EFFECT OF DRYING METHODS AND TEMPERATURE ON THE QUALITY OF APPLE CHIPS AND ITS STORAGE STABILITY

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2024

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A dissertation submitted to the Food Technology Instruction Committee in Tribhuvan University in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology

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January, 2024

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Approval letter

This ***dissertation*** entitled ***Effect of drying methods and temperature on the quality of apple chips and its storage stability*** presented by **Biju Shrestha** has been accepted as the partial fulfillment of the requirement for the **B. Tech. degree in Food Technology.**

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Acknowledgements

I would like to express my deepest gratitude to my supervisor, Asst. Prof. Mahalaxmi Pradhananga (Central campus of technology) for her excellent guidance, valuable suggestions and motivation throughout the work. In addition, I would like to express my sincere thanks to Assoc. Prof. Dr Dil Kumar Limbu (Campus Chief, Central Campus of Technology) and Assoc. Prof. Babita Adhikari (Asst. Campus Chief, Central Campus of Technology), Asst. Prof. Navin Gautam (Head of the department, Department of Food Technology) for providing requisite facilities. Furthermore, thanks are due to all the laboratory and library staffs of Central Campus of Technology, Dharan for their kind co-operation.

I am also heartily thankful to Dharan sub-metropolitan city for providing me financial grant, crucial for the research. Aditionally, I am grateful to my friends Kushum Thapa, Rabina Bishwokarma, Pradip Dahal, Elis Karki, and Suraz Rai for their support in my endeavor.

Lastly, I am very much indebted to my family, my support Alina Subba Tamang and Rijan Rai for their constant encouragement, love and inspiration.

Date of submission: January 11, 2024

(Biju Shrestha)

Abstract

Apple (*Malus domestica*) is High Value Crops (HVC) of mountainous regions of western Nepal. Apple faces the problems due to spoilage loss, poor handling, lack of proper transportation and market. The main aim of this dissertation was to prepare apple chips by using two different pretreatments; blanching in 0.5% Potassium metabisulphite and osmotic dehydration in 40% aqueous glucose. Ten samples were prepared and dried by using different drying methods i.e., cabinet drying, oven drying, and sun drying in varying temperatures of 50°C and 60°C.

The samples were coded as A, B, C, D, E, F, G, H, I, and J in the laboratory and packed in LDPE bags. Sensory data were analyzed by two-way ANOVA (no blocking) using GenStat and means were compared using LSD at 5% level of significance based on sensory attributes i.e., appearance/color, flavor, crispiness, and overall acceptability. From sensory evaluation, Sample coded as A (blanched, cabinet dried at 60°C) was found to be superior than rest of the samples. The best product was evaluated for 3 months in terms of moisture, titratable acidity, pH, TSS, Vitamin C, sensory properties and microbial analysis. As the temperature rose, organic acids became more concentrated, which led to a decrease in pH and an increase in titratable acidity. Similarly, because vitamin C degrades at high temperatures, the amount of vitamin C considerably decreased along with TSS during drying. While pH, TSS, and vitamin C dropped throughout observation, moisture and acidity increased. After 90 days of storage, the sensory qualities in terms of color, flavor, crispiness, and overall acceptability were satisfactory, and microbiological analysis indicated that the product was safe for consumption. The price per 100 grams of apple chips was determined to be NRs. 100.26.

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List of Abbreviations

Abbreviations	Full form
TA	Titratable acidity
TSS	Total soluble solids
ANOVA	Analysis of variance
LSD	Least significant difference
LDPE	Low density polyethylene
CCT	Central Campus of Technology

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Part I

Introduction

1.1 General Introduction

Nepal has different ecological belts endowed with varying climates due to its geographical locations for the production of horticultural crops (Bahadur Thapa and Dhimal, 2017). Vegetables including cauliflower, tomatoes, citrus fruits, apples, pears, mangoes, and bananas are vital horticultural products. Apples are high value crops consumed worldwide and are commercially cultivated and processed for improving the living standard of farmers. In the high mountain regions of western Nepal, it is also the most important fruit in terms of production (Amgai, 2015).

In addition with increasing demand of it the country has to depend on foreign production. The low yield and production could be caused by numerous reasons: It could be inadequate fertilization or lack of modern cultivation practices resulting poor production It was recognized that nearly 30% of the fruits were lost due to spoilage, due to poor handling, weak transportation and lack of cold storage and processing techniques therefore, the demands remain largely unfulfilled from the domestic production. It should be noted that apples are one of the most produced and consumed fruits in the world which can be grown in temperate areas and has a great importance for world agriculture (Gautam *et al.*, 2017).

Apples have great nutritional and organoleptic qualities, making them one of the most popular and famous commercial crops in the world. This fruit is high in fiber, antioxidants, minerals, and polyphenols and it has been linked to a lower chance of developing chronic illnesses, including diabetes, Parkinson’s, Alzheimer’s, and certain types of cancer, as well as cardiovascular disease. Additionally, eating apples has a positive impact on inflammation, vascular function, weight management, and lipid metabolism (Koutsos *et al.*, 2015).

Apple fruit losses are a significant issue in the postharvest chain and are brought on by a wide range of variables, including pre-harvest circumstances, retailer, and consumer behavior. Premature harvesting is one of the contributing factors. Apple harvesting before optimal maturity occurs for several reasons among farmers. Optimal maturity may be delayed by many variables such as early arrival of harvesting laborers, inaccurate harvesting date estimate, or differing environmental conditions. When apples are handled at different stages, like on the farm, during grading, storage, and distribution, they are subjected to a variety of loading actions that might cause bruising. 20% to 50% of the apples overall sustain bruises as a result of various handling procedures. The primary factor influencing the intensity of an apple bruise is its cause, variety, and harvesting conditions (Yuwana and Duprat, 1996).

Drying serves as an invaluable preservation method, crucially extending the fruit's shelf life while concentrating its flavors and nutrients. By removing moisture, the drying process inhibits bacterial growth, preventing spoilage and allowing apples to be stored for prolonged periods without refrigeration. This preservation technique not only retains the essence of the fruit but also creates a versatile ingredient for numerous culinary applications. Dried apples offer a convenient, nutritious snack option, add sweetness and texture to various recipes, and serve as a year-round source of the fruit's vitamins, fiber, and antioxidants, making them a valuable addition to any diet (Polat *et al.*, 2019).

There are various ways by which apples can be dried such as sun drying, oven drying, and cabinet drying. Pretreatments including sulphiting or osmotic dehydration can also be used to enhance the sensory attributes of the product. Any crop’s ability to be produced successfully depends on the post-harvest technologies used. Numerous studies found that issues with post-harvest handling and high-value crop marketing have put the agriculture industry in jeopardy, directly harming farmers’ ability to make a living. Therefore, it is more than justified to put effort into developing relatively simple procedures that make use of easily accessible local resources. The drying temperatures of 50°C and 60°C are optimum for cabinet drying and oven drying of fruits (Seiiedlou *et al.*, 2010).

1.2 Statement of problems

Apples should be handled carefully even after harvesting due to their perishable nature and high danger of spoiling after harvest. For market access, it must be transported over great distances after harvesting. During transit, the containers are conventional in design. Spoilage begins to appear during prolonged shipment. At some point, the produce loses its quality and is deemed unacceptable. Farmers lose out on a fair price as a result, traders incur some of the loss, and consumers are forced to pay more for the remaining portion (Yin *et al.*, 2023). The loss due to this biochemical and microbial changes can be prevented by the development of new products which can be boon for farmers, traders as well as consumers.

In the food sector, one popular way to make apple snacks is by drying them. Because there is less water involved, dying can increase their shelf life, save logistics costs, and give them special physical qualities similar to those of a dry product (Polat *et al.*, 2019).The purpose of this study is to explore an appropriate drying method which is suitable for processing apple chips with the better sensory and physical properties. In addition, this research will also observe the effect in various physicochemical properties of the product due to the applied pretreatments and drying methods.

1.3 Objectives

1.3.1 General objectives

The general objective of this study is the preparation and quality evaluation of dried apple chips.

1.3.2 Specific objectives

1. To carry out pretreatment on apple.
2. To analyze physicochemical properties of apple and apple chips.
3. To prepare apple chips by different drying methods; sun drying, oven drying and cabinet drying.
4. To evaluate the sensory properties of apple chips.
5. To study shelf life of apple chips for 3 months.

1.3 Significance of study

This research work will address the problem faced by apples due to post-harvest losses. The research will be advantageous for the people who are involved in collection, transportation and trading. Finding of this work will be helpful for bulk storage of apple product. Technologically the research will be more advantageous for preventing the financial as well as nutritional loss of apples.

1.4 Limitation of study

1. Only *Malus domestica* was used.
2. Best sample was observed for only 3 months due to time limitation.

Part II

Literature review

2.1 General description of Apple fruit

The apple belongs to the rose family (Rosaceae) and is the pomaceous fruit of the apple tree, species *Malus domestica*. Among the many members of the genus Malus that humans use, it is one of the most extensively grown tree fruits and the most well-known. On small, deciduous trees, apples grow. The tree's wild parent, *Malus sieversii*, is still present in Western Asia, where the tree first appeared. Apples have been cultivated for thousands of years in Europe and Asia, and European settlers carried them to North America. Numerous societies, including the Norse, Greek, and Christian traditions, have included apples in their mythologies and religious practices. After the fruit's genome was deciphered in 2010, new insights into disease prevention and selective breeding in apples were gained (Chaudhary, 2013).

With over 7,500 recognized cultivars, apples can have a variety of desirable traits. Different cultivars are bred for different purposes and tastes, including as making cider, fresh food, and cookery. Although wild apples grow easily from seed, domestic apples are usually propagated by grafting. Numerous bacterial, fungal, and insect issues that affect trees can be managed using both organic and non-organic methods (Hendel, 2013).

China accounted for nearly half of the global apple crop in 2010 with an estimated 69 million tons grown. With about 6% of global production, the US is the second-largest producer. Italy, India, and Poland are in third place, behind Turkey (Ellis *et al.*, 1996). In addition to being consumed raw, apples are a common ingredient in many meals, particularly desserts, and beverages. Apple consumption has been linked to a number of positive health impacts; yet, the fruit's proteins have been linked to two types of allergies and the seeds are somewhat toxic (Boyer and Liu, 2004).

