EFFECT OF ADDITIVES ON THE PHYSIOCHEMICAL PROPERTIES OF COCONUT CRUSH BEVERAGE

A dissertation submitted by

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IN

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Under the Guidance of

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CERTIFICATE

I hereby certify that this dissertation entitled **"Effect of Additives on the Physiochemical Properties of Coconut Crush Beverage"** submitted by **Ms. Alina Mary Luiz (Reg. No. VM23FPT002) 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.

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DECLARATION

I hereby declare that, the report on the project entitled **"Effect of Additives on the Physiochemical Properties of Coconut crush beverage"** 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: Mysuru

Date: Alina Mary Luiz

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LIST OF ABBREVIATIONS

ABBREVIATIONS	EXPANSIONS
WC P	Whole coconut crush with Pectin
WC GG	Whole coconut crush with Gellan gum
CM SA	Coconut milk crush with Sodium alginate
CM P	Coconut milk crush with Pectin
TSS	Total soluble solids
TA	Titrable acidity
TCW	Tender coconut water
MCW	Mature coconut water
VGO	Virgin coconut oil
LDPE	Low density polyethylene

ABSTRACT

The present study aims to develop and optimize a coconut crush beverage by incorporating various additives to enhance its physiochemical properties, sensory attributes and storage stability. The primary objective was to assess the effects of selected additives, primarily preservatives, stabilizers and flavour enhancers on the quality of coconut crush formulations. Four different formulations namely WC P (whole coconut crush beverage with pectin), WC GG (whole coconut crush beverage with gellan gum), CM P (coconut milk crush beverage with pectin) and CM SA (coconut milk crush with sodium alginate) were prepared and subjected to physiochemical analysis, sensory evaluation and shelf life studies. The coconut crush was prepared in two forms: concentrated and reconstituted. The reconstituted version, designed for direct consumption, was formulated at a 1:6 dilution ratio and served chilled. Physicochemical parameters, including pH, total soluble solids, acidity, particle size, color, viscosity, and calorific value, were evaluated over a 30-day storage period at a room temperature of 29°C ± 2°C and a relative humidity of 85% RH. Protein estimation across all formulations revealed an insignificant amount of protein. Fat analysis showed the highest content in CM SA (5.08%) and the lowest in WC GG (3.1%). Turbidity remained consistent throughout the storage period for all formulations (1000 FTU). Particle size analysis indicated that CM SA demonstrated better stability, with particle size remaining relatively consistent (105.8–93.13µm), signifying minimal fluctuation during storage. Sensory characteristics in terms of appearance, colour, flavour, taste, texture and overall acceptability were evaluated using a 9-point hedonic scale and the results proved that CM SA as the best among all the formulation.

CHAPTER 1

INTRODUCTION

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INTRODUCTION

In botanical terms, the name "coconut" can refer to the entire coconut palm, the seed, or the fruit—which is a drupe rather than a nut (Jerard et al., 2008). The coconut palm, a member of the monocotyledonous Palmae family, bears coconuts *(Cocos nucifera)* as the stone of its drupes. Since it includes nearly all of the vital nutrients that the human body requires, it is referred to as the "wonder food" and is considered the ideal diet. It is a food that is strong, nourishing, and filling. It has a lot of oil in it. All of the amino acids required for the body's growth and maintenance are present in this premium protein. It has a lot of K, Na, Mg, and S. A dried coconut has 662 calories per 100 grams (Ogunmefun et al., 2018). Coconut contain biologically useful components and have a special place in human diets. The fat portion of whole coconuts, the fat portion of desiccated coconuts, and the extracted coconut oil all include these physiologically useful ingredients. It has long been known that lauric acid, the main fatty acid found in coconut fat, has special qualities that make it useful for nonfood applications in the soap and cosmetics industries. Coconuts undergo shell removal, paring, and water draining in order to extract the edible section. Then, using a rotary wedge cutter machine, coconut meat can be hand gathered and grated (Enig, 1999).

The coconut (*Cocos nucifera*) is widely harvested in many tropical nations; an estimated 60 million tons of nuts are harvested annually, spanning 12 million hectares of land. India, the world's third-largest producer after Indonesia and the Philippines, has a very advanced use of coconuts; according to reports, about half of the country's domestic coconut production is used for religious and culinary purposes, while 35% is used to make copra. The industry can be enhanced because just 2% of coconuts are used to produce value-added products, while the rest portion finds various applications. There are four primary goods and associated derivatives that can be obtained with enhanced value addition from coconuts, which is sufficiently lengthy (Parisi et al., 2024).

(1) Fresh coconut

(2) Coconut water

(3) Dried coconut (copra)

(4) Coconut sap

Products made from coconuts are quite popular all over the world because of its physicochemical and nutritional qualities. Each year, a considerable number of fruit bunches are lost due to inadequate postharvest and preservation methods. One of the most challenging parts of keeping coconut fresh for a long time is the presence of significant amounts of sugar, oil, and moisture retention. Coconut is prone to microbiological spoiling within a few days, making it difficult to keep fresh for extended periods of time and prone to becoming rancid rather quickly. One of the goods that modern society wants is fresh coconut in the form of grated or crushed coconut. (Gunathilake, 2005).

Fruit crush, according to the Fruit Product Order of 1955, is a beverage made by crushing or squeezing fruit and must have at least 25% fruit juice and 55% sugar. Creation of preserved goods, such as crushes, lowers post-harvest losses and increases product shelf life. (Ravi et al., 2010). Fruit beverages are becoming more and more popular worldwide since they are more nutrient-dense and therapeutic than manufactured beverages. This can be further enhanced by combining two or more fruit pulps or juices that have exceptional flavor, taste, nutritional value, and medicinal potential. Crush has 25% ascorbic acid, citric acid, and mallic acid, pulp, TSS, and less than 55 Brix. It also contains less than 3.5% bioactive compounds, including phenolic and flavanoids, acidity and primarily anthocyanins. Whole fruits are carefully cleaned, scrubbed, and then crushed or blended to create a pulp in order to manufacture fruit crush. After that, the majority of the water content is removed and evaporated (Harsha et al., 2017).

Food Protection Committee of the Food and Nutrition Board defined food additives as one or a group of substances, different from the basic ingredients, present in food because of any aspect of production, such as process, storage or packaging, excluding contaminants. The most commonly used additives in the food industry are nutritional additives, coloring, flavoring, and texturizing agents, and preservatives; however, their use and regulations differ depending on the nation. In order for food to be marketed and accepted by consumers, it is now developed to improve physical appearance, maintain flavor, extend shelf life, and enhance taste in addition to satisfying hunger and providing essential nutrients (Silva et al., 2019).

1.1 OBJECTIVES

- Optimization of processing conditions for the preparation of coconut crush with the addition of various additives.
- Storage stability at room temperature (29℃ $\pm$ 2°C) and physiochemical properties of various coconut crush formulation.

1.2 SCOPE OF INVESTIGATION

Coconut is a rich source of nutrients including amino acids, minerals, antioxidants like phenolics, tocopherols and are likely to get contaminated with microbes. Coconut is naturally hermetically sealed with clear coconut meat inside. Microbial contamination can also occurs when the natural seal is broken during extraction. The shelf life of coconut kernel is short, a small crack in the shell can cause the spoilage. Therefore the shelf life of coconut kernel has to be increased to preserve and in transporting to other parts of the country. In the manufacture of coconut beverages, the quality of fresh coconut meat prior to the production process is the key to obtain a product with high quality. This study aims to analyze the physiochemical properties and storage stability aspects of coconut crush at room temperature 29℃ $\pm$ $2°C$.

CHAPTER 2

REVIEW OF LITERATURE

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Figure 1: Coconut

2.1 HISTORY OF COCONUT

A coconut *(Cocos nucifera)* is the fruit or seed of the coconut palm illustrated in **Figure 1**. The genus Cocos belongs to the Arecaceae family and is monotypic. The fruit is botanically classified as a drupe, hence the term "nut" is misleading. Early Spanish explorers dubbed it "cocos" or "monkey face" because the hairy nut's three indentations (eyes) resemble a monkey's skull and face; "nucifera" means "nut bearing." "Cocoanut" is an outdated spelling of the word "coconut" (Ahuja et al., 2014). The coconut is indigenous to Melanesia and Southeast Asia's coastal regions, or the littoral zone, which includes Malaysia, Indonesia, and the Philippines. Wild forms (niu kafa) are thought to have traveled westward to coastal India, Sri Lanka, East Africa, and tropical islands (such as Mauritius, Andaman, and Seychelles) in the Indian Ocean in prehistoric times, as well as eastward on ocean currents to the tropical Pacific islands (Melanesia, Polynesia, and Micronesia). The palms were successful in establishing themselves on the coralline and sandy shores of these areas. The coconut may be native to the Pacific coast of Central America or it may have been introduced (Edward et al., 2009). In India nearly all of the names for coconut in the Indic languages, such as Hindi nariyal, Urdu nariyal, Marathi nara, Parsi nargil, and Telugu Kobbarikaya/nalikeram, are derived from the Sanskrit term narikela. Additionally, numerous Austronesian names for coconuts, such as Tagalog niyog, Malaysian nyiur, and Hawaiian niu, are similar to the initial element in the Indic languages. It is said that the Malay word nyiur is the root of the Polynesian and Melanesian terms niu and niyog, as well as the Philippine and Guamanian terms. Additional colloquial terms for coconuts include tengu and kobbari in Kannada, nalikeram and thenga in Malayalam, tengai in Tamil, kokosneut in Afrikaans, coco in Catalan, Spanish, and kokoyashi in Japanese, kelapa and nyiur in Indonesian/Malay, kelapa in Portuguese, pol in Sinhalese, cot dua in Vietnamese, niu in Hawaii, maprao in Thai, and so forth. Cocos nucifera, the coconut tree, is one of the most popular and extensively utilized palm trees. According to some, the coconut palm is the "tree of life," or "Kalpavriksha." All around the world, people have been growing a variety of coconut trees. The market for coconut products is growing at the quickest rate because of the antiviral chemicals they contain. Coconuts are used to make oils, and their shells are also utilized to make creative supplies. Coconut trees have been used to produce brooms, and wood is utilized to make hardwood flooring, furniture, and building materials for homes. It demonstrates how the growing of coconut palms has altered people's means of subsistence globally. The top three nations to profit economically from coconut tree plantations are Indonesia, India, and the Philippines (Niral et al., 2018). **Table 1** shows the taxonomical classification of coconut.

Table 1: Taxonomical classification of Coconut

Kingdom	Plantae - Plants
Sub kingdom	Tracheobionta - Vascular plants
Super division	Spermatophyta – Seed plants
Division	Mangnoliophyta – Flowering plants
Class	Liliopsida - Monocotyledons
Sub class	Arecida
Order	Arecales
Family	Arecaceae – Palm family
Genus	Cocos L – Coconut palm
Species	*Cocos nucifera* – Coconut palm

(**Source: Hooda et al., 2012)**

2.2 MORPHOLOGY

The coconut palm *(Cocos nucifera L)* is a tropical perennial tree crop that is monospecific, monoecious, and protandrous. It is a member of the Arecaceae family of palms, which has over 190 genera and 2800 species. It is an an unbranched tree with a light gray to brown trunk that grows between 9 and 18 meters high, and sometimes up to 30 meters, it also has dwarf morphoforms. At its broadest point, its pinnate leaves measure 4–7 m in length and 1–1.5 m in width. Whereas male flowers are small and numerous, female blooms are spherical and scarce. The fruit is a drupe, ovoid and can grow up to 30 cm in length and 20 cm in width (Sudha et al., 2021). Coconuts come in a variety of sizes and forms. The most important feature of coconut fruit are its antiviral properties. It is made up of three main parts that are often used: mesocarp (coir), endocarp (shell), and endosperm (kernel flesh). Fruits often take around a year to fully grow. First, the embryo sac cavity expands significantly, and the husk and shell grow. There is liquid in this cavity. The husk and shell thicken after four months or so. After six months, the solid endosperm starts to form against the cavity's inner wall. This initial layer is gelatinous and thin. The delicate white endocarp turns dark brown and firm after about eight months. In a year, the fruit reaches maturity. The mature coconut fruit, which is around 12 months old, is composed of 35% husk (the fruit's fibrous outer layer), 12% shell (the fruit's inner hard layer), 28% meat (the solid endosperm), and 25% water (the liquid endosperm) (Patil et al., 2018). **Figure 2**, shows a detailed cross-section of coconut fruit.

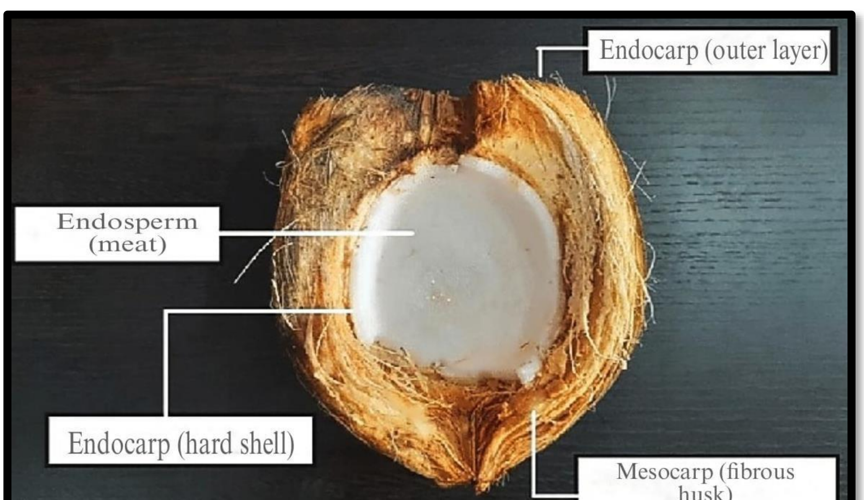


Figure: 2 Cross-section of Coconut fruit (Source: Patil et al., 2018)

2.3 CULTIVATION

After spreading throughout the tropics, coconut is thought to have originated in the Indo-Malayan region. Although it was once found on the narrow sandy shore, it is now found on a variety of soil types, from clays to pure sand, and from moderately acidic to alkaline. The expansion of this non-invasive species, especially inland from its natural habitat, is mostly human-caused. Although it can survive brief exposures to temperatures below 21°C (70°F), it prefers warm, humid weather. Its feather-like frond crown and clusters of huge fruits on long, thin stalks make it easy to identify (Perera, 2012). The coconut is a premium crop that supports millions of people. The fruit, which is commonly consumed and versatile, is typically sold in two stages: immature and mature. Consequently, when harvesting, one of the most crucial factors to take into account is fruit maturity. Fruits of 6–8 months are picked for immature (tender) fruit production, while "snowball" fruit is gathered at 8–9 months, and for kernel-based goods like copra, the fruit is harvested at 11–12 months. Fruit processing can be made faster and less labor-intensive with the aid of machines. The fruit can be processed into a number of different products after basic processing, including milk, desiccated coconut, virgin oil, coconut water, and crude oil (Pandiselvam et al., 2024).

2.4 PRODUCTION

The coconut (*Cocos nucifera L.)* is a staple in many Pacific and Asian traditional dishes and has significant commercial value. Asia is the world's largest producer of coconuts, with 90% of the world's total production grown in Thailand, Indonesia, the Philippines, India, and Sri Lanka. Domestic consumption of coconuts is around 70%, and more than half of the harvest is eaten fresh (Grimwood, 1975). The social and cultural impact of the coconut crop on its cultivators is substantial. The marketability and pricing of coconuts and their derivatives impact farmers' financial situation. In India, Kerala is the state with the largest share in coconut production and area, followed by Tamilnadu. About 60% of the state's farmers rely on coconut production as one of their main sources of income. In addition to meeting important sociocultural needs in our culture, the coconut has grown significantly in importance in the national economy as a plantation product with the capacity to provide money and jobs in rural areas (Yamuna, 2016).

2.4.1 INTERNATIONAL PRODUCTION STATUS

According to 2015 statistics, coconuts are grown on 11.988 million hectares in over 94 countries worldwide, yielding 67.04 billion nuts with a productivity of 5592 nuts ha^{-1}. One of the main crops that gives millions of people in Asia and the Pacific region a stable income is coconut. Together, these two regions account for about 89.60% of the world's coconut area and 85.91% of copra production, which generates over $1.08 billion in export revenue. Coconuts have long been a significant crop in these areas, contributing to the local economy and culture of both the Pacific Islands, where coconut palms are essential to the livelihoods of many smallholders, and major producers like the Philippines, India, and Indonesia (Rethinam, 2018). **Figure 3** represents the worldwide production of coconut by leading countries. Indonesia is the biggest producer of coconuts worldwide. Smallholders possess 99.02% of the coconut plantations in Indonesia, which is the majority of all plantations. In 2021, 2.853.299 tons of coconuts were produced on a total plantation area of 3.374.347 hectares. Primary round coconuts, copra, and processed goods including dried coconut, coconut oil, coconut husks, and other derivatives are among the coconut products that Indonesia exports. With an average yearly growth rate of 16.74%, Indonesian coconut export values have demonstrated a favorable trend from 2010 to 2019 (Elfahmi et al., 2024). **Table 2** displays land, area and coconut production in Indonesia from 2015-2022.

