protein (%), crude fat (%), crude fibre (%), and carbohydrate (%) obtained by Elayabalan *et al.* (2017) in unripe banana were 69 %, 1.4%, 0.2 %, 0.5 %, and 28.7 % which was similar to our study. The difference in proximate composition may be due to factors like varieties, climatic conditions, soil type, maturity, fertility and others.

4.2 Physiochemical characteristics of sunflower oil

The physiochemical characteristics of sunflower oil is shown in Table 4.2.

Table 4.2 Physiochemical characteristics of sunflower oil

Parameters	Value
Acid value (mg of KOH/g of oil)	0.281
Peroxide value (meqv O_2/kg of oil)	6.82
Iodine value	140.84

*Values are in dry basis.

The acid value, peroxide value and iodine value of sunflower oil from our study was found to be 0.281 mg of KOH/g of oil, 6.82 meqv O_2/kg of oil and 140.84 respectively. The data from our study was in range of the standard value of sunflower oil given by DFTQC. (2022).

The acid value, peroxide value and iodine value of sunflower oil by DFTQC. (2022) were <4 mg of KOH/g of oil, <10 meqv O_2/kg of oil and 110-143 respectively.

4.3 Effect of pectin coating on the oil uptake of banana chips

Effect of pectin coating on the oil uptake of banana chips is shown in the Table 4.3 below:

Table 4. 3 Effect of pectin coating on the oil uptake of banana chips

Samples	Fat Content (%)	Reduction in oil uptake (%)
A (0%)	35.4±0.151	-
B (0.5 %)	27±0.051	23.72
C (1 %)	26.5±0.02	25.14
D (1.5 %)	25.2±0.11	28.81
E (2 %)	24.97±0.033	29.4
F (2.5 %)	24.6±0.08	30.22

*Values are the means of triplicates and figures in the parenthesis are standard deviation of the triplicates.

The above Table 4.3 shows that control banana chips absorbed significantly more oil/fat compared to all coated banana chips. Similar observations were observed by Hua *et al.* (2015) in coated potato strips. The oil content in the chips can be affected by the frying temperature and the type of oil used during frying the chips. Moisture removal by evaporation during a frying process makes void spaces within the food which become filled with oils, thus increasing the oil content of fried foods (Maity *et al.*, 2015). The fat content was maximum for control and minimum for 2.5 % pectin coated banana chips i.e., 35.4 % and 24.6 % respectively.

Coating the banana slices with pectin produced a significant reduction in oil absorption, as reflected by the reduction in oil content compared to the control treatment. All the coated samples had a lower oil uptake than uncoated samples. This can be due to lower moisture loss of coated samples during frying and therefore, lower oil uptake (Mirzael *et al.*, 2015).

In the present study the voids were not vacant due to the hydrocolloid pre-treatment for absorption of the oil, thus the oil uptake was reduced significantly. Sothornvit (2011) showed very less oil uptake in fried banana chips treated with guar gum. The reduction in oil uptake was higher in 2.5 % pectin coated banana chips i.e., 30.22 %.

4.4 Sensory evaluation of pectin coated banana chips

Sensory evaluation of six formulations of pectin coated banana chips were carried out by a group of 10 semi-trained panelist. The parameters evaluated were appearance, taste, color, texture, and overall acceptance. The Analysis of Variance (ANOVA) was carried out using least significant difference (LSD) at 5 % level of significance.

4.4.1 Appearance

The mean sensory score for appearance were found to be 7.3, 7.3, 7.5, 7.8, 7.3 and 7.4 for the chips formulations A, B, C, D, E and F respectively. Statistical analysis showed that pectin coating on banana had significant effect ($p < 0.05$) on the appearance of the different chip formulations. The sample A, B and E were not significantly different to each other but significantly different to other, which is shown graphically in Figure. 4.1. Sample C and F were similar to A, B, D and E. The sample D got highest score than other samples.

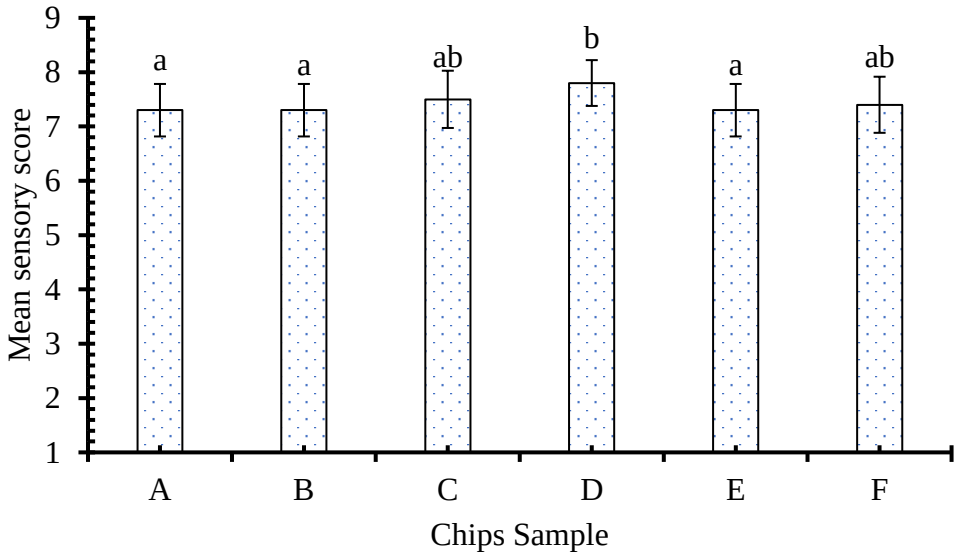


Fig. 4.1 Mean sensory scores for appearance of pectin coated banana chips

*A, B, C, D, E, and F denote banana chips with 0, 0.5, 1, 1.5, 2, and 2.5 % pectin coating respectively. Vertical error bars represent the value of standard deviation. Values of same subscript represents that the samples were similar in terms of appearance.

