PREPARATION AND QUALITY EVALUATION OF READY TO SERVE BEVERAGES FROM PINEAPPLE JUICE ADDED WITH NATA DE COCO JELLY CUBES AND SEMI-RIPE PAPAYA CUBES

A dissertation submitted by

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In Partial fulfilment of the Degree of

MASTER OF VOCATION

IN

FOOD PROCESSING TECHNOLOGY

Under the Guidance of

Dr. Attar Singh Chauhan

Chief Scientist

TRADITIONAL FOODS AND APPILED NUTRITION

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Mysuru-570020

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CERTIFICATE

I hereby certify that this dissertation entitled "**Preparation and Quality Evaluation of Ready To Serve Beverages from Pineapple Juice Added With Nata De Coco Jelly Cubes And Semi-Ripe Papaya Cubes**" submitted by **Ms. Liyana C B V (Reg. No. VM23FPT010)** to **St. Teresa's College (Autonomous), Ernakulam, Mahatma Gandhi University, Kottayam, Kerala**, in partial fulfillment of the requirement for the award of the degree of **Master of Vocation (M. Voc) in Food Processing Technology** is a bonafide report of original research work done by her under my supervision and guidance at the **Department of Traditional Foods and Applied Nutrition (TFAN), CSIR-CFTRI, Mysore** during **December 2024 to April 2025**. It is also certified that this dissertation has not been submitted for any degree to any other University.

The report hereby approved as a bonafide and creditable dissertation work carried out and presented by her in a manner to warrant its acceptance in partial fulfillment of the required credits for the degree of **Master of Vocation (M. Voc) in Food Processing Technology**. However, the undersigned do not necessarily endorse or take responsibility for any statement or opinion expressed or conclusion drawn therein, but only approve the dissertation report for the purpose for which it is submitted.

Place: Mysore

Date: 7/4/25

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DECLARATION

I hereby declare that, the report on the project entitled **" Preparation and Quality Evaluation of Ready To Serve Beverages from Pineapple Juice Added with Nata De Coco Jelly Cubes And Semi-Ripe-Papaya Cubes"** submitted by me to St. Teresa’s College, Ernakulam, affiliated to Mahatma Gandhi University, Kottayam, Kerala, for the partial fulfilment of the requirement for the award of degree of Master of Vocational Studies in Food Processing Technology, is the record of the original work carried out by me under the guidance of Dr. Attar Singh Chauhan, Chief Scientist, Department of Traditional Foods and Applied Nutrition (TFAN), CSIR-CFTRI, Mysuru, Karnataka. I further declare that; the results of present study have not formed the basis for the award of any other degree to any present candidate of any university during the period of my study.

Place: Mysore **LIYANA C B V**

Date:

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LIST OF ABBREVATIONS

ABBREVATION	EXPANSION
TSS	Total Soluble Solids
OD	Optical Density
RTS	Ready-to-Serve
µg	Microgram
mg	Milligram
nm	Nanometer
IU	International Unit
t/ha	Tons per hectare
RE/day	Retinol Equivalence/day
rpm	Rotation Per Minute
GI	Glycemic Index
LDPE	Low Density Polyethylene
PET	Polyethylene Terephthalate
NDC	Nata de coco
PC	Papaya Cubes
PJ-NDC	Pineapple Juice with Nata de coco
PJ-PC	Pineapple Juice with Papaya cubes

ABSTRACT

This study investigates the development and quality analysis ready to serve (RTS) beverages from pineapple juice added with nata de coco jelly cubes (PJ-NDC) and semi-ripe papaya cubes (PJ-PC). Pineapple juice was extracted from fully ripe pineapple (*Ananas comosus*), stored at -18°C until further use. Later, the juice was thawed and used to prepare the beverages. Commercially available nata de coco was incorporated with pineapple juice and other ingredients to prepare the beverage (PJ-NDC), while semi-papaya cubes, was stabilized by giving a 0.2% calcium treatment followed by draining the cubes and soaking it in in 30^0Brix sugar solution for 24 hours, to prepare PJ-PC. Both beverages were stored in PET bottles at 4°C$\pm$1℃ for 30 days, and various physicochemical properties were analyzed. Texture Profile Analysis (TPA) of Nata de coco cubes and stabilized semi-ripe papaya cubes was performed in order to check the influence of pasteurization and storage period. TPA profile revealed a significant increase in hardness and chewiness for nata de coco cubes compared to papaya cubes, while papaya cubes showed lower resilience and increased adhesiveness. Firmness of PJ-NDC also increased during storage. Both juices experienced increased L* values (lightness) and changes in colour, with PJ-PC showing a gradual increase in redness and yellowness (a* and b* values). Particle size pf PJ-PC increased drastically from 107 µm to 257.6 µm, indicating fiber breakdown. Turbidity reduced notably in PJ-NDC (415 FTU) by day 30. Reducing and invert sugar levels followed similar patterns in PJ-PC, while PJ-NDC exhibited significant changes. Beta-carotene content increased significantly in both beverages, suggesting desiccation and moisture absorption. Minor changes were observed in TSS for both the products and its calorific values were noted. Sensory analysis using a 9-point hedonic scale showed higher ratings for PJ-PC in terms of appearance, colour, flavour, taste, and texture of the cubes. Overall, both juices have distinct merits, with PJ-PC being a standout innovative choice.

CHAPTER 1

INTRODUCTION

INTRODUCTION

The term "fruit" in botanical terms refers to the mature ovary of a plant, which includes the seeds, covering, and any closely related tissue, regardless of its edibility. In culinary terms, "fruit" refers to the edible part of a plant, tree, bush, or vine that contains seeds and fleshy surrounding tissue, typically with a sweet or tart flavour. Generally, fruits are consumed as breakfast beverages, breakfast and lunch side-dishes, snacks or desserts. Fruit's classification depends on factors such as shape, cell structure, seed type, and natural habitat (IARC,2003).

Pineapple (*Ananas comosus*, family: Bromeliaceae) is a major commercial fruit crop globally, often referred to as the "queen of fruits" because of its exceptional flavour and taste. It ranks as the third most important tropical fruit worldwide, following banana and citrus. The composition of pineapple varies depending on factors like location, season, processing methods, and harvest timing (Hossain et al., 2015). This delicious exotic fruit can be enjoyed fresh from the garden, dried, or processed into jams and juice. It also serves as a good source of dietary fiber, bromelain, magnesium, copper, vitamin C, B vitamins, calcium, beta-carotene, and zinc. Pineapple skin is naturally free of cholesterol and fat, and is low in sodium and calories (Mohsin et al., 2020). Pineapple contains the proteolytic enzyme bromelain, which aids in digestion by breaking down proteins. This fruit also has anti-inflammatory and digestive benefits. Bromelain helps fight infections by dissolving slough and bacteria-rich surfaces. Additionally, pineapple can assist with digestion, clear bronchial passages in conditions like pneumonia and bronchitis, and reduce symptoms of arthritis. It is also used to relieve pain after surgery or sports injuries. Currently, pineapple is being researched for its potential role in preventing heart disease (Debnath et al., 2012).

Nata de coco, also referred to as "coconut gel," is a chewy, translucent jelly-like food created through the fermentation of coconut water or coconut milk. This process occurs as *Acetobacter xylinum* produces microbial cellulose, which causes the mixture to form a gel (Sharmin et al., 2021). Nata de coco originated in the Philippines and was introduced to Japan in 1991 through its use in diet drinks, where it quickly became popular, especially among young girls. It can be enjoyed in a variety of food items, such as desserts, candies, salads, fruit cocktails, ice cream, juices, dairy products, ketchup, and sauces. Nata de coco in syrup has a fresh taste, translucent appearance, and high nutritional value due to its fiber content. While it has a natural flavour, it can also be flavoured with various fruit or flower juices, such as mango, lychee, pineapple, kiwi, orange, maple syrup, or rose (Phisalaphong et al., 2012).

Papaya (*Carica papaya L.*) is a tropical fruit that is extensively cultivated and consumed, valued for its delightful flavour as well as its numerous health benefits (Oliveira et al., 2011). Papaya is cultivated globally in tropical and subtropical climates. As per a recent papaya production report (2020), India stands as the world's leading producer, contributing 13.9 million tones (mt) annually, which accounts for 43% of the total global papaya production. On the other hand, the United States is the largest consumer of papaya (Koul et al., 2022). Papaya fruit is rich in ascorbic acid, vitamins A, B1, B2, and E, carotenoids, essential minerals such as potassium, iron, calcium, and phosphorus, as well as dietary fibre, among other nutrients. In terms of composition, papaya consists of about 85–90% water, with 10–13% being total sugars (including glucose, fructose, and sucrose). However, the fruit has a low protein content, around 0.6% (Annegowda et al., 2016). Papaya contains a wide range of phytochemicals, including carotenoids, polyphenols, benzyl isothiocyanates, benzyl glucosinates, prunasin (a cyanogenic substrate), papain, chymopapain, alkaloids, phenolic compounds, flavonoids, and vitamins A, C, and E. These compounds offer various health benefits, such as promoting digestion, modulating the immune system, and providing antioxidant, chemoprotective, anti-diabetic, antibacterial, anti-plasmodial, and antifungal properties (Heena et al., 2019).

Fruits and vegetables have a short shelf life because they are perishable. To extend their usability, they are processed into Ready-to-Serve (RTS) beverages. An RTS beverage is a non-fermented drink made from fruits and vegetables in varying concentrations, with added sugar, water, and other ingredients (Rathinasamy et al., 2021). Fruit-based beverages are among the most popular drinks worldwide. These beverages are easily digestible, refreshing, thirst-quenching, flavourful, and nutritionally superior to many synthetic options available in the market. Minimal processing procedures like filtering, clarifying, and pasteurizing are applied to fruit juices or pulp employed in the creation of these goods (Karunarathne et al., 2019).

Although there are plenty of fruit juices available in the market, fruit juices with added fruit pieces or jelly cubes are scarce. This addition of fruit pieces or nata de coco jelly cubes gives a biting texture while consuming the juices with addition of its nutritional benefits. The production of pineapple RTS beverages requires adjusting the juice content, total soluble solids (TSS), and acidity of the pineapple juice according to food authority guidelines. According to

FSSAI standards, RTS beverages must contain a minimum of 10% fruit content, at least 10% total soluble solids, and 0.3% acidity (FSSR, 2011).

The preparation of RTS beverage from pineapple juice with nata de coco jelly cubes starts with fresh pineapple juice, to which crystalline sugar and water are added. The mixture is then heated to dissolve the sugar, followed by the addition of citric acid to balance the acidity. After gently mixing, nata de coco jelly cubes are introduced, adding a chewy texture to the drink. The beverage is pasteurized at 90°C for 120 seconds, cooled to 70°C, and preserved with sodium benzoate. Finally, the drink is filled into pre-sterilized PET bottles and stored at refrigerated temperature (4℃±1℃.). This method results in a refreshing and diversified pineapple beverage with the added benefit of nata de coco.

The preparation of RTS beverage from pineapple juice with semi-ripe papaya cubes starts with immersing papaya cubes in $CaCl_2$ solution for one hour to make it firm, followed by draining the cubes and soaking it in 30^0 Brix sugar solution. This is kept for incubation for 24 hours. Meanwhile for the pineapple beverage, fresh pineapple juice is heated with crystalline sugar and water. The mixture is gently heated to dissolve the sugar followed by the addition of citric acid. After gently mixing, the stabilized papaya cubes are added to the juice. The beverage is pasteurized at 90°C for 120 seconds, cooled to 70°C, and preserved with sodium benzoate. Finally, the drink is filled into pre-sterilized PET bottles and stored at refrigerated temperature (4℃±1℃.).

1.1 OBJECTIVES

1. To optimize and formulate ready to serve (RTS) beverages from pineapple juice added with nata de coco jelly cubes and semi-ripe papaya cubes.
2. To evaluate the physicochemical properties and sensory properties of formulated drinks.
3. Storage stability of formulated drinks in packed formed at 4℃±1℃.

1.2 SCOPE

The scope of this study focuses on the development and quality analysis of ready to serve beverages from pineapple juice added with nata de coco jelly cubes and semi- ripe papaya cubes. Both beverages offer a unique, diversified drinking experience with a delightful biting texture that appeals to both adults and children. The pineapple juice with nata de coco jelly cubes was optimized first to achieve uniform dispersion, followed by the optimization of the juice with semi-ripe papaya cubes. This study includes a thorough evaluation of the sensory attributes, stability, and shelf life of both beverages. The findings aim to serve as a basis for innovation within the Indian beverage industry, particularly for small-scale juice manufacturers seeking to diversify their product offerings.

CHAPTER 2
REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

2.1 PINEAPPLE

Figure 1: Pineapple

Pineapple (*Ananas comosus*) is a perennial fruit-bearing tropical plant that is well known throughout the world **(Figure 1)**. It belongs to the Bromeliaceae family, which has more than 2500 species. Originally cultivated in South America, it then gradually started to be grown in other parts of the world as a result of travellers and historians visiting South America. Today, about 25 million tons of pineapple are produced throughout the world, making it the third most consumed fruit after bananas and citrus fruits. **(**Wali,2019). Pineapple plant is indigenous to South America and is said to originate from the area between southern Brazil and Paraguay (Asare, 2012**).** Although there are many different types of pineapple, the most popular ones are categorized as "Spanish," "Queen," "Cayenne," "Abacaxi," and "Maipure". According to the traditional botanical or horticultural cultivar classification for pineapple, these classifications are based on the characteristics of the leaves, the colour, form, and flatness or sharpness of the spine and eyes of the fruit, as well as the characteristics of the leaves. 'Red Spanish' and 'Smooth Cayenne' are significant commercial variants. The most common cultivar that has been modified for processing and canning is "Smooth Cayenne." The fruit has a high sugar content, weighs between 2 and 2.5 kg, and has a pale to golden yellow fruit pulp. It is also slightly acidic. The leaves are smooth, with the majority of the spines on the tips (Bartholomew et al., 2003). The taxonomic classification of pineapple is given in **Table 1**.

Table 1: Taxonomic Classification of pineapple

Kingdom	Plantae
Sub kingdom	Tracheobionta
Division	Magnoliophyta
Class	Liliopsida
Sub class	Zingiberidae
Order	Bromeliales
Family	Bromeliaceae
Genus	Ananas Mill.
Species	*Ananas comosus* (L.)

Source: (Kerns et al.,1936)

2.2 CULTIVATION

According to FAO, pineapple crop is grown in regions with high relative humidity. Multiple factors contribute to the effective production of pineapple including, rainfall, soil type, nutrient requirements, drainage, and temperature. The most favourable temperature for growth is estimated to be 18–32 °C. Pineapple does not require more water compare to other fleshy fruits as it can be grown in the soil that does not have abundant of water from irrigation or rain; 5 cm^3 water per month is required for optimum growth. Sandy and loamy soil, having a pH range from 4.5 to 6.5 with good water drainage makes soil perfect for pineapple production, for this purpose pineapple fields are deliberately built on slopes to provide good water drainage system (Chaudhary et al.,2019). Generally, the pineapple tree is expected to bear fruit within 15 months or up to two years after planting. Due to the high perishability of overripe pineapple, the optimum harvesting time should be targeted when the peel colour turns from green to yellow either by manual harvesting or semi-mechanised harvesting. In view of the harvesting time, there are several aspects that must be considered including the fruit must be of good quality, free from serious defects, and at the time of harvest selection is based on optimum maturity indices (Ali et al.,2020).

2.3 PRODUCTION

Pineapple is substantially produced because of its fruit; bearing good taste and flavour it is popularly used in different cuisines and by the food industry. Currently, pineapple is produced in almost in every corner of the world and due to its multiple applications, especially its biological importance, makes it incredibly well known worldwide. Annual worldwide production of pineapple is approximately 24.8 million tons. (Medina and García, 2005).

2.4 INTERNATIONAL PRODUCTION STATUS

According to Pineapple Research Institute, Vazhakulam, Kerala, Pineapple exhibits increasing demand worldwide, over the years. The global trade is around 50% as fresh fruit, 30% as canned product and 20% as juice concentrate. World trade on fresh pineapple has shown 100 % increase during the last one decade. According to data from 2022 the top three producers of pineapple globally were Indonesia, the Philippines, and Costa Rica which is illustrated in **Figure 2**. Costa Rica generated 2.9 million metric tons of pineapples in that year.

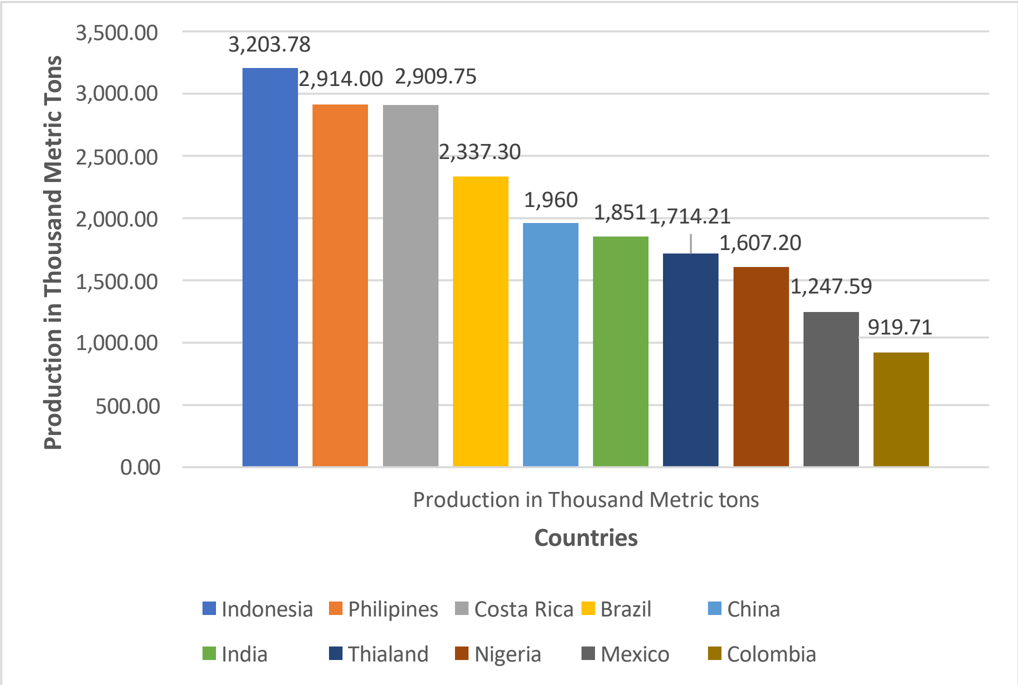

Figure 2: Leading countries in pineapple production in 2022

Source: M. Shabandeh,2024

2.5 NATIONAL PRODUCTION STATUS

India ranked sixth with a share of about 8 % of the world production of pineapples. The total area under pineapple cultivation in India is 84000 hectares with a production of about 1341000 t(tonnes). India exports pineapple mainly to Nepal, Maldives, United Arab Emirates, Saudi Arabia, Kazakhstan, Oman, Bahrain, Bangladesh, Zambia, Pakistan and Qatar. 'Kew' and 'Mauritius' are the two varieties of pineapple grown in India. Percentage share of pineapple of pineapple production in various states of India is shown in **Figure 3**. It is grown in Karnataka, Meghalaya, West Bengal, Kerala, Assam, Manipur, Tripura, Arunachal Pradesh, Mizoram, and Nagaland. It is also cultivated on limited areas in the coastal belt of Tamil Nadu, Goa and Orissa. Though Assam has the largest area under pineapple, West Bengal is the largest producer. Karnataka, West Bengal and Bihar are the three states reporting high productivity. Overall, Indian productivity of 16.00 t/ha poorly compares with the world average of 22.58 t/ha.