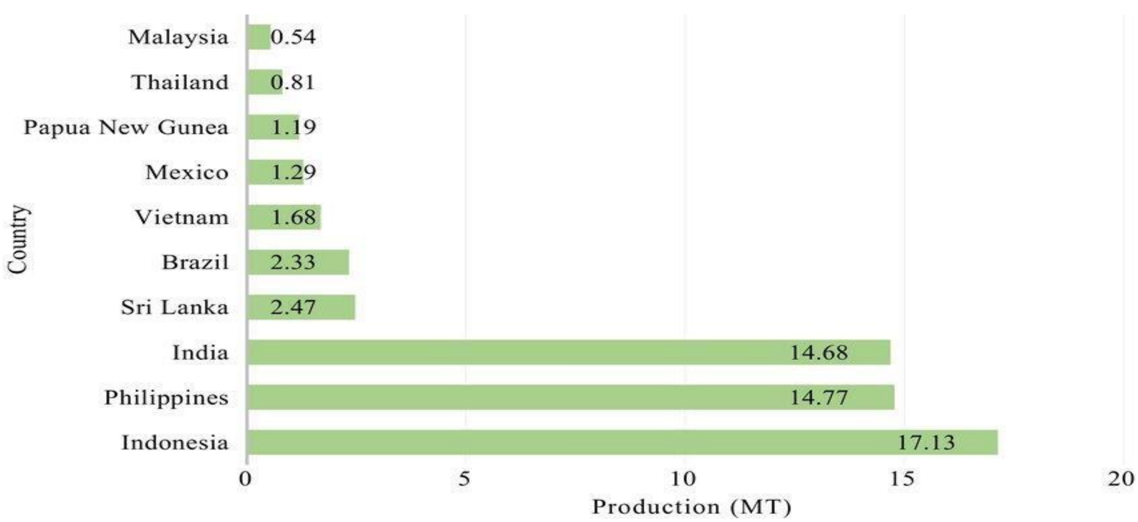


Figure 3: Coconut production worldwide by leading countries

(Source: Nuwarapaksha et al., 2022)

Table 2: Land, Area and Coconut Production in Indonesia from 2015 to 2022

YEARS	AREA (HECTARE)	PRODUCTION (TON)
2015	3.585.599	2.920.665
2016	3.653.745	2.904.170
2017	3.473.230	2.854.300
2018	3.417.951	2.840.148
2019	3.401.893	2.839.852
2020	3.391.993	2.858.010
2021	3.374.347	2.853.299

(Source: Elfahmi et al., 2024)

2.4.2 NATIONAL PRODUCTION STATUS

India is the world's third-largest producer of coconuts and accounts for almost 22% of global nut production. In India, coconut is farmed in 16 states and 4 union territories under a range of soil and climate conditions. Nonetheless, the south peninsular region, which includes the states of Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, accounts for roughly 89 percent of all acreage and 90 percent of all output. With 7.51 billion nuts produced on 7.61 lakh acres, Kerala is the most productive of these states. Karnataka ranks third in terms of production (5.83 billion nuts) and second in terms of acreage (6.34 lakh hectares). With an area of over 4.42 lakh hectares and the greatest output of 13239 nuts per hectare, Tamil Nadu ranks third in terms of area and second in terms of production with 5.87 billion nuts (Narmadha et al., 2022). **Table 3** depicts area, production and productivity of coconut in Coastal areas of India.

Table 3: Area, Production and Productivity in Coastal areas of India

States/ Union Territories	Area (100 hectares)	Production (m nuts)	Productivity (nuts/ ha)
Andaman & Nicobar Islands	16.3	124.8	7,667
Andhra Pradesh	99.5	1,396.9	14,038
Gujarat	24.9	241.2	9,670
Karnataka	518.4	6,273.8	12,102
Kerala	807.1	8,452.1	10,472
Lakshadweep Islands	2.7	87.6	32,753
Maharashtra	27.0	127.9	4,743
Odisha	50.9	341.7	6,712
Pondicherry	1.8	27.8	15,357
Tamil Nadu	441.5	6,020.4	13,637
West Bengal	30.3	377.7	12,484

(Source: Coconut Development Board, 2019)

2.5 COMPOSITION

Coconut is a nutrient dense food having over 66% carbohydrates and roughly 64% soluble sugars. In addition to being high in components, coconut has substantial levels of minerals, dietary fiber, and polyphenols. **Table 5** represents the mineral composition of coconut shell. Various bioactive compounds in coconut is illustrated in **Figure 4.** Especially in Asia and tropical areas, coconut is used extensively in cooking. This fruit's flesh, which may be utilized either fresh or dried, gives food taste and texture. In addition, coconut oil is used for cooking, cosmetics, and medicine. It is also recognized to have antioxidant qualities and to maintain the health of skin and hair. The fatty acid content significantly varies across different maturation stages. Coconut oils from the green and yellow cultivars are composed of carboxylic acids, thioesters, and hydrocarbons. Both of these substances make up 69% and 65% of the oil in unripe coconuts. When it comes to ripe coconuts, the main constituents are 74% for green and 70% for yellow varieties. 99.98% and 98.11% of the primary components are found in dried coconuts (Fonseca, et al., 2014). In addition to oil, proteins with a relatively well-balanced amino acid profile are found in coconuts. Proteins from coconuts are typically categorized based on their amino acid content and solubility. Using various solvents, they can be separated into five parts. Albumin, globulin, prolamin, glutelin-1, and glutelin-2 are the names given to the soluble components of water, sodium chloride, isopropanol, acetic acid, and sodium hydroxide, respectively. Globulin (salt-soluble) and albumin (water-soluble) are the two main proteins found in coconut endosperm or kernel, constituting 40% and 21% of the total protein, respectively (Patil et al., 2018). Proximate composition of mature coconut kernel is displayed in **Table 4**.

Table 4: Proximate composition of mature coconut kernel

Parameters	Value (%)
Moisture content	35.37
Ash content	0.77
Oil	44.01
Protein	5.5
Crude fiber	3.05
Carbohydrates	6.57

(Source: Balachandran et al., 1985)

Table 5: Mineral composition of coconut shell (Source Ewansiha et al., 2012)

Minerals	*Values (mg/100g)*
Phosphorus	11.64±0.02
Calcium	16.02±0.05
Magnesium	1.22±0.22
Sodium	0.76±0.12
Potassium	3.30±0.01
Iron	618.00±0.24
Zinc	1.20±0.10
Manganese	6.00±0.10

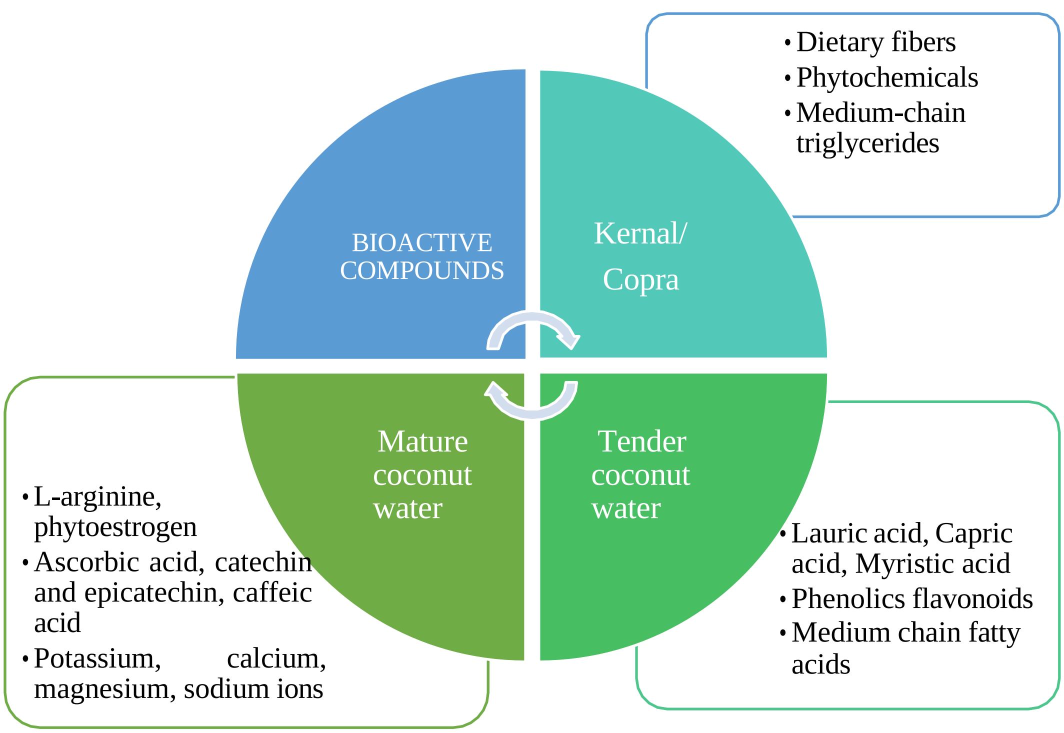


Figure 4: Bioactive compounds in Coconut (Source: Mishra et al., 2024)

2.6 PROCESSING OF COCONUTS

Coconut is one of the main commodity crops in the world, regarded as seed crops. Despite their widespread use in tropical regions, coconuts serve a variety of purposes and are frequently utilized for both food and non-food purposes. Furthermore, the by-products that are left over after the coconuts are processed have been employed for a wide range of commercial purposes. However, according on the species, source, and processing circumstances, the structure and characteristics of the coconuts and by-products produced differ greatly (Reddy, 2019). Steps involved in processing of coconut is depicted in the **Figure 5.**

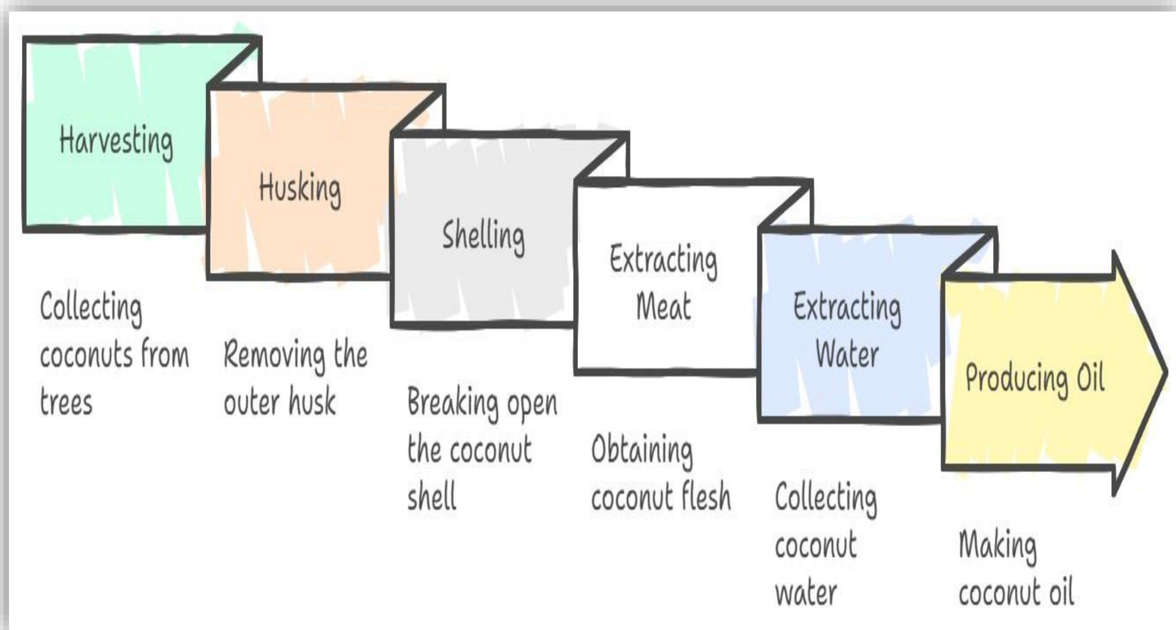


Fig 5: Steps involved in processing of coconut

(Source: Pandiselvam et al., 2022)

2.7 PRODUCTS FROM COCONUT

Coconut is a crop with significant potential for diverse applications and is regarded as the most important and useful among tropical palms. Nearly every component of the coconut serves a purpose, whether in households or industrial settings, earning it the label ‘nature’s supermarket’. To ensure a promising future for this industry, some measures that can be taken include diversifying products, implementing strict quality standards for coconut products, and boosting productivity. Coconut is cultivated by smallholders, and it is a vital source of survival for millions in rural areas. Its advancement, especially in postharvest practices, could serve as a foundation for rural development in countries that produce coconuts (Gosh, 2015). The coconut is a multipurpose tree, a tropical palm that greatly enhances human existence. This is a great illustration of how all of the fruit's edible parts are used as food or as ingredients to make a range of food products that include protein and other vital nutrients. In addition, all of the plant's and the fruit's inedible parts are utilized to produce energy as well as a variety of industrial products and supplies that sustain human life. Coconut products includes a vast variety of items, which is prized for its adaptability and nutritional value. The examination of coconut products shows both conventional and novel uses, emphasizing their importance in the industrial, culinary, and health domains (Yalegama et al., 2024). The list of non edible and edible products from coconut is depicted in **Figure 6 and 7** respectively.

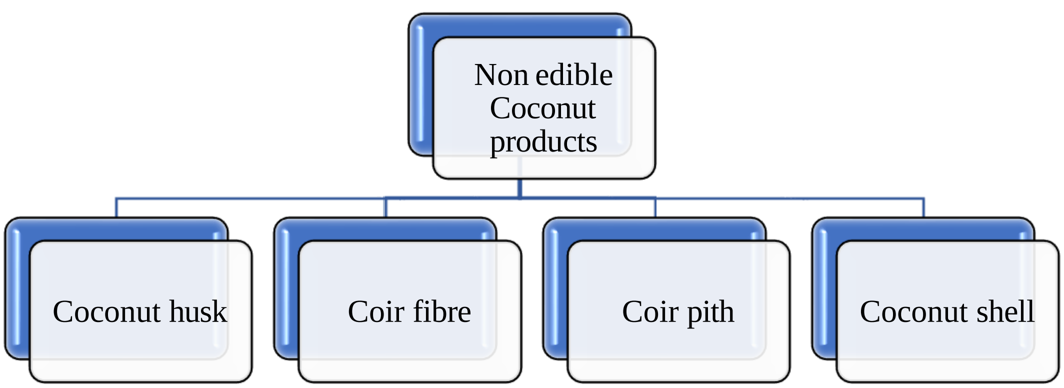


Figure 6: List of non edible coconut products

(Source: Mithra et al., 2013)

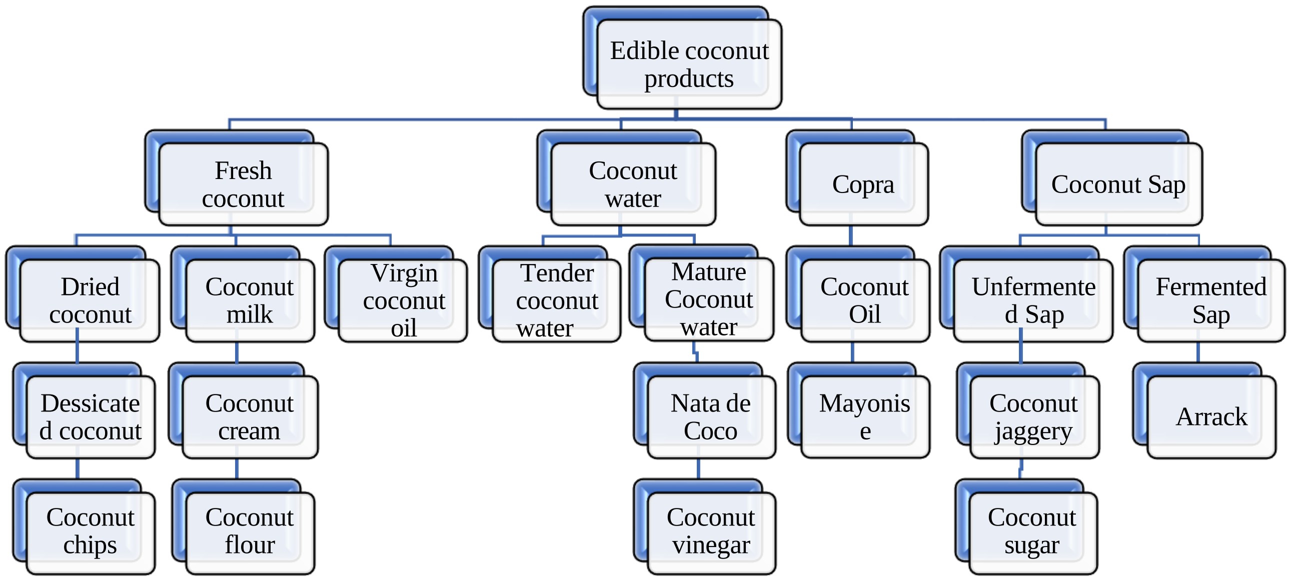


Figure 7: List of edible coconut products

(Source: Mithra et al., 2013)

2.7.1 COCONUT KERNEL

Coconuts have been utilized as a staple food in many tropical nations since prehistoric times. In many Indian cuisines, especially those from Kerala, it is a key component. A complete food that is high in calories, vitamins, and minerals is coconut kernel. The potassium, calcium, magnesium, manganese, iron, copper, phosphorus, sulfur, and chlorine are all present in the kernel, along with vitamins A, thiamine, ascorbic acid, tocopherol, phenolic compounds, and phytohormones. Together with coconut oil, fresh coconut kernels also include 5% proteins and 7% dietary fiber. Fresh coconut kernels include these macro- and micronutrients, which contribute to their biological benefits (Rajamohan et al., 2018). The protein found in coconut kernels is high in globulins (70–80%), which have beneficial biological and digestive properties. The increased concentration of L-arginine in coconut kernel protein is thought to be responsible for its functional qualities, which include anti-diabetic effects (Salil et al., 2011).