The edible coatings can retard the starch gelatinization and retrogradation leading to different crust appearance and texture of fried chips. Similar result was observed by Hua *et al.* (2015).

4.4.2 Color

The mean sensory score for color were found to be 7.3, 7.1, 7.6, 8.5, 7.2 and 7 for the chips formulations A, B, C, D, E and F respectively. Statistical analysis showed that pectin coating on banana had significant effect ($p < 0.05$) on the color of the different chip formulations. The sample A, B, C, E and F were not significantly different to each other which is shown graphically in Figure. 4.2. The sample D got highest score than other samples.

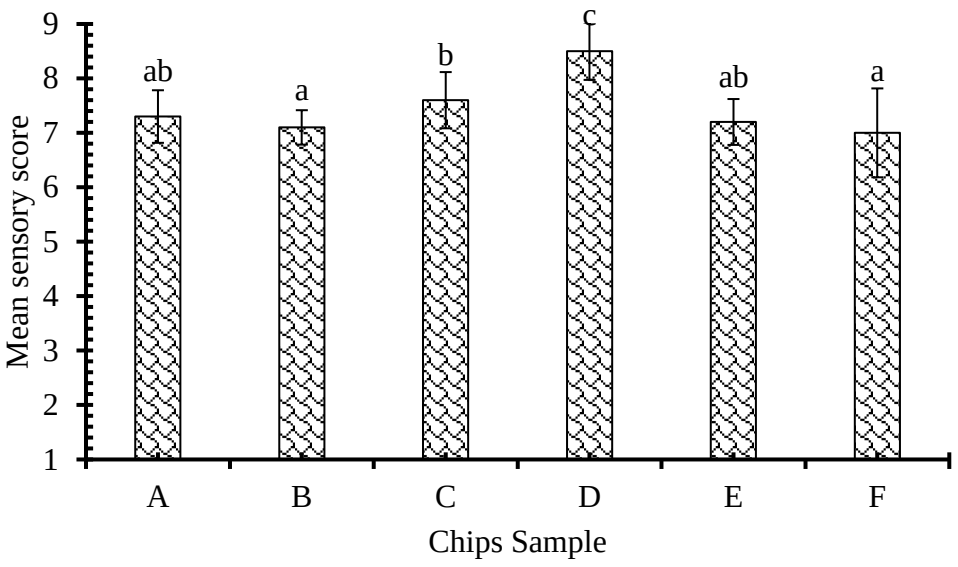


Fig. 4.2 Mean sensory scores for color of pectin coated banana chips

*A, B, C, D, E, and F denote banana chips with 0, 0.5, 1, 1.5, 2, and 2.5 % pectin coating respectively. Vertical error bars represent the value of standard deviation. Values of same subscript represents that the samples were similar in terms of color.

The characteristic golden color of fried chips can be attributed to non-enzymatic browning of starch (Hua *et al.*, 2015). The lower browning of the banana chips covered with

the hydrocolloids is due to the fact that the coating on the sample surfaces may have acted as a barrier against the transfer of heat from the oil to the samples, reducing dehydration due to the hydrocolloids' ability to bind to water, which may have interfered with the Maillard reaction (Santos *et al.*, 2023).

4.4.3 Texture

The mean sensory score for texture were found to be 7.5, 7.5, 7.4, 8.7, 7.3 and 7.4 for the chips formulations A, B, C, D, E and F respectively. Statistical analysis showed that pectin coating on banana had significant effect ($p < 0.05$) on the texture of the different chip formulations. The sample A, B, C, E and F were not significantly different to each other which is shown graphically in Figure. 4.3. The sample D got highest score than other samples.