2.1.1 Botanical classification

Kingdom:	Plantae
Sub-Kingdom:	Angiosperms
	Eudicots
	Rosids
Order :	Rosales
Family:	Rosaceae
Subfamily:	Maloideae or Spiraeoideae
Tribe:	Maleae
Genus:	*Malus*
Species:	*M.domestica*
Binomial name:	*Malus domestica*
Nepali name:	Shyau

Source: Borkh (1803)

2.1.2 Present scenario of apple in Nepal

In Nepal, apple cultivars with high chilling and low chilling temperatures are grown. The main cultivars with high freezing temperatures include Granny Smith, Red, Royal, and Golden Delicious, as well as Mc Intosh, Jonathan, Rome Beautiful, Richared, and Golden Spur. Because of its superior fruit quality, the delicious group of cultivars encompasses a significant portion of the market. The cultivars Katza, Red June, Cox Orange Pippin, Crispin, and Summer Pippin are considered to be mid-chilling. Among the low chilling cultivars are Winter Banana, Tropical Beauty, Anna, and Vered, among others (Devkota, 1999).

As for production areas, Low chilling kinds are produced at elevations as low as 1200 m.a.s.l., where chilling is 600–1000 hours; high and mid chilling cultivars are primarily grown at an altitude range of 1800–2800 m.a.s.l. In terms of elevation, apples can be grown in mid- and high-mountain regions from Eastern to the Far West; however, the best places for producing high-quality apples are limited to the Mid and Far West region where dry to semi-humid conditions exist because of high humidity and heavy rainfall during the growing season (Devkota, 1999).

2.1.3 Nutritional value of apple

Apples are a good source of dietary fiber and a Vitamin A. Most of the Vitamin A, as well as the dietary fiber, are contained within the skin of fruit. The chemical composition of apple per 100g is given in Table 2.1.

Table 2.1: Chemical composition of Apple fruit per 100g

Constituents	**amount**
Energy	50 Kcal (2.5%)
Carbohydrates	13.81 g (11%)
Protein	0.26 g (0.5%)
Total fat	0.17 g (0.5%)
Cholesterol	0 mg (0%)
Dietary fiber	2.40 g (6%)
Folates (Vit. B9)	3 µg (1%)
Niacin (Vit. B3)	0.091 mg (1%)
Pantothenic acid (Vit. B5)	0.061 mg (1%)
Pyridoxine (Vit B7)	0.041 mg (3%)
Riboflavin (Vit. B2)	0.026 mg (2%)
Thiamin (Vit. B1)	0.017 mg (1%)
Vitamin A	54 IU (2%)
Vitamin C	4.6 mg (8%)
Vitamin E	0.18 mg (1%)
Vitamin k	2.2 µg (2%)
Sodium	1 mg (0%)
Potassium	107 mg (2%)
Calcium	6 mg (0.6%)
Iron	0.12 mg (1%)
Magnesium	5 mg (1%)
Phosphorus	11 mg (2%)
Zinc	0.04 mg (0%)
Carotene-ß	27 µg
Crypto-xanthin-ß	11 µg
Lutein-zeaxanthin	29 µg

(Source: USDA National Nutrient data base)

2.1.4 Uses of apple

Apples are eaten dry, juiced, tinned, and fresh. Apples and their juice can also be used to make jams and jellies; typically, they are combined with berries or other fruits. They are ground to make sweet, non-alcoholic apple cider and then filtered to extract apple juice. The juice can be fermented to produce vinegar, ciderkin, and hard cider (alcoholic). Numerous alcoholic beverages, including applejack, and Calvados, can be made through distillation (Brown, 2012).

Apple seed oil and pectin could potentially be manufactured. Apples play a major role in a variety of dessert recipes, including apple cake, crisp, pie, and crumble. They can be dried and eaten, or reconstituted (soaked in water, alcohol, or another liquid) for later use. They are commonly consumed baked or stewed. Apple sauce is the common term for puréed apples. Apples are also used to make apple jam and butter. Additionally, they are utilized in cooked meat meals (Shalini *et al.*, 2010).

2.1.5 Health benefits of apple consumption

Considering the health benefits of apples, the adage "An apple a day keeps the doctor away." originated in Wales in the 19th century (Phillips, 1866). According to research, apples may lower the risk of lung, prostate, and colon cancer. Apples are a strong source of various antioxidant chemicals but have comparatively low levels of vitamin C when compared to many other fruits and vegetables (Boyer and Liu, 2004). Apple's antioxidant content shields cells and tissues from harm. Although it is less than in most other fruits, the fiber content aids in controlling bowel motions and may therefore lower the risk of colon cancer.

Additionally, they might aid in cholesterol management, weight loss, and heart disease prevention. Apples, like most fruits and vegetables, are heavy for their calorie level, but their fiber content lowers cholesterol by blocking its reabsorption (Sharma, 2005). On the other hand, apple seeds have a minor quantity of the cyanogenic glycoside amygdalin, which makes them somewhat toxic. Usually not enough to pose a threat to people, but it can discourage birds. According to research conducted in lab settings, apples have phenolic chemicals that show antioxidant and may prevent cancer (Lee *et al.*, 2004). According to (Lee *et al.*, 2003), quercetin, epicatechin, and procyanidin B2 are the main phenolic compounds found in apples.

2.2 Sulphiting

The phrase "sulphiting agent" typically describes gaseous sulfur dioxide or the salts of hydrogen sulphite (bisulphite), disulphite (metabisulphite), or sulphite ions in sodium, potassium, and calcium. Since they are all transformed into the same ionic or non-ionic species at a specific pH, ionic strength, and non-electrolyte concentration, they are all chemically similar after being added to food (Wedzicha, 1992).

Sulphiting, a technique harnessing sulfur dioxide or sulfites, serves as a pivotal method across multiple industries. Whether in winemaking, food preservation, or water treatment, sulfiting operates as a potent tool to deter spoilage and oxidation. In winemaking, sulfites aid in preserving freshness and impeding microbial growth, vital for maintaining the quality and longevity of the wine. Similarly, in food preservation, sulfites prevent discoloration and spoilage in various edibles, extending their shelf life and upholding visual appeal. Even in water treatment, sulfites play a role, scavenging excess chlorine or oxygen, thereby safeguarding against corrosion and maintaining water quality. However, prudent handling and dosage control are imperative, given the potential for allergic reactions in sensitive individuals and the necessity of adhering to regulatory guidelines to prevent environmental impact. Sulfiting remains a valuable technique, striking a balance between preservation efficacy and mindful application across diverse industrial domains (Mir *et al.*, 2009).

2.3 Osmotic Pretreatment

Foods mostly consist of water, which has an impact on the chemical and microbiological stability of food. It determines how various organoleptic qualities like juiciness, flexibility, softness, and texture are perceived by consumers. In the food sector, dehydration plays a crucial role in the preservation of both raw ingredients and finished goods. Removing water from the raw materials to increase food products' shelf life and lower their water activity is the main goal of food dehydration. Water activity can be reduced in two different ways: either by eliminating solvents like water or by adding humectants (Jin Shi and Xue, 2009).

Osmotic dehydration, which involves eliminating water at low temperatures, has the potential to produce better food products. Since it can lower the overall energy need for additional drying, it has been frequently utilized as a pretreatment step in the food drying process (Schluep *et al.*, 2006).The passage of water molecules down a water potential gradient across a selectively permeable membrane is known as osmosis. To be more precise, it is the transfer of water from an area of high water potential (low solute concentration) to an area of low water potential (high solute concentration) over a selectively permeable membrane (Rastogi *et al.*, 2002).

This procedure is used as a pre-drying, freezing, or pasteurizing step, or to get minimally processed food. When used before drying, it can use less energy since it takes less time to reach the appropriate product moisture content than when drying without pretreatment. It is feasible to keep the flavor and aroma of the raw material in addition to the dyes' stability with this kind of treatment (Kowalska *et al.*, 2018).

2.3.1 Osmotic agent

The osmotic agent type is a crucial factor in determining the diffusion rate. Common osmotic agents include sucrose, glucose, sorbitol, glycerol, glucose syrup, fructo-oligosaccharide, and maize syrup. When opposed to high molecular weight osmotic agents, low molecular weight osmotic agents typically enter fruit cells more easily (El-Aouar *et al.*, 2006).

2.3.2 Factors Affecting Osmotic Dehydration Process

Numerous factors influence the mass transfer process of osmotic dehydration. Terms like water loss, solids or solutes gain, and weight reduction are used to characterize the kinetics of mass transfer (Pękosławska *et al.*, 2009). Some factors that affect the mass transfer during osmotic dehydration are pre-treatment factors, product-related factors and osmotic solution related factors. The rate of dehydration is significantly influenced by the permeability of the cell membrane. Osmotic dehydration will ultimately occur more quickly in the case of good membrane permeability (Toupin *et al.*, 1989).

2.3.3 The Osmotic Dehydration Mechanism

Osmotic therapy, which can reduce the detrimental changes to fresh food components, is really a combination of dehydration and impregnation procedures. The technique of osmotic dehydration, often referred to as the "dewatering impregnation soaking process," includes soaking fruits and vegetables in a solution containing hypertonic salt, sugar, or both in order to decrease their water content and increase their soluble solid content.(Falade *et al.*, 2007).

The raw material is added to concentrated soluble solids solutions that have reduced water activity and a higher osmotic pressure. This causes the osmotic dehydration process to exhibit three different forms of counter mass transfer phenomena.

a) Product diffuses into the solution with water, first more quickly and then more slowly.
b) A solute transfer from the solution to the product; this enables the addition of the appropriate concentration of an active ingredient, preservative, solute, or nutritional interest, or enhances the product's sensory qualities.
c) Leaching of the solutes that a product contains such as sugar, organic acids, minerals, vitamins, etc (Roussos *et al.*, 2014).