2.7.2 COCONUT WATER

Coconut water is located in the cavity of coconut and depending on the age of nut its nutrients and volume fluctuates. Nuts takes about 11-12 months to develop. Coconut water contains minerals, sugars, vitamins and proteins along with a variety of growth promoting factors and neutral lipids. Different elements, such as variety, nut maturity, soil characteristics, and climate, influence the content of coconut water. Sugars and minerals constitute the majority of the chemical composition, with fat, proteins, and other nitrogenous materials forms the minor components. The amount of sugar in the nut water rises from 1.5% to 5.5% as the nut develops and falls to around two percent when it reaches full maturity (Beegum et al., 2022). Coconut water is primarily divided into two categories: mature coconut water (MCW) and tender coconut water (TCW). **Table 6** shows the composition of TCW & MCW. TCW is a natural and nourishing beverage made from fruit that is 6 to 7 months old, while MCW and coconut meat are the primary edible goods made from fruit that is 12 months old. MCW is a significant byproduct of the companies that process coconut meat, including those that produce virgin coconut oil, desiccated coconut powder, coconut milk powder, and coconut chips. Tender coconut water is one of the greatest sources of electrolytes. The liquid endosperm is a biological electrolyte since it contains both positive and negative ions in addition to nuclei. Vitamin C, a significant water-soluble antioxidant and radical scavenger, is abundant in tender nut water (25 mg/dl). Polyphenols are also present (Bhagya et al., 2012).

Table 6: Composition of tender (TCW) and mature coconut water (MCW)

Constituents	TCW	MCW
Total sugar (%)	4.8	3.1
Total reducing sugar (%)	4.0	2.0
Total protein (mg/dI)	150	450
L-arginine (mg/dI)	30	150
Vitamin C (mg/dI)	25	15
Magnesium (mg/dI)	16	14
Potassium (mg/dI)	300	257
Calcium (mg/dI)	40	44

(Source: Sandhya et al., 2008)

2.7.3 NATA DE COCO

A chewy, transparent, jelly-like substance called nata-de-coco is made by fermenting mature coconut water. It can be served with a variety of foods, including drinks, ice cream, puddings, and fruit combinations, and is most commonly sweetened as a candy or dessert. It is developed by fermenting coconut water and cultivating Acetobacter xylinum, which creates microbial cellulose for gel formation. The ideal conditions for producing nata de coco with a soft surface and chewy texture were pH 4, 10% sucrose, and 0.5% ammonium. A culture solution was created by adding sugar to mature coconut water that had been inoculated with Acetobacter xylinum. The mixture was then allowed to sit in a vessel undisturbed for two to three weeks. A substance that resembled jelly developed at the vessel's top. After being separated and cleaned with water to get rid of the acids that were sticking to the jelly's surface, the jelly was sliced into pieces and packaged (Mithra et al., 2013).

2.7.4 COCONUT VINEGAR

Coconut vinegar serves as a substitute for synthetic vinegar, made from coconut water or the sap of the coconut tree. It is rich in calcium, phosphorous, iron, and sodium, as well as having anti-inflammatory and antimicrobial qualities, coconut vinegar is a popular flavoring and preservative ingredient in pickles, salad dressings, and sauces (Shahidi et al., 2008). As a natural product that comes from the fermentation of sugar-enriched coconut water, coconut water vinegar contains 3–4% acetic acid and is a necessary household item. It can be made commercially or as a cottage industry in a village. As a non-synthetic food product, coconut water vinegar is commonly used as a table seasoning or as an ingredient in food processing. It is made by allowing fermented coconut water, combined with other ingredients, to go through fermentation and acetification at room temperature (28 °C) (Gosh, 2015). Following filtration, refined sugar is added to the coconut water to bring the Brix down to 15°, and the liquid is then brought to a boil. After cooling, active dry yeast (1.5g/liter) is added to the pasteurized mixture. For efficient acetic fermentation, mother vinegar or starter culture is added after 5–7 days of alcoholic fermentation. The coconut vinegar was then extracted by siphoning after the acidification process, which lasted for up to seven days (Mithra et al., 2013).

2.7.5 COCONUT OIL

Coconut oil is produced in both commercial and residential settings. The oil that is extracted from wet kernels is referred to as virgin coconut oil, whereas the oil that is recovered from copra by a dry process is called coconut oil or copra oil. Coconut oil is a naturally occurring, light-colored, saturated, and stable oil with a pleasing flavor and odor. About 8–10% of coconut oil is unsaturated and composed of triglycerides of oleic and linoleic acids, whereas 90–92% of the oil is saturated. Lauric acid is the most common medium-chain fatty acid among the saturated fatty acids found in coconut oil. It can be used as frying and seasoning oil for cooking without being refined. The oil is perfect for high-heat cooking because it is biodegradable and extremely resistant to oxidative damage during frying. Coconut oil has special nutritional and therapeutic properties, including simple digestion, absorbability, and a readily oxidizable nature that reduces body fat development (Mithra et al., 2013). **Figure 8** presents multiple mechanisms of action of coconut oil in overall oral health.

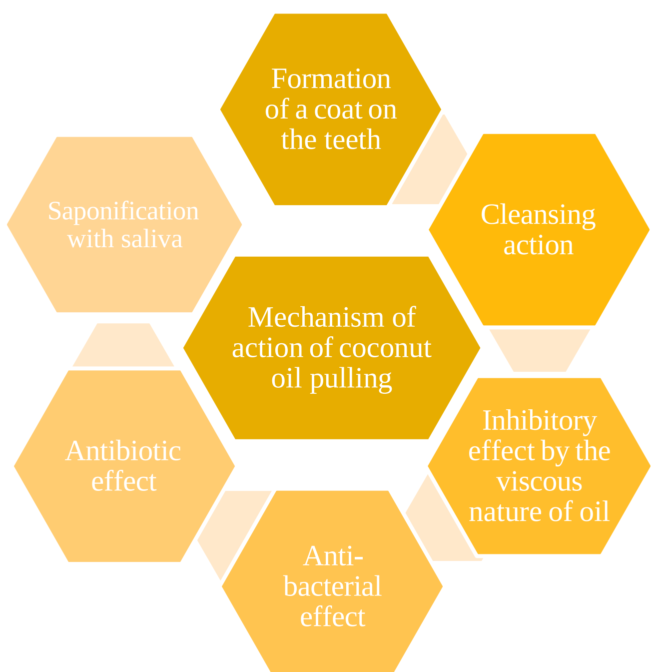


Figure 8: Multiple mechanisms of action of coconut oil in overall oral health

(Source: Beegum et al, 2022)

2.7.6 VIRGIN COCONUT OIL

VCO is extracted from the fresh and mature coconut kernel using mechanical and natural methods, without undergoing chemical treatment or refining, with or without heat, maintaining the fresh coconut's sensory and functional qualities. There are several technique for extracting coconut oil from coconut kernels including solvent extraction, dry method, and wet method (Agarwal et al., 2017). VCO is the finest type of coconut oil, has the inherent flavor and aroma of coconut. VCO solidifies at low temperatures but turns colorless like water when liquefied. The medium chain fatty acids (MCFAs) in VCO are primarily responsible for its high digestion. Since MCFAs burn up right away after consumption, the body uses them right away to produce energy rather than storing them as body fat. Monolaurin, a very useful substance with antiviral and antibacterial qualities, is produced from lauric acid. Refer **Table 7** for fatty acid composition of coconut oil and virgin coconut oil. Additionally, VCO has antioxidant qualities that strengthen the immune system (Marina et al., 2009).

Table 7: Fatty acid composition of coconut oil and virgin coconut oil

Fatty acids	Coconut Oil	VGO
Caprylic acid	8.15	8.050
Capric acid	5.56	5.420
Lauric acid	43.55	45.510
Myristic acid	38.58	19.740
Palmitic acid	8.25	7.830
Stearic acid	2.65	3.140
Oleic acid	6.70	4.700
Linoleic acid	1.49	1.880
Arachidic acid	0.086	0.086

(Source: Nevin et al, 2006)

2.7.7 COCONUT COPRA

Once the coconut is dehusked, the hard yet fragile shell is visible, and a machete can be used to cut it in half. The flesh that is still attached to the shell is dried after the coconut's water has been drained. The meat becomes smaller and easier to remove from the shell as it dries. The dried meat of coconuts is used to make copra. The way the meat is dried affects the quality of the copra. The three most popular drying techniques are hot air drying, kiln drying, and sun drying. For many nations in Asia, the Pacific, and Africa that grow coconuts, copra, coconut oil, and the cake made from it are important sources of foreign exchange (Gosh, 2015). When the moisture content of well-dried copra drops to roughly 4-5%, which is the equilibrium moisture content of copra under most current storage conditions, it is processed into coconut oil (CNO) and copra cake. Since it has a balanced ratio of protein, carbs, and fat, copra cake is frequently used as feed for milking cows, pigs, and poultry. It increases the production of high-quality butter and produces more milk with a pleasant aroma, making it the ideal feed for nursing cows (Gurate et al., 1996).

2.7.8 COCONUT MILK

Coconut milk can be made at home by manually pressing grated meat, but on a commercial or industrial scale, the milk is extracted using a screw press or hydraulic. Coconut milk serves as an oil-in-water emulsion, where the oil is the dispersed phase and the water is the continuous phase. The durability of the coconut milk emulsion is dependent on the interfacial active protein layer that envelops the oil droplets. In general, the content of the coconut meat utilized for extraction determines the composition of coconut milk. Operational elements like the temperature of the supplied water and the pressing condition control the effectiveness of the extraction and composition of coconut milk from coconut meat (Patil et al., 2018). Coconut milk is primarily comprised of water and fat, with additional ingredients like protein, minerals, and carbs. Coconut milk is sold commercially and can be used to make soups, curries, or packaged as such. The mellow flavor of milk is attributed to its fat level, which also affects the keeping quality of milk (Pandiselvam et al., 2022).

2.7.9 COCONUT CREAM

Coconut cream is a smooth, white liquid with a great coconut flavor and 20–30% fat, packed aseptically. The product is ready for serving right away or for use in other food preparation processes because it is easily pourable. Coconut cream is primarily utilized as a fat source for newborn milk powders and for reconstitution of skimmed dairy milk. The cream could be used to make three different kinds of milk products: drinkable, evaporated, and sweetened condensed. It could also be used to make recombined milk or filled milk (Muralidharan et al., 2011). Although coconut cream and coconut milk are similar, coconut cream has a thicker, paste-like consistency. In order to produce cream, food additives such as stabilizers and emulsifiers are added to the coconut milk. After thoroughly mixing the mixture to get the required consistency, it was transferred to plate heat exchangers for pasteurization at 80°C and then heated before being placed into the container. Once opened, it had a shelf life of over six months. It can be used straight or diluted with water to prepare a variety of foods, including curries, desserts, puddings, cakes, cookies, jam, ice cream, and fish and meat meals. When coconut cream was added to soy milk, the amount of tofu produced increased (Escueta et al., 1985).

2.7.10 DESICCATED COCONUT

Desiccated coconut is the white, shredded, dehydrated coconut kernel. It is made from fully ripe coconut kernels for human consumption under very tight hygiene conditions. Fresh coconut kernels and desiccated coconut have the same nutritional value. It keeps all of the natural nutrients as well as the distinctive qualities of the wet kernel. The wet kernel of a good desiccated coconut has a sweet, pleasant, and fresh flavor and is crisp and snow white in color. The steps in the process are shelling, paring, dissolving, drying, sifting, and packing (Gosh, 2015). The desiccated coconut is less difficult to transport and has a longer shelf life. It is frequently used in baking, ice cream, puddings, and confections. Desiccated coconut can be used as a garnish for savory dishes, to provide texture and flavor, as a dusting for the exterior, or as an alternative to raw grated coconut (Mithra et al., 2013).

2.7.11 COCONUT FLOUR

Coconut flour is an excellent, nutritious source of dietary fiber that can be used as a filling agent, bulking agent, and, to a certain extent, as a replacement for wheat, rice, and potato flour. The flour can also be added to a variety of food products, including baked products, snacks, extruded foods, and steamed goods (Trinidad et al., 2003). Coconut flour is prepared from fresh coconut meat which has 58% total dietary fiber and 14% coconut oil. This natural ingredient is of superior quality and serves as a great source of nutritional fiber. Foods high in dietary fiber can aid in diabetes management and weight maintenance. **Figure 9** displays the composition of coconut flour. The preparation of coconut flour affects its aroma. After processing, the more coconut oil that remains in the flour, the greater the coconut smell. Depending on how much grinding and milling the flour has undergone, the granulation will vary. Typically, the range is between 30 and 200 mesh (Endaya et al., 2006). The coconut flour is devoid of phytic acid and gluten and is packed with many nutrients. The advantages of coconut flour for health comprises improved energy production, substantial blood pressure reduction, stroke prevention, thyroid function enhancement, blood sugar and insulin balance, and internal system cleansing (Gunathilake et al., 2008).

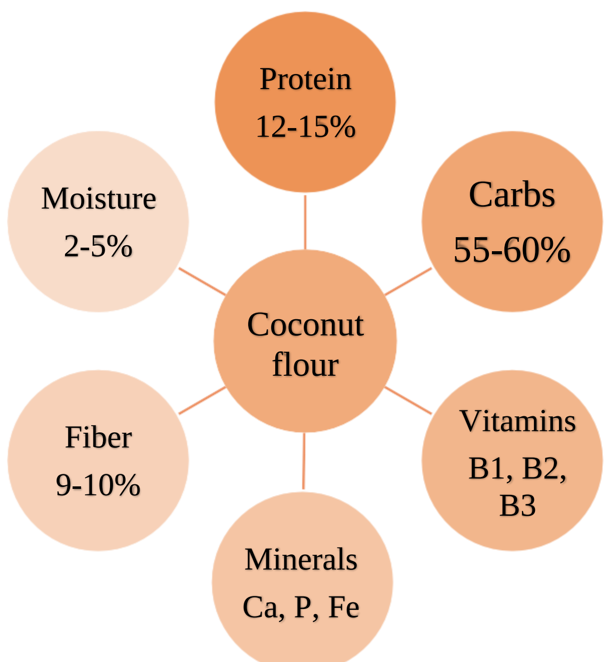


Figure 9: Composition of Coconut Flour

(Source: Banzon, 1990)

2.7.12 COCONUT CHIPS

Coconut chips are a ready-to-eat snack produced from coconuts that are 9 to 10 months old. It can be made by drying the intermediate moisture coconut kernel which is the mature coconut kernel, obtained after osmotic dehydration, by utilising osmotic mediums like sugar syrup to partially remove the moisture content of the kernel. Coconut chips with various flavors can be produced by adding the desired flavor essence to the osmotic medium. It is also possible to make medicated and salted coconut chips in place of sweet ones by making the appropriate adjustments to the osmotic medium (Muralidharan et al., 2011). The nature of the coconut chips is hygroscopic. In order to preserve the chips' flavor and crispness for up to six months without compromising their microbiological and biochemical properties, they must be packaged in aluminum foil laminated with LDPE pouches. The coconut chips are ready to eat and have a crunchy texture. It doesn't need to be fried before eating. It has a nice coconut flavor of its own because no oil is required when cooking. It can serve as a snack. It is also possible to utilize the chips as new kernel after they have been rehydrated (Gosh, 2015).

2.7.13 COCONUT MAYONISE

Mayonnaise, a semi-solid food product, is blended with fresh vegetables or cooked meat to boost flavor. It's made by combining coconut oil with vinegar or citric acid and emulsifiers. To adjust the taste and prevent crystallization, carbohydrates, spices, and flavor enhancers are included. The final mixture comprises 70% VCO, 6% natural vinegar, 7% fresh yolk, and 1% emulsifiers along with cooled boiled water. Farmer families can increase their income by running mayonnaise production units at home or on a micro-scale (Muralidharan et al., 2011). In the community, mayonnaise is available in both full-fat and reduced-fat varieties. Due to its low fat content, the community will opt for reduced fat mayonnaise, necessitating a reduction in the oil used in the product. Reduced fat mayonnaise was created to contribute to a healthy lifestyle by lowering the oil content used in its production. The procedure for making reduced-fat mayonnaise is the same as that for regular mayonnaise, with the only difference being that less oil is required. Virgin Coconut Oil comprises medium chain fatty acids that are easily digested and oxidized by the body, preventing their accumulation (Agustin et al., 2019).

2.7.14 COCONUT TESTA

Testa is the brown portion, or brown skin, that covers the coconut kernel. It is a by-product of the coconut processing industries, which divide wet coconut to make items like desiccated coconut, coconut milk, and virgin coconut oil. In the process of making desiccated coconut, coconut milk, and virgin coconut oil, testa is eliminated by combining wet and dry coconut since it gives the oil a brown hue and makes other products look gloomy. The bottom layer of the kernel turns brown as the coconut ages due to an increase in testa thickness. Historically, testa was primarily utilized as animal feed and as a raw material for bio-disel production. In contrast, it is now employed in bakery goods as a feed and flour substitute for wheat. It was discovered that replacing up to 30% of the flour with coconut testa was acceptable without compromising the overall quality of the cookies (Appaiah et al., 2014).