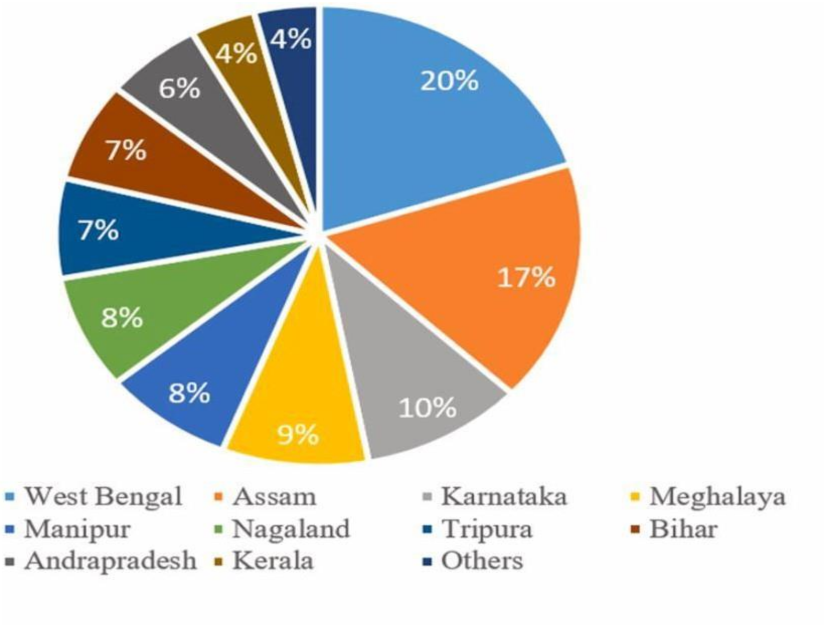

Figure 3: Percentage share of pineapple production in various states of India

Source: (Abraham et al.,2023)

2.6 EXPORT/IMPORY TRENDS OF PINEAPPLE

The majority of pineapple plants are found in West Africa and Latin America. Seventy-five percent of the pineapples in the EU (European Union) are imported from Costa Rica, which supplies the majority of the pineapples sold in Europe. In 2015, the Costa Rican tropical fruit export business was estimated to be worth $1.22 billion. The global pineapple market has grown significantly in recent years, with production rising by about 50% since 1998. With almost 24.8 million tons produced in 2013, pineapples rank as the eleventh most grown fruit, according to FAO figures. According to FAO, global exports of pineapples are anticipated to grow by approximately 4 percent in 2024, to 3.3 million tones, determined largely by higher supplies from Costa Rica and the Philippines, the world's leading exporters with market shares of around 65 percent and 21 percent, respectively, **(Figure 4)**. Based on preliminary trade data, global exports of pineapples are anticipated to grow by approximately 4 percent in 2024, to 3.3 million tones, determined largely by higher supplies from Costa Rica and the Philippines, the world's leading exporters with market shares of around 65 percent and 21 percent, respectively.

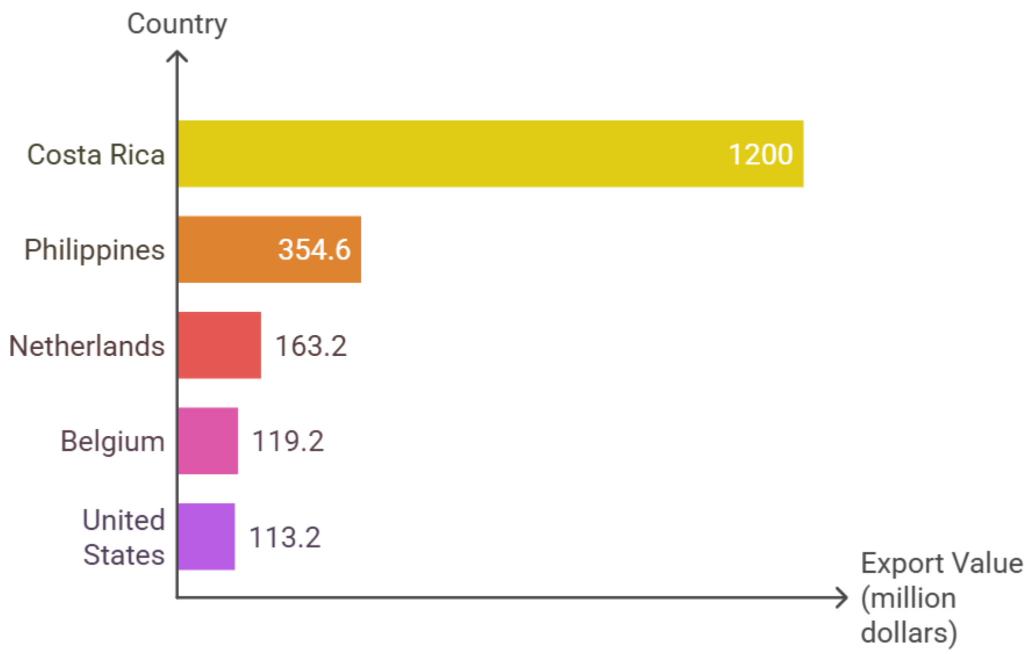

Figure 4: Pineapple Export Values by Country in 2023

Source: FAO

2.7 NUTRITIONAL COMPOSITION

The composition of pineapple is highly dependent on many factors including the ripening process and type of cultivar. The fruit is abundant in minerals (manganese, copper, calcium, and zinc), fiber, β-carotene, bromelain, and vitamins (thiamine, riboflavin, and niacin), as shown in **Table 2**. Along with being low in calories and sodium, the fruit pulp is also free of fat and cholesterol. (Chaudhary et al., 2019). Additionally, pineapple fruit includes the proteolytic enzyme bromelain, which aids in digestion and being essential for the therapeutic effects associated with bromelain. There are several possible applications for bromelain as an antioxidant, anti-inflammatory, anti-cancer, and cardioprotective substance (Ali et al.,2020). Pineapple contains many bioactive compounds such as bromelain, carotenoids etc. which is shown in **Figure 5**. Furthermore, pineapple's bromelain helps to alleviate menstrual disorders, which is advantageous for women, particularly during pregnancy and menstruation, since it lessens the body's excessive water retention. (Khalid, Suleria, & Ahmed, 2016). At harvest, there are roughly 47.8 mg of ascorbic acid (Vitamin C) per 100 g of fresh fruit. Half a cup of pineapple juice provides 50 percent of an adult's daily recommended amount of vitamin C. Malic acid makes up 13 percent of pineapple juice's acidic content. Malic acid is also beneficial for health. It boosts immunity; promotes smooth, firm skin; helps maintain oral health; and reduces the risk of toxic metal poisoning. Pineapple is also a good source of vitamin B1, vitamin B6, copper and dietary fiber. Pineapple is a digestive aid and a natural anti-inflammatory fruit (Hossain et al., 2020).

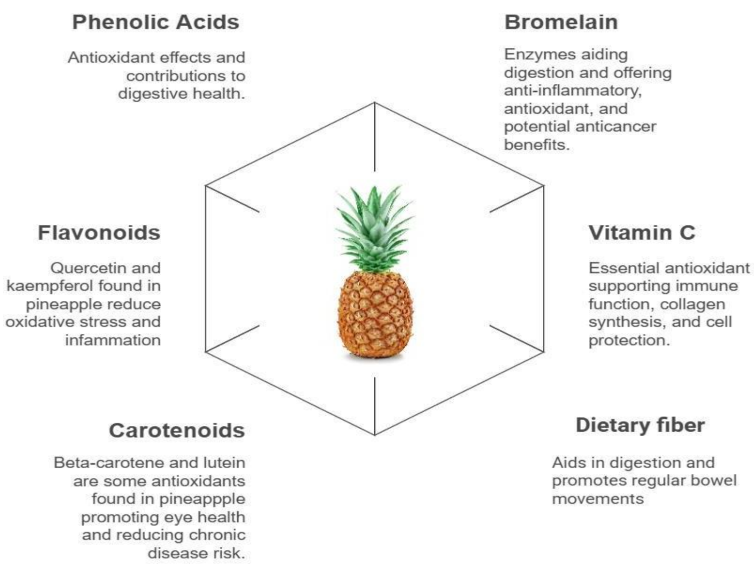

Figure 5: Bioactive Compounds in pineapple, Source: (Yani et al., 2025)

Table 2. Nutrients in 100 grams (g) pineapple

NUTRIENTS	AMOUNT
Energy	52 Calories
Dietary fibre	1.40g
Carbohydrates	13.7g
Protein	0.54g
Iron	0.28mg
Magnesium	12mg
Calcium	16mg
Potassium	150mg
Phosphorus	11mg
Zinc	0.10mg
Vitamin A	130 I. U
Vitamin B1	0.079mg
Vitamin B2	0.031mg
Vitamin B3	0.489mg
Vitamin B6	0.110mg
Vitamin C	47.8mg

Source: C (Hossain et al., 2020).

2.8 BIOACTIVE COMPOUNDS IN PINEAPPLE

2.8.1 BROMELAIN

Bromelain, a group of proteolytic enzymes found in pineapple fruit and stem has many therapeutic benefits. Chemical structure of bromelain found in pineapple juice is shown in **Figure 6**. Bromelain primarily acts as a proteolytic enzyme; this property allows bromelain to aid in protein digestion, facilitating the breakdown and absorption of dietary proteins in the gastrointestinal tract (Kansakar et al., 2024). Bromelain is a blend of various thiol endopeptidases and other compounds such as phosphatase, glucosidase, peroxidase, cellulase, escharase, and protease inhibitors. Research shows that bromelain has fibrinolytic, anti-oedematous, antithrombotic, and anti-inflammatory effects. It is well absorbed in the body, retaining its proteolytic activity without causing significant side effects. Bromelain offers numerous therapeutic benefits, including treating angina, bronchitis, sinusitis, surgical trauma, thrombophlebitis, wound debridement, and improves absorption of drugs, especially antibiotics. It also helps with osteoarthritis, diarrhoea, and various cardiovascular conditions, and has some antitumour properties (Pavan et al., 2012). Besides its clinical uses, bromelain is also utilized in various sectors of food industry, including food processing, breweries, meat processing, textiles and cosmetics. (Hikisz et al., 2021).

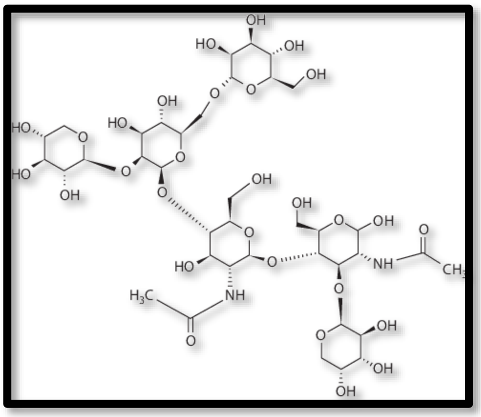

Figure 6: Chemical Structure of Bromelain found in pineapple juice

Source:(Shahidi et al., 2016)

2.8.2 CAROTENOIDS

An oxygenated derivative of lipid-soluble hydrocarbons known as carotenes, or carotenoids, is referred to as xanthophyll. Beta-carotene is the most well-known carotenoid in pineapples**.** Chemical structure of β-carotene is shown in **Figure 7.** Beta-carotene gives ripe pineapples their yellow-orange colour and acts as an antioxidant. It can be converted into vitamin A in the body, supporting vision, immunity, and skin health. Pineapples contain small amounts of vitamin A (52–57 IU/100g or 3μg retinol equivalents/100g), primarily from beta-carotene. Other carotenoids like lutein and zeaxanthin are also present in lesser amounts. Moreover, Vitamin A, essential for vision and skin health, can be obtained from fruits and vegetables, mainly as beta-carotene. The Recommended Dietary Allowance (RDA) for Vitamin A is 900 μg RE/day for adult males and 700 μg RE/day for adult females (IOM 2000). Consuming a small portion of pineapple can help meet part of the daily Vitamin A requirement. (Salihah Yani et al., 2025).

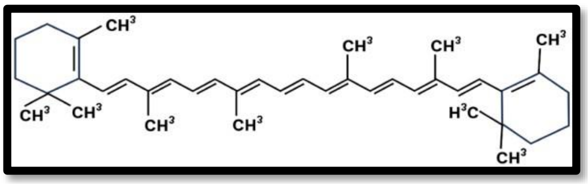

Figure 7: Structure of β-carotene

(Source: Mandrich et al., 2023)

2.8.3 ASCORBIC ACID

Pineapple is known to be a rich source of Vitamin C, measured as total ascorbic acid content (AA), which can vary significantly depending on the variety. Structure of ascorbic acid is depicted in **Figure 8**. Besides the variety, factors like clone, climate, geographical conditions, and acidity also influence the Vitamin C levels. At harvest, there are roughly 47.8 mg of ascorbic acid (Vitamin C) per 100 g of fresh fruit Moreover, studies have reported differences of up to 150% in ascorbic acid content between different fruits of the same variety (Sánchez-Moreno *et al*. 2012). Vitamin C is a vital nutrient that humans cannot produce on their own, so it must be obtained from food or supplements. It is the most potent and least harmful antioxidant, offering several health benefits. Regular consumption of Vitamin C-rich foods helps prevent scurvy, enhances the immune system to fight off infections, and neutralizes harmful free radicals and metals that can cause inflammation. Additionally, Vitamin C is a key cofactor in at least eight enzymatic reactions, including those involved in collagen production. Collagen is the primary structural protein in the body, crucial for maintaining the strength and health of blood vessels, skin, organs, and bones (Ancos et al., 2017).

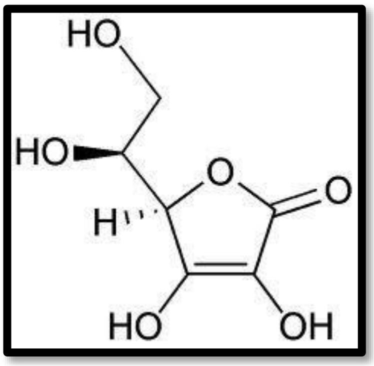

Figure 8: Structure of Ascorbic acid

Source: (Waheed-Uz-Zaman et al., 2013)

2.8.4 VITAMIN B

Pineapples are rich in B-complex vitamins, including thiamine (B1), riboflavin (B2), niacin (B3), and pyridoxine (B6), which act as coenzymes in metabolism and are essential for nervous system function. Thiamine, in its active form as thiamine diphosphate (TDP), acts as a cofactor for enzymes involved in carbohydrate metabolism, while thiamine triphosphate (TTP), found in the nervous system, plays a crucial role in neurological processes. Riboflavin is necessary for oxidative energy production and is involved in the Kreb cycle. It also supports glutathione reductase (GSH), which is important for maintaining the cellular redox balance. Niacin, which includes nicotinic acid and nicotinamide, is crucial for many biological redox reactions as part of the coenzymes NAD (Nicotinamide Adenine Dinucleotide) and NADP (Nicotinamide Adenine Dinucleotide Phosphate). Vitamin B6, also known as pyridoxine hydrochloride, exists in other forms like pyridoxal and pyridoxamine. It is a highly versatile enzyme cofactor, with pyridoxal phosphate playing a critical role in amino acid transformations. Sweet pineapple varieties like 'MD-2' have higher Vitamin B6 content (0.114 mg/100g) compared to traditional varieties like 'Smooth Cayenne' (0.106 mg/100g) (Ancos et al., 2017).

2.9 PROCESSING OF PINEAPPLE

The major steps involved in the post-harvest processing of pineapple are shown in **Figure 9**. Pineapples must be harvested at peak ripeness based on colour, texture, and flavour. After harvesting, cooling is essential to prevent spoilage, and fruits are sorted and graded by quality. Non-standard fruits and foreign materials are removed. Proper packaging and storage under controlled conditions extend shelf life. Storage facilities should protect against pests, moisture, and damage. They must also offer inspection, cleaning, and sterilization while being cost-effective (Ningombam et al., 2019).

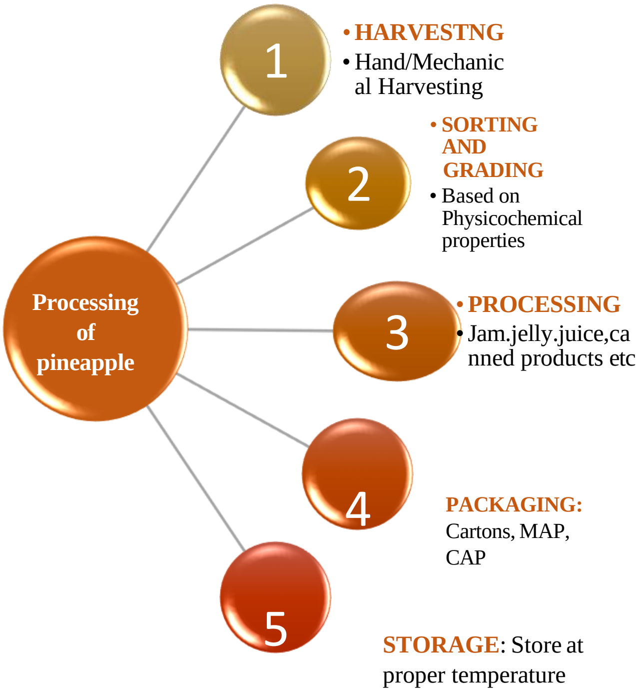

Figure 9: Post-harvest Processing of pineapple

Source: (Abraham et al.,2023)

For processed pineapple products to be safe, high-quality, and long-lasting, post-harvest processing procedures are essential. About 80% of pineapple sales is processed, with 48% of that quantity being sold as concentrated juice and 30% as canned fruit. Canned pineapple slices, tetra-packaged drinks, ready-to-serve pineapple juice, squash, dehydrated pineapple slices, and jam are the main pineapple items on the market. For making candies, the core of the pineapple fruit can be utilized. Due to the widespread acceptance of these processed foods, there is a strong need to create novel pineapple-based food products with little alterations to their nutritional value (Vipul et al., 2019).

2.10 PINEAPPLE PARTS UTILISATION

Pineapple waste can be used in a number of different applications, depending on the form in which the waste is collected and processed as shown in **Figure 10**. Here are a few examples:

Animal feed: Pineapple waste can be added to animal feed, especially for chickens and pigs. For simpler handling and storage, the waste might be dried and pulverized into a powder or pellet.

Composting: In composting systems, pineapple waste can be utilized as an organic matter source. In order to produce a nutrient-rich compost that may be utilized to enhance soil fertility and structure, it can be combined with other organic materials, such as food scraps and yard trash.

Production of Biogas: Anaerobic digestion can be utilized to produce biogas from pineapple waste which is a renewable energy source for cooking, heating, and electricity production. **Production of ethanol:** The sugars in pineapple trash can also be fermented to produce ethanol. **Food and Beverage:** Pineapple waste can be utilized as a component in a number of food and drink items, including smoothies, jams, and jellies.

Natural dyes: Waste pineapple can be processed to extract pigments that can be used as a dyeing agent, and pineapple waste can be utilized as a natural dye for textiles and other materials.

Cosmetics: Pineapple waste is a useful component of cosmetics and personal hygiene items like face masks and body washes. Enzymes with exfoliating and skin-softening qualities can be extracted from the waste by processing.