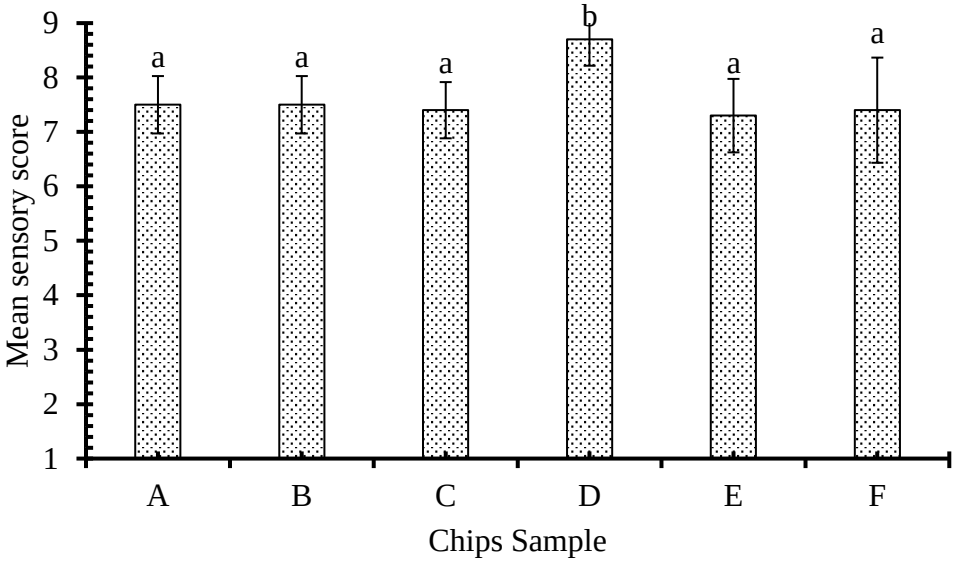


Fig. 4.3 Mean sensory scores for texture of pectin coated banana chips

*A, B, C, D, E, and F denote banana chips with 0, 0.5, 1, 1.5, 2, and 2.5 % pectin coating respectively. Vertical error bars represent the value of standard deviation. Values of same subscript represents that the samples were similar in terms of texture.

The dry and crispy crust and tender inside is due to complexing of moisture, starch, lipid and protein (Hua *et al.*, 2015). Paramasivam *et al.* (2022) observed in their study with banana chips that hardness increased with increasing hydrocolloid concentration, suggesting that

this result may be due to the inherent property of hydrocolloids that provides a higher mechanical strength to banana chip tissues, which in turn, resulted in improved structural integrity and therefore less crispiness.

4.4.4 Taste

The mean sensory score for appearance were found to be 7.3, 7.2, 7.7, 7.8, 7.3 and 7.3 for the chips formulations A, B, C, D, E and F respectively. Statistical analysis showed that pectin coating on banana had significant effect ($p < 0.05$) on the taste of the different chip formulations. The sample A, C, E and F were not significantly different to each other and was also similar to sample B and D which is shown graphically in Figure. 4.4. The sample D got highest score than other samples. The flavors are consisted of derivatives of starch, protein and lipids during frying (Hua *et al.*, 2015).

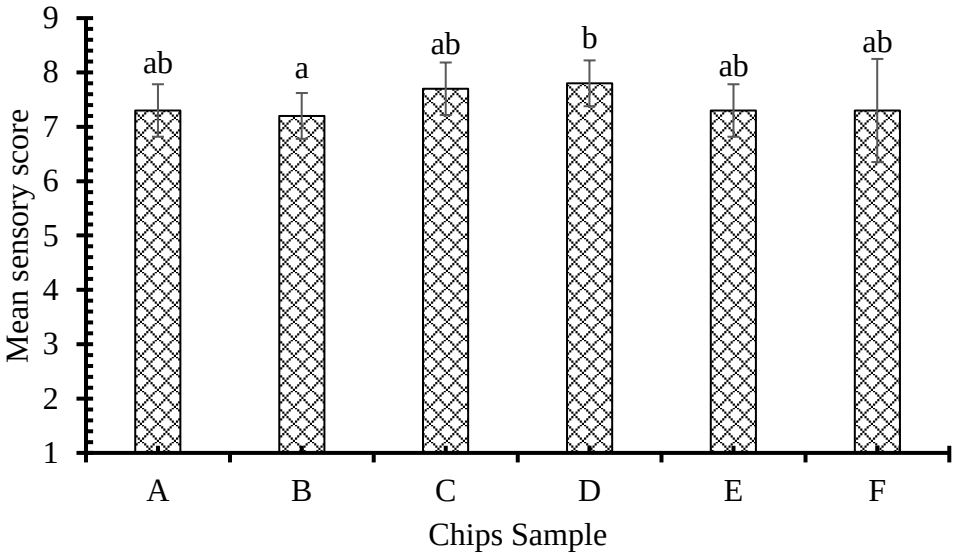


Fig. 4.4 Mean sensory scores for taste of pectin coated banana chips

*A, B, C, D, E, and F denote banana chips with 0, 0.5, 1, 1.5, 2, and 2.5 % pectin coating respectively. Vertical error bars represent the value of standard deviation. Values of same subscript represents that the samples were similar in terms of taste.

4.4.5 Overall acceptability

The mean sensory score for appearance were found to be 7, 7.3, 7.5, 8.7, 7.2 and 7.1 for the chips formulations A, B, C, D, E and F respectively. Statistical analysis showed that pectin

coating on banana had significant effect ($p < 0.05$) on the overall acceptability of the different chip formulations. The sample B, E and F were not significantly different to each other and were also similar to A and C which is shown graphically in Figure. 4.5. The sample D got highest score than other samples in terms of overall acceptability. Sample A (Control) got the lowest score.