2.7.15 COCONUT JAGERRY

Coconut jaggery is produced by concentrating unfermented coconut sap or blossom. Along with many other vitamins and minerals, it has significant levels of calcium and iron. It can be used as a natural sweetener with little calories and as a digestive aid. To eliminate about 80% of the water in the collected sap, evaporation is necessary. Before being boiled, the sap is filtered through sand filters to remove impurities, and a little amount of alum is added to encourage the precipitation of magnesium and lime. This will improve the final jaggery's color, make it much less delicious, and keep it tough for a long period. A dense mass is created after evaporation, which crystallizes when heated further and solidifies when cooled. The final result has a dark tint since the sugar caramelized (Devi et al., 2022).

2.7.16 NEERA

Neera is a nutritious and revitalizing beverage gathered from the sweet coconut sap before fermentation. Neera in its fresh form is translucent, oyster-white, sweet, and has a lower fructose content. It has high levels of vitamins, minerals, and amino acids. It has a low calorific value, a low glycemic index (around 35), and a neutral pH. Neera offers many health advantages, such as better digestion, immediate energy, cell protection, lowering blood pressure, lowering cholesterol, and supporting healthy skin. Additionally, because of its high electrolyte content, it helps with postoperative care. Neera is quite prone to spontaneous fermentation by the natural yeasts, especially Saccharomyces cerevisiae. Neera contains a significant amount of sugar (14–18% w/v), which is quickly converted to alcohol through fermentation. The alcoholic beverage known as "toddy" is made from fermented neera. As an alternative, "coconut vinegar" can be produced by an acetic fermentation process. Techniques for post-harvest processing and preservation are crucial to the shelf life of coconut neera. In particular, one of the main quality concerns with coconut neera is the elimination of yeast (Leena et al., 2021).

2.7.17 COCONUT TODDY

Neera turns into toddy during fermentation as a result of the sugar being converted to alcohol. Coconut toddy is also reffered to as palm wine, is a sweet alcoholic beverage. In many countries of Asia, Africa, the Caribbean, and South America, it is a popular beverage with a variety of regional names. It treats sleeplessness and digestive problems in small doses. Toddy is evaporated in some places to create jaggery, an unprocessed sugar (Rajamohan et al., 2018). Toddy is made by the natural fermentation of sap, which begins rapidly as the sap exits the spadix. Bacteria and fungi are among the flora that cause coconut sap to ferment. In 6-8 hours, the toddy is completely fermented. The toddy's alcohol concentration is between 4 and 6%, and its shelf life is short. Although glucose, fructose, maltose, and raffinose are present, sucrose is the primary component of the fermented sap, with very little reducing sugar. Coconut arrack is an alcoholic beverage made from toddy that is typically distilled to 33% to 50% alcohol by volume. Coconut fenny is the term for the commercial arrack made in Goa from the distillation of coconut toddy (Hariharan, 2014).

2.7.18 COCONUT FIBRE/ COIR

Coconut fiber is obtained from the outer shell of coconut. It comes in two varieties: brown fiber from mature coconuts and white fiber from young coconuts. Coconut fibre have a low heat conductivity and are strong and rigid. Three types of coconut fibers which are widely available are decorticated (mixed fibers), mattress (very short), and bristle (long fibers). The main components of coconut fibers are cellulose, hemicellulose, and lignin., which influences various characteristics of coconut fibers (Ali, 2011). The raw material used in the coir industry is coconut husk. Either mechanical methods or natural retting (a microbiological process) are used to extract the coir fiber. In preparation for further processing, the extracted fiber is thoroughly washed and allowed to dry in the shade. The fibre is rated on the basis of its color, length, and other characteristics. Coir pith and coir ply are the by products of extracting coir fibre from husk, are extremely light, highly compressible, and highly hygroscopic. It serves as a desiccant, surface mulch, and rooting media in addition to soil conditioner (Mishra et al., 2020). **Table 8** represents number of coir industry in different states of India.

Table 8: Number of coir industry in different states of India

State	No. of Units
Kerala	5124
Karnataka	217
Tamil Nadu	262
Andhra Pradesh	265
Orissa	100
West Bengal	75
Maharashtra	5
Pondicherry	6
Goa	3
Total	6531

(Source: Naresh Kumar, 2007)

2.8 GLOBAL EXPORT OF COCONUT PRODUCTS

Every year, more than US$1.2 billion worth of coconut products are exported worldwide. Even though over 50 coconut products are exported, only 14 of them—namely. The export of coir-based products, copra, coconut oil, desiccated coconut, coconut milk, coconut powder, cream, coconut water, neera, coco sugar, coco chemicals, virgin coconut oil, shell charcoal, and activated charcoal is increasing. **Table 9** represents world export of various coconut products during 2011-2015. Less than six exporting nations typically account for more than 80% of the total quantity traded in the highly concentrated coconut and coconut product export market. With an annual revenue of US$841 million, the Philippines leads the world in coconut product exports, followed by Indonesia, Sri Lanka, Malaysia, India, and Thailand. India's primary exports are coir and its byproducts, such as coir pith and geotextiles. Coconut oil continues to be the most important product exported. However, the growth rate has a trend of oscillation. Since the copra-producing nations themselves have recently begun manufacturing coconut oil and other value-added products, copra exports have significantly decreased. The amount of desiccated coconut exported worldwide fluctuated over time as well, reaching 3.04 lakh mt in 2015. Desiccated coconut is imported by India from Sri Lanka. Activated carbon exports rose from 152,490 t to 189,938 mt over the previous five years. Additionally, there were variations in the export of coir and coir products, which fell from 331,221 mt in 2014 to 286,671 mt in 2015. The two main producers of coconut fiber are India and Sri Lanka ((Rethinam, 2018).

Table 9: world export of various coconut products during 2011-2015

Products	2011	2012	2013	2014	2015
Fresh coconut (mt)	445,837	373,179	491,835	791,551	682,018
Copra (mt)	161,584	167,866	106,794	186,962	154,130
Copra meal (mt)	611,643	1,060,417	1,184,585	851,428	696,469
Coconut oil (mt)	1,862,669	2,142,817	2,228,404	2,100,013	2,096,558
Desiccated coconut (mt)	386,286	360,916	379,881	440,500	304,280
Coconut milk/cream and Coconut milk powder (mt)	25,618	42,556	42,724	50,208	63,395
Charcoal (mt)	275,905	261,749	308,964	360,525	414,269

Activated carbon (mt)	152,490	256,720	209,311	239,594	189,938
Coconut shell (mt)	275,905	261,749	308,964	355,288	414,269
Coir yarn (mt)	6339	6588	6362	6392	6630
Coir and coir products (mt)					
APCC countries	304,305	295,421	290,458	331,025	286,475
Other countries	200	196	196	196	196
Total	304,505	295,654	290,654	331,221	286,671

(Source: APCC Statistical Yearbook, 2015)

2.9 FOOD ADDITIVES

Food additives are substances or ingredients that become part of the final food product, either through direct addition to achieve a desired effect or indirectly due to production or processing. Direct additives encompass antioxidants, leavening agents, texturizing agents, preservatives, colors, and flavors. The concentrations of these agents in food are typically low, with colors and flavors being at the lowest concentrations. Functions of food additives are mentioned in **Figure 10.** Currently, we have over 2500 additives intended for use during the production, processing, packaging, or storage of food. Hence, a widely accepted definition of an additive is "any substance added to food in limited amounts other than the original food components during production, processing, packaging, or storage". General classification of food additive is as follows:

- ❖ Direct food additives: Any substance that is intentionally added to food in small amounts for functional purposes during processing. Direct additives are further classified based on their functionality
- ❖ Indirect food additives: These are substances that make their way into food in minimal amounts during processing or packaging (Branen et al., 2002).

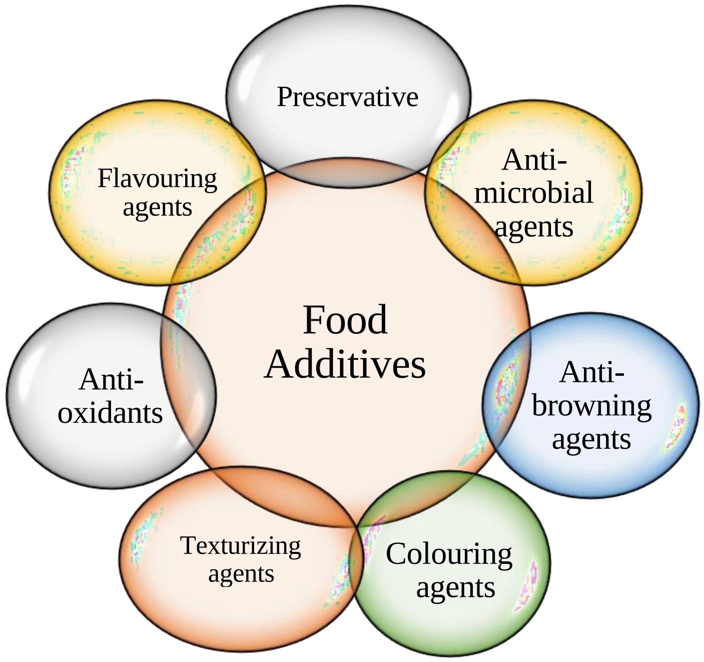


Figure 10: Functions of a Food Additive

(Source: Silva et al., 2019)

2.9.1 CLASSIFICATION OF FOOD ADDITIVES

In the USA, food additives are categorized into 26 functional classes: sweeteners, colorants, preservatives, antioxidants, carriers, acids, acidity regulators, anticaking agents, antifoaming agents, firming agents, foaming agents, gelling agents, glazing agents, bulking agents, raising agents, emulsifiers and emulsifying salts, flavor enhancers, humectants, modified starches, packaging gases, propellants, sequestrants, stabilizers, thickeners, and flour treatment agents. The European Commission (Regulation (EC) No 1333/2008) identifies the primary additives used in industrialized beverages as phosphoric and phosphate acids, sorbic acid, benzoic, ascorbic, citric, fumaric, succinic, saccharin, sucralose, and others. **Figure 11** shows detailed classification of food additives.

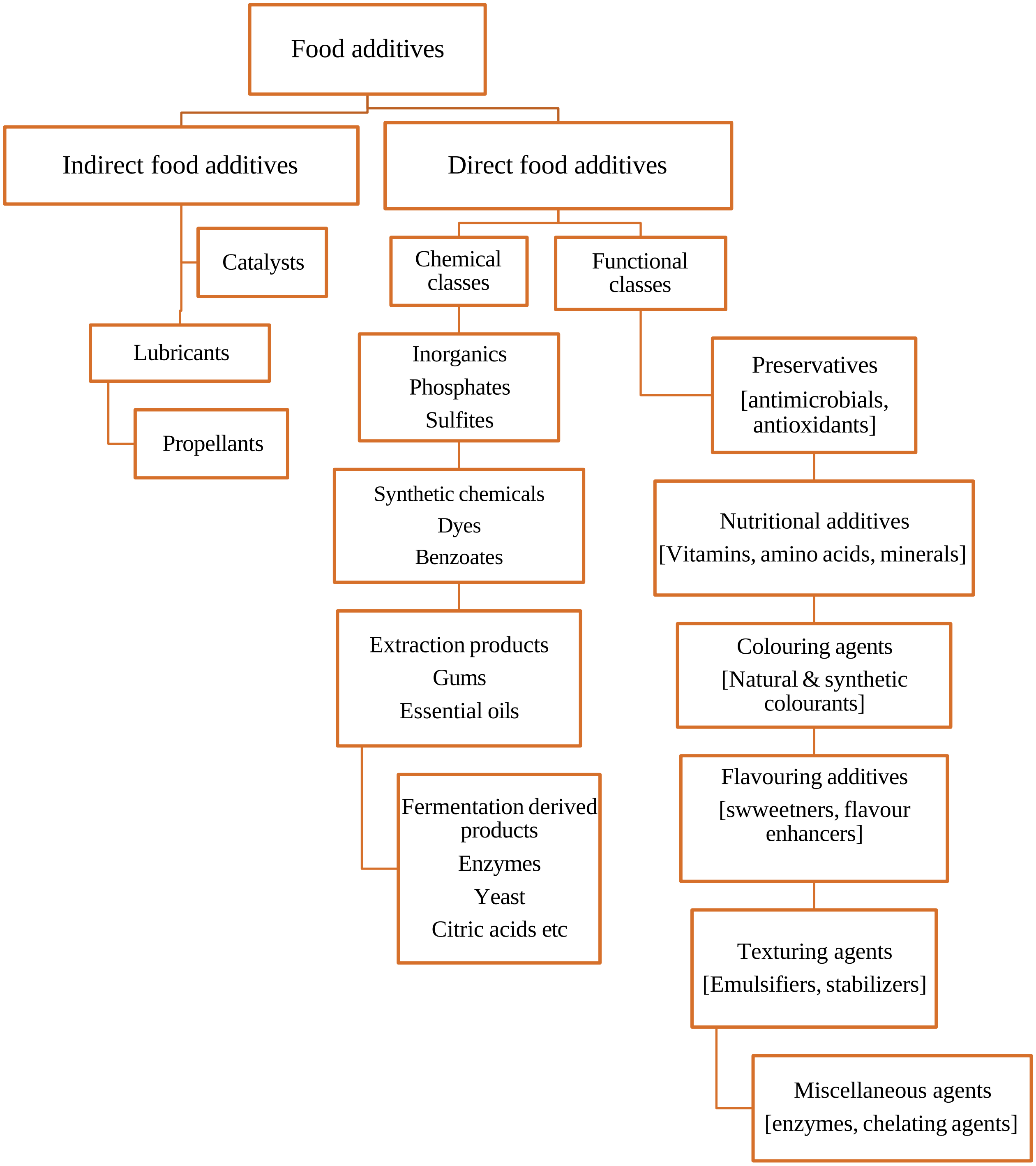


Figure 11: Classification of food additives

(Source: Raju et al., 2006)

2.9.2 REGULATIONS

Fruit, vegetables, and their products—including food additives and pesticides/biocides—are governed by international and national regulations through food laws. Food additives must receive approval from regulatory authorities regarding both their application and dosage, as they are essentially foreign substances added to food items to provide various benefits, including enhancements to sensory quality, nutritional value, and storage stability, in addition to serving as processing aids. (Sumner et al., 2002). It is essential to regulate food additives, as their improper use can have extensive health consequences for both children and adults. Food safety requires strict regulations to guarantee complete safety for consumers. Various nations possess distinct regulatory standards that include lists of approved additives and the methods for enforcing these standards. Among the primary governmental regulations are the Food and Drug Act (FDA), European Union standards, and Codex Alimentarius, which serves as the joint regulatory body of FAO/WHO. These entities dominate the global food sector as they encompass an umbrella of both developed and developing nations engaged in international trade (Somojyi, 1996). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) evaluates the available toxicological data and chemical specifications of an additive as part of its assessment, and determines an acceptable daily intake (ADI). The ADI represents the quantity that can be consumed daily over a lifetime in a human diet without risk. Unless otherwise specified, ADIs are expressed in mg per kg of body weight; flour treatment agents are one of the exceptions, with their values given in parts per million. (Ottaway, 2003).

2.10 BEVERAGES

A beverage is generally described as a drink that is specially made for people to consume. The term “beverage” comes from the French term boivre, which means “to drink.” These beverages come in a wide variety of flavors, including soda water, tonic water, diet/lite options, herbal or botanical varieties, energy drinks, and carbonated drinks. Throughout many centuries, the consumption of drinks in their diverse forms has occurred to satisfy the essential need of humankind for hydration (Ibrahim et al., 2020). Besides satisfying thirst, they also offer nutritive supply. Some specialty drinks are formulated for specific situations, including sports beverages, medicinal drinks, and herbal beverages. To satisfy consumers' needs based on their age group and nutritional requirements, beverage manufacturers are consistently creating unique and designer drinks (Mudgil et al., 2018). **Table 10** represents the classification of beverages.

Table 10: Classification of beverages

Classification Criteria	**Classes**	**Examples**
Ingredients used in the manufacture	Natural Beverages Synthetic Beverages	Fruit-based beverages, Dairy-based beverages, malt beverages Soft drinks containing flavored syrups
Carbonation	Carbonated Beverages Non-carbonated beverages	Cola-beverages, lemonade beverages Fruit and Dairy based beverages
Alcohol Presence	Alcoholic Beverages Non-alcoholic Beverages	Beer, wine, spirits Fruit and vegetable juices, soft drinks, soda water
Serving Temperature	Hot Beverages Cold Beverages	Tea, coffee, cocoa beverages Iced tea, cold coffee, soft drinks,
Physiological effects	Stimulating Beverages Non-stimulating Beverages	Tea, coffee, herbal beverages Fruit and vegetable juices, soft drinks, bottled water

(Source: Mudgil et al., 2018)

2.10.1 CRUSH BEVERAGE

The Food Safety and Standard Authority of India (FSSAI) has established regulations for fruit crush under the category of "Squashes, Crushes, Fruit Syrups/Fruit Sharbats and Barley Water". According to Food Safety and Standard Act (FSSAI), 2006 of India, Crush means the product prepared from unfermented but fermentable fruit juice/puree or concentrate clear or cloudy, obtained from any suitable fruit or several fruits by blending it with nutritive sweeteners and water. **Table 11** displays requirements for different fruit beverages as per FPO. It should comprise 25% fruit juice, 55% TSS, and no more than 3.5% acidity. Its similarity to squash is more or less the same, and it is diluted prior to serving (Muzzaffar et al., 2016).