The first layer of cells in a cellular solid material that is submerged in a hypertonic solution shrinks as a result of the cells' loss of water due to the concentration gradient between the cells and the hypertonic solution. A "chemical potential difference of water" forms between the first and second layers of cells as the first layer's cells start to lose water. The second layer cells subsequently start to shrink and pump water to the first layer cells. As a function of operating time, the mass transfer and tissue shrinkage phenomena propagate from the material's surface to its center. After an extended duration of solid–liquid contact, the material center's cells finally lose water and the mass transfer mechanism tends to equilibrate. Tissue shrinkage and mass transfer happen at the same time during the osmotic dehydration process.(John Shi *et al.*, 2003)

2.4 Drying

2.4.1 Introduction

Fluid extraction from a material is referred to as drying. Using a variety of techniques, the moisture in the material is extracted during the drying process when technical drying is implemented. Thus, the definition of drying is the reduction of the material's moisture content to the required drying values in a specific amount of time.In order to remove water vapor once it separates from the solid, drying requires applying heat to evaporate volatile substances (moisture) and using a methodical approach (Jayaraman and Gupta, 2020). Water migrates from the drying product's core to the surface during the process of drying, where it evaporates as a result of heat and mass transfer.

Heat is transmitted to the product's surface from the ambient air. A portion of this heat is transmitted to the product's interior, where it raises the temperature and produces water vapor. The remaining heat is used to evaporate the moisture that is present on the surface (López *et al.*, 2009). Food preservation through dehydration is the oldest technique used by humans. For thousands of years, humans have survived during the year's off-season by drying and/or smoking meat, fish, fruits, and vegetables.

These days, the food industry's dehydration division is vast and present in every nation on the planet. Simple sun or hot air driers to large, complex spray or freeze-drying equipment are examples of drying facilities. There is an enormous variety of dehydrated foods that are readily available and contribute significantly to the convenience food industry. When heat is applied to remove the majority of the water that is typically present in food, evaporation or sublimation, the phrases dehydration and drying are used interchangeably. The primary purpose of drying food is to increase its shelf life beyond that of fresh food, eliminating the need for refrigerated storage and transportation. This is accomplished by lowering the water activity or available moisture to a level that prevents the growth and development of pathogenic microbes and spoilage, as well as by lowering the activity of enzymes and the rate at which unwanted chemical changes take place (B. Singh *et al.*, 2009).

2.4.2 General principles

The process of thermally eliminating moisture to produce a solid product is known as drying. In a solid, moisture can be found either bound or free. Bound moisture is defined as moisture with a vapor pressure less than that of a pure liquid; moisture that is present in excess of bound moisture is referred to as unbound moisture. Heat and mass transfer are the two most significant thermodynamic processes in food drying. The food and the drying air exchange mass and heat simultaneously when hot-air drying (Maroulis *et al.*, 1995).

a) Heat transfer
   - Convective heat (energy) transfer from the air to the food`s surface (external heat transfer).
   - Conductive heat transfer within the food (internal heat transfer)

b) Mass transfer

- Moisture transport within the food toward its external surface (internal mass transfer).
- Evaporation and convective transfer of the vapour into the air (external mass transfer)

The methods of moisture transfer may alter as drying time passes because the physical structure of the drying solid is susceptible to modification (Larbi, 2014). Although convection is a common and predominant mechanism, energy transfer as heat from the surrounding environment to the wet solid can occur as a subsequence of convection, conduction, or radiation, or in some cases as a result of a combination of these effects (Aguilera and Stanley, 1999). Heat is often first transported to the wet solid's surface and then its inside. This heat transfer to the food surface raises the temperature of the sample and provides the necessary latent heat of vaporization for the water in the product as well as the water on the surface. Concurrently, the food's internal moisture (mass) moves to the surface and subsequently evaporates into the hot air around it (Aversa *et al.*, 2007). Both internal and external resistance to heat and/or mass transmission are involved in transport phenomena. The drying rate is determined by the elements that slow down these processes (Ramaswamy and Marcotte, 2005).

To put it another way, the drying rate is regulated by the resistance mechanisms. It is generally acknowledged that, depending on the drying conditions, the pace of drying may be restricted by the rate at which water molecules migrate internally to the surface or by the rate at which water molecules evaporate from the surface into the air (R. Singh and Heldman, 2009). This suggests that the resistance to heat transfer may be disregarded since the resistance to mass transfer is thought to be the main rate-limiting mechanism. This is because heat is typically transferred through food more readily than moisture, so it is reasonable to assume that temperature gradients inside food are flat (that is, there is no resistance to internal heat transfer), especially in contrast to the steep gradient of moisture content (Fortes and Okos, 1981).

Furthermore, as the product's water evaporates, it is recognized that the thermal conductivity of the material may restrict heat transport within the meal (Donsì *et al.*, 1996). While only the physical characteristics of the food, its moisture content, and temperature affect internal mass transfer, the resistance to external heat and mass transfer is influenced by air temperature, air humidity, air velocity, and exposed surface area. Since the food's internal resistance is low enough to keep the surface saturated at the start of the drying process, evaporation occurs at a steady pace that is mostly dependent on mass transfer and external heat. Resistance to internal mass transfer controls the process when the drying rate begins to decline as a result of insufficient water at the surface. Therefore, as the product dries out, the majority of meals 24 transition from an external drying process to an internal drying process (Ramaswamy and Marcotte, 2005).In addition, the food sample's drying rate, which starts to decline at a constant temperature at the outset of the process, would suggest that the drying is controlled by internal resistance to mass transfer (Uddin *et al.*, 1990).

2.4.3 Drying mechanism

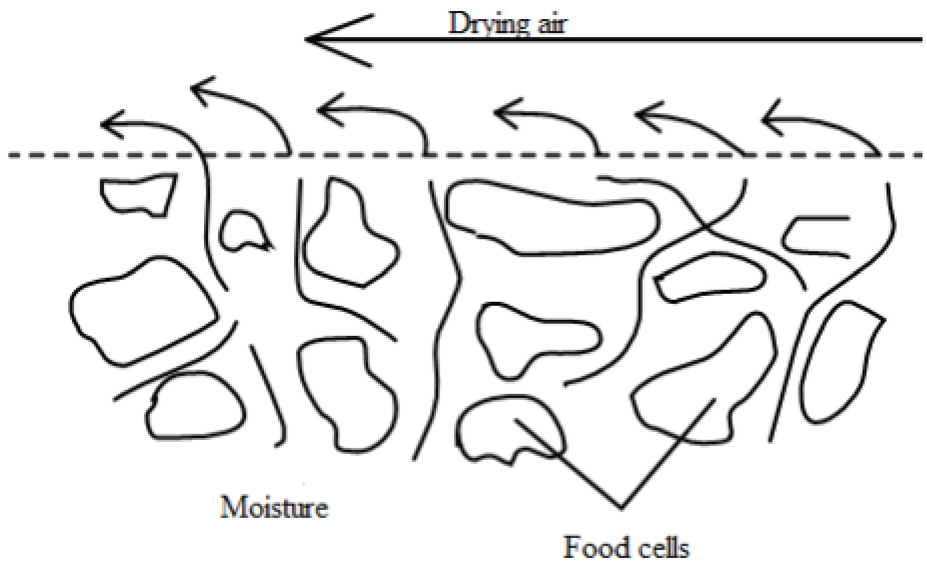


Fig. 2.1: Movement of moisture during drying (Geankoplis, 2003)

Heat is transported to the surface of wet food when hot air is blown over it, and water evaporates due to latent heat of vaporization. Water vapor is carried away by the moving air after diffusing through a boundary film of air. As a result, there is a drop in water vapour pressure at the food's surface and a rise in water vapour pressure from the food's moist interior to the dry air. The force behind the food's water elimination is this gradient (Kharel, 2006).

Water moves to the surface by the following mechanisms:

a. Liquid movement by capillary forces
b. Diffusion of liquids, caused by differences in the concentration of solutes in different regions of the food
c. Diffusion of liquid which is adsorbed in layers at the surface of solid components of the food, and
d. Water vapour diffusion in air spaces within the food caused by vapour pressure gradients.

The entire amount of moisture that can be lost from a specific food will depend on the air's temperature and humidity. During the drying process, dissolved particles such as salt, sugar, and acid are transported to the surface by the outflow of water. Here, the soluble solids concentrate and may even precipitate at the surface when the water evaporates into the atmosphere. The drying process itself may limit the amount of water removed as it goes on. Food tissue frequently sinks because it loses moisture, its structure can alter, and the water can't escape. Case hardening is the term for this state, in which the inside is still moist but the outer trough surface has formed. A product with a hard exterior surface is more resistant to water absorption and is more vulnerable to microbial deterioration. This issue is resolved by occasional conditioning and less severe drying (Kharel, 2006).

2.4.4 Factors affecting drying

The rate of drying principally depends on internal and external condition (Mujumdar, 2006).

a) External condition

   Temperature, humidity, air velocity and direction, the solid's physical form, the need for agitation, and the technique used to maintain the solid during the drying process are the key external variables. When unbound surface moisture is eliminated during the early stages of drying, external drying conditions are particularly crucial. High moisture gradients from the interior to the surface are created in some situations by excessive surface evaporation after the initial free moisture has been removed, such as in materials like ceramics and wood that experience significant shrinkage (Mujumdar, 2006).

This could lead to over drying, excessive shrinkage, and high tension inside the material, which could cause warping and breaking. In these circumstances, the maximal safe rate of internal moisture movement by heat transfer should be maintained while surface evaporation is postponed by using high air relative humidity. The diffusion of vapor from a solid's surface into the surrounding atmosphere through a thin layer of air in contact with the surface regulates surface evaporation (Mujumdar, 2006).

b) Internal conditions

A temperature gradient forms inside the solid as a result of heat transfer to a wet solid, and moisture evaporation happens from the surface. As a result, moisture migrates from the solid's interior to the surface via one or more mechanisms, including diffusion, capillary flow, and internal pressures created by the solid's shrinking during the drying process. Understanding this internal moisture movement which happens after the critical moisture content in a drying process carried out to low final moisture contents is crucial when it becomes the determining factor.

The rate of surface evaporation is typically accelerated by variables like temperature and air velocity; these factors are less significant until they accelerate the rates of heat transfer. Extended periods of stay and, where appropriate, elevated temperatures become important. Simultaneously with the movement of liquid moisture, the temperature gradient established in the solid will also produce a vapor-pressure gradient, which will lead to the diffusion of moisture vapor to the surface (Mujumdar, 2006).