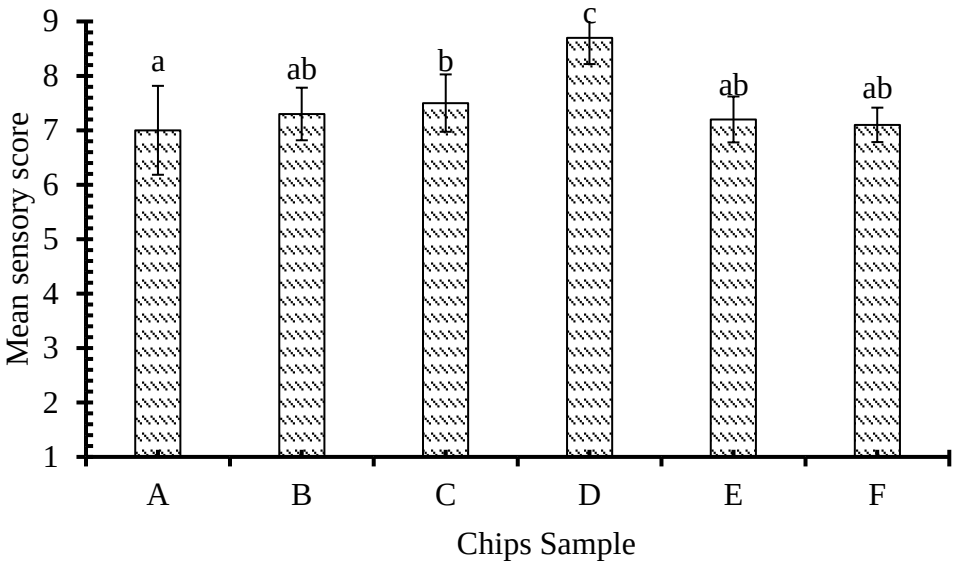


Fig. 4.5 Mean sensory scores for overall acceptance of pectin coated banana chips

*A, B, C, D, E, and F denote banana chips with 0, 0.5, 1, 1.5, 2, and 2.5 % pectin coating respectively. Vertical error bars represent the value of standard deviation. Values of same subscript represents that the samples were similar in terms of overall acceptability.

Control chips recorded lower scores as they were perceived oily. In general, when employed at very low concentration (0.5% –1.5%), the pectin treatments applied did not reduce the consumer acceptability and hardly altered the sensory attributes (Paramasivam *et al.*, 2022). The edible coatings have retained more moisture and less lipid inside of fried chips, thereby generating different mouth-feelings (Hua *et al.*, 2015).

The overall acceptability of sample D was higher due to the improvement in color, taste and texture with respect to other samples. The overall sensory evaluation result for uncoated banana chips was the lowest due to pale color, less crispy and plain taste chips. The addition of coating not only impact in reducing the fat content of banana chips but it also provided slightly improvement of the sensory attributes. Therefore, from the sensory evaluation of the

product conducted on the attributes like appearance, color, texture, taste and overall acceptability, the sample coated with 1.5 % pectin was rated as best in all attributes.

4.5 Proximate analysis of best product

Thus, from statistical sensory analysis, the best product was found to be sample D containing 1.5 % pectin coating on banana chips. Proximate analysis of sample A (Control, 0 % pectin) and sample D (Best) was done. The value of proximate analysis is shown in Table 4.4.

Table 4.4 Proximate analysis of product

Parameters	Sample A (Control)	Sample D (Best)
Moisture	2.12^{a}±0.06	3.40^{b}±0.115
Crude protein (%, db)	1.98^{a}±0.05	1.983^{a}±0.03
Crude fat (%, db)	35.4^{a}±0.151	25.2^{b}±0.11
Crude fiber (%, db)	7.21^{a}±0.08	7.63^{b}±0.07
Total ash (%, db)	1.82^{a}±0.02	1.85^{a}±0.03
Carbohydrates (by difference)	51.47^{a}±0.31	59.937^{b}±0.24

*Values in the table are arithmetic mean of triplicate samples. Figure in the parentheses indicates standard deviation. Values in the column having different superscripts are significantly different at 5 % level of significance.

The moisture content, crude protein, crude fat, crude fiber, ash and carbohydrate of sample A (Control) were found to be 2.12 %, 1,98 %, 35.4%, 7.21 %, 1,82 %, and 51.47 % respectively. The moisture content, crude protein, crude fat, crude fiber, ash and carbohydrate of banana chips as reported by USDA. (2019) were 4.3 %, 2.3 %, 33.6 %, 7.7 %, 1.4 % and 58.4 %. The moisture, protein, fiber and carbohydrate content of control chips from our study was found to be lower and fat and ash content was found to be higher than the value reported by USDA. (2019). Also, similar result was obtained by Deboch and Mezgebe (2023) and the value for moisture content, crude protein, crude fat, crude fiber, ash

and carbohydrate of local banana chips were 3.64 %, 3.96 %, 8.60 %, 10 %, 2.5 % and 22.1 % respectively.

The moisture content, crude protein, crude fat, crude fiber, ash and carbohydrate of sample D (Best) were found to be 3.40 %, 1.983 %, 25.2 %, 7.63 %, 1.85 % and 59.937 % respectively. There was significant increase in moisture content of sample D with respect to sample A. Increase in water content due to coating, may be result of barrier properties of coating agents which prevent water loss during frying and by this mechanism water content of coated chips were higher than non-coated chips (Mirzael *et al.*, 2015). Pectin treated banana chips appeared to be significantly lower in fat content than the control banana chips. Similar result was obtained by Paramasivam *et al.* (2022). It was also observed that the lower oil content correlated with the higher moisture content in banana chips, since oil absorption happens as moisture is removed from the food during the frying process (Mellema, 2003). The fiber content of the best sample increases than the control. There was no significant difference in the protein and ash content of the control and best sample. Pectin coating does not affect the protein and ash content. There was significant increase in the carbohydrate content of the pectin coated banana chips than control.