Table 11: Requirements for different fruit beverages (Source: FPO)

Name of the products	Fruit juice/ puree in the final product Min (%)	Total soluble solids Min (%)	Acidity expressed as citric acid Max (%)
Squash	25	40	3.5
Crush	25	55	3.5
Fruit syrup/ Fruit Sharbats	25	65	3.5
Cordials	25	30	3.5
Barley water	25	30	2.5

2.10.2 BEVERAGES IN NUTRITION AND HEALTH

Natural fruit and vegetable beverages are delicious, nutritious, and packed with vitamins, minerals, and phytonutrients—specifically, natural bioactive compounds that have beneficial interactions with food fibers and other components found in food. Beverages made from fruits and vegetables contribute to a balanced diet, promoting health and vitality. Nutritionists recommend them for a healthy lifestyle, as they play an active role in cellular regeneration, detoxification, and the treatment of various diseases (Marian et al., 2019). Typically, majority of the beverages consist of water and carbohydrates. water is essential to human health through hydration. the carbohydrate found in drinks provides an immediate energy source and contributes to their sweetness. Fruit-based drinks are rich in vitamins, minerals, and dietary fiber, all of which are crucial for human health. Dietary fiber from fruit-based beverages is classified as a carbohydrate that does not provide calories but serves various physiological roles beneficial to human health, including reducing cholesterol and blood glucose levels and supporting the digestive system. Dairy-based beverages and sports drinks supply a sufficient quantity of minerals needed for good health. Minerals are crucial for maintaining the body's electrolyte or salt balance. Insufficient or excessive quantities of these substances can result in significant health issues for humans. Functional and herbal beverages include particular bioactive substances and offer specific health advantages beyond basic nutrition. Thus, beverages can be seen as an ideal means for delivering certain nutrients essential for good health (Mudgil et al., 2018).

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The dissertation project was based on conducting the formulation of concentrated and reconstituted coconut crush beverages. The study also evaluates the physiochemical and sensory properties of formulated drinks in packed form at 29℃ ± 2℃ 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) **Coconut:** Coconut 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 concentrated and reconstituted beverages. I used this as my primary ingredient.

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

c) **Hydrocolloids:** Hydrocolloids such as pectin, gellan gum, sodium alginate and carrageenan were procured from the chemical store and brought to the department.

d) **Chemicals:** such as Citric acid, Sodium benzoate were purchased from Chemical store and brought to the department.

3.2 TOOLS AND EQUIPMENTS

- **Induction stove:** This is used as the heat source.
- **Blender:** Used for blending and obtaining the puree.
- **Strainer:** Used to strain
- **Muslin cloth:** Used to strain and obtain fine coconut milk and puree
- **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 final product.
- **Knife:** Used for cutting and removing brown layer.
- **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

3.1.1 PREPARATION OF COCONUT PUREE

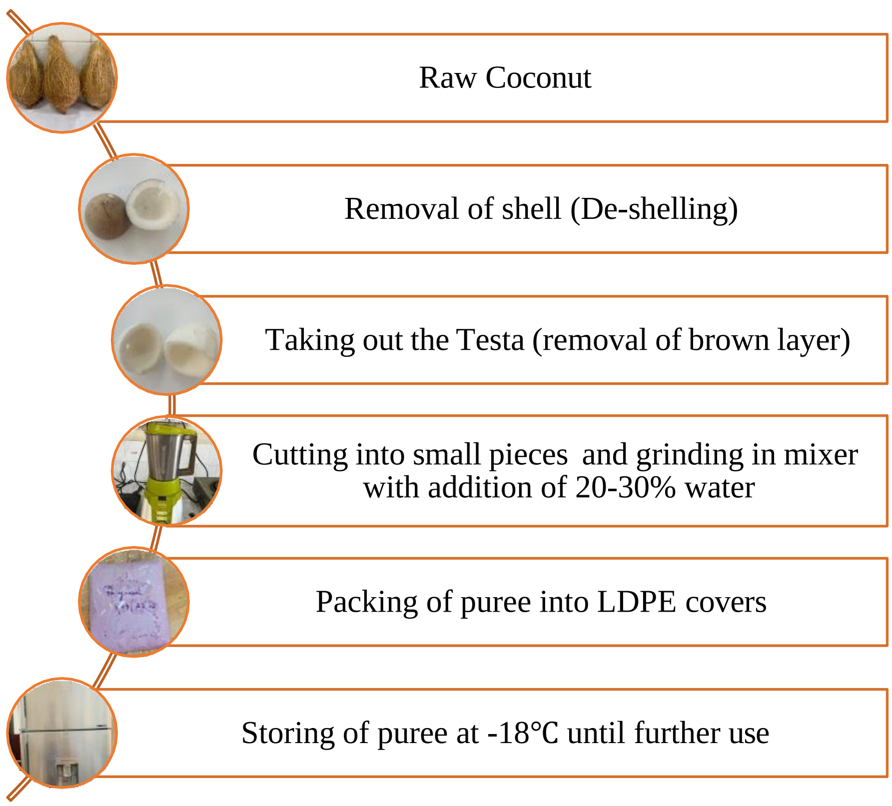


Figure 12: Preparation of coconut puree

3.4 PRODUCT DEVELOPMENT

3.4.1 PREPARATION OF COCONUT CRUSH BEVERAGE FROM WHOLE COCONUT

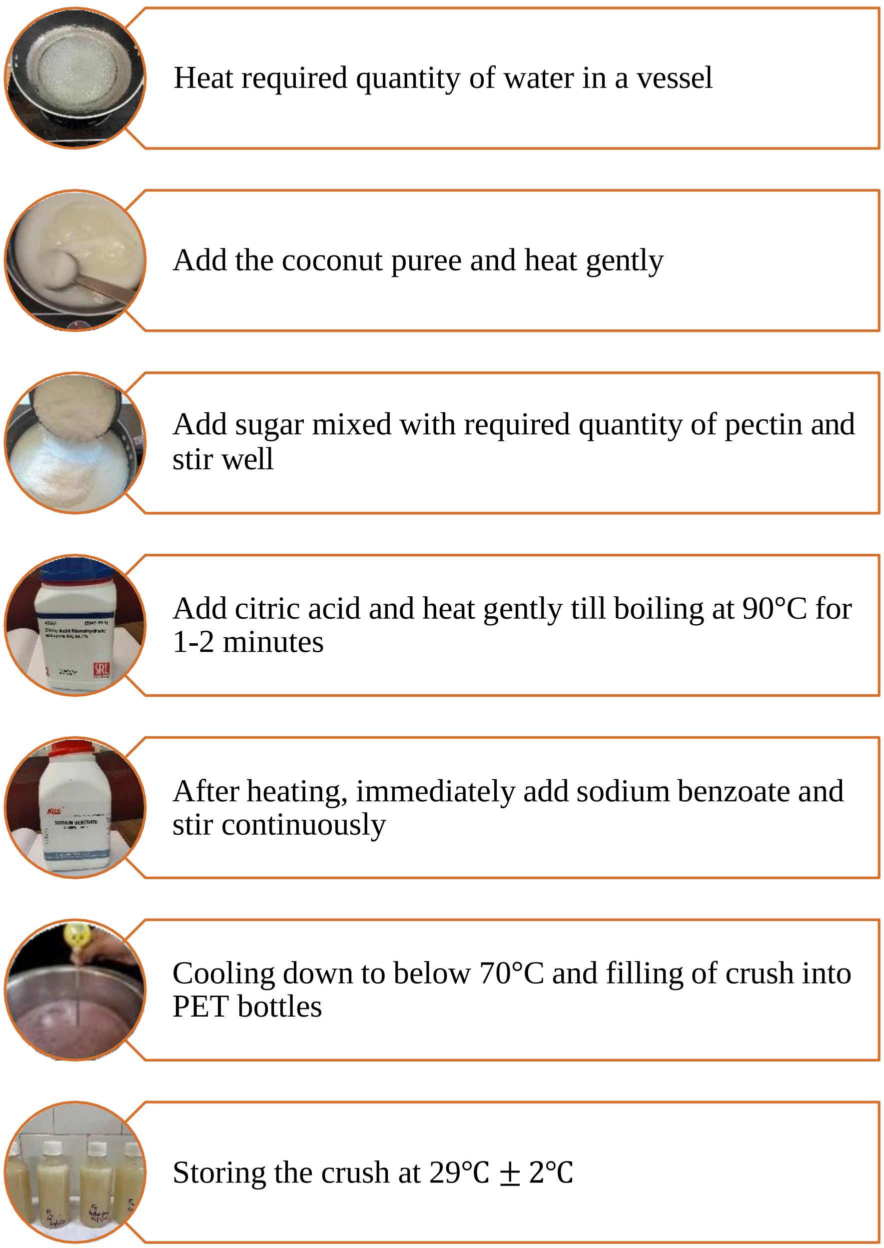


Figure 13: Preparation of coconut crush beverage from whole coconut

3.4.2 PREPARATION OF COCONUT CRUSH BEVERAGE FROM COCONUT MILK

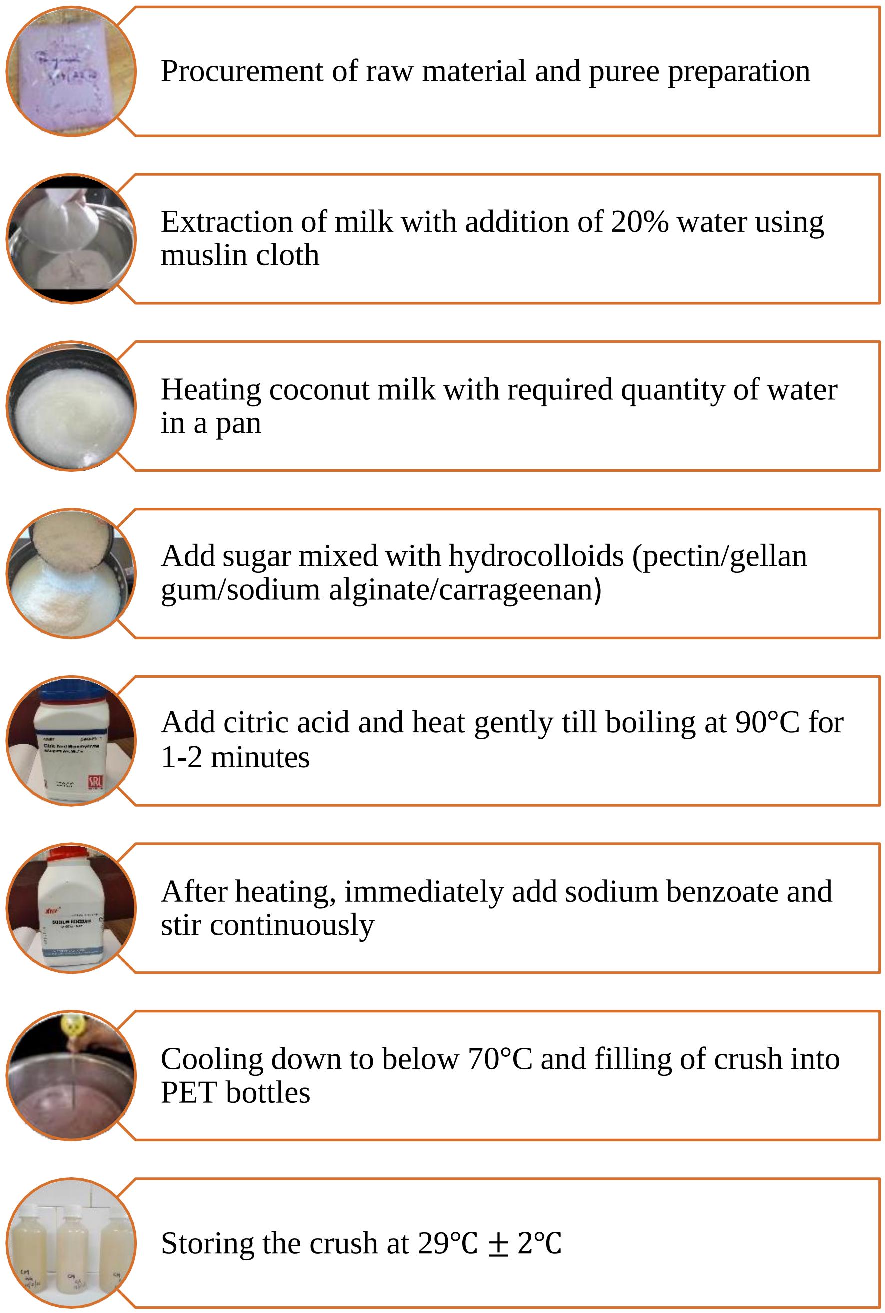


Figure 14: Preparation of coconut crush beverage from coconut milk

3.4.3 PREPARATION OF COCONUT CRUSH BEVERAGE FROM COCONUT FIBRE

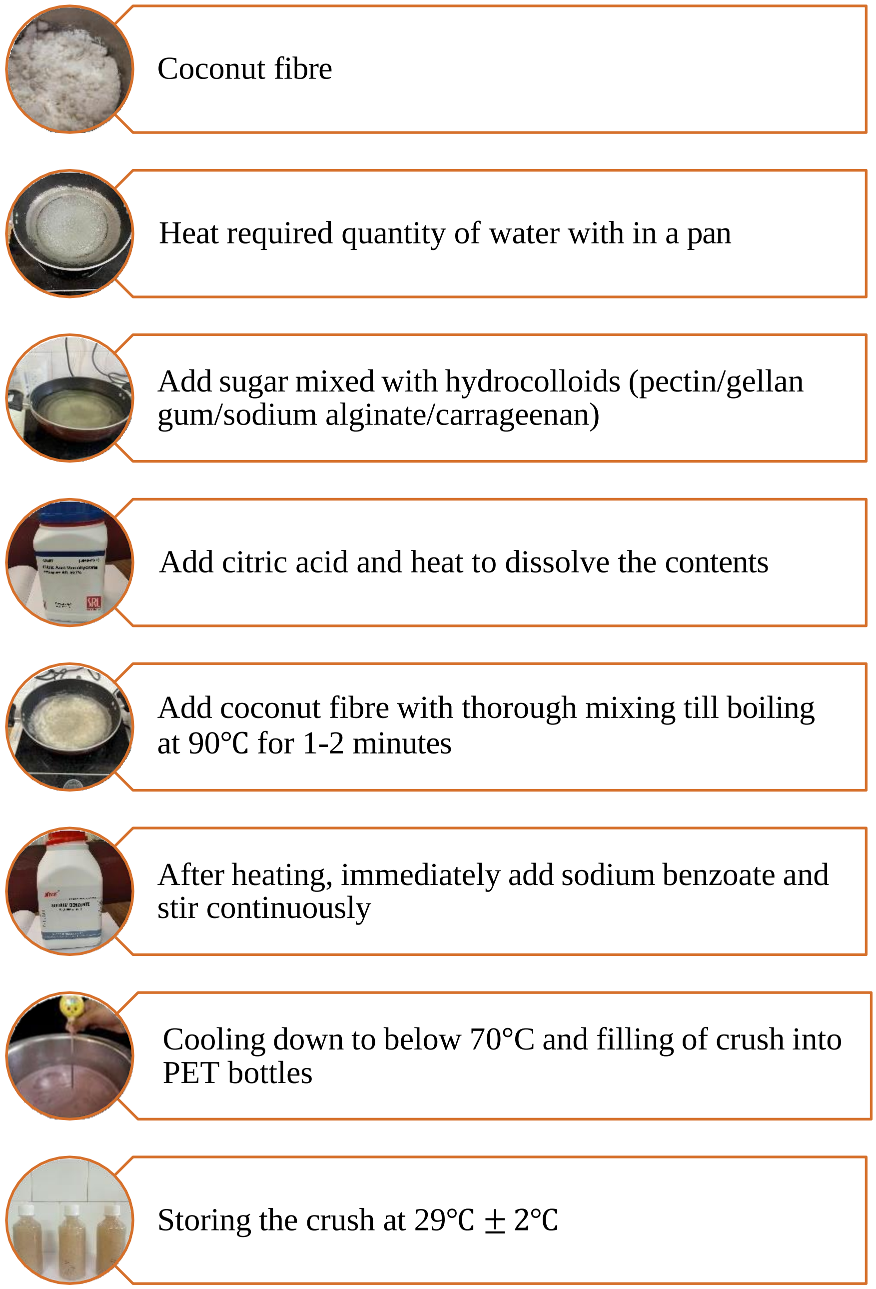


Figure 15: Preparation of coconut crush beverage from coconut fibre

3.5 TRIALS AND OPTIMISATION

Trials and optimization was done to determine the particle size of various emulsifiers in the coconut crush beverage. Four different formulations namely WC P (whole coconut crush beverage with pectin), WC GG (whole coconut crush beverage with gellan gum), WC CR (whole coconut crush beverage with carrageenan), CM P (coconut milk crush beverage with pectin) CM SA (coconut milk crush with sodium alginate), CF P (coconut fibre crush beverage with pectin), CF SA (coconut fibre crush beverage with sodium alginate) were prepared with other ingredients such as water, sugar, citric acid and sodium benzoate and subjected to physiochemical analysis, sensory evaluation and shelf life studies. The coconut crush was prepared in two forms: concentrated and reconstituted. The reconstituted version, intended for direct consumption was formulated at 1:6 dilution ratio. Preliminary sensory using 9-point hedonic scale was also done to determine the best formula.