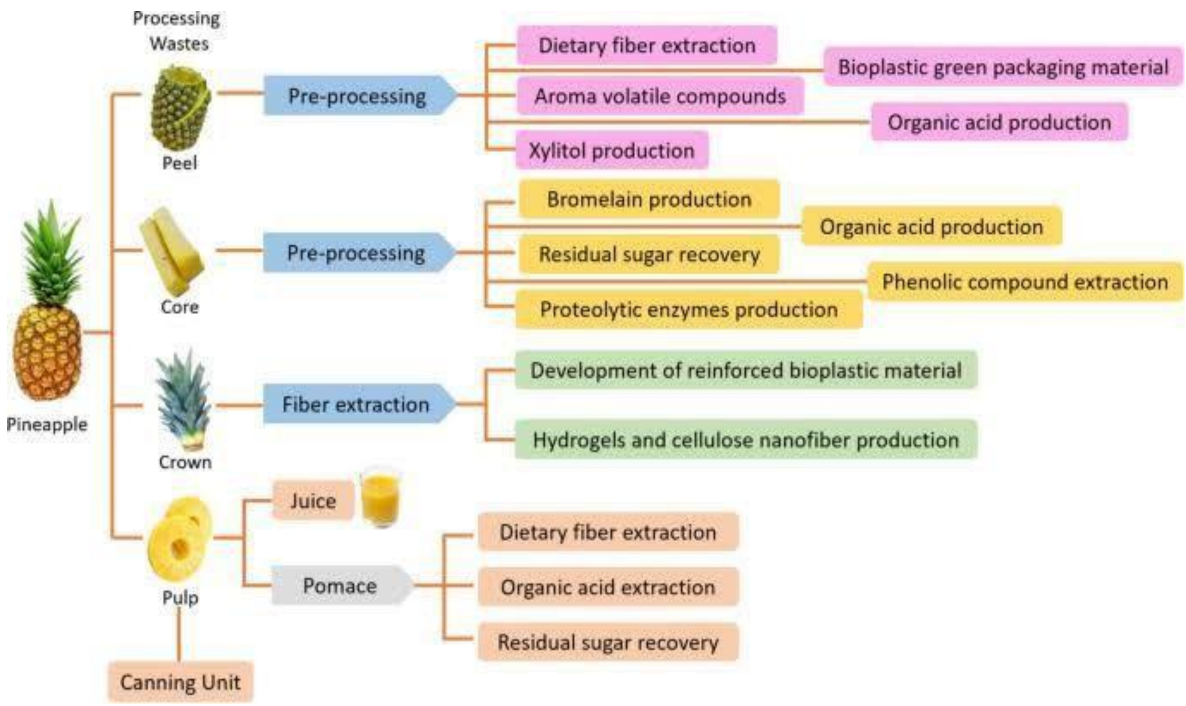

Figure 10: Pineapple parts utilization

Source: (Meena et al. 2022)

2.11 PINEAPPLE PRODUCTS

Pineapple can be processed into a wide variety of foods such as juices, ready to serve (RTS) beverages, jam, jellies, squash, etc. Nevertheless, only 10% of the pineapple produced is processed in India (Vipul et al., 2019).

2.11.1 Pineapple Juice

Pineapple juice is packed with an adequate number of vitamins and minerals. Sliced and cored pineapples are cleaned before their juice is extracted. The extracted juice will undergo filtration and 30 seconds of pasteurization at 80°C. After that, the extracted juice is put into sterile cans or bottles for marketing purposes. The addition of enzymes improves pineapple juice yield and juice recovery. The shelf-life of the processed juice can be extended by up to 6–7 months by adding preferred preservatives, such as ascorbic acid, citric acid, benzoates, sorbates, etc., to a certain amount as advised by the FSSAI. (FSSAI 2022; Nath et al., 2019). It has been demonstrated that pasteurization and ultrafiltration (UF) and microfiltration (MF) are equivalent in terms of guaranteeing the end product's microbiological stability and avoiding spoiling. With this method, flavour, juice freshness, and nutritional and bioactive components are maintained compared to conventional treatments. (Meher, 2023). However, more research on the technologies' applicability in the pineapple juice industry is required.

2.11.2 Pineapple Jam

As per FSSAI, Jam means the product prepared from sound, ripe, fresh, dehydrated, frozen or previously packed fruits including fruit juices, fruit pulp, fruit juice concentrate or dry fruit by boiling its pieces or pulp or puree with nutritive sweeteners namely sugar, dextrose, invert sugar or liquid glucose to a suitable consistency. Pineapple jam is a thick gel that is created with pineapple juice, pectin, or sugar. At least 65 percent total soluble solids (TSS) should be present in jam. Pineapple being a fruit rich in sugar, especially sucrose, glucose and fructose, and components such as minerals and vitamins makes it an ideal raw material for jam preparation Fruit jam processing processes include steps such as extracting, clarifying, boiling, and stabilizing. However, the quality of the jam is highly dependent on the concentration of each ingredient and processing parameters (Chalchisa et al., 2022).

2.11.3 Pineapple Squash

Squash is non-alcoholic concentrated syrup made from fruit juice, water and sugar or sugar substitute. Before drinking, squash is typically diluted with 2-3 times the amount of water

Fruits quash could be consumed by older infants, children and adults to meet nutrient needs particularly those of micronutrients (Kanne Sushmitha et al., 2024). Pineapple juice is one of the best suited raw materials for preparation of squash. According to Indian Food Laws, the fruit squash shall contain at least 25% fruit juice or pulp and not less than 40% TSS.

2.11.4 Pineapple Candy

Candy is a confection prepared from fruits or vegetables by impregnating them with sugar syrup followed by draining of excess syrup and then drying the product to make it shelf stable. A mature fruit with heavy sugar syrup till it becomes tender and transparent is known as preserves. J S Jothi (2014) developed pineapple preserve and candy and concluded that the pineapple preserves containing 65˚ Brix syrup and candies processed with 70˚ Brix syrup were best based on sensory attributes. Ansari (2022) studied the preparation of until gummy candy from a blend of pineapple and beetroot juice concluded that the gummy candy can be successfully prepared by using pineapple juice and carrot juice with addition of agar-agar and sugar. Gummy candy is composed of agar-agar or gelatine, flavourings, colourings, sweeteners (corn syrup, sucrose) and water.

2.11.5 Canned Pineapple

Canned pineapple is a popular food product that undergoes a series of processing steps before reaching the consumer. The pineapples are first sized, peeled, cored, and trimmed. The resulting coreless pineapple cylinder is then cut into slices, chunks or pieces. The pineapple is typically packed with a syrup containing 20 to 24% TSS before the cans are sealed and either exhausted or passed through a vacuum chamber. Following this, the cans undergo retort processing and are then cooled. Due to the low pH of canned pineapple, it has a long shelf life. This versatile product is commonly used in a variety of dishes, including appetizers, main courses, salads, side dishes, beverages, and desserts (Siow et al., 2017).

2.11.6 Pineapple Powder

Pineapple powder is a novel product and it has benefits such as extended shelf life at ambient temperature, convenience to use and low transportation expenditure. Pineapple powder can be used as an instant juice or flavouring agent. So far, just a few experiments on pineapple powder manufacture have been conducted. Some researchers claimed that drying fruit juice might yield the fruit powder, which when reconstituted gives a product resembling the original juice (Gabas et al., 2007).

3.1 NATA DE COCO

Figure 11: Nata de coco

Nata de coco, also referred to as "coconut gel," is a chewy, translucent jelly-like food created through the fermentation of coconut water or coconut milk as depicted in **Figure 11**. This process occurs as *Acetobacter xylinum* produces microbial cellulose, which causes the mixture to form a gel (Sharmin et al., 2021).

3.2 ORIGIN OF NATA DE COCO

Nata de coco was first introduced in the Philippines in 1973 as a way to preserve coconut water and transform it into a jelly-like substance. While nata de coco is mainly made from coconut water and has a low nutritional value, it is rich in dietary fiber because it consists of cellulose. Cellulose, the key structural component of plant cell walls, is a polysaccharide with the formula $(C_6H_{10}O_5)n$, made up of long chains of β-D-glucose units linked together as illustrated in **Figure 12**. In the 1990s, nata de coco gained popularity in Japan, and today, it is available in various flavours and shapes. Although it can be eaten on its own, it is most commonly used as an ingredient in fruit salads, yogurts, ice cream, and beverages (Tallei et al., 2022). Nata de coco is renowned for its high fiber content. The chewiness of nata de coco is proportional to the fiber content. There are many brands of nata de coco available in the market (Rahmayanti et al., 2018). Proximate composition of nata de coco is shown in **Table 3**.

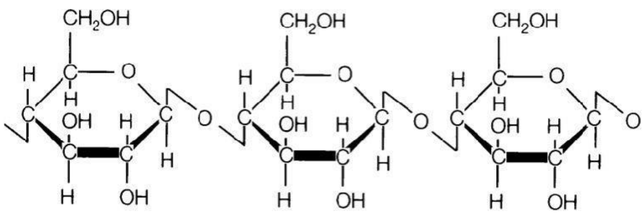

Figure 12: The structure of cellulose

Source: (Luther swift, 2008)

Table 3: Proximate Composition of Nata de coco

Nutrients	Concentration (%)
Water	96.77%
Ash	0.45%
Protein	0.024%
Fibre	3.23%
Fat	0.45%
Carbohydrate	2.43%

Source: (Andasuryani et al., 2021)

3.3 PRODUCTION OF NATA DE COCO

According to Jagannath et al. (2008), the ideal conditions for producing nata de coco with a soft surface and chewy texture include a Ph of 4, 10% sucrose, and 0.5% ammonium. To prepare the culture solution, sugar is added to mature coconut water, which is then inoculated with *Acetobacter xylinum*. The mixture is left undisturbed in a vessel for 2-3 weeks. During this time, a jelly-like substance forms at the top of the vessel. Once formed, the jelly is separated, washed with water to remove any acids on its surface, cut into pieces, and packed ((Mithra et al., 2013).

3.4 HEALTH BENEFITS OF DIETARY FIBER

Nata de Coco, which is primarily made from coconut water, has a relatively simple nutritional profile. A 118-gram serving (about one cup) contains 109 calories (Sharmin et al., 2021). Nata has become increasingly popular due to its high dietary fiber content. Health benefits of dietary fiber are presented in **Figure 13**. Dietary fiber is essential for maintaining a healthy digestive system. Cellulose, an insoluble fiber may help reduce appetite and overall food intake. It also accelerates the movement of food through the digestive system, promoting smoother bowel movements. Large-scale cohort studies have linked the intake of insoluble cereal fiber to a reduced risk of developing type 2 diabetes. Additionally, higher whole-grain consumption has been associated with a lower risk of several diseases, including coronary heart disease, cardiovascular disease, stroke, respiratory diseases, and infections, as highlighted by meta-analyses of prospective studies (Benisi-Kohansal et al., 2016).

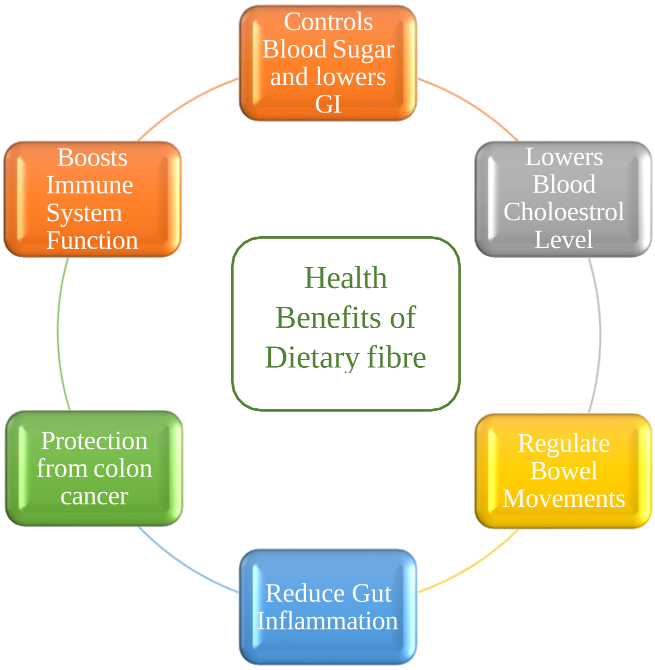

Figure 13: Health Benefits of Dietary Fiber

Source: (Tallei et al., 2022)

3.5 DEMAND FOR NATA DE COCO

Nata de Coco can be enjoyed by itself or used as an ingredient in various dishes such as fruit salads, halo-halo, coconut cakes, ice creams, soft drinks, bubble tea, and yogurts. The demand for Nata de Coco drinks is rising, particularly among young people and school-aged children. This ready-to-drink beverage is made from a variety of recipes, typically including citric acid and sugar to lower the product's Ph (Sharmin et al., 2021). In the 1990s, the Philippines benefited from nata de coco exports. However, a lack of organized research, along with other factors, has led to a decline in nata exports globally in recent years. There are no standardized international guidelines for nata de coco intended for export. Specifications, such as texture, colour, pH, sugar concentration, preservatives (if any), microbial standards, and the size and shape of the product, are typically determined by the importing country, but clear and consistent standards are urgently needed (Jagannath et al.,2008).

4.1 PAPAYA

Figure 14: Papaya

Papaya (*Carica papaya L.*) is a flavourful tropical fruit known for its sweet taste, musky notes, and distinctive aroma. **Figure 14** displays a picture of a papaya. Originally cultivated in Mexico centuries ago, it is now grown in many tropical regions worldwide. Every part of the papaya plant including the roots, leaves, peel, latex, flowers, fruit, and seeds holds both nutritional and medicinal value. Papaya is versatile, used in cooking, as a food ingredient, and in traditional medicine. It is regarded as a low-calorie, nutrient-rich fruit The United States, Mexico, and Puerto Rico are currently the leading commercial producers of papaya. Many genetically modified hybrid varieties are now widely available for cultivation, offering improved resistance to diseases (Amanat et al., 2011). Over the past four decades, papaya production has seen a significant increase, with an estimated output of 10.21 million tons in 2009 (FAO, 2010). Papaya can be processed into various preserved products, including candies, jams, and jellies. It can also be made into beverages like ready-to-drink drinks and nectar. Additionally, dried and canned papaya products are available. By-products of papaya, such as pectin and papain, are valuable for use in the food industry (Devaki et al., 2015).

4.2 NUTRITIONAL COMPOSITION

Papaya is often called the "common man's fruit" because it is inexpensive and packed with excellent nutritional value. The fruit, both ripe and unripe, as well as the leaves, contain beneficial phytonutrients. Papaya is highly regarded for its high levels of thiamine, folate, riboflavin, niacin, vitamins A, B1, B2, and C, and fibre. It is ranked among the top five fruits, along with kiwi, watermelon, grapefruit, and guava, based on its nutritional profile (Koul et al., 2022). Major nutrients in papaya are shown in **Figure 15** and composition of papaya is displayed in **Table 4**.

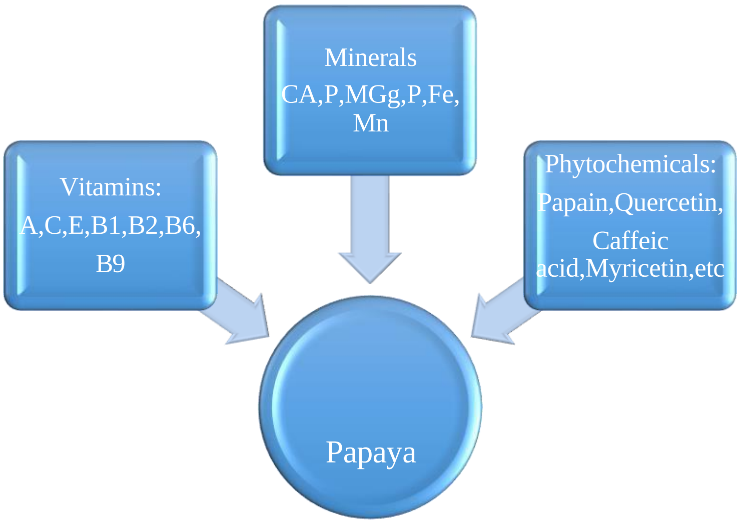

Figure 15: Nutrients in Papaya

Source: (Chuwa et al., 2022)

Table 4: Composition of Papaya

Parameters	Composition
Total Energy	34.26 kcal/100g
Total Sugar	7.35%
Reducing Sugar	2.05%
Acidity	0.06%
Crude Protein	0.06%
Crude Fat	0.14%
Crude Fiber	0.19%
Total Carbohydrate	8.51%
Ascorbic Acid	59.26mg/100g
Beta-Carotene	13.04mg/100g
Ash	0.72%

Source: (Chuwa et al., 2022)

4.3 HEALTH BENEFITS OF PAPAYA

Papayas not only provide a delicious tropical flavour and vibrant colour but are also rich in antioxidants like carotenes, vitamin C, and flavonoids, along with B vitamins, folate, pantothenic acid, potassium, magnesium, and fiber. These nutrients support heart health and help protect against colon cancer (Rahman et al., 2013).

Following are the health benefits of Papaya:

1. The papain enzyme in papaya helps digest protein and has been used in traditional medicine to treat indigestion (Adeyi et al., 2019).
2. Jiao et al. (2022) reported that papain, which is the enzyme extracted from unripe papaya, has potential antioxidant properties. Antioxidants help to reduce oxidative stress, which is a major contributor to the development of various diseases, including anxiety and depression.
3. Unripe papaya is a useful treatment for impotence and ulcers, and it helps regulate menstrual irregularities, promoting smoother menstrual flow (Elizabeth 1994).
4. Vitamins A and C in papaya help improve vision, prevent early childhood blindness, protect against colds and coughs, and boost the immune system of children who frequently suffer from colds (Koul et al., 2022).
5. Papaya fruit and can be consumed by people with diabetes due to its intermediate GI foods (>55-<70) therefore, eating papaya may lower blood sugar also, it has a hypoglycaemic effect on the body (Chuwa et al., 2022).
6. Papaya extract has been found to have activity towards tumour destruction, and components of papaya extract, such as tocopherol, lycopene, and flavonoids, have been shown to stimulate anti-tumour effects and inhibit tumour cell growth (Rameshthangam et al., 2025).
7. Fresh papaya fruit has low in calories (34.26 Kcal/ 100 g) therefore, consuming papaya before dinner and lunch can suppress appetite which aids in weight management.
8. Papaya contains several unique protein-digesting enzymes including papain and chymopapain which help lower inflammation to improve healing from burns.
9. The massive amounts of essential vitamins A, C and antioxidants lycopene present in papaya can make your skin look radiant, even-toned and youthful. Papaya has skin lightening properties can help in getting rid of blemishes and pigmentation (Ali et al., 2011).

10. Papayas solves the problem of constipation immediately because its good source of dietary fiber. Since we don't digest it, the fiber in food passes into the intestine and absorbs water. The undigested fiber creates "bulk" that the muscles within the intestine can push waste out of the body. Eating enough fiber helps to stop constipation (Chuwa, et al., 2020).

5.1 BEVERAGES

Beverages are the most significant component of human diet. The consumption of beverage starts from starts from first phase of human life i.e. infancy. They are enjoyed among all age groups including children, adults, and elderly as they are thirst quenching and some beverages like fruit juice can provide nutritional benefits. Beverages are defined as fluids or liquids which are fundamentally manufactured for human drinking. The range of products under beverage category includes packaged drinking water, sports beverages, energy beverages, fruit-based beverages, synthetic beverages, market milk, dairy based beverages, alcoholic beverages, stimulating beverages (tea, coffee), cocoa based beverages and many more (Poonia, 2018). Major classification of beverages is outlined in **Figure 16**.