2.4.5 Drying methods

2.4.5.1 Traditional sun drying

The conventional technique for drying, called "sun drying," entails merely placing the product on drying floors, mats, or roofs and leaving it in the sun. Little capital is needed because the energy sources; sun and wind are easily accessible in the surrounding area. Fruits and vegetables are still commonly sun-dried (Bux *et al.*, 2002).

Heat is transmitted from the surrounding air during sun drying by convection, which occurs when direct and diffuse radiation are absorbed by the crop's surface. A portion of the converted heat is utilized for efficient moisture diffusion from the interior to the surface and another portion is used to raise the temperature of food products. The water on the surface evaporates using the energy that is left over. Natural convection assisted by wind forces must be used to remove the evaporated water from the crop's surroundings (Bux *et al.*, 2002).

The benefits of sun drying are low capital and running expenses, ease of use, and minimal skill requirement. However, there are also a lot of technical issues, which include unpredictabilities like rain and clouds, external contamination, and an inability to control drying conditions. It needs a lot of space and time to dry. The finished product may have a comparatively high moisture content, be low and changeable in quality as a result of over- or under-drying, be contaminated by dust, insects, or birds, and experience problems with microbial and enzyme activity. It can only be found in regions with intense winds, a dry atmosphere, and scorching temperatures (Jayaraman and Gupta, 2020).

2.4.5.2 Solar drying

When constructed properly, solar dryers offer a few advantages over sun drying. By raising the air's temperature to 10–30ºC above ambient, they can achieve faster drying rates by reducing humidity, accelerating air flow through the dryer, and keeping insects away. Faster drying lowers the chance of spoiling, enhances product quality, and increases throughput, all of which lower the required drying area. When drying fruits, it's important to take caution to avoid drying them too quickly, since this could lead to case hardening and the subsequent formation of mold. Foods are shielded from dust, insects, birds, and animals by solar dryers as well. They don't require fuel and may be built for a relatively small upfront cost using locally accessible materials. They can therefore be helpful in places with high air humidity but plenty of sunshine, expensive or scarce land for sun drying, and high fuel or electricity costs. In addition, they could be helpful in lowering fuel expenses by heating the air for artificial dryers (Fellows, 1997).

The design of solar dryers is based on the following principle: relative and absolute humidity are crucial factors in drying. Moisture can be absorbed by air, but not completely. The absolute (highest) humidity is at this limit, and it varies with temperature. Food that has been moistened will absorb moisture from the air until it is almost completely saturated, or until absolute humidity is reached. However, the temperature of the air affects its ability to absorb this moisture. The absorption of moisture increases with temperature, as does the absolute humidity. Warm air allows the air to absorb more moisture from its surroundings since it has the same amount of moisture but a lower relative humidity (Gavhale *et al.*, 2015).

2.4.5.3 Cabinet Drying

Convectional hot-air drying at atmospheric pressure is the most widely used method in industrial drying facilities due to its simplicity and affordability. Convectional hot-air dryers have therefore been used to dry a wide range of food products, including fruit, vegetables, herbs, and cereal crops. Additionally, these dryers, especially cabinet dryers make it simple to set and manage the ideal drying conditions. Kiln, cabinet (tray), tunnel, belt, or conveyor dryers are examples of common atmospheric hot-air dryers (Jayaraman and Gupta, 2020).

The fundamental design of an atmospheric hot-air drier consists of a heated, enclosed chamber that holds food materials. In order to facilitate the movement of hot air around and across the food, it is additionally outfitted with ducts and a blower, or fan. Natural convection is how drying happens in the absence of a fan. In an atmospheric dryer, the product must be heated in addition to having water removed from its surface (Rahman and Perera, 2007). Conventional convective drying techniques use a consistent, ongoing air temperature to remove moisture from food products. Convection is the process by which thermal energy is transferred from the heater to the food material. The material's thermal conductivity determines how much of this thermal energy can permeate it. As the food dries, gas (air) replaces the moisture that exits its pores in the outer layers. Because air has a lower thermal conductivity than water, this causes the thermal conductivity of the outer layers to drop. The product surface acts as an insulator as a result.

Water moves more slowly to the surface, where evaporation takes place, and the amount of heat that is provided to the food sample's interior is gradually reduced. Therefore, without a discernible increase in the drying kinetics, large heat transfer rates applied at the surface will merely cause the surface layer to overheat or over dry, resulting in quality issues (Lewis, 1990).

Part III

Materials and methods

3.1 Materials

3.1.1 Raw materials

3.1.1.1 Apple collection

Fresh apples produced in Marpha, commonly known as Shyau were brought from local market of Dharan.

3.1.1.2 LDPE packaging

LDPE plastic bag (15 x 22) of 40 µ was bought from local market of Dharan.

3.1.1.3 Glucose

The glucose required for osmotic pretreatment was provided by CCT.

3.2 Methods

3.2.1 Washing

Apples were washed with clean tap water to remove dust particles.

3.2.2 Slicing

Apples were sliced into uniform thickness of 0.1 cm with a slicer.

3.2.3 Pretreatments

Two types of pretreatments were applied i.e, sulphiting and osmotic dehydration.

3.2.3.1 Sulphiting

Apples were sulphited with 0.5 % Potassium metabisulphite with ratio of material to liquid of 1:6 for 1 minute (Xiao *et al.*, 2017).

3.2.3.2 Osmotic dehydration

Another sample was osmotically dehydrated in 40% aqueous glucose solution for 30 minutes (Chavan and Amarowicz, 2012).

3.2.4 Draining

After the sulphiting and dewatering time, the respective samples were separated from the solution, rinsed for a few seconds under cold running tap water, dried on blotting paper to remove excess moisture.

3.2.5 Drying

The different samples were oven dried at the temperature of 50±5ºC and 60±5ºC, another samples were cabinet dried at the temperature of 50±5ºC and 60±5ºC and next samples were sundried until equilibrium moisture content was obtained. The types of pretreatments, drying methods and temperature range used are shown in table 3.1.

Table 3.1: Types of pretreatments, drying methods and temperature range used

Sample	Pretreatment	Drying method	Drying temp. (°C)
A	Sulphiting	Cabinet dried	60
B	Sulphiting	Cabinet dried	50
C	Sulphiting	Oven dried	60
D	Sulphiting	Oven dried	50
E	Sulphiting	Sun dried	-
F	Osmotic dehydration	Cabinet dried	60
G	Osmotic dehydration	Cabinet dried	50
H	Osmotic dehydration	Oven dried	60
I	Osmotic dehydration	Oven dried	50
J	Osmotic dehydration	Sun dried	-

Drying fruit at low temperatures helps preserve its nutritional content and flavor. High temperatures can break down certain enzymes and nutrients in fruits, leading to a loss of vitamins, minerals, and antioxidants. By using lower temperatures, the drying process takes longer but allows the fruit to retain more of its original nutritional value and taste. Additionally, low-temperature drying helps prevent the fruit from cooking or caramelizing, preserving its color and natural sugars. This method also inhibits the growth of bacteria and molds, extending the shelf life of the dried fruit.

The flow diagram for the drying of apple slices is shown in **Fig. 3.1.**

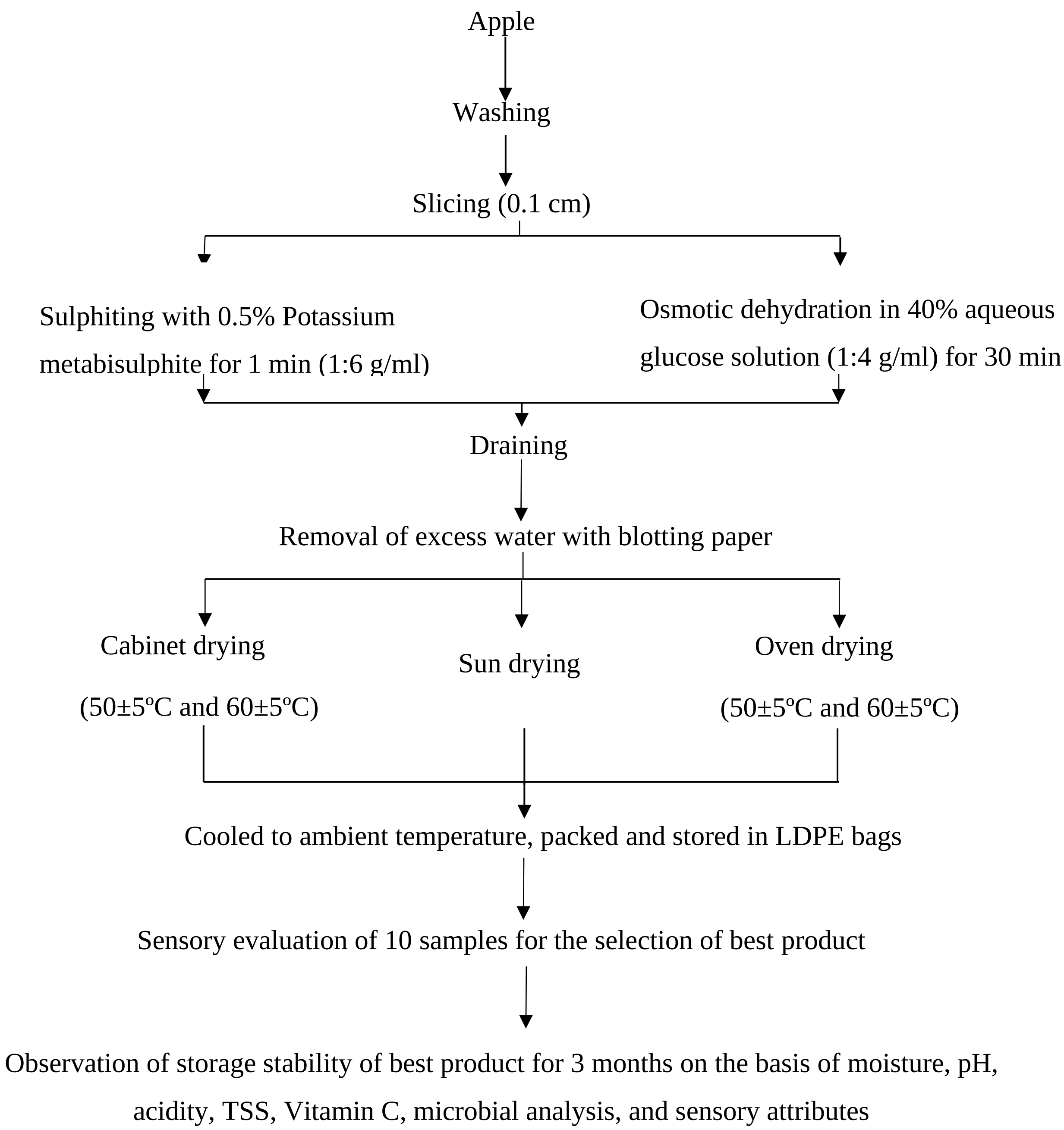


Fig 3.1: Flowchart for the preparation of apple chips

Source: (Zhu *et al.*, 2022)

3.2.6 Storage

The dried samples were stored in LDPE pouches (15 x 22) of 40 µm for 3 months for further analysis.