3.5.1 COMPOSITION OF VARIOUS FORMULATIONS OF COCONUT CRUSH BEVERAGE FROM WHOLE COCONUT (1L BATCH)

Composition of various formulations of coconut crush beverage from whole coconut is represented in **Table 12**.

Table 12: Various formulations for the preparation of whole coconut crush beverage

INGREDIENTS	WC P	WC GG	WC SA	WC CR
Water (ml)	186	186	186	186
Coconut puree (%)	25	25	25	25
Sugar (g)	550	550	550	550
Citric acid (g)	12	12	12	12
Sodium benzoate (mg)	480	480	480	480
Pectin (g)	2	-	-	-
Gellan gum (g)	-	2	-	-
Sodium alginate (g)	-	-	2	-
Carrageenan (g)	-	-	-	2

Figure 16 depicts concentrated and reconstituted whole coconut Crush Beverage

Figure 16: Concentrated and reconstituted whole coconut crush beverage

In terms of sensory analysis WC CR scored the least and WC P scored the highest, which had the optimum particle size and consistency. WC GG scored the second highest and thus whole coconut crush beverage with hydrocolloid pectin and gellan gum was chosen for storage studies.

3.5.2 COMPOSITION OF VARIOUS FORMULATIONS OF COCONUT CRUSH BEVERAGE FROM COCONUT MILK (1L BATCH)

Composition of various formulations of coconut crush beverage from coconut milk is represented in **Table 13**.

Table 13: Various formulations for the preparation of coconut milk crush beverage

INGREDIENTS	CM P	CM GG	CM SA
Water (ml)	240	240	240
Coconut milk (%)	20	20	20
Sugar (g)	550	550	550
Citric acid (g)	12	12	12
Sodium benzoate (mg)	720	720	720
Pectin (g)	2	-	-
Gellan gum (g)	-	2	-
Sodium alginate (g)	-	-	2

Figure 17 depicts concentrated and reconstituted coconut milk crush beverage

Figure 17: Concentrated and reconstituted Coconut Milk Crush Beverage

In terms of sensory analysis CM GG scored the least and CM P scored the highest, which had the optimum particle size and consistency. CM SA scored the second highest and thus the coconut milk crush beverage with hydrocolloid pectin and sodium alginate was chosen for storage studies.

3.5.3 COMPOSITION OF VARIOUS FORMULATIONS OF COCONUT CRUSH BEVERAGE FROM COCONUT FIBRE (500 ML BATCH)

Composition of various formulations of coconut crush beverage from coconut fibre is represented in **Table 14**.

Table 14: Various formulations for the preparation of coconut fibre crush beverage

INGREDIENTS	CF P	CF GG	CF SA
Water (ml)	170	170	170
Coconut fibre (%)	20	20	20
Sugar (g)	225	225	225
Citric acid (g)	6	6	6
Sodium benzoate (mg)	720	720	720
Pectin (g)	2	-	-
Gellan gum (g)	-	2	-
Sodium alginate (g)	-	-	2

Figure 18 depicts concentrated and reconstituted coconut fibre crush beverage

Figure 18: Concentrated and Reconstituted Coconut Fibre Crush Beverage

The sensory analysis revealed that the fibre coconut crush beverage was deemed unacceptable due to its coarse particle size and undesirable mouthfeel, which affected overall consumer preference. Hence it was rejected.

3.6 STANDARDIZED COMPOSITION OF COCONUT CRUSH BEVERAGE

Standardized composition of coconut crush beverage is displayed in **Table 15**.

Table 15: Standardized composition for the preparation of coconut crush beverage

INGREDIENTS	WC P	WC GG	CM P	CM SA
Water (ml)	186	186	240	240
Coconut fibre (%)	25	25	20	20
Sugar (g)	550	550	550	550
Citric acid (g)	12	12	12	12
Sodium benzoate (mg)	480	480	720	720
Pectin (g)	2		2	
Gellan gum (g)	-	2	-	-
Sodium alginate (g)	-	-	-	2

Figure 19 depicts the standardized formulations of concentrated and reconstituted coconut crush beverage.

Figure 19: Standardized Concentrated and Reconstituted Formulations for the preparation of Coconut Crush Beverage

3.7 STORAGE STUDIES

Prepared coconut crush beverages were stored in PET bottles of capacity 220 ml at room temperature 29℃ ± 2℃ for a period of 30 days. Physio-chemical changes in the samples during storage were evaluated over 0-30 days.

3.8 ESTIMATION OF PHYSIO-CHEMICAL PROPERTIES

3.8.3 COLOUR MEASUREMENT

The samples were analyzed for color intensity using a Minolta Chroma Meter CM-5 benchtop spectrophotometer **(Figure 20),** which has a wavelength range of 360 nm to 740 nm. It assesses the color of liquid, solid, or paste-like samples based on either reflectance or transmittance. To quantify color, the hunter lab parameters (L*, a*, b*, and dE) were recorded. The L* value indicates the ratio of Whiteness to Darkness. The a* value of the sample is situated between its red (+) and green (-) components. The b* value indicates the equilibrium between yellowness (+) and blueness (-); Values closer to zero indicate a reduction in intensity (-). The values for a* and b* that are nearer to zero indicate a less intense color, whereas values that are farther from zero indicate more pronounced chroma characteristics (Ranganna, 2002). The instrument was calibrated first with the standard and then samples were put in a petri dish, and the reflectance of each sample was measured three times.

Figure 20: Colour Measuring System

3.8.4 PARTICLE SIZE ANALYSIS

The reconstituted crush beverage, intended for direct consumption were examined for particle size using a Microtrac S3500 Particle Size Analyzer **(Figure 21)**. To collect several drops of the sample, a controlled ultrasonic probe was employed within an automated fluid circulation system. Using laser diffraction, the system measures both the size and distribution of particles within a clear water solution. After one gram of the sample and two liters of distilled water were passed through the particle analyzer, measurements were taken. It relies on the dimensions of a collection of particles. The concept that a laser beam's scattering is inversely connected to the dimensions of the particles (i.e., as the light scattering angle increases, the particle light scattering angle decreases). The readings arrive within a minute, encompassing data analysis and measures of particle size ranging from 0.02 to 2800 microns.

Figure 21: Particle Size Analyzer

3.8.5 VISCOSITY

The viscosity of reconstituted crush is assessed at designated shear rates using the Brookfield DV-II+Pro Viscometer **(Figure 22).** Viscosity measures a fluid's resistance to flow. The DV-II+Pro provides an impressive range of control options, with three distinct modes of operation: traditional standalone, automated through downloadable PC programs, and full PC control using Brookfield Rheocalc32 Software. In the DV-II+Pro's basic operational mode, a calibrated spring drives a spindle that is immersed in the test fluid. The spring deflection quantifies the fluid's viscous drag on the spindle. Spindle No. 4 operates at a speed of 100 rpm, and stable values have been recorded for samples. Measurements were given in Centipoise (cP) units.

Figure 22: Viscometer

3.8.6 pH

A statistical tool that tracks the hydrogen-ion activity in water-based solutions and determines their acidity or alkalinity, expressed as pH, is a pH meter (measured from 0.0 to 14.0 pH units) **(Figure 23).** A solution is deemed basic if its pH is greater than 7.0 and acidic if its pH is less than 7.0. A neutral pH is 7.0. By monitoring the electrical potential between two electrodes—a reference electrode and a measuring electrode—a pH meter determines the pH of a solution. The pH of the solution is determined by the interaction between the measuring electrode and the hydrogen ions (H^+) in the solution when the electrodes are submerged in it.

Figure 23: pH Meter

3.8.7 TOTAL SOLUBLE SOLIDS

The TSS value is the quantity of sugar and soluble minerals present in fruits and vegetables. To calculate TSS, or Brix, a Hanna HI 96801 refractometer was used, shown in **Figure 24**. Measurements are made using the HI96801 using the refractive index of a sample. The way light behaves as it travels through a sample is measured by its refractive index. The makeup of the sample will affect how light refracts and reflects. A linear image sensor is used to measure this activity, and the refractive index of the sample is translated into the sucrose percentage (% brix). The refractometer's LCD shows the TSS value in a mere 1.5 seconds after a little drop of sample is placed on the prism.

Figure 24: Digital Refractometer

3.8.8 TITRATABLE ACIDITY

A solution's total acid concentration is indicated by its titratable acidity (TA). The volume of the base needed to neutralize the acids in the sample is measured after a known amount of food sample is titrated with a standard base (NaOH) in order to calculate TA. 10 ml of distilled water is combined with 2 ml of the sample, and the mixture is titrated against a 0.1N NaOH solution. After adding the phenolphthalein indicator, the solution's color changes to purple, indicating the endpoint which is depicted in **Figure 25.** The titre values are noted and percentage acidity is calculated in terms of malic acid using the formula:

$$\%\text{Acidity (\% anhydrous malic acid)} = \frac{6.7 \text{ x Normality of NaOH} \times \text{Titre value}}{\text{Weight of sample}}$$

Figure 25: Titration

3.8.9 TURBIDITY

Turbidity is a measure of cloudiness or haziness of the crush which results from the presence of suspended particles such as pulp, fibers, and other solid components. Turbidity of RTD crush was assessed using an HI 93703 Turbidity Meter **(Figure 26).** The HI93703 uses a light detector positioned at a 90° angle to detect dispersed light in order to assess turbidity. Juice's optical characteristic of turbidity makes light scatter and absorb instead than transmit. When light travels through a liquid, the suspended particulates in the juice are the main source of the scattering. There is more scattered light when the turbidity is higher. It is possible to detect turbidity in the range of 0.00 to 1000 FTU (Formazine Turbidity Unit).

Figure 26: Turbidity Meter

3.8.10 WATER CONDUCTIVITY

The ability of a liquid to carry electricity is known as water conductivity. Electrolytes like potassium and sodium are generally seen as beneficial to health. Drinks have more electrolytes. The water conductivity rises in conjunction with the electrolyte concentration. The COM-80 instrument **(Figure 27)** was used to measure the conductivity of the sample. Water conductivity is often represented by µS or mS.

Figure 27: Water Conductivity Meter

3.9 NUTRITIONAL PROFILING

3.9.1 SUGARS

The Lane and Eynon method was used to estimate the reducing sugar and total sugars described by Ranganna (1999). Carbohydrates that have a free aldehydic (-CHO) or ketonic (-CO-) group in their structure are known as reducing sugars. These sugars can transfer electrons, or reduce, other molecules in a chemical reaction when an oxidizing agent is present. Monosaccharides like glucose, fructose, and galactose, as well as disaccharides like lactose and maltose, are examples. When sucrose (table sugar) is hydrolyzed in the presence of an acid, it produces two simpler sugars, fructose and glucose, which together make up invert sugar.

3.9.1.1 FEHLING'S FACTOR CALCULATION

Using the Lane and Eynon approach shown in **Figure 28**, the first step in measuring reducing sugars is calculating the Factor for Fehling's solution, which is the amount of invert sugar in grams needed to completely reduce Fehling's solution (often 5 ml each of Fehling's A and B solutions). In order to determine Fehling's factor, fill a 100 ml volumetric flask with 25 ml of the standard invert sucrose solution after weighing it. Add a couple of drops of 54 henolphthalein indicator and fifty milliliters of distilled water. Make it pink by neutralizing it with NaOH pellets. Add enough to fill the burette to reach 100ml. 5 ml of Fehling's A and Fehling's B should be boiled in a conical flask with 10 ml of distilled water each. The end point should be brick red after titrating it against the burette solution. Fehling's factor was calculated using the following formula:

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

3.9.1.2 REDUCING SUGAR

A conical flask is filled with 10 ml of the sample and 50 ml of distilled water. The solution, which is prepared up to 100 ml in a volumetric flask, is then neutralized with NaOH crystals until a pink color is achieved when a few drops of phenolphthalein indicator are added. Fill the burette with the filtered solution. Ten milliliters of distilled water are added to a conical flask containing five milliliters of Fehling's A and five milliliters of Fehling's B. An automatic coil stove is used to heat this combination. When it is ready to boil, two to three drops of methylene blue are added, and titration is carried out against the solution in a burette. When the solution turns brick red, titre value is noted. Experiment repeated for 3 times and reducing sugar was calculated using the formula;

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

3.9.1.3 TOTAL INVERT SUGAR

In a 100 ml standard flask, 10 ml of the sample and 50 ml of distilled water were added. After that, 5 ml of concentrated HCI was added, and the mixture was left to invert for 24 hours at room temperature. A few drops of phenolphthalein indicator were added after a day. Then, using purified water and filtering, the volume was increased to 100ml and NaOH crystals were added till the pink color remained. In the burette, the filtrate was taken. Next, a conical flask containing 5 ml of Fehling's A solution, 5 ml of Fehling's B solution, and 10 ml of distilled water was filled and brought to a boil. Two to three drops of methylene blue indicator were added when the boiling process had just begun, and the solution in the burette was titrated against it. Brick red was the end point, and the titre value was recorded. 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

(a) Fehlings A & B with distilled water **(b) End point with brick red colour**

Figure 28: Lane and Eynon Method

3.9.2 FAT

Lipids are substances that are generally soluble in ether, chloroform, or other organic solvents, but have limited solubility in water. Lipids consist of a wide range of substances that share some common characteristics and compositional similarities. Triacylglycerols, which are fats and oils, constitute the most common category of substances known as lipids. Fats typically denote those lipids that are solid at room temperature, while oils denote those that are liquid at room temperature (Ellefson, 2017). The estimation of crude fat was done using the Soxhlet method **(Figure 29)** as per AOAC (2000). To calculate the fat content of the samples, empty round-bottom flasks were weighed. Thimbles were filled with a 5g sample contained within the Soxhlet apparatus extractor. The extractor was packed with petroleum ether (40°C–60°C), and the whole apparatus was secured. The fat extraction process was carried on for 8 hours. Once the extraction process was completed, thimbles were removed from the extractor. Subsequently, rotavapor was used to distill petroleum ether out of the flask. To remove any residual petroleum ether after the solvent was completely eliminated, the flasks were kept in the oven at 100° C. The flasks were weighed after being cooled in a desiccator. The percentage fat was calculated by the formula:

$$\text{Fat Content (\%)} = \frac{\text{Difference in the weight of the round bottom flask x 100}}{\text{Sample weight (g)}}$$

Figure 29: Soxhlet apparatus

3.9.3 PROTEIN

In all cells, proteins are plentiful components, and nearly all of them, storage proteins being the exception, play crucial roles in biological functions and cell structure. They consist of components such as hydrogen, carbon, nitrogen, oxygen, and sulfur. Nitrogen is the element that most characterizes proteins. The nitrogen content of different food proteins varies from 13.4% to 19.1% because of differences in the specific amino acid composition of the proteins (Chang et al., 2017). The Protein analyzer in the **Figure 30** was employed to determine the relative Protein content in various organic and inorganic chemical products and substances, regardless of their nature or origin. Samples may exist as solids, liquids, or gases. With the FLASH 2000 Series, the procedure for accurately assessing nitrogen levels has undergone a revolution. Samples weighing between 30 and 60 mg were placed in tin capsules, which were then automatically inserted into the sampler and introduced into an oxidation/reduction reactor maintained at a temperature of 900 to 1000 °C. Oxygen is injected into the reactor at the ideal moment for combustion. At elevated temperatures, the reaction between oxygen and the tin capsule initiates an exothermic process that raises the temperature briefly to 1800 °C. This extreme heat transforms both organic and inorganic materials into elemental gases. These gases are separated in a chromatographic column and detected using an extremely sensitive thermal conductivity detector after further reduction.

Figure 30: Protein Analyser

3.10 SENSORY ANALYSIS

The sensory evaluation of coconut crush beverage was carried out by reconstituted crush in the ratio 1:6 under pre-chilled conditions at 4℃ ± 1℃ for 2 hours. The beverage was then assessed for its appearance, taste, texture, colour and overall acceptability, to identify the formulation with best sensory attributes and quality. It was done using a 9 point Hedonic rating scale shown in the **Table 16**. 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 16: 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

3.11 STATISTICAL ANALYSIS

The data were evaluated to establish the final conclusions of statistical analysis using a single factor ANOVA (Analysis of Variance) in Microsoft Excel. 5% error bars were added to the plots to illuminate the variability and uncertainty.

CHAPTER 4

RESULT AND DISCUSSION

CHAPTER 4

RESULT AND DISCUSSION

The present study evaluates the effect of different additives on the physiochemical of coconut crush beverage over a storage period of 30 days**.** Various formulations were analyzed for parameters such as pH, total soluble solids (TSS), viscosity, color, and sensory attributes to assess the impact of additives on product stability and quality. The results obtained were compared to identify the most suitable formulation with optimal characteristics.