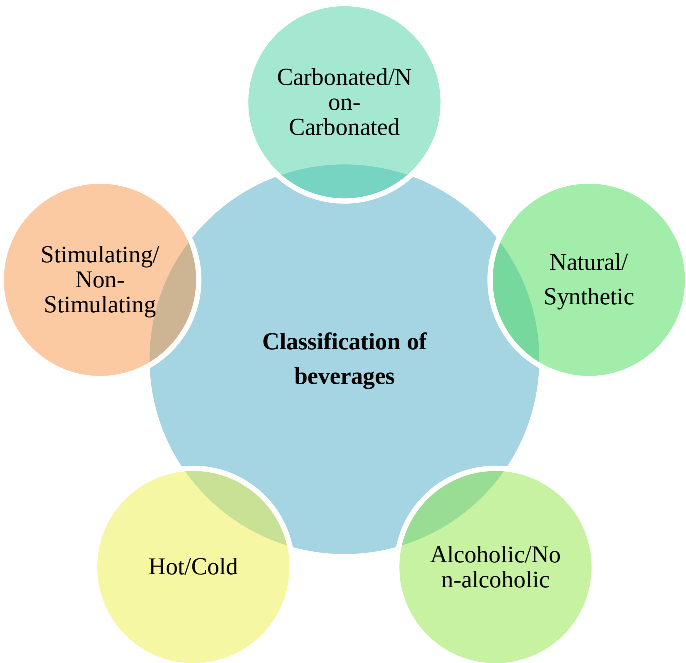

Figure 16: Classification of Beverage

Source: (Poonia, 2018)

5.2 READY TO SERVE BEVERAGE

Fruits and vegetables are essential parts of the human diet. It lowers the risk of numerous diseases when consumed regularly since it contains vitamins, minerals, fiber, and energy. In recent times the demand for natural RTS beverages is rising due to dietary and lifestyle changes. A ready to serve (RTS) beverage is a non-fermented beverage prepared from mixing edible portion of fruit, sugar, water, and additives for direct consumption. By introducing value-added natural RTS beverages, the nation's socioeconomic standing could improve (Gaikwad et al. 2013). The benefit of RTS beverages is that they don't require additional dilution with water, unlike other concentrated liquids like syrup or squash, which are carefully diluted with water before being consumed (Hemalatha 2018). This is a type of fruit beverage which contains at least 10 per cent fruit juice and 10 per cent total soluble solids besides about 0.3 per cent acid (Nadella et al., 2022).

5.3 RTS FRUIT BEVERAGE

Among the most popular types of beverages consumed worldwide are those made from fruit. The popularity of fruit-based beverages has expanded significantly since they are more easily digested, health aware, refreshing, thirst relieving, palatable, and nutritionally superior than the majority of the synthetic beverages on the market (Karunarathna et al., 2019). Fruits like grapes, gooseberries, litchi, pineapple, orange, and others are used to make a variety of RTS beverages, including blended, refreshing, and functional drinks. Natural RTS beverages are made with fruits or vegetables, sugar, water, and preservatives. Citric acid, sodium benzoate, potassium metabisulphite, and sodium metabisulphite are the most often used preservatives (Rathinasamy et al., 2022).

5.6 RTS PINEAPPLE JUICE

Pineapple juice is a widely consumed product, experiencing growing demand in various countries. It is globally marketed due it’s appealing aroma, tase, and health benefits. The nutritional compounds in pineapple juice that contributes to human health are primarily identifies as phytochemicals, including vitamin C, carotenoids, flavonoids, and phenolic compounds. (Samreen et al., 2020). Pineapple juice adds a sweet and tangy flavour to drinks, and its natural sweetness brings a refreshing tropical taste. It is no wonder that with India's growing health-conscious population, there is a surge in demand for locally produced, organic pineapple juice (Source: Statista, 2023).

New trends in pineapple juice market have led to the development of a new type of product, which is based on the addition of fruit pulp/fibers or enrichment of juice by discrete fruit pieces to satisfy current consumer demands. Consumers often look for RTS beverages featuring small pieces of fruit. These drinks combining juices together with real fruit bits provide a refreshing beverage with a mouthfeel similar to eating a whole fruit. However, achieving this is the biggest challenge for an industrialist as delicate handling is required throughout all processing phases. If real fruit chunks are used, they need to stay intact throughout the entire production cycle, which usually does not happen (Pal et al., 2022). There are limited papers published regarding fruit juice incorporated with addition of nata or fruit cubes. Nathalal (2019) developed a RTS mango beverage with incorporation of Nata de mango. Sharmin (2017) developed strawberry flavoured drink with added nata de coco. The demand for nata de coco drink is also increasing, particularly among young people and school-aged children.

5.7 INDIAN FRUIT JUICE INDUSTRY

Hot and humid weather is common in coastal states of India, making hydration essential. This creates opportunities for beverage industries in India. Recent studies have shown that regular consumption of alcohol and carbonated drinks lead to various health issues. However, with increased awareness through media, many people are shifting to fresh fruit and vegetable juices as a healthier alternative because they are seen as organic and rich in vitamins. Minerals, and antioxidants (Rivankar et al., 2019). The diverse climate of India ensures all varieties of fruit production in the nation making it a suitable fruit juice market. For instance, according to the 2021 FAO report, India ranks first in banana (26.45%), mangoes (43.80%), and papayas (39.30%) production and thus contributes significantly to the expanding fruit juice market. According to the APEDA reports, India is ranked second in the production of fruits and vegetables all over the world. The Indian Fruit Juice Market is expected to grow at a robust 7.76% CAGR (Compound Annual Growth Rate), reaching a market size of US$537.172 million in 2030 from US$369.703 million in 2025 as represented in **Figure 17.**

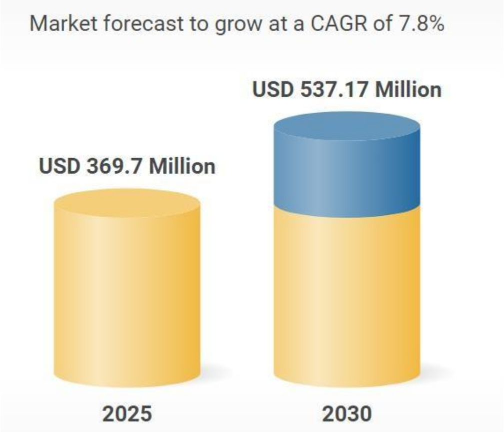

Figure 17: Indian Fruit Juice Market

Source: Indian Fruit Juice Market - Forecasts from 2025 to 2030

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The dissertation project was based on conducting the formulation of ready to serve beverages from pineapple juice: one with nata de coco cubes and other with papaya cubes. The study also evaluates the physiochemical and sensory properties of formulated drinks in packed form at 4℃±1℃ for a 30-day storage period to look into changes that occurred during the storage period which is analyzed using various methodologies. This chapter deals with the materials, methods, tools and equipment needed for the particular processes and experiments.

3.1 MATERIALS

3.1 1 RAW MATERIALS

a) Pineapple: Pineapple of optimum maturity were procured from the local market of Mysore and brought to the Department of Traditional Foods and Applied Nutrition at the Central Food Technology Research Institute in Mysore, Karnataka, India, for the development of Ready-to-serve drinks. I used this as my primary ingredient.

b) Nata de coco: Nata de coco jelly cubes of 8mm size was procured from Amazon and brought to the Department of Traditional Foods and Applied Nutrition at the Central Food Technology Research Institute in Mysore.

c) Papaya: Papaya of varying maturity were procured from the local market of Mysore and brought to the department for developing papaya cubes for the drink.

d) Sugar: Sugar, for sweetness was procured from the local market and was brought to Department.

e) Chemicals: Chemicals such as Citric acid, Sodium benzoate and hydrocolloids such as Pectin were purchased from chemical store and brought to the department.

3.2 TOOLS AND EQUIPMENT

- **Induction stove:** This is used as the heat source.
- **Blender:** Used for blending, homogenizing and obtaining the pulp.
- **Strainer:** Used to strain
- **Muslin cloth:** Used to strain and obtain fine juice
- **Measuring cylinders:** To measure accurate amount of ingredients.
- **Weighing balance:** To measure accurate amount of ingredients.
- **Ladle:** To stir the mixture.
- **Digital thermometer:** To determine the temperature during boiling, pasteurization and cooling.
- **Refractometer:** To determine the TSS of pineapple juice and final product.
- **Knife:** Used for cutting and Peeling.
- **Peeler:** To remove outer skin of raw material
- **Vessels:** Used for washing, boiling and cooking.
- **PET bottles:** To store the puree and product.
- **Polyethylene pouches:** To store the puree.
- **Refrigerator:** To store the puree and product at a required temperature.

3.3 PREPARATION OF RAW MATERIALS

3.3.1 PREPARATION OF FRESH PINEAPPLE JUICE

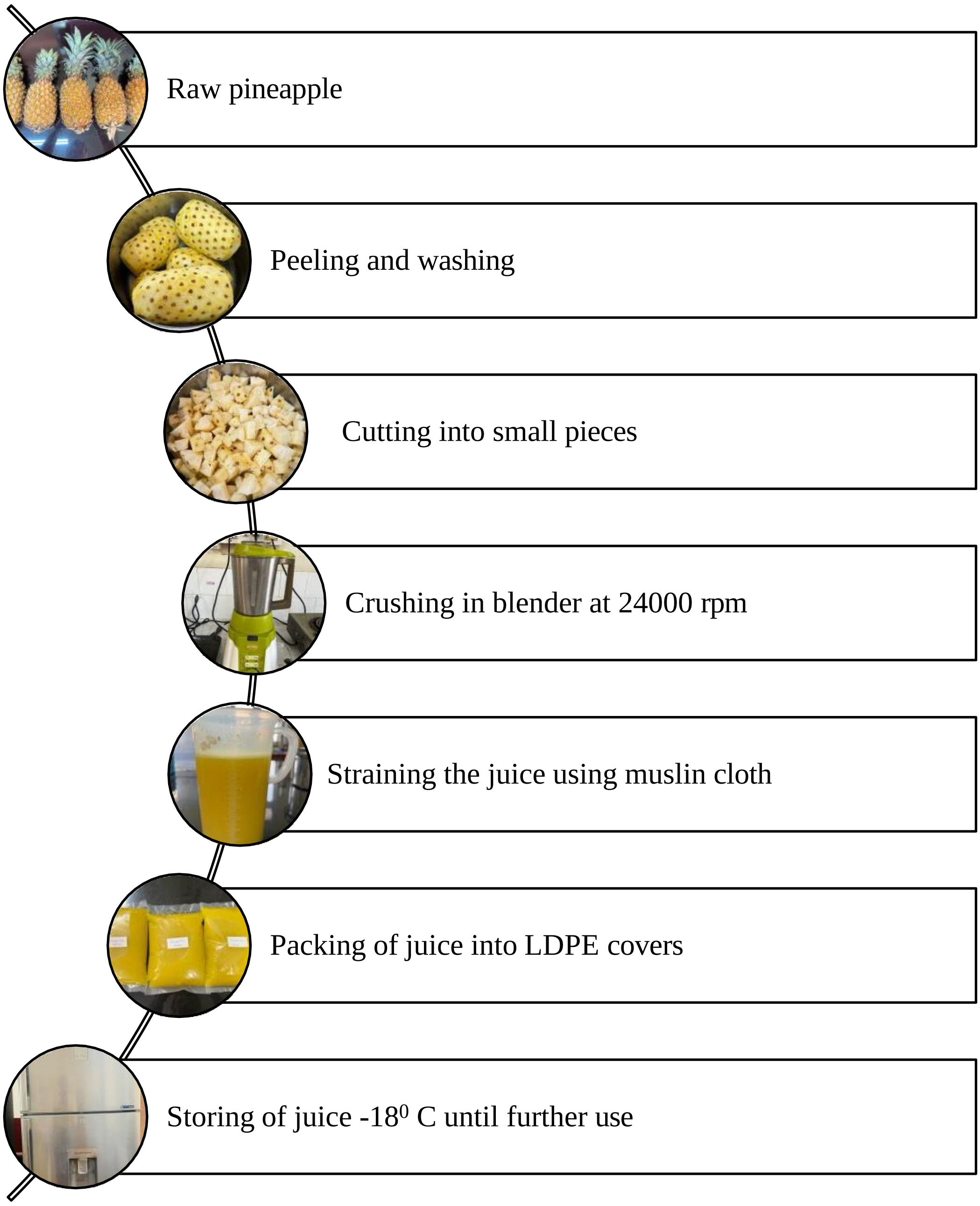

Figure 18: Preparation of pineapple juice

3.3.2 PREPARATIONS OF NATA DE COCO

Nata de coco which was originally in a 12^0 Brix solution was strained using a strainer and kept in refrigerated condition until further use.

3.3.3 PREPARATION OF STABILISED PAPAYA CUBES

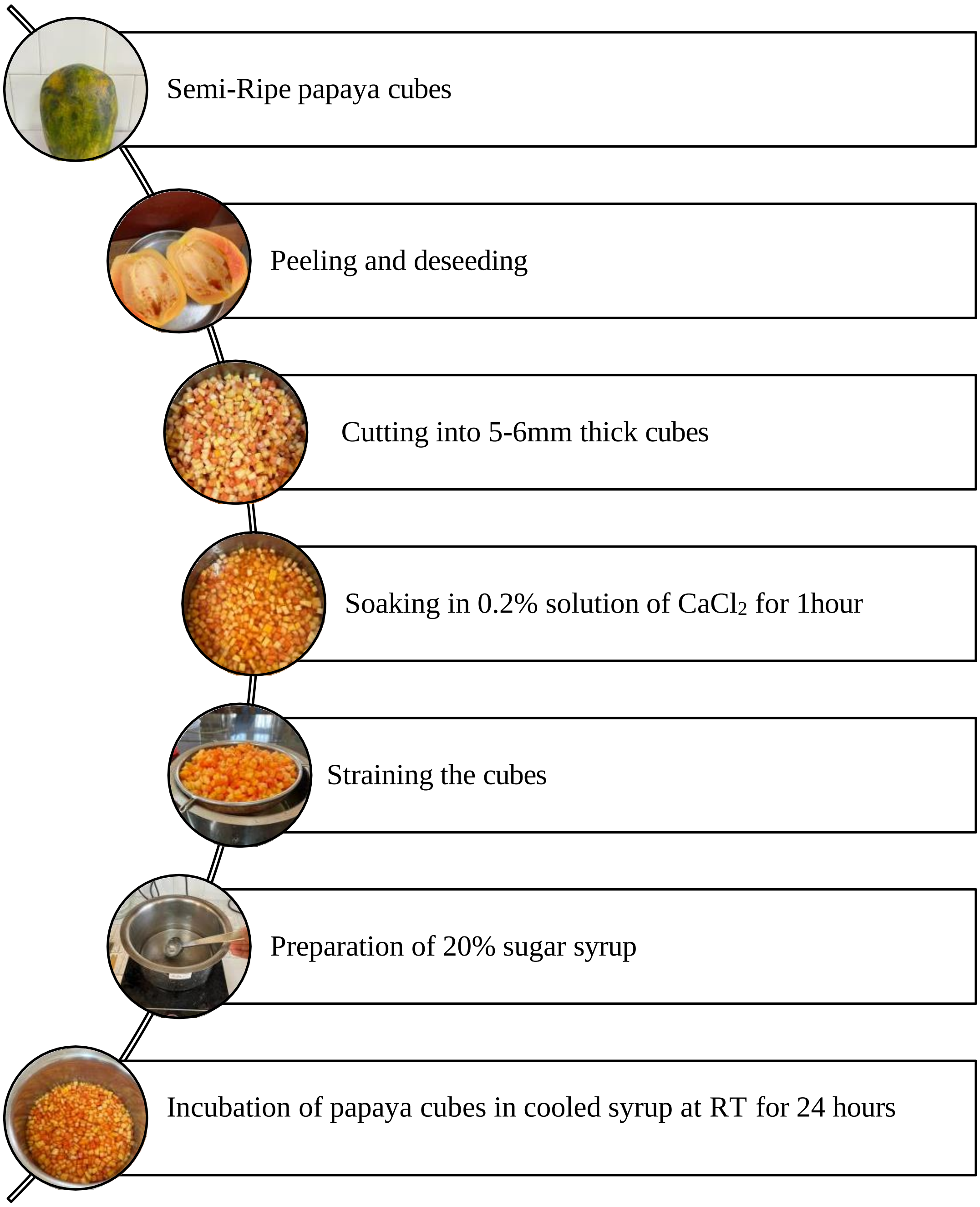

Figure 19: Preparation of papaya cubes

3.3 PRODUCT DEVELOPMENT

3.3.1 PREPARATION OF BEVERAGE FROM PINEAPPLE JUICE WITH ADDED NATA DE CO JELLY CUBES

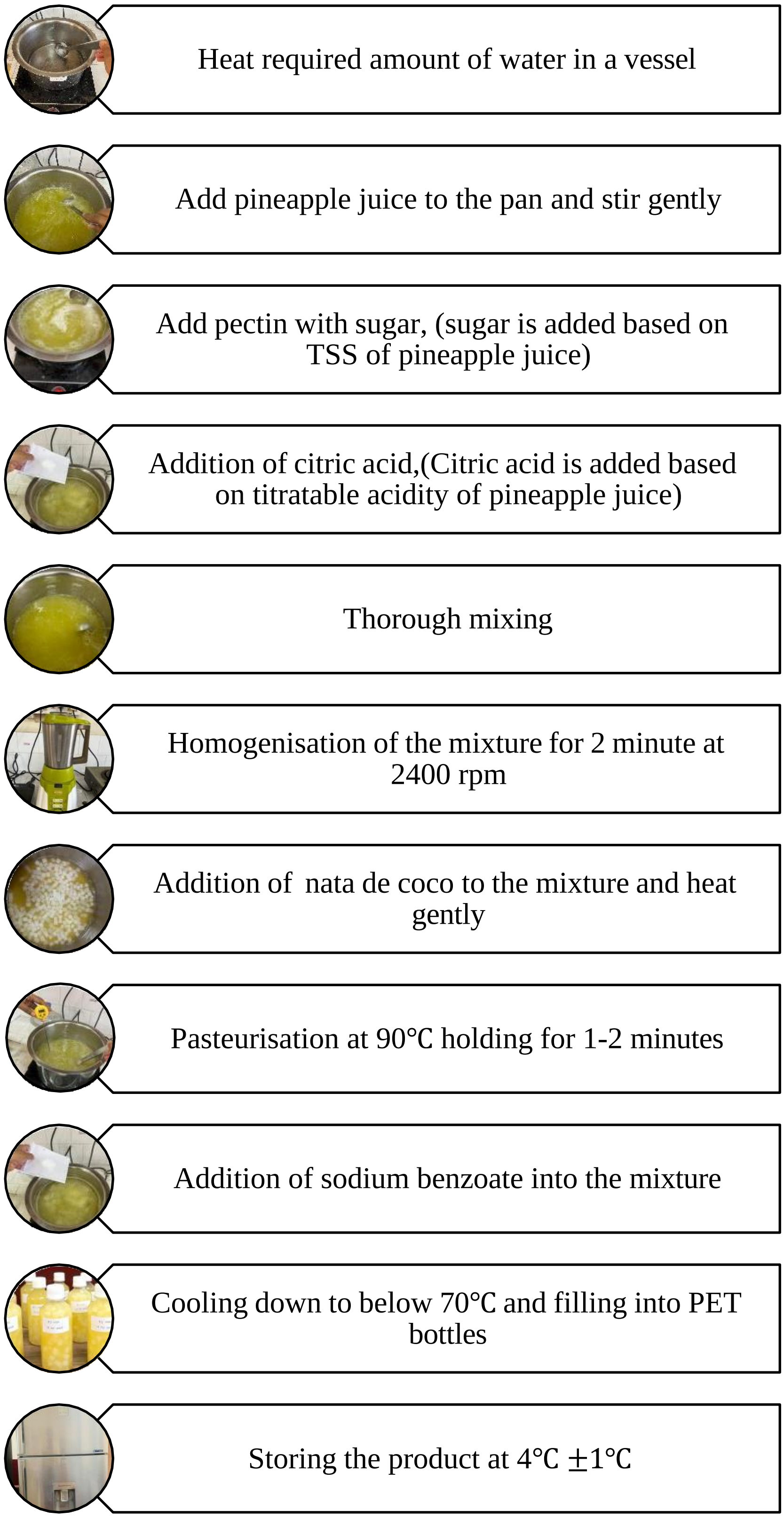

Figure 20: Preparation of Beverage from pineapple juice with added nata de coco jelly cubes