4.6 Shelf life of the product

The best product (Sample D) of pectin coated banana chips was found best with respect to appearance, color, texture, taste and overall acceptance. Hence it was subjected to further study for the shelf-life evaluation in the laboratory. The banana chips were packed in PP packaging and shelf life was studied for 40 days with triplicate samples. The samples were stored in room temperature (27 ± 3 °C). The moisture content of the product, acid value and peroxide value of the extracted fat, was evaluated from the date of manufacture up to 40 days as follows:

4.6.1 Moisture content

The moisture content of the sample A (control) was observed to be 2,12 at initial which reached 2.42, 2.72, 3.18 and 3.58 within 10, 20, 30 and 40 days respectively. Similarly, for sample D (best) the moisture content was observed to be 3.41 at initial which reached 3.56, 3.75, 3.96 and 4.19 within 10, 20, 30 and 40 days respectively. The change or increasing trend of moisture content of sample A and sample D is shown in Figure. 4.6.

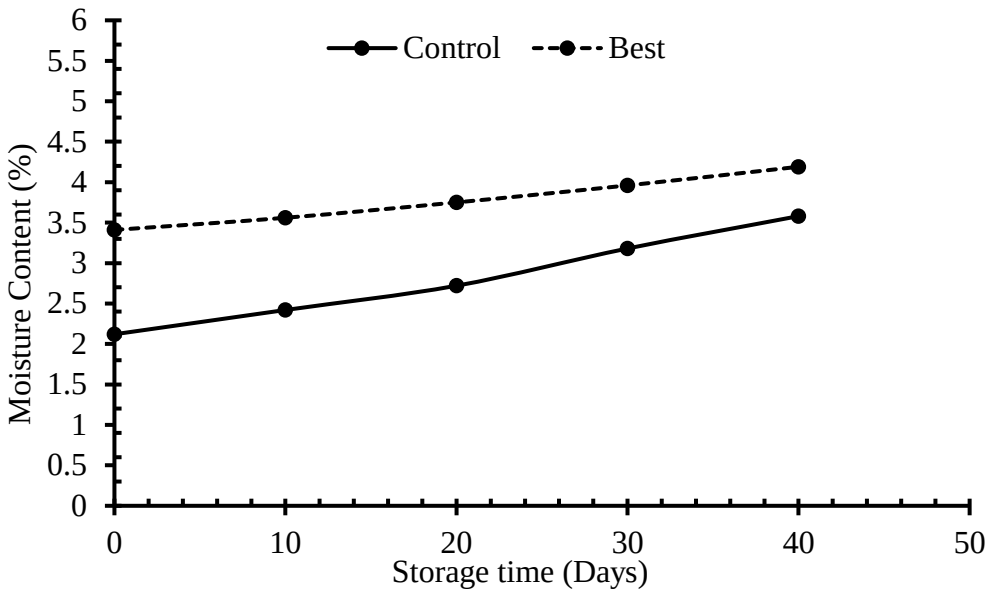


Fig. 4.6 Change in moisture content during storage of control and best sample

The initial higher moisture content of pectin coated banana chips was result of barrier properties of coating agents which prevent water loss during frying and by this mechanism water content of coated chips were higher than non-coated chips. Hence, because of the barrier properties, moisture content of the best sample increases by lower amount during storage and there was gradual increase in the moisture content of the control sample during storage period. The moisture differences of banana chips were also due to differences in thickness of banana chips. In this study banana slice of thickness 1.3 mm were used.

4.6.2 Peroxide Value

The peroxide value of the sample A(Control) was observed to be 2.34 at initial which reached 3.2, 4.3, 5.21 and 6.41 within 10, 20, 30 and 40 days respectively. Similarly, for sample D (Best) peroxide value was 1.88 at initial which reached 2.3, 2.8, 3.315 and 3.915 within 10, 20, 30 and 40 days respectively but the PV obtained was far below the unacceptable level of maximum 10 MeqO_2 /kg fat as described by DFTQC. (2022) till the last date of analysis. The rapid increase in the peroxidase value of sample A might be due to the presence of high amount of unsaturated fatty acid in chips. The increase amount of unsaturated fatty acid is prone to rancidity. The change in peroxide value of the sample A and sample D is shown in Figure. 4.7.