3.2.7 Physiochemical analysis of fresh apple and apple chips

3.2.7.1 Determination of moisture content

The moisture determination was carried out by hot-air oven method (Ranganna, 1986).

3.2.7.2 Determination of TSS

The determination of TSS was done using Atago refractrometer (Ranganna, 1986).

3.2.7.3 Determination of total and reducing sugars

Total sugar and reducing sugar was determined by Lane and Eynon's method from the process given by Ranganna (1986) .

3.2.7.4 Determination of titratable acidity and pH

Acidity was determined by titration with the standard sodium hydroxide (0.1N) solution and expressed as % malic acid (Ranganna, 1986). pH was determined using pH meter.

3.2.7.5 Determination of vitamin C

The vitamin C content was determined by 2, 6-Dichlorophenol-indophenol visual titration method (Ranganna, 1986).

3.2.8 Storage stability

Storage stability of the product was observed for three months. Moisture content, TSS, acidity, pH, vitamin C, sensory attributes, and microbial condition were observed every 15 days until 3 months.

3.2.9 Sensory evaluation

The product was subjected to sensory evaluation by semi-trained panel of judges using 9 points hedonic scale.

3.2.10 Statistical analysis

At the 5% level of significance, the collected data were examined using a two-way ANOVA (no blockings). The LSD approach (Genstat 5 Release 12.1, a software package created by

Lawes Agricultural Trust, Rothamsted Experimental 35 Station, 2009) was used to compare the treatment means. Using Fisher's LSD (least significant difference) approach at the 5% level of significance, the means of the data were separated to determine their significance.

Part IV

Results and discussions

The apples were washed and sliced into uniform thickness of 0.1 cm. One sample was blanched in 0.5% potassium metabisulphite whereas another was osmotically dehydrated in 40% dextrose solution for 30 minutes. One batch was sun dried, another cabinet dried and the last was oven dried. The drying temperatures for oven and cabinet dryer were of 50±5ºC and 60±5º.After the completion of drying, they were cooled and packed in LDPE packaging then stored for further analysis in terms of moisture content, colour, acidity, pH, vitamin C, sensory attributes, and microbial condition for 3 months. There was observable change in every attribute but the product was still in good condition after completion of 90 days, even after going through physiochemical changes in terms of analyzed parameters.

4.1 Chemical composition of fresh apple fruit

It was found that apple's moisture content was 85.74±0.04%, whereas vitamin C content was found to be 11.72±0.02 mg/100g, slightly more than the USDA's recommended value of 8%, and apple acidity, at 0.66±0.01% which was lower compared to Karadeniz and Eksi (2002). The acidity was 1.3%, according to Karadeniz and Eksi (2002). The variation in the outcome could be caused by variations in the apple's maturity and the method used to determine it. The results showed that the total sugar and reducing sugar percentages were 10.42±0.06% and 6.66±0.02%, respectively, which were comparable to the USDA data source and Karadeniz and Eksi (2002). The result obtained is delineated in table 4.1.

Table 4.1: Physicochemical properties of fresh apple

Parameter	Value
Moisture (% db)	85.74±0.04
Sugar	
-Reducing sugar (% DM)	6.66±0.02
-Total sugar (% DM)	10.42±0.06
Total acidity as malic acid (%)	0.66±0.01
Vitamin C (mg/100g)	11.72±0.02
pH	4.86±0.04
TSS (°Bx)	16.31±0.06

*Values in the table are arithmetic mean of triplicate samples. Figures in the parentheses indicate standard deviation.

4.2 Sensory evaluation

Ten samples were prepared by varying the pretreatments (sulphiting and osmotic treatment) as well as drying temperatures of 50±5ºC and 60±5ºC and Sensory evaluation of samples was carried out in terms of color, flavor, crispiness and overall acceptability using a 9-point hedonic scale by semi trained panelists. The specimen of evaluation card is shown in appendix A.

4.2.1 Colour

Regarding color of the prepared apple chips, the analysis showed that the mean sensory scores for sample A, B, C, D, E, F, G, H, I, and J were found to be 8±0.57, 6.16±0.68, 7±0.81, 6±0.57, 6.33±0.47, 6.66±0.94, 6.5±0.95, 6.5±0.53, 6.66±0.74 and 6.16±0.89 respectively. Sample A was found to be superior whereas sample D obtained lowest scores. Statistical analysis showed that there was significant difference LSD at 5% level of significance between sample A and rest of the samples. It indicated that the samples were significantly different in terms of colour.

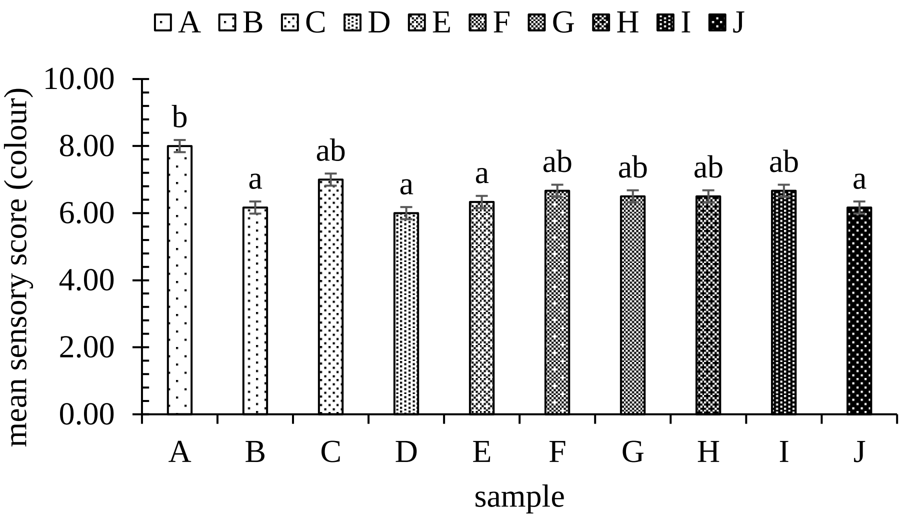


Fig. 4.1: mean sensory scores for ten samples in terms of colour

The figure represents the mean sensory scores for color of apple chips. Values on the top of the bars bearing similar superscript are not significantly different at 5% level of significance. The vertical error bar represents ±standard deviation of scores given by panelist.

The superiority in colour of sample A may be due to the use of potassium metabisulphite that preserved its colour and drying in proper drying temperature also prevented caramelization and browning of the product. Similarly, the rest of the samples were found similar as they were also dipped in hypertonic glucose solution as soon as they were sliced which caused reduced oxygen exposure. Submerging apple slices in water creates a barrier between the cut surface of the apple and the air. This limits the amount of oxygen that comes into contact with the enzymes in the apple, slowing down the enzymatic browning reaction (Sahu *et al.,* 2019).

4.2.2 Flavour

As for the flavour of the prepared apple chips, the analysis showed that the mean sensory scores for samples A, B, C, D, E, F, G, H, I, and J were found to be 8±0.57, 6.83±0.68, 6.66±0.74, 7.16±0.68, 6.66±0.47, 6.83±0.68, 6.33±0.74, 7.16±0.68, 6.66±0.47, and 6.83±0.68 respectively. With the highest score, sample A was found to be superior than rest of the samples while sample G had the lowest score. Statistical analysis showed that there was significant difference LSD at 5% level of significance between sample A and sample G. It indicated that the sample A and sample G were significantly different in terms of flavour.

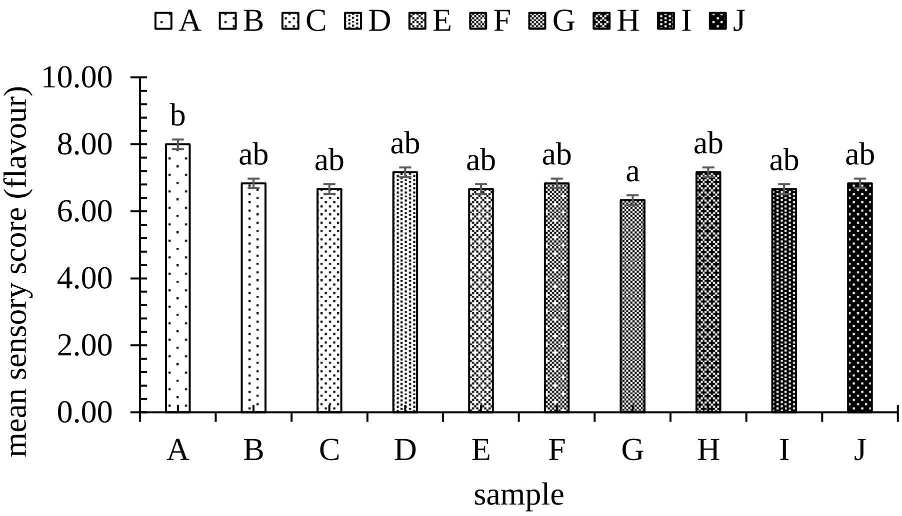


Fig. 4.2: : mean sensory scores for ten samples in terms of flavour

The figure represents the mean sensory scores for flavour of apple chips. Values on the top of the bars bearing similar superscript are not significantly different at 5% level of significance. The vertical error bar represents ± standard deviation of scores given by panelist.