3.3.2 PREPARATION OF BEVERAGE FROM PINEAPPLE JUICE WITH ADDED PAPAYA CUBES

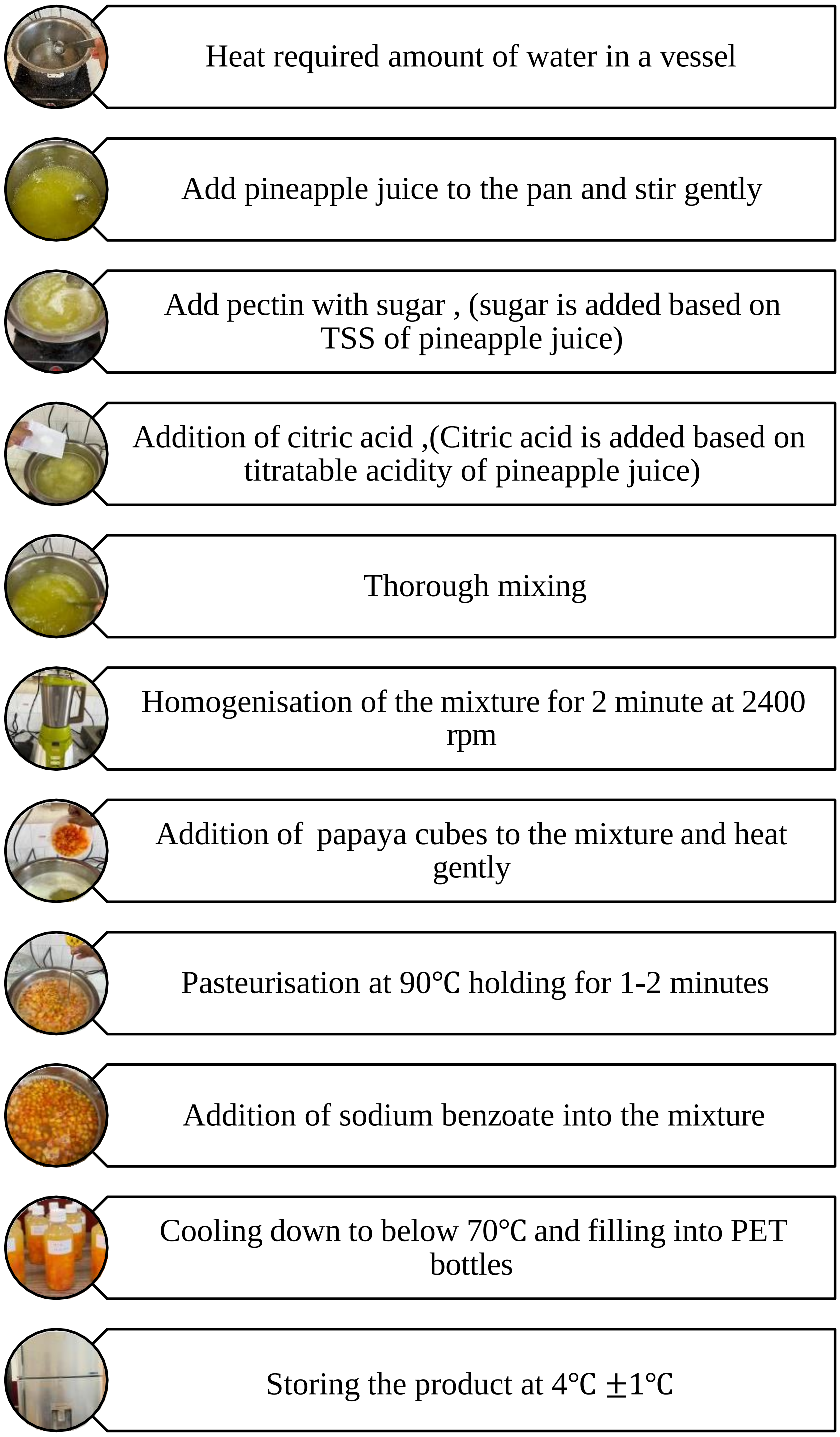

Figure 21: Preparation of Beverage from pineapple juice with added papaya cubes

3.6 TRIALS AND OPTIMISATION

3.6.1 Composition of RTS Beverage from pineapple juice with added nata de coco cubes

Trials and optimisation were done to determine the colour and uniform dispersion of nata de coco jelly cubes (NDC) in the beverage. **Table 5** depicts the composition of RTS beverage from pineapple juice with NDC. Three formulations were prepared namely F1 (20% pineapple juice without pectin) **(Figure 22)**, F2 (20% pineapple juice without pectin), **(Figure 23)** and F3 (25% pineapple juice with pectin), **(Figure 24)**. Quantity of NDC also varied in F1(300g), F2(280g), and F3(240g). 1L of each formula was prepared which gave 4 bottles each. Sugar and citric acid were was calculated and added based on Total Soluble Solids (TSS) and Titratable acidity of pineapple juice. Preliminary sensory evaluation using 9-point hedonic scale was also done to determine the best formula.

Table 5: Composition of RTS Beverage from pineapple juice with NDC

Ingredients	F1	F2	F3
Water (ml)	710	680	680
Pineapple juice (%)	20	25	25
Sugar (g)	87.2	69.7	69.7
Citric acid (g)	2.062	0.655	0.655
Pectin (g)	-	-	2
Sodium benzoate (mg)	120	120	120
Nata de coco (g)	300	280	240

Figure 22: F1 (20% juice)

Figure 23: F2 (25% juice)

Figure 24: F3 (25% juice +Pectin)

F1 and F2 was shown to have less colour and the dispersion of NDC in pineapple juice was not uniform. The colour of the F3 was great and the NDC was uniformly dispersed. This may due to the addition of pectin along with homogenisation. While F1 and F2 had 75g & 70g of nata de coco and 180ml of juice per bottle, F3 had 60g of NDC and 180ml of juice per bottle. This accounts to 33% of NDC cubes per bottle. In terms of sensory evaluation, F2 scored the least, while F3 scored the highest. The parameters evaluated includes appearance, colour, taste, flavour and texture of NDC. So F3 was chosen as the final composition for the bulk preparation since it scored the highest in terms of sensory and uniform dispersion of NDC.F3 contains 33% of nata de coco jelly cubes with 180ml of prepared pineapple juice beverage.

3.6.2 Composition of RTS Beverage from pineapple juice with added papaya cubes

Trials and optimisation were done to optimise papaya cubes (PC)in RTS pineapple juice. **Table 6** shows the composition of RTS beverage from pineapple juice with stabilised papaya cubes. F4 (25% Juice with semi-ripe papaya cubes) which is displayed in **Figure 25** was prepared using semi-ripe papaya cubes, while F5 (25% Juice with raw papaya cubes) which is depicted in **Figure 26** was prepared using raw papaya cubes. Quantity of PC was same in both F4(240g), and F5(240g). 1L of each formula was prepared which gave 4 bottles each. Sugar and citric acid were calculated and added based on Total Soluble Solids (TSS) and Titratable acidity of pineapple juice. Preliminary sensory using 9-point hedonic scale was also done to determine the best formula.

Table 6: Composition of RTS Beverage from pineapple juice with papaya cubes

Ingredients	F4	F5
Water (ml)	680	680
Pineapple juice (%)	25	25
Sugar (g)	69	70
Citric acid (g)	1.325	1
Pectin (g)	2	2
Sodium benzoate (mg)	120	120
Papaya cubes (g)	240	240

Figure 25: F4

(25% Juice with Semi-ripe papaya cubes)

Figure 26: F5

(25% Juice with Raw papaya cubes)

F4 scored the highest in terms of sensory which used stabilised semi-ripe papaya cubes. F5 used stabilised raw papaya cubes. The parameters evaluated includes appearance, colour, taste, flavour and texture of PC. Panellists preferred semi-ripe papaya cubes due its soft biting texture. Raw papaya cubes had a hard texture which made it difficult to chew. In terms of appearance, F5 was a more attractive. So F4 was chosen as the best composition for RTS pineapple juice with added papaya cubes and made in bulk. Each bottle had 60g(30%) of papaya cubes and 180ml of prepared pineapple juice beverage.

3.6 STANDARDISED PROCESS CONDITIONS FOR RTS BEVERAGE FROM PINEAPPLE JUICE WITH ADDED NATA DE COCO JELLY CUBES AND SEMI-RIPE PAPAYA CUBES

Table 7: Standardised Composition of RTS Beverage from pineapple juice with added NDC and PC

Ingredients	PJ-NDC (3L)	PJ-PC (3L)
Water (ml)	2050	2050
Pineapple juice (%)	25	25
Sugar (g)	192	192
Citric acid (g)	2.8	2.8
Pectin (g)	6	6
Sodium benzoate (mg)	360	360
Papaya Cubes (g)	-	720
Nata de coco (g)	720	-

PJ-NDC (Pineapple juice Beverage with nata de coco jelly cubes), **PJ-PC** (Pineapple Juice Beverage with semi-ripe papaya cubes)

Figure 27: PJ-NDC

Figure 28: PJ-PC

3.7 MATERIAL BALANCE:

3.8 1 Material Balance of PJ-NDC and PJ-PC

- Weight of pineapple (after removal of Calyx) = 3208g
- Weight of peel = 820g
- Weight of pomace= 256g
- Volume of pineapple juice =2100g

3.8 2 Juice Yield

Juice yield (%) $= \frac{Weight\ of\ pineapple\ juice}{Weight\ Of\ pineapple}$ x 100

$$= \frac{2100}{3208} \text{ x } 100$$

= 65.4%

3.8 3 Solid Waste Yield

Solid Waste Yield (%) $= \frac{Weight\ of\ peel + weght\ of\ pomace}{Weight\ Of\ pineapple}$ x 100

$$= \frac{810+260}{3208} \text{ x } 100$$

=33.35 %

3.8 4 Uncounted losses

Uncounted loss (%) = 100- (Puree yield+ solid waste yield)

= 100-(65.4 + 33.35)

= 100-98.75

= 1.25 %

3.10 STORAGE STUDIES

Prepared RTS beverages (PJ-NDC and PJ-PC) were stored in PET bottles at 4℃ ±1℃ in refrigerator for a period of 30 days. Chemical and sensory changes in samples during storage were evaluated in between a gap of 15 days for 30 days.

3.11 ESTIMATION OF PHYSICO-CHEMICAL PROPERTIES

3.11.1 TEXTURE PROFILE ANALYSER (TPA)

TPA of nata de coco and papaya cubes was performed using texture analyser (Model TA.HD.plus Texture Analyser, stable Micro Systems), **(Figure 29)**. It was compressed to 50% strain using a 35mm cylindrical probe and 50kg probe cell at a speed of 5.00mm/sec to carry out TPA analysis. Hardness, chewiness, cohesiveness, gumminess, resilience, springiness and adhesiveness were determined and the values were reported. Figure 30 and 31 demonstrates the TPA of nata de coco and papaya cubes respectively.

Figure 29: Texture Analyser

Figure 30: TPA of nata de coco

Figure 31: TPA of Papaya cubes

3.11.2 FIRMNESS

Firmness of nata de coco and papaya cubes was performed using texture analyser (Model TA.HD.plus Texture Analyser, stable Micro Systems). Firmness is defined in this method as the work in grams-centimetre required to shear one piece of cubes (AACC. 1983). Nata de coco and papaya cubes was compressed to 100% strain using 1mm flat Perspex Knife Blade and 5kg load cell at a speed of 0.17mm/sec to carry out firmness analysis as shown in **Figure 32** and **Figure 33**. Units displayed can be converted automatically according to standards or other requirements.

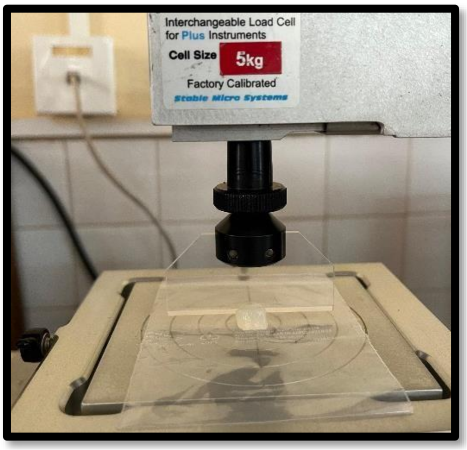

Figure 32: Firmness of nata de coco

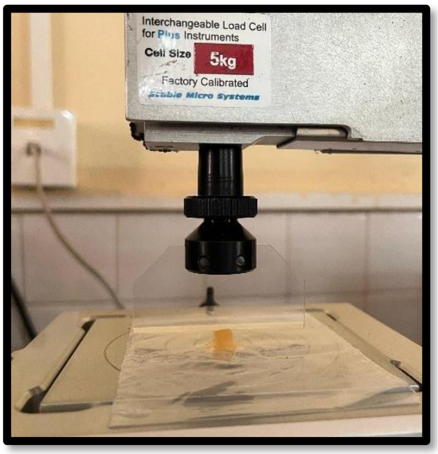

Figure 33: Firmness of papaya cubes

3.11.3 COLOUR ESTIMATION

The colour intensity of the samples was analysed using a Minolta Chroma Meter CM-5 benchtop spectrophotometer **(Figure 34)**, which operates within a wavelength range of 360 nm to 740 nm and is capable of measuring the colour of liquid, solid, or pasty samples in either reflectance or transmittance modes. The Hunter Lab parameters—L*, a*, b*, and ΔE—were recorded to quantify the colour characteristics of the samples. The *L value** indicates the sample's degree of lightness or darkness, where higher value corresponds to lighter shades and lower values to darker shades. The *a value** measures the redness (+) or greenness (-) of the sample, while the *b value** measures the balance between yellowness (+) and blueness (-). A value closer to zero for both a* and b* reflects less intense colour, while values farther from zero correspond to more intense colour characteristics (Ranganna, 2002). First, the instrument was calibrated and after that samples were placed in petri dish and reflectance of each sample was recorded in triplicates for accuracy.

Figure 34: Colour Measuring System

3.11.4 PARTICLE SIZE ANALYSIS

To measure the size of particle in the juice, a Microtrac S3500 Particle Size Analyzer **(Figure 35)** was used. Primary technology used is a laser diffraction to measure the size and distribution of the particles in clear water solution. The system includes a controlled ultrasonic probe that helps to disperse the sample in the liquid evenly. Measurements were performed after one gram of the sample and two litres of distilled water were run through the particle analyser. When the laser passes through the sample, the particles cause the light to scatter. The light scattering is inversely proportional to particle size i.e., larger particles scatter light at smaller angles, while smaller particles scatter light at larger angles. This relationship is used to determine the size of particle. The results come in a minute, including data analysis and measures particle size from 0.02 to 2800 microns.

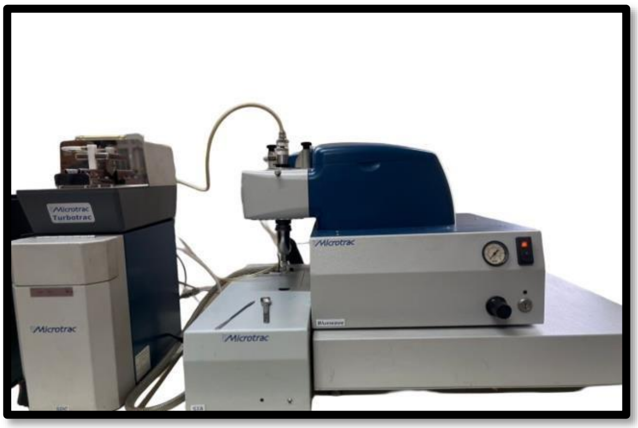

Figure 35: Particle Size Analyzer

3.11.5 VISCOSITY

Viscosity of the juice is measured using the Brookfield DV-II+Pro Viscometer **(Figure 36)** which measures fluid viscosity at given shear rates. Viscosity assesses' a fluids resistance to flow, providing important insights into various quality attributes such as final texture, consistency, processing, stability and consumer perceptions of the juice. The viscosity can reveal the presence and stability of suspended solids, such as pulp and fibres (Yani et al., 2025). The principal of operation of the DV-II+Pro is to drive a spindle (which is immersed in the test fluid) through a calibrated spring. The viscous drag of the fluid against the spindle is measured by the spring deflection. Spindle No.3 is used at 100 rpm and stable values are noted for samples. Readings were expressed in the unit Centipoise(cP).

Figure 36: Viscometer

3.11.6 pH

pH is essential for quality control and product development in beverage production, affecting taste, safety, and consumer satisfaction (Andŕes-Bello et al., 2013). This analysis measures the acidity or alkalinity of the juice by determining the concentration of hydrogen ions(H^+) in the juice blend (Reddy et al., 2015). A pH meter, **(Figure 37)** (measured from 0.0 – 14.0 pH units) is a statistical tool that monitors the hydrogen-ion activity in water-based solutions. Solutions with a pH higher than 7.0 are considered as basic and pH lower than 7.0 as acidic. A pH of 7.0 is neutral. A pH meter measures the pH of a solution by detecting the electrical potential between two electrodes: a reference electrode and a measuring electrode. When the electrodes are placed in the solution, the measuring electrode interacts with the hydrogen ions (H^+) in the solution, which determines its pH.

Figure 37: pH meter

3.11.7 TOTAL SOLUBLE SOLIDS

The total soluble solids (TSS) measure the concentration of dissolved substances in the juice. This includes sugars (such as sucrose, glucose, and fructose) as well as other soluble components like acids, vitamins, minerals, and amino acids (Berk, 2016). TSS is important to determine the quality of the fruit juices as it is related to the internal quality of the raw material used (Basak et al., 2022). Additionally, TSS determination is essential to evaluate the sweetness of beverages to maintain quality control within beverage production (Mansor et al., 2024). TSS, or Brix was calculated using a Hanna HI 96801 refractometer, **(Figure 38)**. The HI96801 takes measurements based on a sample’s refractive index. Refractive index is a measurement of how light behaves as it passes through the sample. Depending on the sample’s composition, light will refract and reflect differently. By measuring this activity with a linear image sensor, the sample’s refractive index is converted to the sucrose percent (% brix). When a small drop of sample is placed on the prism, the refractometer's LCD (Liquid Crystal Display) displays the TSS value in just 1.5 seconds response time.