4.1 COMPOSITION OF END PRODUCT

Composition of the final concentrated and reconstituted coconut crush beverage is given in **Table 17**. Acoording 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 17: Composition of end product

PARAMETERS	COCONUT CRUSH (CONCENTRATED)				COCONUT CRUSH (RECONSTITUTED)			
	WC P	WC GG	CM P	CM SA	WC P	WC GG	CM P	CM SA
TSS (°BRIX)	69.6	68.7	67.7	68.8	10.9	10.9	10.5	10.6
pH	2.59	2.52	2.74	2.75	2.8	2.8	2.73	2.79
Titratable Acidity (%)	2.08	2.08	1.92	1.92	0.35	0.32	0.35	0.38
Reducing sugar (%)	23.45	21.36	24.39	30.86	3.7	2.2	3.45	3.51
Invert sugar (%)	57.8	57.14	69.44	69.44	11.47	11.41	10.48	10.48
Water conductivity (µS)	38.6	72.3	74.3	77.3	658	687	695.6	724.6
Calorific Value (Kcal/100g)	278.4	274.8	270.8	275.2	43.6	43.6	42	42.4

4.2 EFFECT OF COLOUR

Color is one of the most essential sensory attributes for assessing a product's quality and freshness. It is influenced by several factors, including storage temperature, sugar concentration, storage duration, and packaging type. **Table 18 & Figure 31** provides the details of the colour variation observed in the crush over 0-30 days. CM SA provided the best colour stability over 30 days in both concentrated and reconstituted form, suggesting it is an effective additive in preserving colour. WC GG and WC P showed the most colour instability with lightness (L*) decreasing and dE increasing significantly indicating darkening over time.

Table 18: Colour variation of Concentrated crush beverage during 0-30 days

SAMPLES	0 DAY				15 DAY				30 DAY			
	L*	a*	b*	dE	L*	a*	b*	dE	L*	a*	b*	dE
WC P	44.82 ±0.07	1.36 ±0.01	1.66 ±0.02	52.5 ±0.07	46.35 ±0.06	1.38 ±0.01	2.45 ±0.05	50.93 ±0.06	53.05 ±0.02	0.86 ±0.02	6.82 ±0.02	48.88 ±0.02
WC GG	60.89 ±0.14	2.06 ±0.02	4.06 ±0.06	35.87 ±0.13	46.85 ±0.06	2.29 ±0.01	0.74 ±0.03	50.39 ±0.06	55.95 ±0.15	1.63 ±0.01	5.34 ±0.06	51.6± 0.14
CM P	43.71 ±0.08	2.22 ±0.01	2.89 ±0.04	53.56 ±0.08	49.43 ±0.10	1.74 ±0.02	0.62 ±0.02	48.05 ±0.10	47.47 0.06	2.03 ±0.01	1.65 ±0.01	42.9 ±0.06
CM SA	49.06 ±0.14	2.22 ±0.01	0.22 ±0.04	48.15 ±0.14	52.56 ±0.01	1.98 ±0.02	2.33 ±0.02	44.69 ±0.01	54.02 ±0.22	1.86 ±0.02	2.15 ±0.05	49.46 ±0.22

Table 19 & Figure 32 provides the details of the colour variation observed in the reconstituted crush over 0-30 days.

Table 19: Colour variation of Reconstituted crush beverage during 0-30 days

SAMPLES	0 DAY				15 DAY				30 DAY			
	L*	a*	b*	dE	L*	a*	b*	dE	L*	a*	b*	dE
WC P	59.92 ±0.19	0.96 ±0.01	1.11 ±0.01	36.55 ±0.19	54.93 ±0.45	1.07 ±0.01	1.67 ±0.03	42.20 ±0.44	53.55 ±0.51	0.95 ±0.01	1.64 ±0.05	48.95 ±0.51
WC GG	52.41 ±0.22	1.08 ±0.03	1.99 ±0.11	44.01 ±0.21	50.27 ±0.73	1.28 ±0.01	2.76 ±0.07	47.01 ±0.73	48.61 ±0.47	1.22 ±0.01	2.94 ±0.02	44.09 ±0.47
CM P	49.07 ±0.5	1.29 ±0.01	3.11 ±0.01	48.16 ±0.5	45.91 ±0.18	1.23 ±0.01	3.5 ±0.05	51.64 ±0.18	46.15 ±0.43	1.23 ±0.01	3.62 ±0.07	41.69 ±0.42
CM SA	47.72 ±0.59	1.34 ±0.02	2.34 ±2.41	49.5 ±0.59	44.46 0.41	1.27 ±0.22	3.08 ±0.04	53.01 ±0.42	47.28 ±0.13	1.39 ±0.02	3.08 ±0.06	42.79 ±0.13

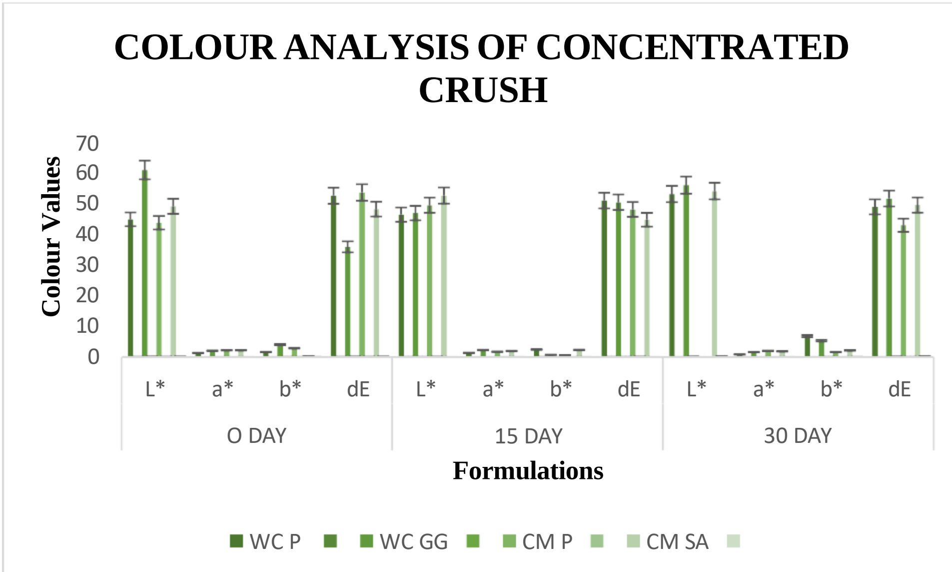


Figure 31: Colour variations in concentrated coconut crush beverage during 30 days storage

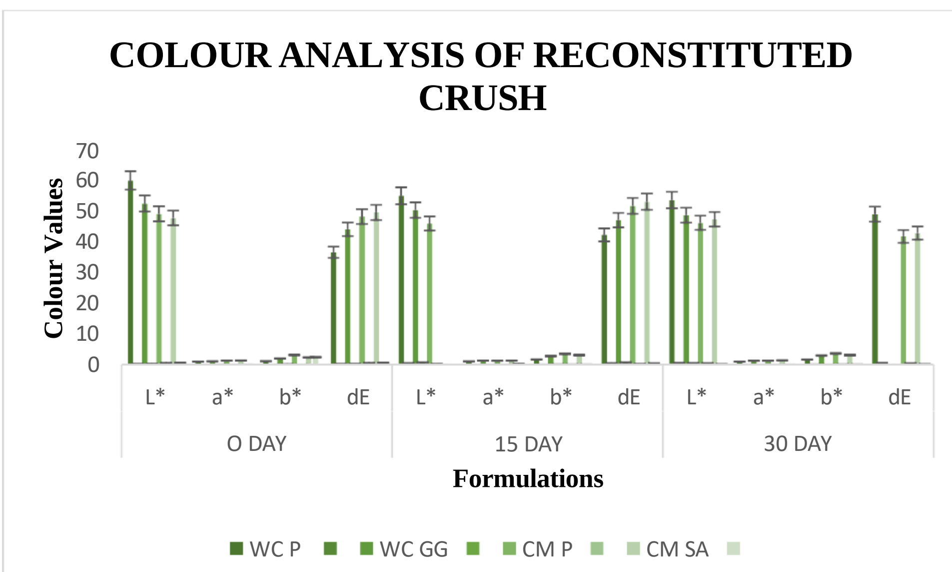


Figure 32: Colour variations in Reconstituted coconut crush beverage during 30 days storage

4.3 EFFECT OF PARTICLE SIZE

The size of the product's particles has a major effect on the mouthfeel, texture, processing, and solubility of the ingredients used in it. **Table 20** provides the details of particle size variation observed in the reconstituted crush over 0-30 days. CM SA provided better stability as particle size remained more consistent (105.8-93.13μm) indicating least fluctuation over storage ensuring better suspension. WC GG showed the highest particle size variation, diameter increased drastically (197.0-443.61μm) indicating instability and aggregation over time.

Table 20: Particle size variation in reconstituted crush during 0-30 days

RECONSTITUTED CRUSH	0 DAY			15 DAY			30 DAY		
	DIA (μm)	VOL (%)	WID (μm)	DIA (μm)	VOL (%)	WID (μm)	DIA (μm)	VOL (%)	WID (μm)
WC P	155.9	100	168.8	151.86	100	324.73	157.08	100	167.8
WC GG	197.0	100	273.43	443.61	100	231.66	211.7	100	257.0
CM P	48.79	100	112.2	41.82	100	92.13	40.0	100	89.18
CM SA	105.8	100	154.3	97.35	100	112.5	93.13	100	87.0

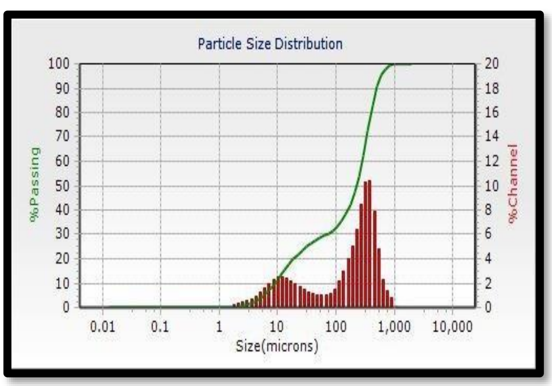


Figure 33: Particle size of WC P (0 DAY)

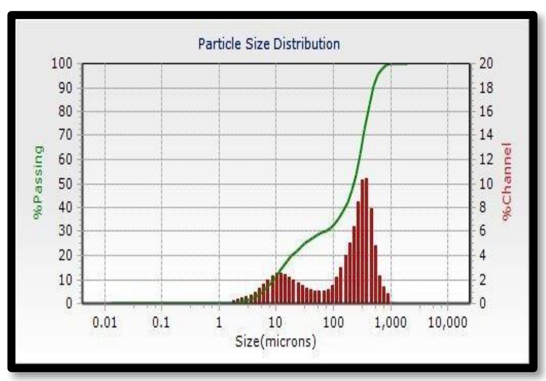
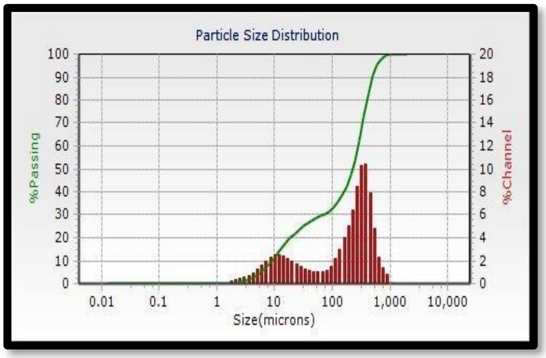


Figure 34: Particle size of WC GG (0 DAY)



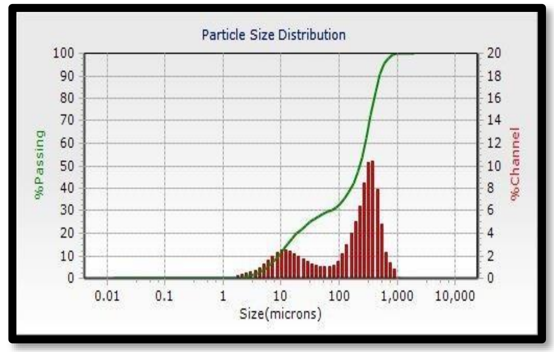
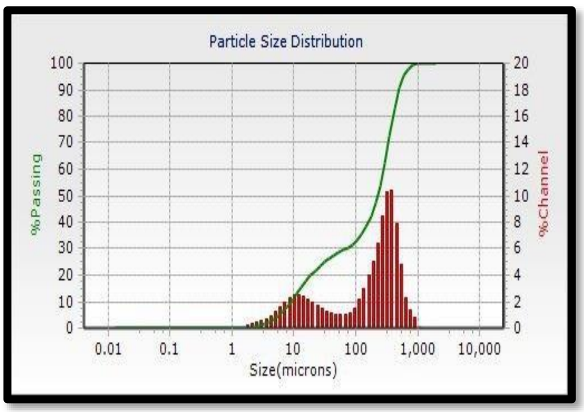


Figure 35: Particle size of CM P (0 DAY)

Figure 36: Particle size of WC GG (0 DAY)



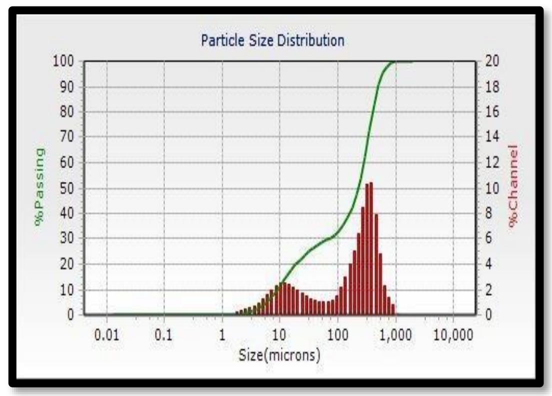
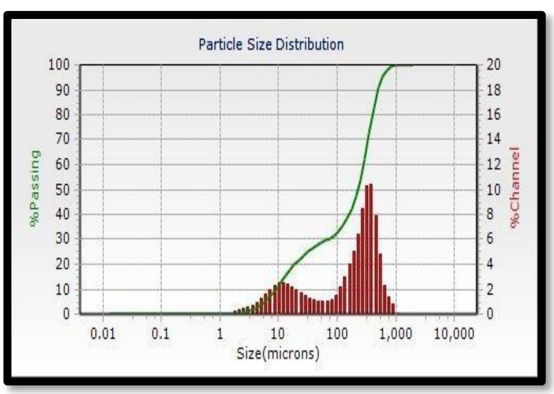


Figure 37: Particle size of WC P (15 DAY)

Figure 38: Particle size of WC GG (15 DAY)



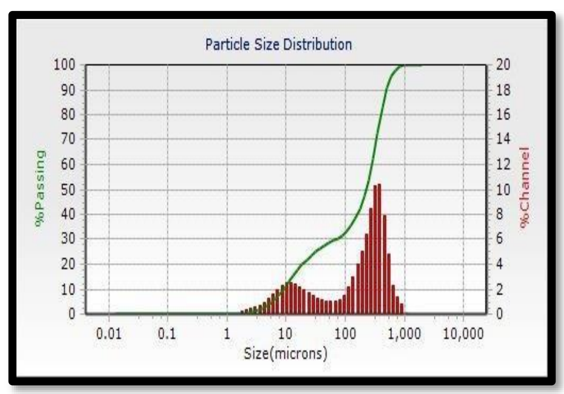
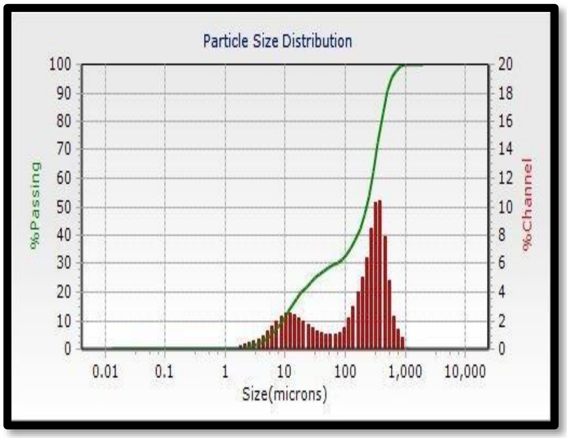


Figure 39: Particle size of CM P (15 DAY)

Figure 40: Particle size of CM SA (15 DAY)



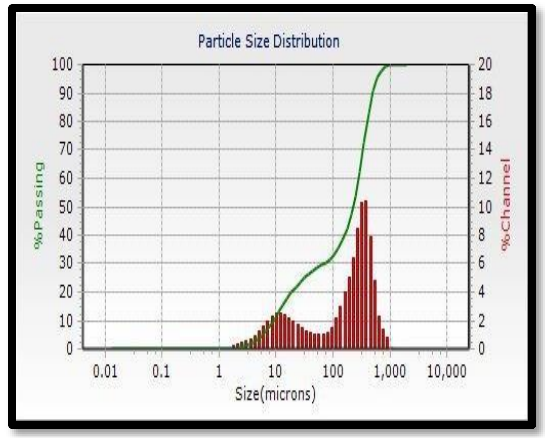
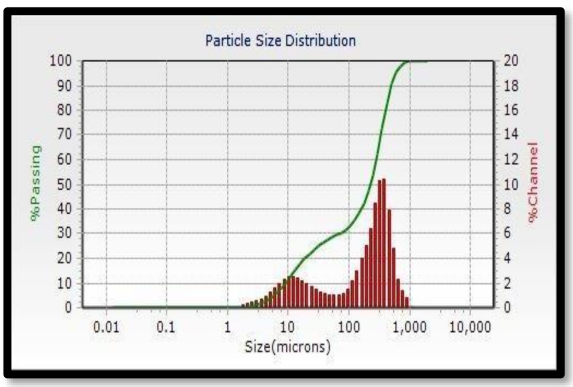


Figure 41: Particle size of WC P (30 DAY) **Figure 42: Particle size of WC GG (30 DAY)**



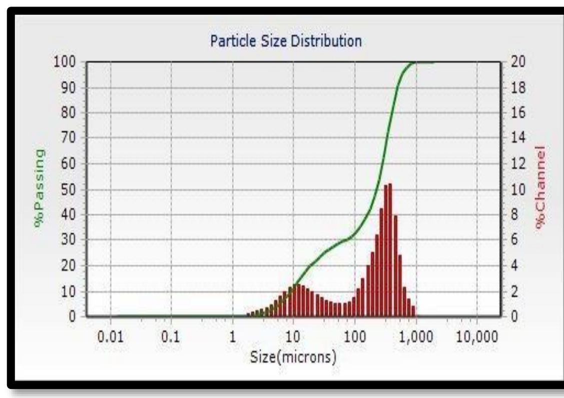


Figure 43: Particle size of CM P (30 DAY) **Figure 44: Particle size of CM SA (30 DAY)**

4.4 EFFECT OF VISCOSITY

Viscosity is the measure of a liquid's resistance to flow. Factors such as temperature, fat content and the presence of stabilizers or emulsifiers influence viscosity. **Table 21 & Figure 45** provides the details of viscosity variation observed in the reconstituted crush over 0-30 days. Whole coconut crush (WC) has more fat than coconut milk crush (CM) due to its higher solid content and less dilution which decreases its viscosity due to fat separation and instability. WC GG shows good viscosity retention, thereby helping in thickening and preventing phase separation. CM P and CM SA shows moderate stability while WC P experiences biggest drop making it less stable. **Table 22** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various reconstituted coconut crush beverages was significantly different from each other at p value ≥ 0.05 level.