There was uniform drying of product in cabinet drying because of the precise temperature control whereas, the oven showed repeated fluctuation in temperature that resulted in longer time. In addition, due to the decrement of moisture, the samples that were sulphited also tasted sweeter than raw apple due to which there was no prominent difference due to the types of pretreatments.

4.2.3 Crispiness

Regarding crispiness of the prepared apple chips, the analysis showed that the mean sensory scores for samples A, B, C, D, E, F, G, H, I, and J were found to be 8.5±0.5, 7.16±0.37, 6.33±0.47, 6.83±0.68, 5.83±0.68, 6.66±0.47, 7±0.81, 6±0.57, 6.66±0.47, and 7±0.57 respectively.

Sample A had highest score and sample G was at the bottom. Statistical analysis showed that there was significant difference LSD at 5% level of significance indicated that the samples were significantly different in terms of crispiness. Samples A had significant difference with rest of the samples in terms of crispiness.

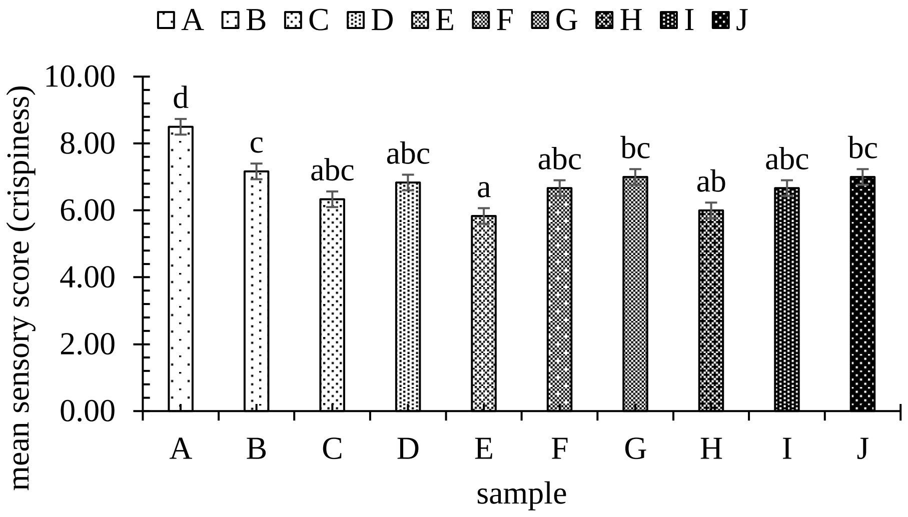


Fig. 4.3 : mean sensory scores for ten samples in terms of crispiness

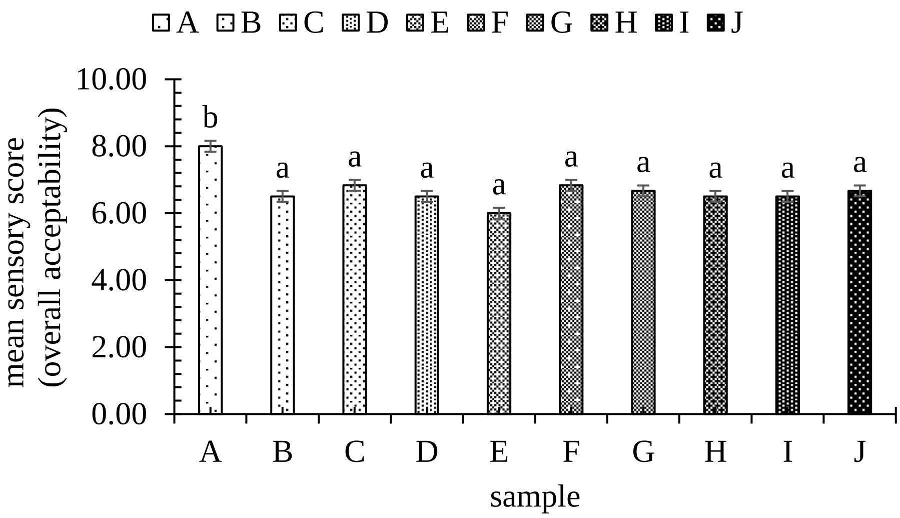
The figure represents the mean sensory scores for crispiness of apple chips. Values on the top of the bars bearing similar superscript are not significantly different at 5% level of significance. The vertical error bar represents ± standard deviation of scores given by panelist.

Highest crispiness may be due to uniform drying in cabinet dryer. At higher temperatures, the moisture content within the chips evaporates rapidly. This is crucial for achieving crispness because moisture leads to a softer texture. Removing moisture quickly helps create a crispy exterior (Aversa *et al.*, 2007).

4.2.4 Overall acceptability

For overall acceptability, the analysis showed that the mean sensory scores for samples A, B, C, D, E, F, G, H, I, and J were found to be 8±0.57, 6.5±0.5, 6.83±0.68, 6.5±0.53, 6±0.57, 6.83±0.68, 6.66±0.47, 6.5±0.5, 6.5±0.51, and 6.66±0.47 respectively.

Sample A was found to be superior than rest of the samples. Statistical analysis showed that there was significant difference LSD at 5% level of significance indicated that the samples were significantly different in terms of overall acceptability. Sample A had significant difference with all other 9 samples while rest of the samples were not significantly different with each other in terms of overall acceptability.



. **Fig 4.4:** mean sensory scores for ten samples in terms of overall acceptability

The figure represents the mean sensory scores for overall acceptability of apple chips. Values on the top of the bars bearing similar superscript are not significantly different at 5% level of significance. The vertical error bar represents ± standard deviation of scores given by panelist.

The color, flavour, and crispiness of sample A was preferred. Therefore, the overall acceptability of sample A was found to be significantly superior based on the sensory characteristics.

4.3 Physicochemical properties of best product

Physicochemical analysis of the best sample was done and the results obtained are tabulated below in table 4.4

Table 4.3: Physicochemical properties of best product

Parameters	Values
Moisture (% db)	5.08±0.01
Sugar	
-Reducing sugar (% DM)	5.56±0.02
-Total sugar (% DM)	8.36±0.02
Total acidity as malic acid (%)	0.72±0.004
Vitamin C (mg/100g)	4.23±0.04
pH	4.12±0.004
TSS(°Bx)	11.86±0.05

*Values in the table are arithmetic mean of triplicate samples. Figures in the parentheses indicate standard deviation.

The amount of vitamin C in the product reduced in comparision to raw apple. It may be due to the combination of exposure to heat, light, and air along with the concentration effect due to water loss. The concentration of acids increased, causing reduction in pH.

4.4 Study of physicochemical properties of best sample for 3 months

4.4.1 Moisture

The moisture content of product in day 0,15,30,45,60,75 and 90 were found to be 5.08±0.01 %, 6.11±0.01%, 7.32±0.02%, 8.01±0.08%, 8.73±0.02%, 9.27±0.04% and 9.76± 0.1%

respectively. The obtained values were close to those reported by (Klewicki *et al.*, 2009).The sorption phenomena results in the increment of moisture content with respect to storage period (Goula *et al.*, 2008).

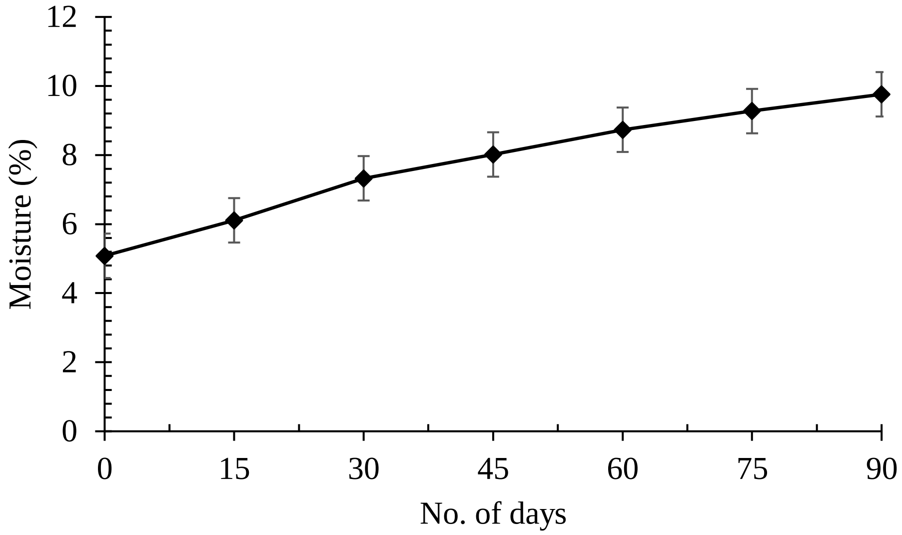


Fig 4.5: Change in moisture with respect to time

Loss of crispiness can occur due to gain of moisture, which can even make the product undesirable among the consumers. Products that are dehydrated may absorb moisture from their surroundings, which could compromise their stability, sensory, physicochemical, and overall quality. Foods' ability to retain moisture is mostly dependent on the physical state (crystalline or amorphous) and composition of the system's constituent parts, which are affected by the kind and circumstances of the technical treatments the food undergoes throughout processing (Escobedo *et al.*, 2011).

4.4.2 Titratable Acidity

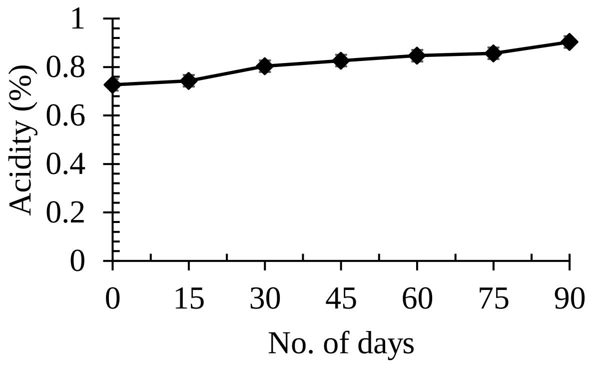


Fig 4.6: Change in acidity with respect to time

The titratable acidity of product in day 0,15,30,45,60,75 and 90 were found to be 0.72±0.004%, 0.74±0.004%, 0.80±0.003%,0.82±0.004%, 0.84±0.004%, 0.85±0.004% and 0.90±0.004% respectively. It can be observed that apple chip had higher values of TA than fresh samples. During storage, TA values increases with increase in time.