Figure 38: Digital Refractometer

3.11.8 TITRATABLE ACIDITY

The titratable acidity (TA) of a solution is a measure of its total acid content. The acidity levels of samples were determined following the method outlined by Ranganna, (2001). To determine TA a known quantity of food sample is titrated with a standard base (NaOH), and the volume of the base required to neutralize the acids in the sample is measured. The pineapple juice contains a number of organic acids such as malic acid and citric acid, which are readily neutralized by strong bases such as sodium hydroxide. 2 ml sample is mixed with 10 ml of distilled water and titrated against 0.1N NaOH solution. Phenolphthalein indicator is added and the endpoint is determined by the change in colour of the solution to purple as shown in **Figure 39**. The titre values are noted and percentage acidity is calculated in terms of malic acid using the formula:

$$\%\text{Acidity} = \frac{6.7 \text{ x Normality of NaOH} \times \text{Titre value}}{\text{Weight of sample}}$$

(% anhydrous malic acid)

Figure 39: Titration

3.11.9 TURBIDITY

Turbidity is referred as the measure of cloudiness or haziness of the juice**.** Turbidity is caused by the presence of suspended particles as pulp, fibers, and other solid components in a beverage. Turbidity of ready to serve (RTS) juices was measured using HI 93703 Turbidity mete which is shown **Figure 40**. The HI93703 measures turbidity using a light detector at 90° for detection of scattered light. Turbidity of juice is an optical property that causes light to be scattered and absorbed, rather than transmitted. The scattering of light that passes through a liquid is primarily caused by the suspended solids present in the juice. The higher the turbidity, the greater the amount of scattered light. Turbidity measurements can be made in the 0.00 to 1000 FTU (Formazine Turbidity Unit).

Figure 40: Turbidity Meter

3.12 NUTRITIONAL PROFILING

3.12.1 SUGARS

Reducing Sugar and total sugars were estimated as per the method of Lane and Eynon described by Ranganna (1999), **(Figure 41)**. Reducing sugars are carbohydrates that have a free aldehydic (-CHO) or ketonic (-CO-) group in their structure and function as reducing agents i.e. reducing sugars have the ability to donate electrons (or reduce) other molecules in a chemical reaction, in the presence of an oxidizing agent. Examples include monosaccharide such as glucose, fructose, galactose and disaccharides such as maltose and lactose. Invert sugar is a mixture of two simpler sugars: glucose and fructose which is formed by the hydrolysis of sucrose (table sugar) into these two monosaccharides in presence of an acid.

3.12.1.1 FEHLING’S FACTOR CALCULATION

The first step in the estimation of reducing sugars by Lane and Eynon method is the determination of Factor for Fehling’s solution which is the quantity of invert sugar in grams required to completely reduce the Fehling’s solution (usually 5 ml each of Fehling’s A and B solutions). For Calculating Fehling’s Factor, weigh 25ml of standard invert sucrose solution and transfer it into 100ml volumetric flask. Add 50ml distilled water and 2-3 drops of phenophthalein indicator. Neutralize it with NaOH pellets until pink color is obtained. Make up to 100ml and fill in burette. Boil 5ml of Fehling's A & Fehling’s B each with 10 ml of distilled water in a conical flask. Titrate it against burette solution until the end point is brick red colour. Fehling’s factor was calculated using the following formula:

$$\text{Factor of Fehling's solution} = \frac{\text{Titre value} \times 2.5}{1000}$$

3.12 1 2 REDUCING SUGAR

In a conical flask, 10 ml of sample is taken and 50 ml of distilled water is added into it. Then, few drops of phenolphthalein indicator are added and the solution is neutralised using NaOH crystals until pink colour is obtained, which is made up to 100 ml in a volumetric flask. Filter the solution and fill it in the burette. Take 5 ml of Fehling’s A and 5 ml of Fehling’s B in a conical flask, and add 10 ml of distilled water into it **(Figure A)**. This mixture is heated on an automatic coil stove, when it is about to boil, 2-3 drops of methylene blue is added, and titration is done against solution filled in burette. When the solution turns brick red, titre value is noted **(Figure B)**. Experiment is repeated for 3 times and reducing sugar was calculated using the formula;

$$\%\ \text{Reducing Sugars} = \frac{\text{Fehling's factor x volume x 100}}{\text{Titre value x weight of sample}}$$

3.12 1 3 INVERT SUGAR

10ml of sample was taken and 50ml distilled water in 100ml standard flask. Then 5ml of conc. HCI was added and kept at room temperature for 24 hours for inversion. After 24 hours a few drops of phenolphthalein indicator were added. Then NaOH crystals were added until pink colour persisted and volume was made up to 100ml by using distilled water and filtered. Filtrate was taken in burette. Then 5ml Fehling’s A solution, 5ml Fehling’s B solution and 10ml distilled water were taken in conical flask and boiled **(Figure A)**. When the boiling just starts, 2-3 drops of methylene blue indicator were added and titrated against the solution in burette. End point was brick red colour **(Figure B)** and titre value was noted. Experiment was repeated for three times and reducing sugar was calculated using the formula;

- $$\% \text{ Total Invert Sugars} = \frac{\text{Fehling's factor x volume x 100}}{\text{Titre value x weight of sample}}$$
- %Sucrose = (% Total inverted sugars - %reducing Sugar) x 0.95
- %Total Sugars = % Reducing Sugar+ % sucrose

Figure A: Fehling's A & B with distilled water

Figure A: End point brick red colour

Figure 41: Lane and Eynon Method

3.13 PIGMENTS

3.13.1 CAROTENOIDS

3.13.1.1 β -CAROTENE

In order to determine the β -carotene, take 10ml of fresh sample and 10ml of acetone in a centrifuge tube. Keep for incubation at room temperature in dark room for 30 min. After 30 minutes, add 10ml of petroleum ether and shake well. Then leave it for 20 min at (room temperature (RT) in dark room. Two layers will separate out on standing. Discard the lower layer and collect upper layer in another centrifuge tube. Take optical density at 452 nm in UV(Ultraviolet) spectrophotometer using petroleum ether as blank. For determining β -carotene, UV spectrophotometer, Model UV-1800 Shimadzu, **(Figure 42)** was used. β -carotene was calculated using the formula:

$$\beta\text{-carotene (mg/100g)} = \frac{\text{OD at 452 nm} \times 13.9 \times 10^4 \times 100}{\text{Weight of sample} \times 560 \times 1000}$$

β -carotene (mg/100g) x 1000= β -carotene (μg/100g)

Figure 42: UV Spectrophotometer

3.13.1.2 VITAMIN A

After obtaining the β-carotene values, the following formula can be used to compute the Vitamin A content, which is represented in International Unit (IU).

$$\text{Vitamin A (IU)} = \frac{\beta\text{−carotene}}{0.6}$$

3.14 SENSORY ANALYSIS

The sensory evaluation two RTS pineapple juices was done for its appearance, taste, texture, colour and overall acceptability, in order to select the formulation with best sensory attributes and quality. It was done using a Hedonic rating scale (9-point scale) which is shown in **Table 8** as per the 42-procedure described by Ranganna (1999). The numerical values from 1 to 9 indicates how much the panellist liked or disliked the product. In this evaluation, 1-9 panellists were involved.

Table 8: Hedonic Scale

SCALE	HEDONIC RATING
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like or dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

3.14 STATISTICAL ANALYSIS

The data were analysed to establish the final results of statistical analysis using a single factor ANOVA (Analysis of Variance) and significance was observed at P-value 0.05 in Microsoft Excel. To illustrate the uncertainty and variability, 5% error bars were added to the graphs.

CHAPTER 4

RESULTS AND DISCUSSIONS

CHAPTER 4

RESULTS AND DISCUSSIONS

The main goal of this study was to optimize and formulate ready to serve beverages from pineapple juice added with nata de coco cubes and stabilised semi-ripe papaya cubes and analyse the physicochemical parameters of formulated drinks. This chapter deals with discussion of the results of both the formulated (PJ-NDC AND PJ-PC) drinks during the storage period of 30 days at 4℃ ± 1℃.

4.1 COMPOSITION OF FRESH PINEAPPLE JUICE AND END PRODUCT

Composition of fresh pineapple juice and final products PJ-NDC (Pineapple Juice beverage with nata de coco jelly cubes) and PJ-PC (Pineapple Juice Beverage with Semi-ripe papaya cubes) is given in **Table 9**. According to 'Chemical Methods for Analysis of Fruit and Vegetable Products' by J.A. Ruck, 1963, to estimate the calorie content of juice, take refractometer of sample at 20℃, multiply the reading by 4 to estimate number of calories per 100g.

Table 9: Composition of Pineapple Juice, PJ-NDC and PJ-PC

PARAMETERS	Pineapple Juice	PJ-NDC	PJ-PC
TSS (^{0} BRIX)	12.12	13.6	14
pH	3.46	3.40	3.38
Titratable Acidity (%)	0.938	0.368	0.402
Turbidity (FTU)	1000	497	478
Reducing Sugar (%)	2.62	2.72	6.01
Invert Sugar (%)	11.02	22.3	20.91
Beta-Carotene	170	57.08	44.67
Vitamin-A (I.U)	283.3	95.14	74.46
Viscosity (cP)	16	8	8
Calorific Value kcal/100g	48.48	54.4	56

4.2 CHANGES IN TEXTURE

Table 10 represents the Texture Profile Analysis (TPA) of PJ-NDC and PJ-PC during storage. Hardness, which reflects the force required to compress the cubes, increased for both PC and NDC. The increase in nata de coco is higher, likely due to structural changes in NDC over time, possibly due to water absorption or gel strengthening. Papaya cubes also hardened, possible due to stabilisation effects, however, hardness remained significantly lower than NDC, showing papaya cubes remained softer overall. Chewiness increased from 69.08 to 144.54 for NDC, but chewiness for PC increased only slightly (10.17 to 18.27), indicating papaya cubes retained a soft texture during storage. Cohesiveness had minor changes for both PC and NDC. Resilience, which reflects the ability of the sample to regain shape after compression increased slightly for PJ-NDC, indicating that nata de coco maintained its structure better. Gumminess is defined as the product of hardness x cohesiveness. It is a characteristic of semi-solid foods with a low degree of hardness and high degree of cohesiveness. Gumminess increased for both samples. PJ-NDC remained much higher in gumminess compared to PJ-PC, reinforcing that nata de coco provides a firmer and more cohesive structure, making more resistant to breakdown. In case of Springiness, NDC showed a slight increase but PC had no changes during storage. PJ-NDC showed lower adhesiveness over time (-1.96 to -3.17), indicating reduced stickiness due to moisture redistribution or surface hardening. PJ-PC exhibited higher adhesiveness (-2.77 to 5.91), suggesting increased stickiness from sugar migration from cubes into the juice. This implies that nata de coco became less adhesive, while papaya cubes became more adhesive during storage.

Table 10: TPA of PJ-NDC and PJ-PC during storage

PARAMETERS	0 DAY		30 DAY	
	PJ-NDC	PJ-PC	PJ-NDC	PJ-PC
Hardness (N)	1810.07± 70.83	369.22± 42.38	2247.1± 264.02	591.05± 48.85
Chewiness	69.08± 65.3	10.17± 0.65	144.54± 8.93	18.27± 7.03
Cohesiveness	0.12± 0.08	0.08± 0.01	0.14± 0.00	0.09± 0.00
Gumminess	271.29± 137.13	31.31± 7.46	319.11± 54.02	53.39± 9.01
Resilience	0.11± 0.06	0.04± 0.01	0.14± 0.01	0.04± 0.00
Springiness	0.27± 0.12	0.33± 0.05	0.45± 0.04	0.33± 0.07
Adhesiveness(N)	-1.96± 0.02	-2.77± 2.35	-3.17± 3.58	5.91± 0.10

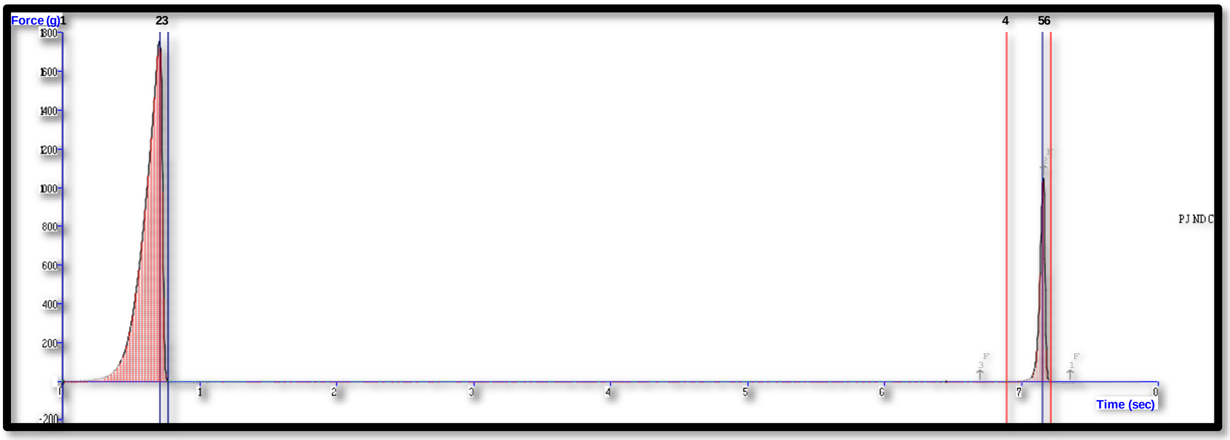

Figure 43: TPA results for PJ-NDC at 0 Day

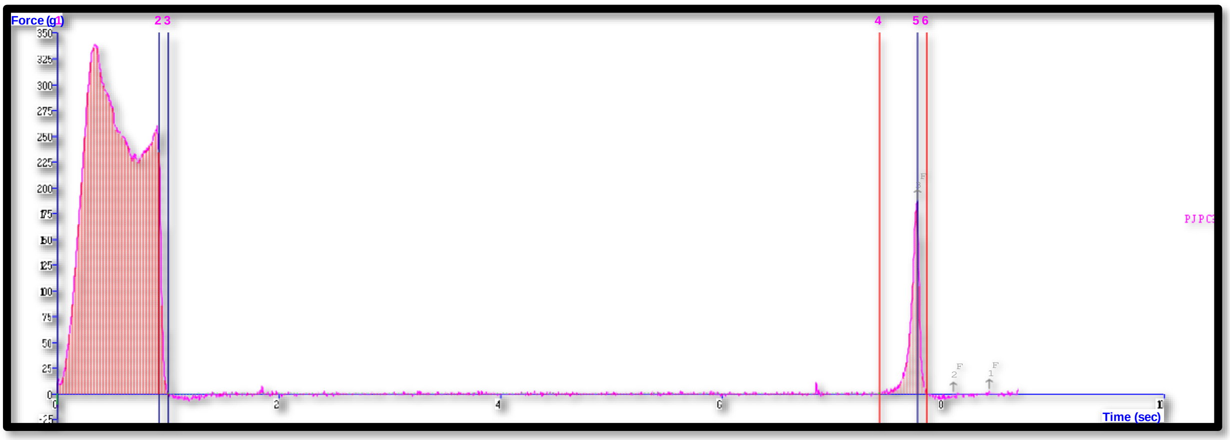

Figure 44: TPA results for PJ-PC at 0 Day

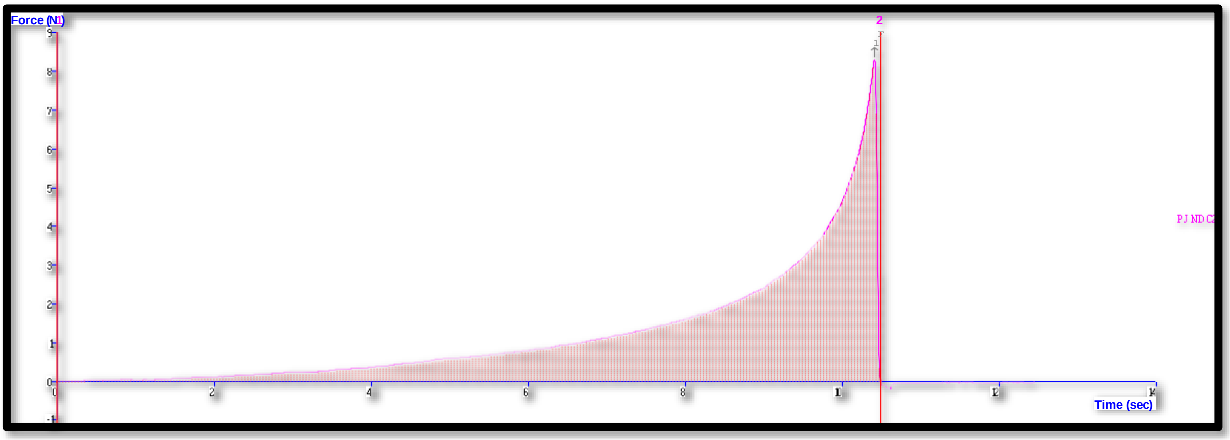

Figure 45: TPA results for PJ-NDC at Day 30

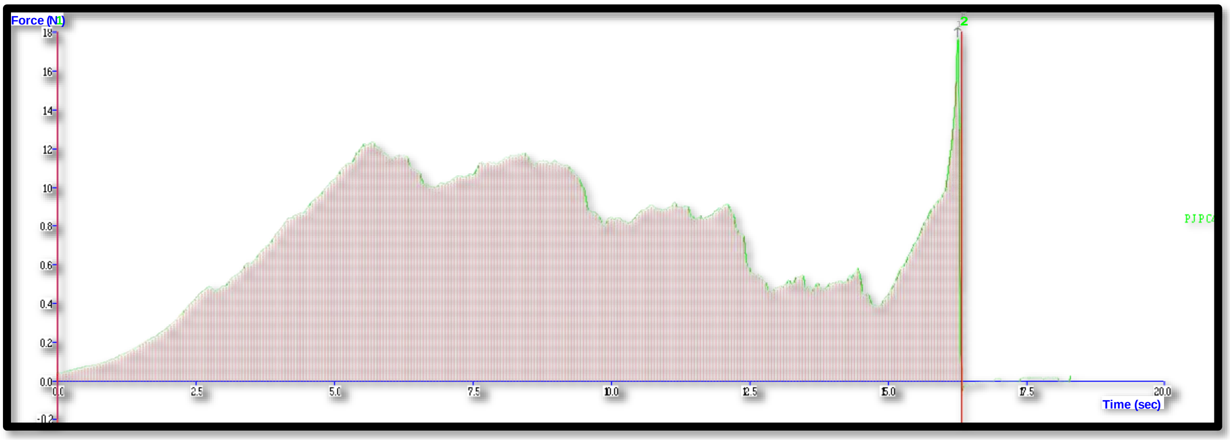

Figure 46: TPA results for PJ-PC during Day 30

4.3 CHANGES IN FIRMNESS

Firmness of nata de coco and papaya cubes are represented in **Table 11**. Firmness of NDC increased from 4.57 N to 9.02 N after 30 days and work of shear decreased from 19.27 N. sec to 13.25 N. sec indicating more force to shear. Firmness of PC increased slightly from 1.67 N to 1.78 N. So overall, nata de coco became firmer compared to papaya cubes.