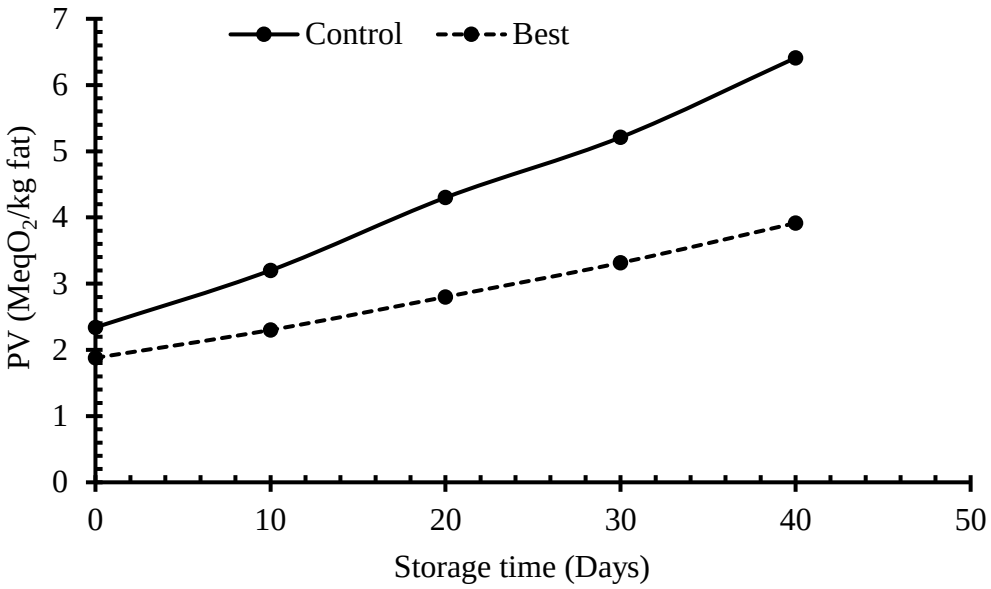


Fig. 4.7 Change in peroxide value during storage of control and best sample

The oxidative state of frying is assessed by the measure of peroxide value (PV). Peroxide value provides a means of predicting the risk of the development of flavor rancidity. The hydrocolloid films having lower light and oxygen permeability resulted in banana chips with lower PV. The increase in PV of chips increases with the lipid oxidation in the presence of light and oxygen (Marina et al., 2009). The hydrocolloid coatings could have lowered the oxygen permeability, which resulted in banana chips with lower PV. Pectin, being a linear polysaccharide with small chains formed by other sugars has the ability to react with in the cell wall and can be more productive as its coordinative reaction can quickly induce gel (Hua *et al.*, 2015). Nevertheless, the peroxide value less than 25 meq oxygen/ kg is the safe limit for storage of chips (Manikantan *et al.*, 2014) and it is evident that all the samples (including control) fell below this level and is deemed fit for consumption.

4.6.3 Acid Value

The acid value of sample A was observed to be 0.4 at initial which reached 0.422, 0.46, 0.52, and 0.58 within 10, 20, 30, and 40 days respectively. Similarly, for sample D acid value was 0.36 at initial which reached 0.371, 0.391, 0.421, and 0.456 within 10, 20, 30, and 40 days respectively but the acid value was below the unacceptability level of 4 mg KOH/mg of oil as described by DFTQC. (2022). The change in the acid value of the sample A and sample D is shown in Figure. 4.8. The acid value of sample A was greatly increased than that of

sample D. It might be due to the presence of lipase enzyme, which hydrolyses the fat present to the free fatty acid and glycerol (Oropeza, 2018). The increase in the fatty acid ultimately increases the acid value.

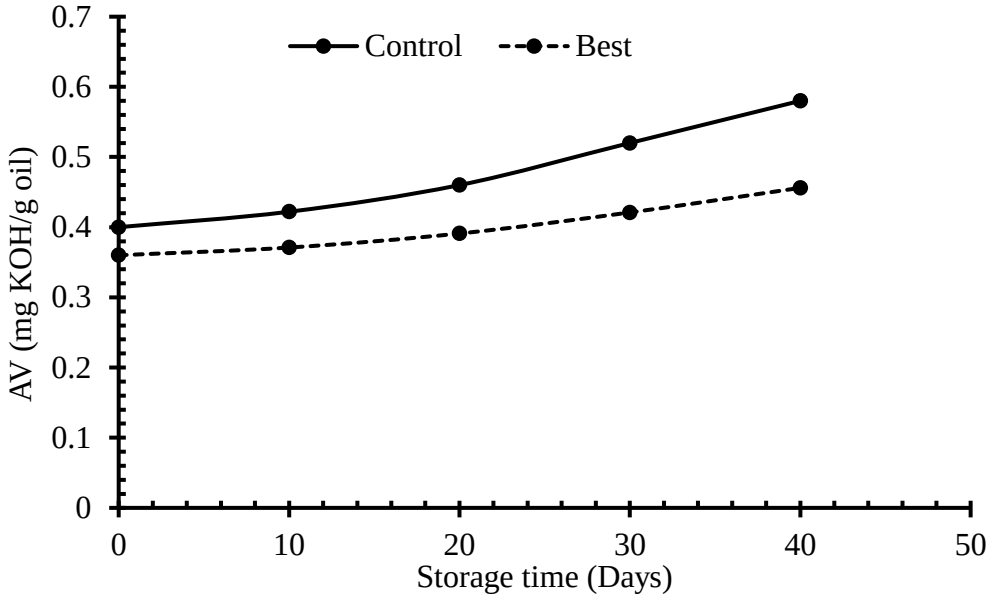


Fig. 4.8 Change in acid value during storage of control and best sample

In general, the acid value is the indication of free fatty acid content in the product. The increment in the fatty acid of the product was found increased with storage time and also depends on storage condition. Higher FFA values during frying are due to nucleophilic attack at the ester bond on triacylglycerol and the hydrolysis that happens upon removal of water from the food being fried (Manikantan *et al.*, 2014).