The increase in TA of apple chips is due to the organic acids in apples that become more concentrated as the temperature increases. Perception of fruit taste is given by the apples' acidity. Moreover, it is considered that sour taste depends on organic acid contents such as malic or citric acids (Ghinea *et al.*, 2022).

4.4.3 pH

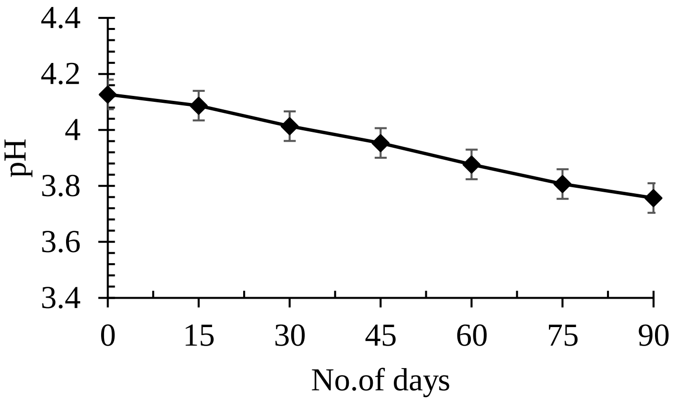


Fig 4.7: Change in pH with respect to time

The pH of product in day 0,15,30,45,60,75 and 90 were found to be 4.12±0.004, 4.08±0.004,4.01±0.004,3.95±0.004,3.87±0.01,3.80±0.004, and 3.75±0.004 respectively. It can be observed that the pH value decreases after drying.

According to Kahraman *et al.* (2021), decreases in pH values of dried apple samples may be associated with the dissociation of organic acids with temperature. A food's pH level is directly correlated with the amount of free hydrogen ions it contains. These hydrogen ions are released by the acids in food, giving acidic foods their characteristic sour taste. So, one way to think of pH is as a measurement of free acidity. More specifically, the negative log of the concentration of hydrogen ions defines pH. The pigments (such as chlorophyll, carotenoids, anthocyanins, etc.) that give fruits, vegetables, and meat their distinct colors are greatly impacted by pH (Andrés-Bello *et al.*, 2013).

4.4.4 TSS

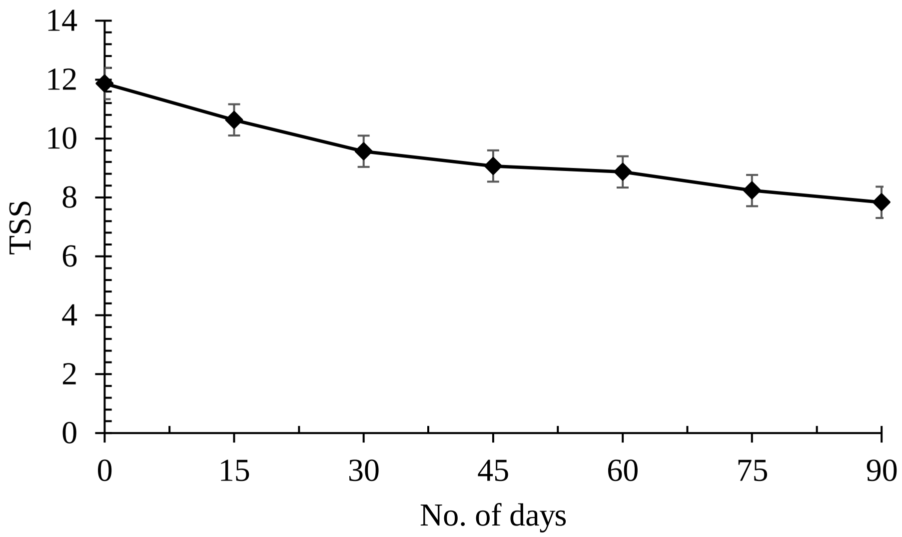


Fig 4.8: Change in TSS with respect to time

The TSS of product in day 0,15,30,45,60,75 and 90 were found to be 11.86±0.04, 10.63±0.04,9.56±0.04,9.06±0.04,8.86±0.04,8.23±0.04, and 7.83±0.04 respectively. It can be observed that the TSS value decreases after drying and also during the storage period.

TSS values of dried apple samples decrease compared to values of fresh apple samples due to reactions that occur when the temperature rises. Storage conditions, such as temperature, humidity, and exposure to light, can influence the rate of enzymatic and microbial activities, potentially accelerating the breakdown of soluble solids.The acceptance of rich nutrients and the financial rewards in the fruit trade are determined by the total soluble solids, which is a crucial factor in the fruit maturity process (Owusu *et al.*, 2012).

4.4.5 Vitamin C

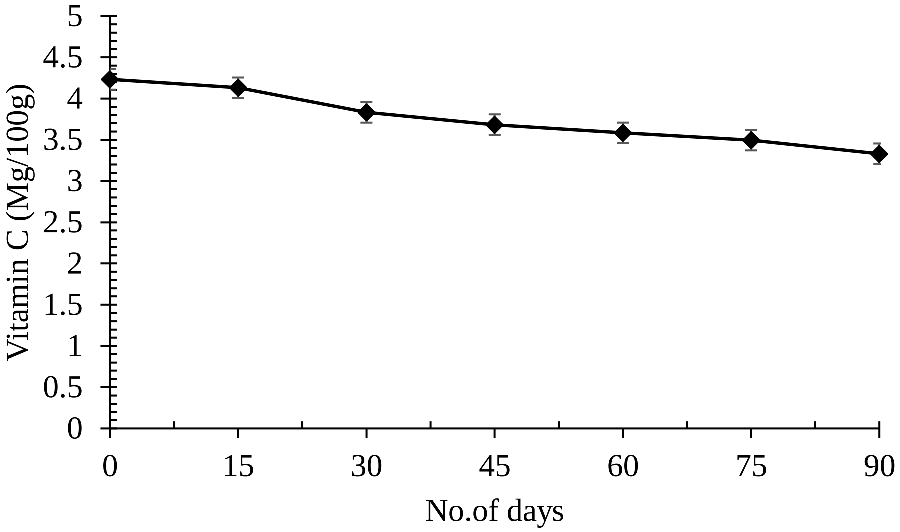


Fig 4.9: Change in Vitamin C with respect to time

The amount of vitamin C(mg/100g) of product in day 0,15,30,45,60,75 and 90 were found to be 4.23±0.04, 4.13±0.04, 3.83±0.04, 3.68±0.02, 3.58±0.01, 3.4±0.004 and 3.33±0.02 respectively. It can be observed that the vitamin C value decreases after with time.

Drying in high temperature causes vitamin C degradation. The primary causes of the reduction in vitamin C content are the oxidation of ascorbic acid in high temperature environments and its depletion as a result of its use in preventing the oxidation of polyphenols. Sunlight can also contribute to the degradation of vitamin C. Fruits stored in well-lit areas might experience faster vitamin C loss compared to those stored in darker conditions. (Joshi *et al.*, 2011).

4.4.6 Sensory attributes

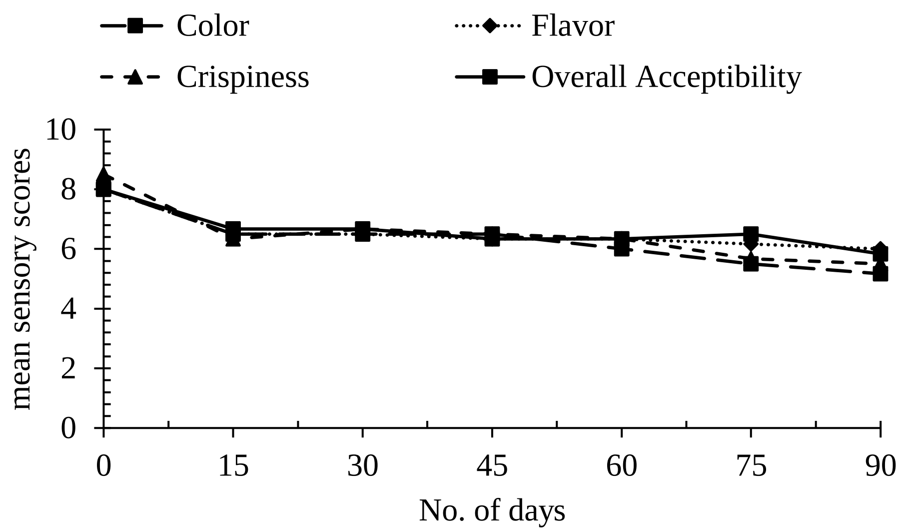


Fig 4.10: Change in mean sensory score with respect to time

Color, flavor, crispiness and overall acceptability were observed to have lower sensory scores with respect to storage time. The mean sensory scores for color, flavor, crispiness and overall acceptability on day 0 were 8±0.57, 8±0.57, 8.5±0.5 and 8±0.57 respectively whereas on the 90th day, the mean sensory scores were observed to be 5.16±0.37, 6±0.57, 5.5±0.5 and 5.83±0.68 respectively. The overall visual condition of the product was still good after 90 days, even after some physicochemical and it was edible.