Table 11: Firmness (N) of PJ-NDC and PJ-PC during storage

PARAMETERS	0 DAY		30 DAY	
	PJ-NDC	PJ-PC	PJ-NDC	PJ-PC
Mean Max. Force 'Firmness' (N)	4.57± 0.22	1.84±0.15	9.02± 0.99	1.78± 0.02
Mean Area (F-T) 'Work of shear' (N. sec)	19.27± 1.68	45.12± 2.64	13.25± 1.23	12.28± 1.91

4.4 CHANGES IN COLOUR

Colour is one of the most crucial characteristics for determining a product's quality and freshness. **Table 12**, **Table 13** and **Figure 47** provides the details of the colour variations observed in PJ-NDC and PJ-PC over 0-30 days. The colour of the product (PJ-NDC and PJ-PC) is influenced by extrinsic factors such as storage temperature, storage period, processing methods as well some intrinsic factors such as product composition including pigment, pH levels and interaction between ingredients. There was a noticeable decrease in colour in case of both PJ- NDC and PJ-PC. L*(degree of lightness) increased over time for both juices likely due to pigment degradation or oxidation. Whereas a*(Red-green axis) increased more significantly in PJ-PC from 2.47(0 day) to 5.58 (30 day). This suggests a shift towards a more reddish hue possible due to presence of papaya carotenoids in PJ-PC. b* (yellow-blue axis), also increased more in PJ-PC from 4.02(0 day) to 9.58 (30 day), suggesting an increase in yellowness likely from papaya's carotenoids.

Table 12: Colour variation in PJ-NDC and PJ-PC during 0-15 days

SAMPLE	0 DAY				15 DAY			
	dE	**L***	**a***	**b***	**dE**	**L***	**a***	**b***
PJ-NDC	76.31± 0.12	21.19± 0.19	2.21± 0.04	4.11± 0.06	72.37± 0.06	25.01± 0.07	2.67± 0.08	4.56± 0.06
PJ-PC	73.86± 0.04	23.53± 0.04	2.47± 0.01	4.02± 0.03	72.21± 0.05	27.42± 0.05	4.4± 0.04	7.02± 0.09

Table 13: Colour variation in PJ-NDC and PJ-PC during 30 days.

SAMPLE	30 DAY			
	dE	**L***	**a***	**b***
PJ-NDC	69.6± 0.07	32.04± 0.06	4.04± 0.02	6.88± 0.04
PJ-PC	70.61± 0.12	27.63± 0.14	5.58± 0.04	9.58± 0.16

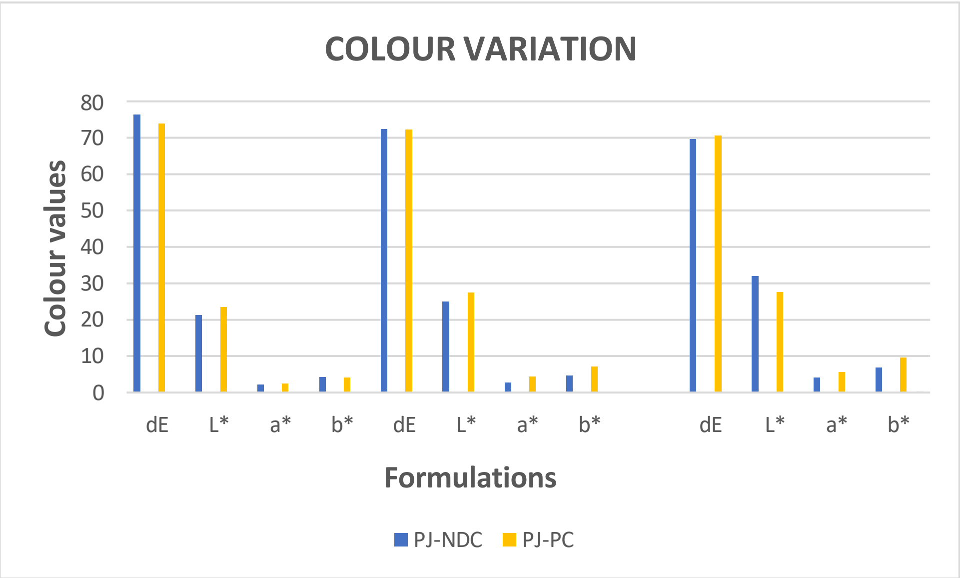

Figure 47: Colour variations in products during storage

4.5 CHANGES IN PARTICLE SIZE

Particle size variations of PJ-PC and PJ-NDC is shown in **Table 14** and **Figure 48** and **Figure 49** over 0-30 days. Particle size influences mouthfeel, appearance, texture and viscosity of juices. The diameter of particles in PJ-NDC exhibited moderate growth, whereas width decreased over time. This is likely due to aggregation of particles reducing their individual width. Volume percentage remained stable until day 15, but dropped to 50% at day 30 indicating phase separation. In case of PJ-PC particle diameter increased drastically from 107.3 μm to 257.6 μm while width doubled. This is likely due to breakdown of papaya fibre. So, PJ-PC is more prone to instability.

Table 14: Particle size of PJ-NDC and PJ-PC during storage

	PARTICLE SIZE			PARTICLE SIZE			PARTICLE SIZE		
SAMPLE	**Diameter (μm)**	**Vol %**	**Width (μm)**	**Diameter (μm)**	**Vol %**	**Width (μm)**	**Diameter (μm)**	**Vol %**	**Width (μm)**
	0 DAY			**15 DAY**			**30 DAY**		
PJ-NDC	124.3	100	230.9	160.1	100	176.7	176.1	50	101.86
PJ-PC	107.3	100	131	188.2	50	247.7	257.6	100	323.6

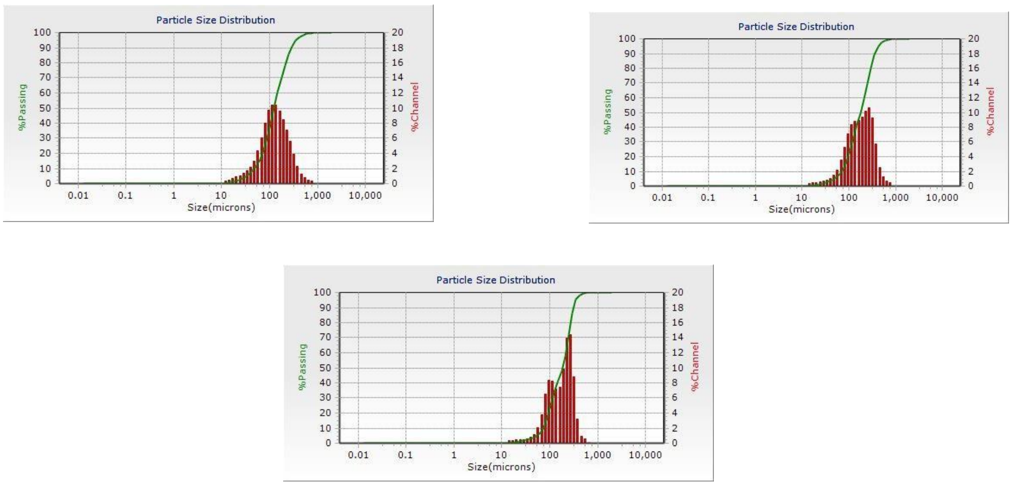

Figure 48: Graph obtained from particle size analyser for PJ-NDC during 0,15,30 day

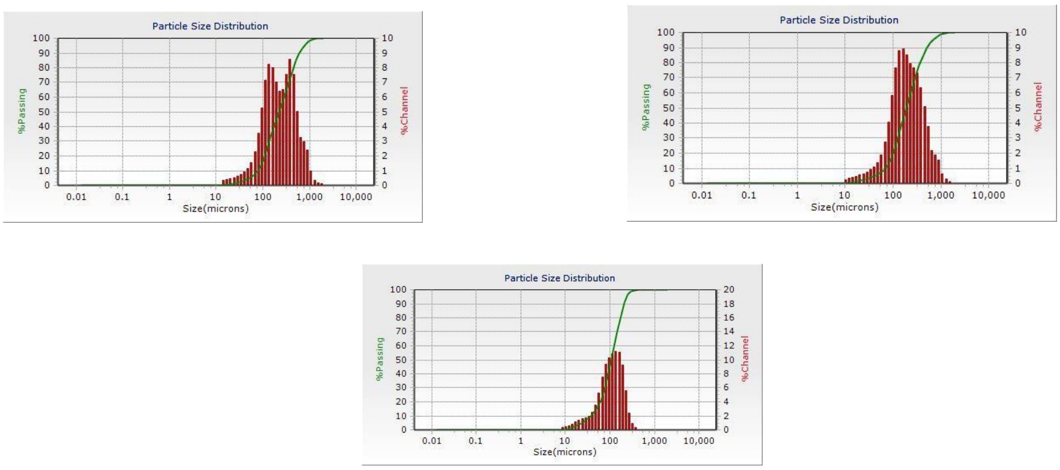

Figure 49: Graph obtained from particle size analyser for PJ-PC during 0,15,30 day

4.6 CHANGES IN VISCOSITY

Viscosity is a measure of a fluid's resistance to flow, and both PJ-NDC and PJ-PC exhibit a consistent rise in viscosity. The details of viscosity variations observed during 0 day, 15 day and 30 day is presented in **Table 15** and graphically presented in **Figure 50**. This increase in the viscosity of the RTS beverage samples can be attributed to the interactions between pectin, citric acid, sugar, and the liquid phase of the beverage. Pectin, used as an emulsifier, was added to prevent sedimentation in the RTS beverage. The viscous material has a high water-holding capacity, forming a cohesive network structure. Additionally, pectin is highly hygroscopic, meaning it absorbs water to create a gel-like network (Hemalatha et al., 2018). Moreover, Papaya contains pectin, a natural thickening agent, which can break down and dissolve into the juice, increasing viscosity. NDC and PC may absorb moisture, further increasing the thickness of juice. Statistical analysis of variance (ANOVA) was performed for viscosity of PJ-NDC and PJ-PC and the data **(Table 16)** revealed that it is significantly different from each other at P-value ≥ 0.05.

Table 15: Viscosity (cP) of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	8	14	18
PJ-PC	8	16	20

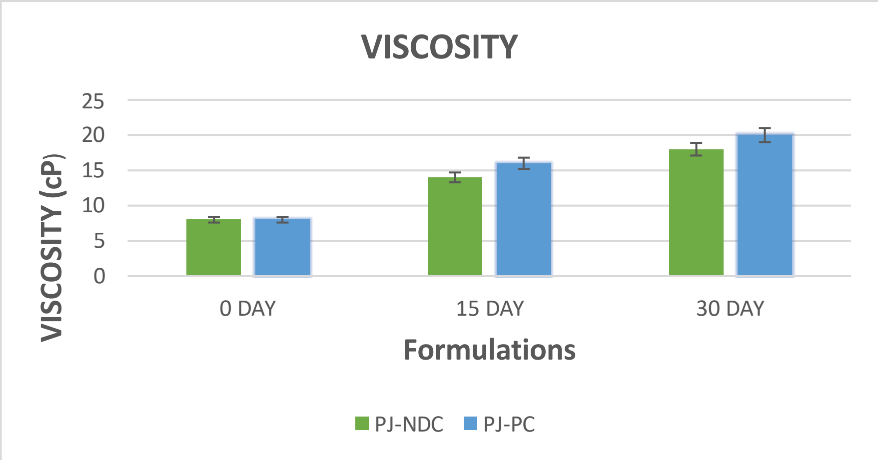

Figure 50: Viscosity (cP) variations in products during storage

Table 16: ANOVA for viscosity variations (cP) in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	124	2	62	46.5	0.005524	9.552094
Within Groups	4	3	1.333333			
Total	128	5				

4.7 CHANGES IN pH

Fruits, in general have low pH (<7), indicating their acidic nature. Pineapple is naturally acidic due to presence of citric and malic acids. During product formulations, citric acid was added which ensures an initially low pH, which helps preserve the juice and enhance the tartness. The details of pH variations observed during 0-30 day is presented in **Table 17** and **Figure 51**. The pH of PJ-NDC is almost similar during the storage period. The pH of PJ-PC is increased slightly from 3.38 (0 day) to 3.51 (30 day). This increase pH in might be due to decrease in titratable acidity, as acidity and pH are inversely proportional to each other. ANOVA was performed, **(Table 18)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 17: pH of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	3.40	3.43	3.48
PJ-PC	3.38	3.42	3.51

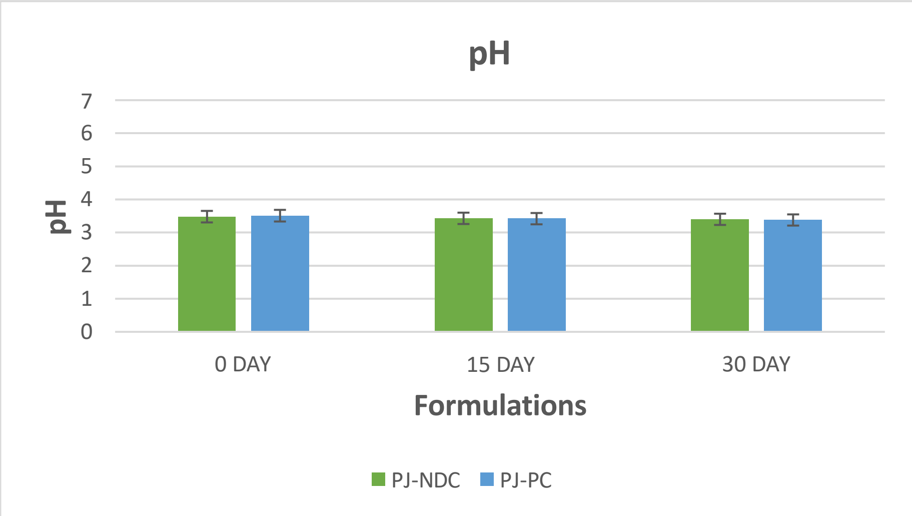

Figure 51: pH variations in the products during storage

Table 18: ANOVA for pH variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.011433	2	0.005717	24.5	0.013857	9.552094
Within Groups	0.0007	3	0.000233			
Total	0.012133	5				

4.8 CHANGES IN TOTAL SOLUBLE SOLIDS

Total sugar (Brix) refers to the sugar content in an aqueous solution. One degree Brix equals 1 gram of sucrose in 100 grams of solution and indicates the solution's strength as a percentage by weight (Robbert et al., 1991). The details of TSS variations observed during 0-30 day is presented in **Table 19**. The trend of the total sugar reduction is as shown in **Figure 52**.TSS remains nearly constant for PJ-NDC for the first 15 days, showing minimal change. By day 30, TSS drops slightly to 13.32^{0}Brix, indicating some loss of soluble solids. PJ-PC experience a steady TSS decline from 13.6(0 Day) to 12.8(30 day), this is likely because papaya cubes might have absorbed moisture which causes TSS to drop slightly. ANOVA was performed for TSS **(Table 20)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 19: TSS of PJ-NDC and PJ-PC during storage (^{0}BRIX)

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	14	14.02	13.32
PJ-PC	13.6	13.2	12.8

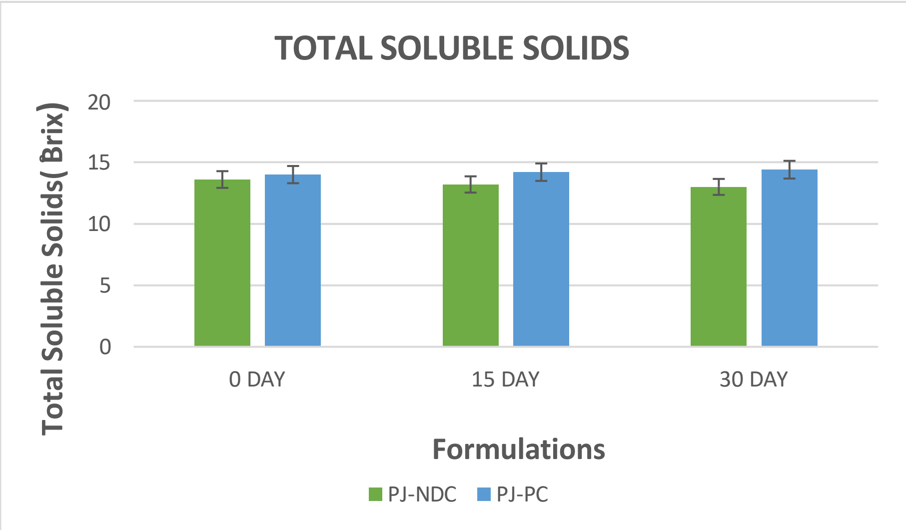

Figure 52: TSS variations in products during storage

Table 20: ANOVA for TSS variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.011433	2	0.005717	24.5	0.013857	9.552094
Within Groups	0.0007	3	0.000233			
Total	0.012133	5				

4.9 CHANGES IN TITRATABLE ACIDITY

Minimal changes in titratable acidity were found in PJ-NDC during storage period which is illustrated in **Table 21** and graphically represented in **Figure 52**. A significant decrease in titratable acidity on day 0,15, and 30 was found in PJ-PC. This might be due to the bioconversion of acids into sugars or it may be due to the chemical interaction between the organic constituents of the juice induced by temperature and action of enzymes (particularly invertase). ANOVA was performed for titratable acidity **(Table 22)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 21: Titratable Acidity (% anhydrous malic acid) of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	0.3685	0.345	0.3238
PJ-PC	0.402	0.3685	0.3573

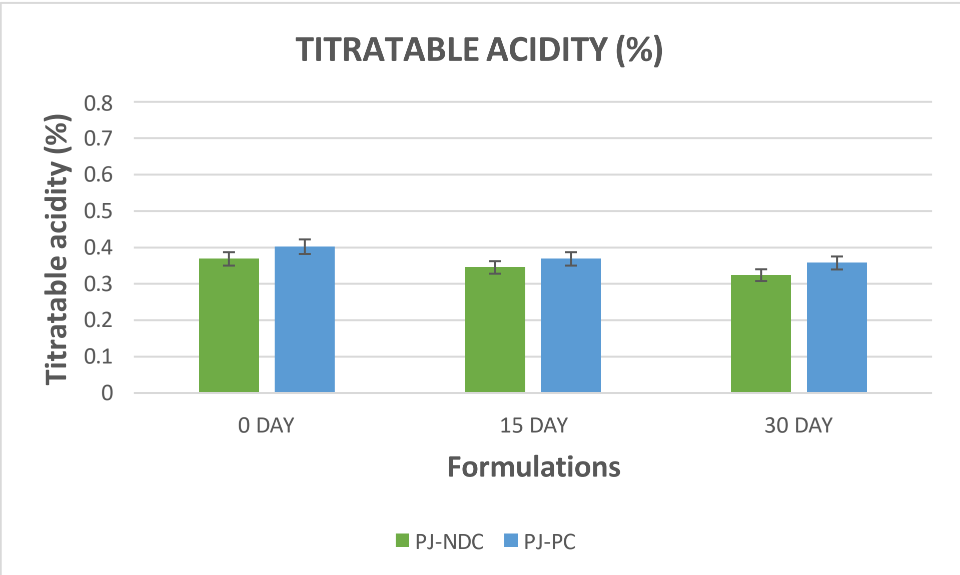

Figure 52: Titratable Acidity (% anhydrous malic acid) variations in products during storage

Table 22: ANOVA for Titratable Acidity variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.002049	2	0.001024	2.197393	0.258401	9.552094
Within Groups	0.001398	3	0.000466			
Total	0.003447	5				