Oil in the chips often becomes rancid during storage and the rancidity may be caused by the conversion of oil into free acids which is reflected by the acid value or it may be caused by oxidation of fat leading to the formation of peroxides. Therefore, both acid value and peroxide value were determined. Although changes in acid value were similar to that in peroxide value, differences were greater in peroxide value. Peroxide value appears to be a fairly reliable index of the extent of oxidative deterioration of chips (Ezekiel and Rani, 2006).

Hence, from the above study, the prepared pectin coated banana chips and non-coated banana chips were fit for consumption till the last day of analysis in terms of moisture content, peroxide value and acid value.

Part V

Conclusion and recommendations

5.1 Conclusion

Banana chips was prepared by coating pectin on different levels and storage stability of the prepared chips was studied. On the basis of the research following conclusions were drawn;

1. The moisture content, crude protein, crude fat, crude fiber, total ash content and carbohydrate of raw banana was found to be in acceptable level.
2. The acid value, peroxide value and iodine value of sunflower oil was found to be in acceptable level of Nepalese standard.
3. The effect of pectin coating on oil uptake of banana chips was studied and oil uptake was reduced to 30.22 % in 2.5 % pectin coated banana chips.
4. From sensory analysis of the product conducted on the attributes like appearance, color, taste, texture and overall acceptability, banana chips with 1.5 % pectin coating i.e., Sample D was rated as best in all attributes.
5. The moisture content, crude protein, crude fat, crude fiber, total ash content and carbohydrate of best sample was found to be in acceptable range. The fat content of best sample (D) was reduced by 28.81 %.
6. The moisture content, acid value and peroxide value of the best sample increased in lower rate than control but both the samples were in acceptable range till the last day of analysis (40 days).

5.2 Recommendations

The experiment can be further continued with the following recommendations:

1. Double and triple-layer of hydrocolloid coating can be used for the production of low-fat products.
2. The shelf life of banana chips could further be studied.
3. Frying time and frying temperature can be varied.
4. Different packaging materials can be experimented.

Part VI

Summary

Banana is essentially a tropical and subtropical crop, which is available throughout the whole year in different part of the world. Banana chips are a popular processed product obtained from banana. It contains high amount of oil which is undesirable for health. Pectin coating on the chips reduces oil uptake during frying, increases the texture and overall acceptability of chips and lowers the chance of fat rancidity and hence increase shelf life of chips.

For the preparation of pectin coated banana chips, unripe bananas (Malbogh variety) were washed, peeled and cut into strips of thickness 1.3 mm. After that, hot water blaching for 10 minutes was done, cooled and sulphiting was performed by dipping banana slices on potassium metabisulphite (KMS) solution. Then, it was dip in the pectin solution at 27±3°C for 2 minutes. The slices were drained and then dried in hot air oven at (135°C for 3min). Then, the banana slices were fried in sunflower oil at 160±10 °C for 2 min 41 seconds. The obtained pectin coated banana chips were drained, cooled, packed in PP packaging and stored. Six different formulations namely A, B, C, D, E and F with the pectin coating concentration of 0, 0.5, 1, 1.5, 2 and 2.5 % respectively were prepared.

The proximate analysis of the raw banana for various parameters like moisture content, crude protein, crude fat, crude fibre, ash and carbohydrate were found to be 69.08, 1.15, 0.28, 0.51, 0.85 and 28.13 % respectively. The acid value, peroxide value and iodine value of sunflower oil from our study was found to be 0.281 mg of KOH/g of oil, 6.82 meqv O_2/kg of oil and 140.84 respectively. The reduction of oil uptake was highest in 2.5 % pectin coated banana chips i.e., 30.22 %. Sensory evaluation of six formulations of pectin coated banana chips was carried out. According to the sensory evaluation, it was concluded that 1.5 % pectin coating on banana chips was best whose moisture content, crude protein, crude fat, crude fiber, ash and carbohydrate were found to be 3.40, 1.983, 25.2, 7.63, 1.85 and 59.937 % respectively. The moisture content of sample D was 3.41, 3.56, 3.75, 3.96 and 4.19 % peroxide value were 1.88, 2.3, 2.8, 3.315 and 3.915 meqv O_2/kg and acid value was 0.36, 0.371, 0.391, 0.421 and 0.456 mg of KOH/g within 0, 10, 20, 30 and 40 days respectively. The product was safe for consumption till the last day of analysis (40 days).

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Appendices

Appendix-A

SENSORY ANALYSIS SCORE CARD

Name: …… Date: ……

Name of the product: Pectin coated banana chips

Dear panelist, you are provided with six samples of Pectin coated banana chips. Please test the following samples of chips and check how much you prefer for each of the samples. Give the points for your degree of preferences for each parameter for each sample as shown below:

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

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

Parameters	**Sample**					
	A	**B**	**C**	**D**	**E**	**F**
Appearance						
Taste						
Color						
Texture						
Overall acceptability						

Comments if any:

Signature: ……

Appendix B

ANOVA results of sensory analysis

Table B.1 ANOVA (no interaction) for appearance of pectin coated banana chips

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Chips type	5	1.9333	03867	1.57	<.001
Panelist	9	1.7333	0.1926	0.78	0.633
Residual	45	11.0667	0.2459		
Total	59	14.7333			