4.4.7 Microbial analysis

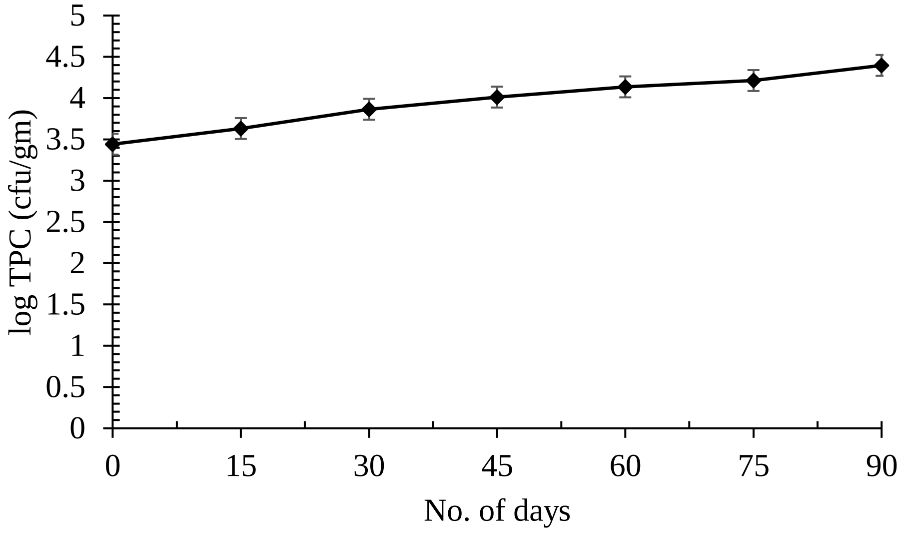


Fig 4.11: Change in mean log TPC (cfu/gm) with respect to time

The best product was microbiologically tested for 90 days of storage and the results are presented in fig 4.11. The initial total plate count of product was found to be 3.42 log(cfu/g) which increased upto 4.39 log (cfu/g) on the 90^{th} day. The obtained value lies within the limit (<10^4) (FDA, 2013).

4.5 Cost evaluation

The total cost of the best sample was calculated which is shown in appendix B. The price for 100 gm chips was found to be NRs. 100.26 per 100 g (as of 2023). It can be considered as a precise price as there is no sudden increase in price because it does not require many kinds of raw materials or additives. Thus, it is an affordable product which is children, youngsters, and elderly friendly.

Part V

Conclusion and recommendations

5.1 Conclusion

As stated in the objectives, pretreatments of apple were carried out and ten samples were prepared by three different drying methods, out of which the best sample according to sensory evaluation was analyzed for three months. As per the objectives and my study, following conclusions were drawn:

1. From the sensory evaluation of the product conducted on the attributes like appearance/color, flavor, crispiness and overall acceptability, sample which was sulphited with 0.5% Potassium metabisulphite and cabinet dried at 60°C was found to be better than rest of the samples.
2. Titratable acidity increased because organic acids became more concentrated as the temperature increased, consequently causing reduction in pH. Similarly, TSS also declined and amount of vitamin C also decreased significantly due to its degradation in high temperature.
3. During observation, moisture and acidity increased whereas pH, TSS, and vitamin C decreased. The reduction in vitamin C during storage was not significant as compared to that during drying.
4. The sensory attributes in terms of colour, flavour, crispiness and overall acceptability were acceptable after 90 days of storage and there was no significant change during the storage period.
5. According to microbial analysis, the product was safe for consumption after 90 days.
6. The cost of apple chips was calculated to be NRs.100.26 per 100 g.

5.2 Recommendations

Based on the result obtained, following recommendations could be made:

1. Moisture uptake and rehydration ratios could be studied.
2. Sensory attributes could be maintained better by using other packaging materials.

Summary

High Value Crops (HVC) in the mountainous region of western Nepal are apples (*Malus domestica*). Apple is having issues with spoilage loss, improper handling, inadequate market and transportation. This dissertation's primary goal was to make apple chips utilizing two distinct pretreatments: osmotic dehydration in 40% aqueous glucose and blanching in 0.5% kms. Ten samples were made and dried at various temperatures between 50°C and 60°C using various drying techniques, such as cabinet drying, oven drying, and sun drying.

Firstly, physicochemical analysis of apple fruit was done and the moisture (%), reducing sugar (% dm), Total sugar (% DM), Total acidity as malic acid (%), Vitamin C (mg/100g), pH, and TSS were found to be 85.74±0.04, 6.66±0.02, 10.42±0.06, 0.66±0.01, 11.72±0.02, 4.86±0.04 and 16.31±0.06 respectively. Then, ten samples were prepared by using two different pretreatments; osmotic dehydration and blanching followed by three different drying methods; sun drying, cabinet drying and oven drying at 50±5ºC and 60±5ºC. The samples were packaged in LDPE bags and coded as A, B, C, D, E, F, G, H, I, and J. A two-way ANOVA (without blocking) was used to evaluate the sensory data using GenStat. Based on the sensory qualities of appearance/color, flavor, crispiness, and overall acceptability, means were compared using LSD at a 5% level of significance. Sample A, which was blanched and cabinet dried at 60°C, was found to be the best based on sensory evaluation whose moisture (%), reducing sugar (% dm), Total sugar (% DM), Total acidity as malic acid (%), Vitamin C (mg/100g), PH, and TSS were found to be 5.08±0.01, 5.56±0.02, 8.36±0.02, 0.72±0.004, 4.23±0.04, 4.12±0.004 and 11.86±0.05 respectively. Then, the best sample was observed for 3 months in terms of moisture, pH, acidity, vitamin C, TSS, sensory attributes, and microbial condition. As a result of absorbing the surrounding moisture, the moisture content increased slightly. Because of the possible dissociation of organic acids over time, the titratable acidity increased while the pH declined. Ascorbic acid may have been oxidized over time, particularly under high temperatures, as seen by the gradual decrease in TSS and vitamin C.

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Appendices

Appendix A

Sensory evaluation card

Name: ……………………. Date: …………….

Product: Apple chips

Observe the product based on sensorial attributes. Use appropriate scale to show your attitude by checking at the point that best describes your feeling of the product. An honest expression of your personnel feeling will help to choose the right product.

Quality description:

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

Sensorial panelist is requested to give ranks on their individual choice.

Table A.1: Sensory evaluation card

Sample	colour	flavour	crispiness	Overall acceptibility
A				
B				
C				
D				
E				
F				
G				
H				
I				
j				

Comments (if any): ………………………...

Signature:…………………….

Appendix B

Table B.1 Cost evaluation

The cost evaluation of product was done for 100 g pack of apple chips.1 kg apples were required to produce 170 g of apple chips. Thus, 588.23 g of apple was required to produce 100 g of the product. As for kms, material to liquid ratio of 1:6 was used so 17.64 g of kms was required to make 3529.38 ml 0.5% kms.

Particulars	**Quantity (g)**	**Rate (NRs)**	**Amount (NRs)**
Apple	588.23	120/kg	70.58
Potassium metabisulphite	17.64	315/kg	5.55
LDPE pack	1	1 per piece	1
Sub total			77.13
Labor and processing cost	10%		7.71
Overhead cost	20%		15.42
Total			100.26

Appendix C

ANOVA output of sensory scores of color, flavor, crispiness, and overall acceptability of ten apple chips samples at 5% level of significance (two way no blocking).

Table C.1 : mean sensory scores of samples with lsd and F pr.

sample	colour	flavour	crispiness	Overall acceptability
A	8±0.57^{b}	8±0.57^{b}	8.5±0.5^{d}	8±0.57^{b}
B	6.16±0.68^{a}	6.83±0.68^{ab}	7.16±0.37^{c}	6.5±0.5^{a}
C	7±0.81^{ab}	6.66±0.74^{ab}	6.33±0.47^{abc}	6.83±0.68^{a}
D	6±0.57^{a}	7.16±0.68^{ab}	6.83±0.68^{abc}	6.5±0.53^{a}
E	6.33±0.47^{a}	6.66±0.47^{ab}	5.83±0.68^{a}	6±0.57^{a}
F	6.66±0.94^{ab}	6.83±0.68^{ab}	6.66±0.47^{abc}	6.83±0.68^{a}
G	6.5±0.95^{ab}	6.33±0.74^{a}	7±0.81^{bc}	6.66±0.47^{a}
H	6.5±0.53^{ab}	7.16±0.68^{ab}	6±0.57^{ab}	6.5±0.5^{a}
I	6.66±0.74^{ab}	6.66±0.47^{ab}	6.66±0.47^{abc}	6.5±0.51^{a}
J	6.16±0.89^{a}	6.83±0.68^{ab}	7±0.57^{bc}	6.66±0.47^{a}
Lsd	0.96	0.86	0.68	0.67
F.pr	0.009	0.039	<.001	<.001

Appendix D

Table D.1 ANOVA (no blocking) for appearance/color of apple chips

Source of variation	d.f	s.s	m.s	v.r	F.pr	l.s.d
Sample	9	17.733	1.9704	2.89	0.009	0.009
Panelist	5	2.0000	0.4000	0.59	0.59	0.710
Residual	45	30.6667	0.6815			
Total	59	50.4000				

Table D.2 ANOVA (no blocking) for flavor of apple chips

Source of variation	d.f	s.s	m.s	v.r	F.pr	l.s.d
Sample	9	11.0833	1.2315	2.22	0.039	0.8670
Panelist	5	0.4833	0.0967	0.17	0.971	0.6716
Residual	45	25.0167	0.5559			
Total	59	36.5833				

Table D.3 ANOVA (no blocking) for crispiness of apple chips

Source of variation	**d.f**	**s.s**	**m.s**	**v.r**	**F.pr**	**l.s.d**
Sample	9	29.6000	3.2889	9.61	<.001	0.6803
Panelist	5	4.6000	0.9200	2.69	0.033	0.5269
Residual	45	15.4000	0.3422			
Total	59	49.6000				

Table D.4 ANOVA (no blocking) for overall acceptability of yoghurt

Source of variation	**d.f**	**s.s**	**m.s**	**v.r**	**F.pr**	**l.s.d**
Sample	9	14.2667	1.5852	4.71	<.001	0.6743
Panelist	5	3.2000	0.6400	1.90	0.113	0.5223
Residual	45	15.1333	0.3363			
Total	59	32.6000				

Appendix E

Table E.1 List of equipment used:

Physical apparatus	Physical apparatus
Incubator	Thermometer
Hot air oven	Heating arrangement
Desiccators	Stainless steel vessels
Refractometer	Titration apparatus
Daily routine glassware	Electric balance

Table E.2 List of chemicals used:

chemicals	chemicals
0.1N NaOH solution	Fehling- I
pH buffer solution	Fehling- II
Distilled water	Dextrose
Carrez-I	Potassium metabisulphite
Carrez-II	Metaphosphoric acid
Phenolphthalein indicator solution	Methylene blue indicator

Colour plates

Plate 1 : Determination of reducing sugar

Plate 2 : Analysis of fruit and product

Plate 3 : Drying of apple slices

Plate 4 : Apple slices after drying

Plate 5 : Packaging of apple chips in LDPE pouch