4.10 CHANGES IN TURBIDITY

Turbidity refers to measure of cloudiness or haziness. Turbidity trend is shown in **Table 23** and graphically represented in **Figure 53**. PJ-NDC shows a notable reduction in turbidity over time from 497FTU (0 day) to 415FTU (30 day). This is possibly due to sedimentation of particles. Whereas, PJ-PC maintains a more consistent turbidity with only a small decrease, suggesting a better suspension stability. ANOVA was performed for turbidity **(Table 24)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 23: Turbidity (FTU) of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	497	439	415
PJ-PC	478	473	469

Table 24: ANOVA for Turbidity variations (FTU) in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.002049	2	0.001024	2.197393	0.258401	9.552094
Within Groups	0.001398	3	0.000466			
Total	0.003447	5				

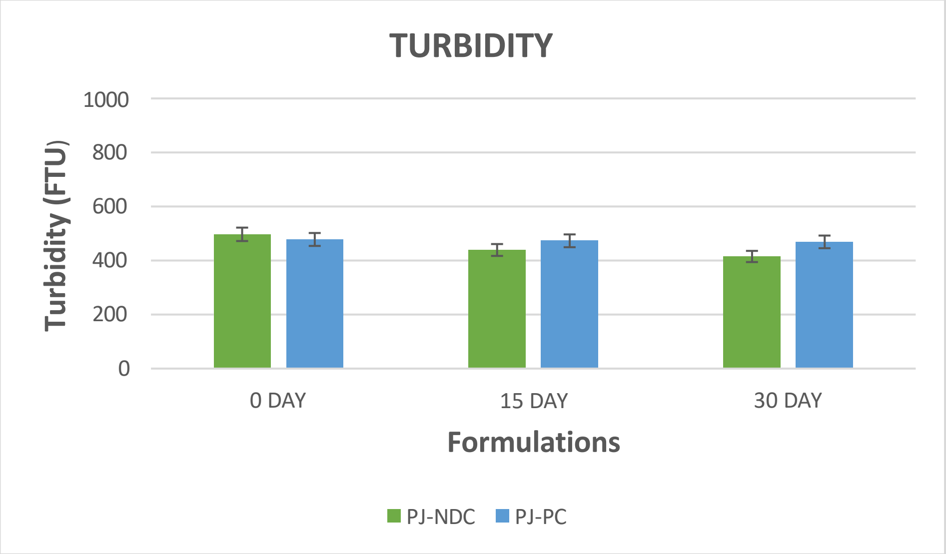

Figure 53: Turbidity (FTU)variations in products during storage

4.11 CHANGES IN SUGARS

4.11.1 CHANGES IN REDUCING SUGAR

Reducing sugar variations is presented in **Table 25** and graphically represented in **Figure 54**. The analysis revealed that the reducing sugars were nearly constant for PJ-NDC for day 0 and for day 15, but it rises more noticeably to 3.62% on day 30. Sakhale et al. (2012) reported that the increase in reducing sugars might be due to the conversion of non-reducing sugars into reducing sugars in presence of citric acid (acid hydrolysis). In case of PJ-PC, reducing sugar increased slightly from the minimum (6.01%) on the day of preparation to the maximum (6.57%) at 30 days of storage. Papaya contains natural enzymes such as papain, which may contribute to the breakdown of complex sugars into simpler reducing sugar. ANOVA was performed for reducing sugar **(Table 26)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 25: Reducing Sugar (%) of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	2.72	2.74	3.62
PJ-PC	6.01	6.059	6.57

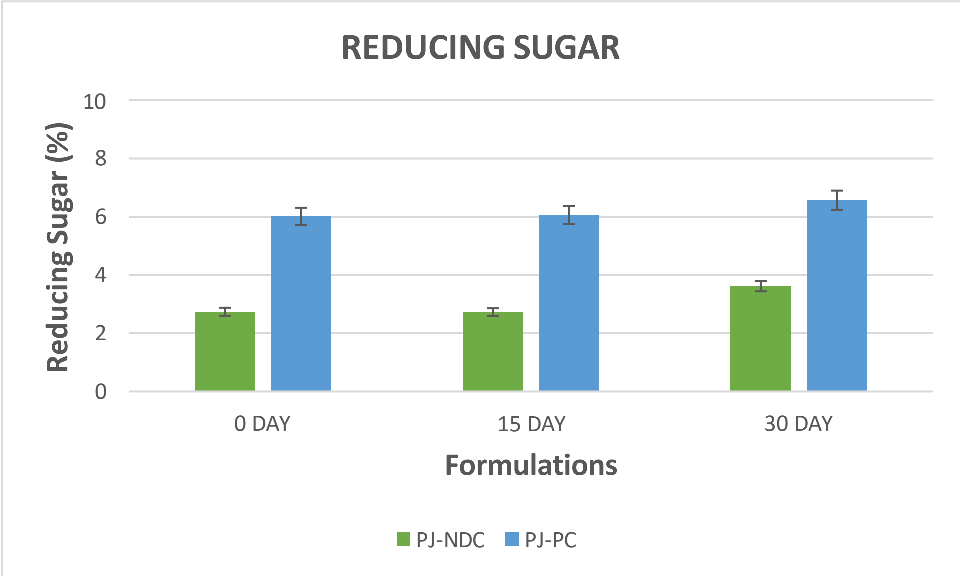

Figure 54: Reducing sugar (%) variations in products during storage

Table 26: ANOVA for Reducing Sugar (%) variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.67756	2	0.33878	0.066549	0.93696	9.552094
Within Groups	15.27216	3	5.09072			
Total	15.94972	5				

4.11.2 CHANGES IN INVERT SUGAR

Invert sugar variations are presented in **Table 27** and graphically represented in **Figure 55**. PJ-PC maintains a relatively stable invert sugar content up to day 15, but by day 30, a noticeable drop occurs. The invert sugar content in PJ-NDC declines gradually over time from 22.3% on day 0 to 18.59% on day 30. Some invert sugars can recombine into sucrose in presence of acids which can lead to a slight decrease in measured invert sugar content. ANOVA was performed for invert sugar **(Table 28)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 27: Invert Sugar (%) of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	22.3	18.95	18.59
PJ-PC	20.91	20.87	18.81

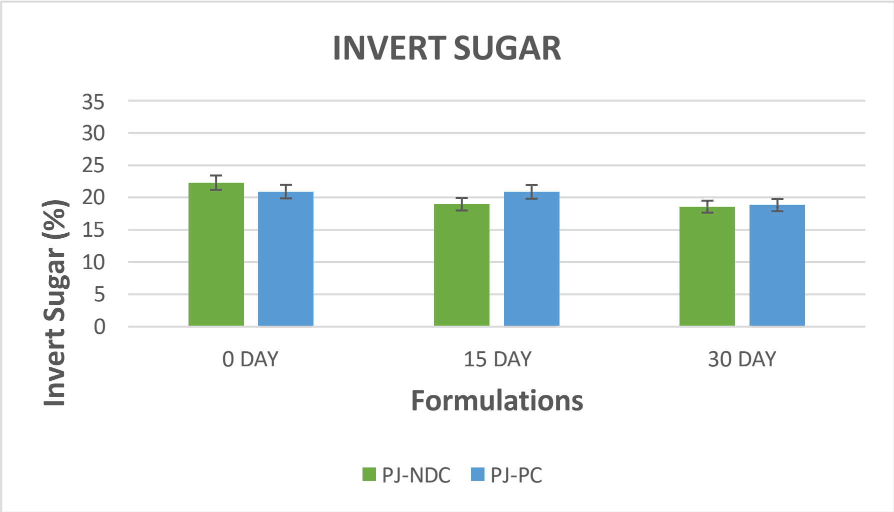

Figure 55: Invert sugar (%) variations in products during storage

Table 28: ANOVA for Invert Sugar (%)variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.517433	2	4.258717	4.509044	0.124718	9.552094
Within Groups	2.83345	3	0.944483			
Total	11.35088	5				

4.12 β -CAROTENE

The beta carotene content of the juice increased during storage in both PJ-PC and PJ-NDC as shown in **Table 29** and **Figure 56.** Since the product was stored at 4℃ ± 1℃, due to cooling effect, desiccation process might have take place and resultant product has increased beta-carotene content over 30 days. Additionally, both nata de coco cubes and papaya cubes might have absorbed the juices which in turn increased the beta-carotene content. ANOVA was performed for β -Caroten **(Table 30)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 29: β -Carotene ($\mu g/100g$)of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	57.08	94.32	143.96
PJ-PC	44.67	79.4	141.48

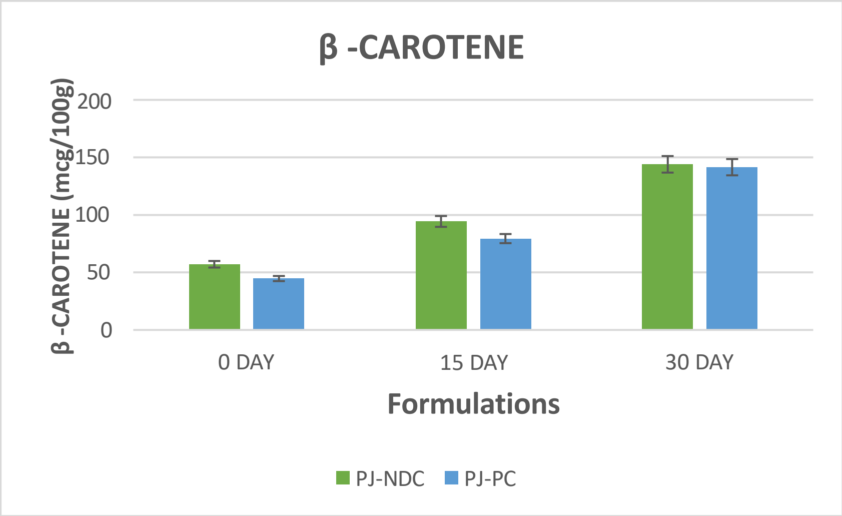

Figure 56: Beta-carotene ($\mu g/100g$) variations in products during storage

Table 30: ANOVA for β -Carotene ($\mu g/100g$) variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8567.176	2	4283.588	67.14703	0.00323	9.552094
Within Groups	191.3825	3	63.79415			
Total	8758.558	5				

4.13 VITAMIN-A

Vitamin A variations are shown in **Table 31** and **Figure 57** which is observed over 0-30 days. Since beta- carotene is precursor of vitamin A, vitamin A is also increased in case of both PJ-NDC and PJ-PC. ANOVA was performed for Vitamin A **(Table 32)** and it depicted that the data is significantly different from each other at P-value ≥ 0.05.

Table 31: Vitamin-A (I.U) of PJ-NDC and PJ-PC during storage

SAMPLES	0 DAY	15 DAY	30 DAY
PJ-NDC	95.14	157.2	239.93
PJ-PC	74.46	132.3	235.80

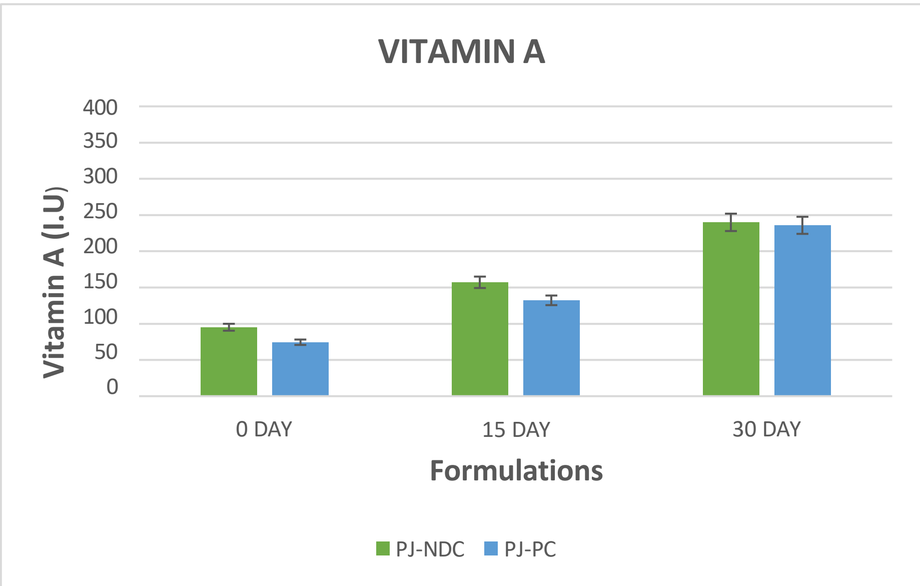

Figure 57: Vitamin A (I.U) variations in products during storage

Table 32: ANOVA for Vitamin A (I.U) variations in PJ-NDC and PJ-PC during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23795.53	2	11897.77	67.04671	0.003237	9.552094
Within Groups	532.3647	3	177.4549			
Total	24327.9	5				

4.14 SENSORY EVALUATION

Figure 58 shows the sensory evaluation of PJ-PNDC (Pineapple juice with nata de coco) and PC-PC (Pineapple juice with semi-ripe papaya cubes) which was done using a 9-point Hedonic scale. The parameters evaluated are appearance colour, flavour, taste, texture and overall acceptability**.** Sensory analysis was done initially in order to determine the best formulation.

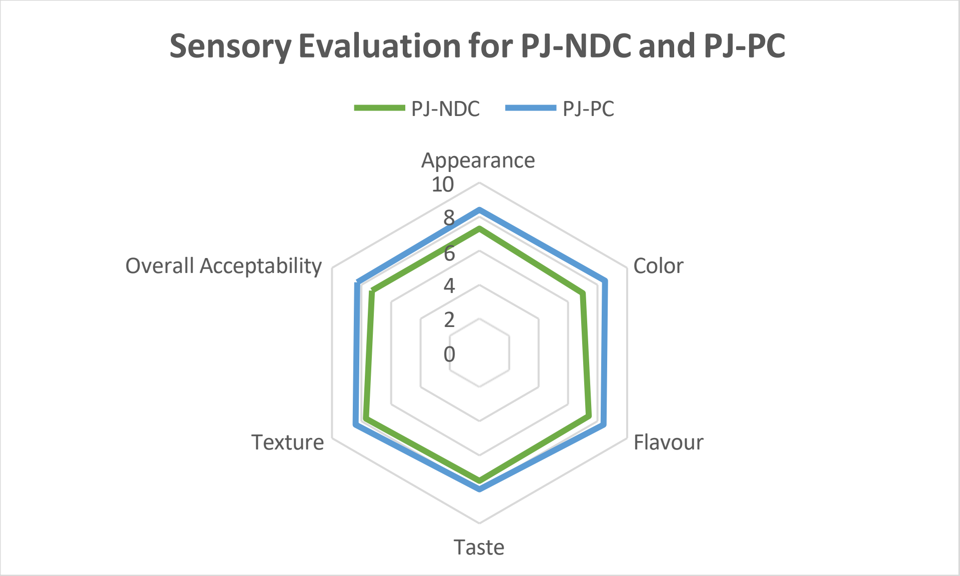

Figure 58: Sensory Evaluation of PJ-PC and PJ-NDC

4.13.1 APPEARANCE

Appearance of the RTS beverages was evaluated by the panel members. Appearance of PJ-PC (8.4) was liked by the majority of the members. Appearance is affected by many factors, including the colour of cubes, colour of juice and overall attractiveness. Evaluated results were converted into a graph for easy interpretation.

4.13.2 COLOUR

In terms of colour, PJ-PC was preferred (8.7). The bright orange colour of papaya cubes along with the yellow pineapple juice might have attracted the panellist more profoundly than PJ-NDC.

4.13.3 FLAVOUR

PJ-PC (8.7) appears to have received slightly higher flavour ratings than PJ-NDC(8.1)across most panellists. Some panellists rated PJ-PC noticeably higher than PJ-NDC, while others rated both products quite similarly.

4.13.4 TASTE

In terms of taste, both products received similar ratings. Preference varies among individual panellists, which suggest that taste perception is subjective. Taste of the drink was evaluated in terms of sweetness and sourness of the juice and cubes (nata de coco and papaya cubes).

4.13.5 TEXTURE

In terms of texture of cubes, papaya cubes (8.5) were rated higher by panellists than nata de coco (7.4). Texture of cubes was analysed based on firmness, chewiness and residual mouthfeel. The difference in texture perception suggests that the papaya cubes had more pleasant and desirable texture. Some panellists felt nata de coco too chewy, which might have affected its acceptance.

4.13.6 OVERALL ACCEPTABILITY

PJ-PC was preferred overall due to its better flavour, texture and colour when compared to PJ-NDC. PJ-NDC was still acceptable but its slightly lower scores suggests that some panellists may not have liked its chewy texture as much.

CHAPTER 5

CONCLUSION

This study explores the preparation and quality analysis of ready to serve beverages from pineapple juice added with nata de coco jelly cubes (PJ-NDC) and semi-ripe papaya cubes (PJ-PC), to develop a diversified beverage with a delightful biting texture. Both formulations exhibited uniform dispersion of cubes and remained stable over a 30-day storage period. With growing consumer demand for fruit-based beverages with unique sensory attributes, this study highlights the potential for innovative fruit drinks that benefit both food manufacturers and farmers.

Pineapple juice, the base ingredient in both formulations, is well known for its sweet-tangy taste, aroma, and health benefits. It is rich in phytochemicals such as vitamin C, carotenoids, flavonoids, and phenolic compounds. Nata de coco, derived from coconut water, contributes a chewy, translucent texture and it is a good source of dietary fiber, while papaya cubes enhance the beverage with a tropical flavour and essential nutrients, including carotenoids, vitamin C, B vitamins, folate, pantothenic acid, potassium, magnesium, and fiber. Combining these ingredients results in a nutritionally enriched and sensorially appealing beverage.

During the storage period, textural changes were observed in both nata de coco and papaya cubes. The hardness and chewiness of nata de coco increased significantly due to water absorption and gel strengthening, whereas papaya cubes showed low resilience, indicating softening over time. Adhesiveness increased for PJ-PC suggesting an increased stickiness. The colour of both RTS drinks decreased, likely due to pigment degradation. However, PJ-PC exhibited an increase in a* and b*value, suggesting a shift toward a reddish and yellowish hue, possibly due to carotenoids leaching from papaya cubes into the juice.

Particle size analysis showed that the diameter of papaya cubes in PJ-PC increased from 107.3 µm to 257.6 µm, while the width doubled, indicating fiber breakdown from papaya. Viscosity increased for both beverages, likely due to interactions between pectin, citric acid, and sugar. Minimal changes were observed in pH, total soluble solids (TSS), and titratable acidity (TA) in both formulations. Turbidity decreased in PJ-NDC from 497 FTU to 415 FTU, possibly due to particle sedimentation. Reducing sugars remained stable in PJ-PC but increased in PJ-NDC, likely due to acid-induced conversion of non-reducing sugars. The β-carotene content of both beverages increased during storage, possibly due to juice absorption by nata de coco and papaya cubes. Since the products were stored at 4°C±1°C, desiccation process may have contributed to nutrient changes. Sensory evaluation revealed that panellist preferred PJ-PC over PJ-NDC in terms of appearance, colour, flavour, and texture.

In conclusion, both beverages exhibited distinct qualities. However, PJ-PC stands out as a superior choice due to its innovative nature, nutritional benefits, and enhanced sensory attributes. The combination of pineapple juice and papaya cubes creates a novel, visually appealing, and nutritionally rich RTS beverage, making it a promising candidate for commercial production.

CHAPTER 6

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