Table B.2 ANOVA (no interaction) for color of pectin coated banana chips

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Chips type	5	15.35	3.07	11.69	<.001
Panelist	9	3.6833	0.4093	1.56	0.157
Residual	45	11.8167	0.2626		
Total	59	30.85			

Table B.3 ANOVA (no interaction) for color of texture coated banana chips

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Chips type	5	13.9333	2.7867	8.14	<.001
Panelist	9	6.6	0.7333	2.14	0.045
Residual	45	15.4	0.3422		
Total	59	35.9333			

Table B.4 ANOVA (no interaction) for taste of pectin coated banana chips

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Chips type	5	3.1333	0.6267	1.82	<.001
Panelist	9	2.0667	0.2296	0.67	0.735
Residual	45	15.5333	0.3452		
Total	59	20.7333			

Table B.5 ANOVA (no interaction) for overall acceptability of pectin coated banana chips

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Chips type	5	19.7333	3.9467	14.48	<.001
Panelist	9	2.9333	0.3259	1.20	0.321
Residual	45	12.2667	0.2726		
Total	59	34.9333			

Appendix C

Table C.1 t-test (two-sample assuming unequal variance) for moisture of the best sample (sample D) with control (sample A).

	Sample A (Control)	Sample D (Best)
Mean	2.12	3.406667
Variance	0.0036	0.013233
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-17.1768	
P(T<=t) one-tail	0.000215	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.00043	
t Critical two-tail	3.182446	

Table C.2 t-test (two-sample assuming unequal variance) for protein of the best sample (sample D) with control (sample A).

	Sample A (Control)	Sample D (Best)
Mean	1.98	1.983
Variance	0.0025	0.0009
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.08911	
P(T<=t) one-tail	0.467304	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.934608	
t Critical two-tail	3.182446	

Table C.3 t-test (two-sample assuming unequal variance) for fat of the best sample (sample D) with control (sample A).

	Sample A (Control)	Sample D (Best)
Mean	35.4	25.2
Variance	0.022801	0.0121
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	94.56749	
P(T<=t) one-tail	3.748E-08	
t Critical one-tail	2.1318468	
P(T<=t) two-tail	7.497E-08	
t Critical two-tail	2.7764451	

Table C.4 t-test (two-sample assuming unequal variance) for fiber of the best sample (sample D) with control (sample A).

	Sample A (Control)	Sample D (Best)
Mean	7.21	7.63
Variance	0.0064	0.0049
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	-6.8433806	
P(T<=t) one-tail	0.00119292	
t Critical one-tail	2.13184679	
P(T<=t) two-tail	0.00238585	
t Critical two-tail	2.77644511	

Table C.5 t-test (two-sample assuming unequal variance) for ash of the best sample (sample D) with control (sample A).

	Sample A (Control)	Sample D (Best)
Mean	1.82	1.85
Variance	0.0004	0.0009
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-1.44115	
P(T<=t) one-tail	0.1222597	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.245194	
t Critical two-tail	3.182446	

Table C.6 t-test (two-sample assuming unequal variance) for carbohydrate of the best sample (sample D) with control (sample A).

	Sample A (Control)	Sample D (Best)
Mean	51.47	59.935
Variance	0.0961	0.057603
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	-37.397831	
P(T<=t) one-tail	1.567E-06	
t Critical one-tail	2.1318468	
P(T<=t) two-tail	3.053 E-06	
t Critical two-tail	2.7764451	

Appendix D

Table D.1 List of equipment used

Physical apparatus	
Heating arrangement	Soxhlet assembly
Thermometer	Electric balance
Kjeldahl digestion and distillation set	Muffle furnance
Titration apparatus	Hot air oven
Iodine flask	Desiccators
Blotting paper	Chopping board and knife
Slicer	Daily routine glassware

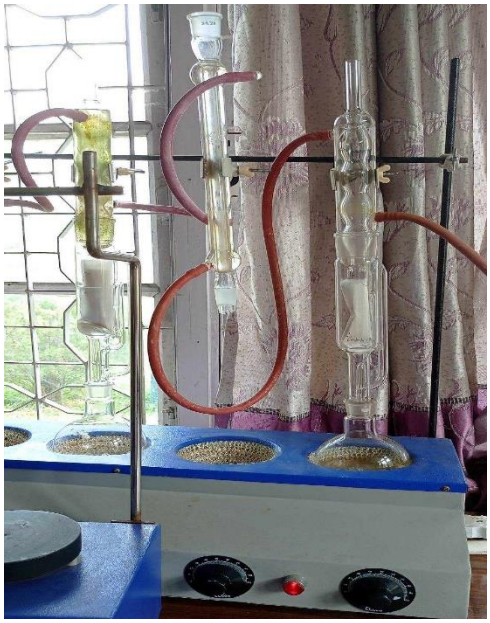
Table D.2 List of chemicals used

Chemicals	
Sodium hydroxide	Potassium Iodide
Sodium thiosulphate	Boric acid
Ethanol	Acetic acid
Phenolphthalein	Chloroform
Petroleum ether	Catalyst mixture
Potassium metabisulphite	Sulphuric acid

Color Plates

P.1 Sensory evaluation

P.2 Titration for protein determination



P.3 Soxhlet apparatus

P.4 Banana chips