Table 21: Viscosity (cP) of Reconstituted crush beverage during 0-30 days

SAMPLES	O DAY	15 DAY	30 DAY
WC P	12	10	6
WC GG	16	10	10
CM P	8	10	10
CM SA	8	10	10

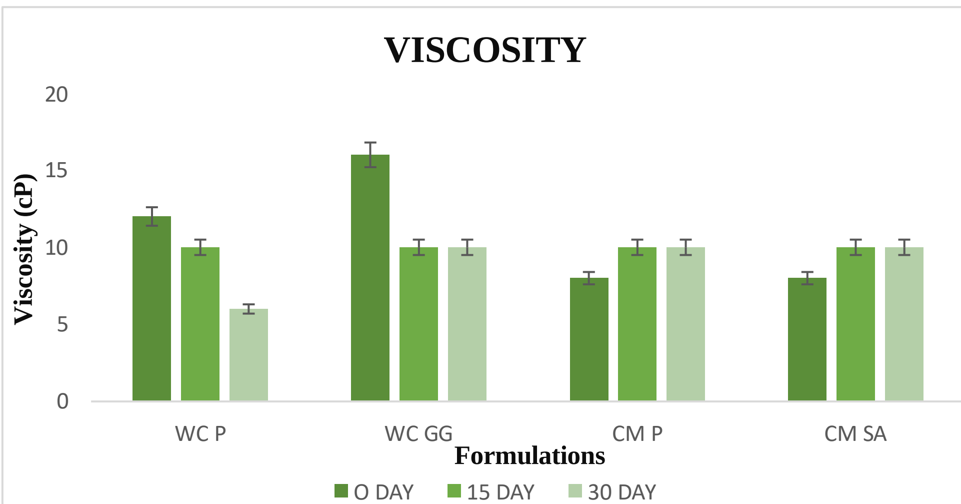


Figure 45: Viscosity (cP) variations in Reconstituted crush beverage during 0-30 days

Table 22: ANOVA for viscosity (cP) variations in reconstituted crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8	2	4	0.642857	0.548323	4.256495
Within Groups	56	9	6.222222			
Total	64	11				

4.5 EFFECT OF pH

The pH of all coconut crush formulations increased over the 30 day storage period, indicating a slight reduction in acidity. **Table 23 & Figure 46** provides the details of pH variation observed in the concentrated and reconstituted crush over 0-30 days. Reconstituted samples showed a higher pH increase compared to concentrated ones, likely due to dilution effects. Among formulations, CM P and CM SA exhibited better pH stability, while WC P and WC GG showed more variation. **Table 24** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various concentrated and reconstituted coconut crush beverages was non significant from each other at p value ≤ 0.05.

Table 23: pH of Concentrated and Reconstituted crush beverage during 0-30 days

PRODUCT VARIANT	COCONUT CRUSH (CONCENTRATED)			COCONUT CRUSH (RECONSTITUTED)		
	0 DAY	**15 DAY**	**30 DAY**	**0 DAY**	**15 DAY**	**30 DAY**
WC P	2.59	2.71	2.89	2.8	2.84	2.94
WC GG	2.52	2.7	2.64	2.8	2.89	2.98
CM P	2.74	2.76	2.80	2.73	2.94	2.96
CM SA	2.75	2.77	2.82	2.79	2.93	2.95

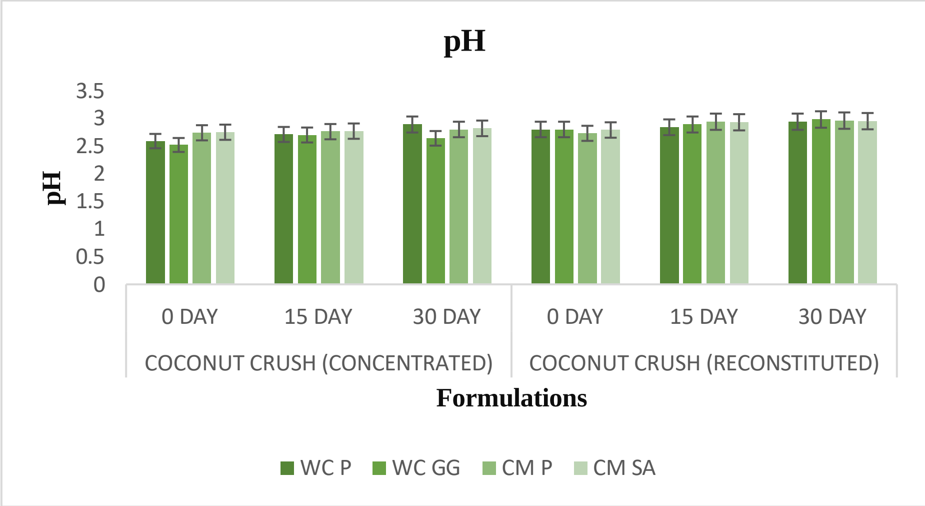


Figure 46: pH variations in coconut crush beverage during 0-30 days

Table 24: ANOVA for pH variations in coconut crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.248283	5	0.049657	10.36313	8.36E-05	2.772853
Within Groups	0.08625	18	0.004792			
Total	0.334533	23				

4.6 EFFECT OF TITRABLE ACIDITY

The titrable acidity of all coconut crush formulations decreased over 30 days, indicating a reduction in organic acid content. **Table 25 & Figure 47** provides the details of TA variation observed in the reconstituted crush over 0-30 days. Concentrated samples showed a slower decline in acidity compared to reconstituted ones, likely due to dilution effects. WC P and WC GG started with higher acidity but declined to 1.6% (concentrated) and 0.19% (reconstituted), while CM P and CM SA showed a similar trend. This decrease in acidity aligns with the increase in pH, suggesting acid degradation over storage. **Table 26** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various concentrated and reconstituted coconut crush beverages was significantly different from each other at p value ≥ 0.05.

Table 25: TA (% Anh. C.A) of Concentrated and Reconstituted crush beverage during 0-30 days

PRODUCT VARIANT	COCONUT CRUSH (CONCENTRATED)			COCONUT CRUSH (RECONSTITUTED)		
	0 DAY	15 DAY	30 DAY	0 DAY	15 DAY	30 DAY
WC P	2.08	1.9	1.6	0.35	0.31	0.19
WC GG	2.08	1.9	1.6	0.32	0.31	0.19
CM P	1.92	1.6	1.4	0.35	0.22	0.19
CM SA	1.92	1.6	1.4	0.38	0.22	0.19

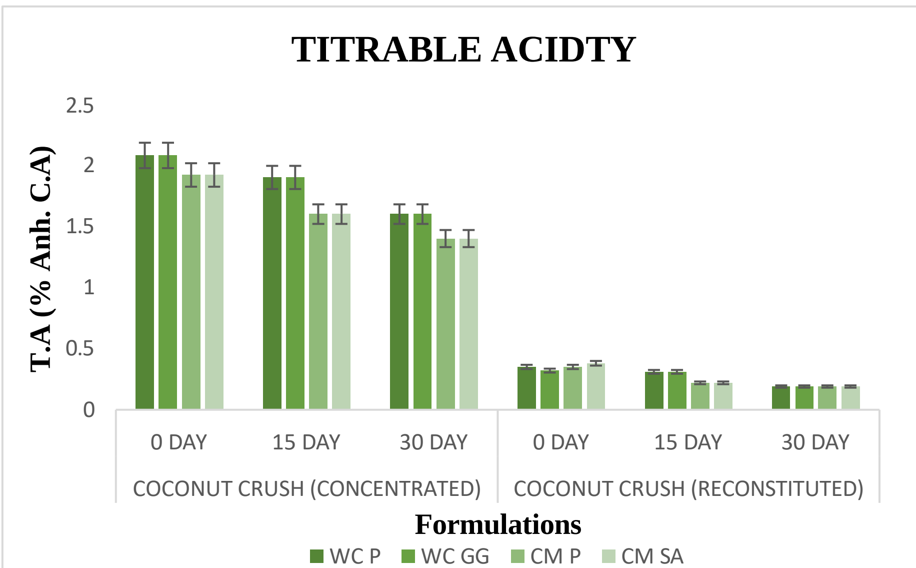


Figure 47: Acidity (% Anh. C.A) variations in coconut crush beverage during 0-30 days

Table 26: ANOVA for TA (% Anh. C.A) of coconut crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.72328	5	2.744657	298.5125	1.18E-16	2.772853
Within Groups	0.1655	18	0.009194			
Total	13.88878	23				

4.5 EFFECT OT TOTAL SOLUBLE SOLIDS

The changes in TSS of concentrated and reconstituted samples over 0-30 days are illustrated in **Table 27 & Figure 48**. The TSS of concentrated samples remained mostly stable with minor fluctuations, while reconstituted samples showed a gradual decline over 30 days, likely due to sugar degradation, dilution effects or sedimentation. CM P and CM SA exhibited better TSS retention, indicating improved stability compared to WC P and WC GG. **Table 28** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various concentrated and reconstituted coconut crush beverages was non significant from each other at p value ≤ 0.05.

Table 27: TSS (°Brix) of Concentrated and Reconstituted crush beverage during 0-30 days

PRODUCT VARIANT	COCONUT CRUSH (CONCENTRATED)			COCONUT CRUSH (RECONSTITUTED)		
	0 DAY	**15 DAY**	**30 DAY**	**0 DAY**	**15 DAY**	**30 DAY**
WC P	69.6	69.4	69.5	10.9	9.9	9.9
WC GG	68.7	67.7	67.4	10.9	9.5	9.5
CM P	67.7	67.7	67.5	10.5	9.8	9.5
CM SA	68.8	68.8	67.5	10.6	10	9.8

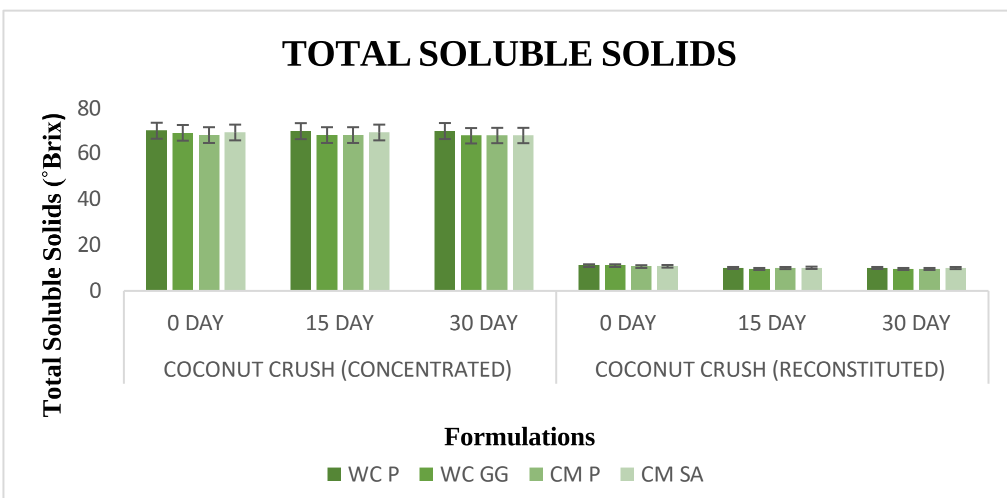


Figure 48: TSS (°Brix) variations in coconut crush beverage during 0-30 days

Table 28: ANOVA for TSS (°Brix) of coconut crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20391.2	5	4078.241	9836.963	2.89E-30	2.772853
Within Groups	7.4625	18	0.414583			
Total	20398.67	23				

4.6 EFFECT OF WATER CONDUCTIVITY

Conductivity in fruit beverages depends on the presence of dissolved ions such as minerals, salts, acids and sugars. In fruit beverages conductivity generally increases over time due to mineral leaching, acid breakdown or fermentation. **Table 29 & Figure 49** provides the details of water conductivity variation observed in the reconstituted crush over 0-30 days. Reconstituted samples had higher conductivity than concentrated ones, likely due to greater ion mobility in liquid form. CM P and CM SA exhibited higher conductivity and a more controlled increase, suggesting better mineral retention whereas WC GG and WC P showed a steeper rise possibly due to greater ion release or breakdown of soluble compounds. **Table 30** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various concentrated and reconstituted coconut crush beverages was non significant from each other at p value ≤ 0.05 level.

Table 29: Water Conductivity (µS) of Concentrated and Reconstituted crush beverage during 0-30 days

PRODUCT VARIANT	COCONUT CRUSH (CONCENTRATED)			COCONUT CRUSH (RECONSTITUTED)		
	0 DAY	**15 DAY**	**30 DAY**	**0 DAY**	**15 DAY**	**30 DAY**
WC P	38.6	52.3	60.5	658	693	722
WC GG	72.3	101	122	687	766	790
CM P	74.3	87.3	98.2	695.6	740	767
CM SA	77.3	91.6	115	724.6	763	780

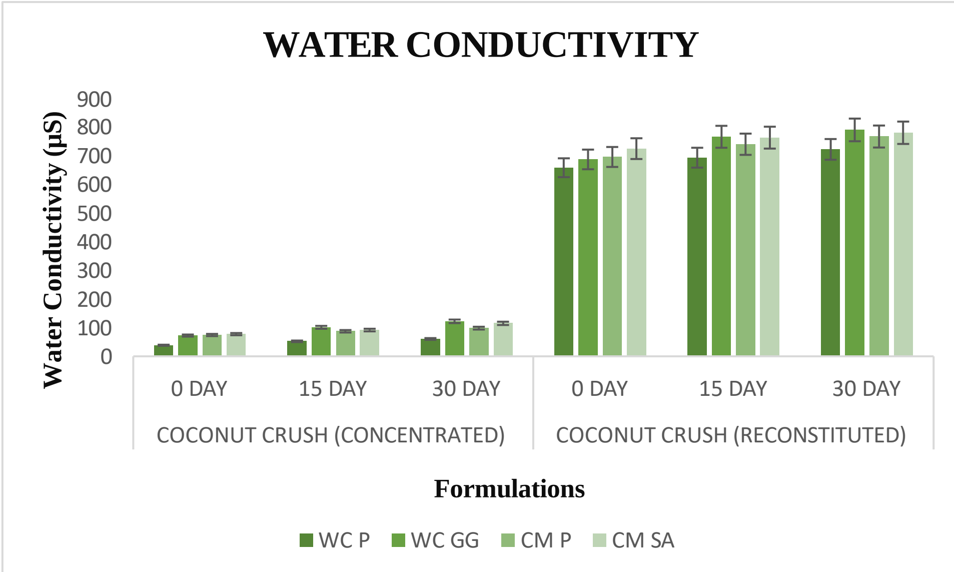


Figure 49: Water conductivity (µS) variations in coconut crush beverage during 0-30 days

Table 30: ANOVA for water conductivity (µS) of coconut crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2545695	5	509139	705.8426	5.47E-20	2.772853
Within Groups	12983.78	18	721.3208			
Total	2558679	23				

4.7 EFFECT OF TURBIDITY

Table 31 and Figure 50 provides the effect of turbidity observed in the reconstituted crush over 0- 30 days. Turbidity remained constant at 1000 across all the product variants over 0, 15 and 30 days. This suggests no significant changes in particle dispersion, stability or precipitation over time. Additives might have played a role in maintaining uniform dispersion, preventing sedimentation or phase separation.

Table 31: Turbidity (FTU) of Reconstituted crush beverage during 0-30 days

SAMPLES	0 DAY	15 DAY	30 DAY
WC P	1000	1000	1000
WC GG	1000	1000	1000
CM P	1000	1000	1000
CM SA	1000	1000	1000

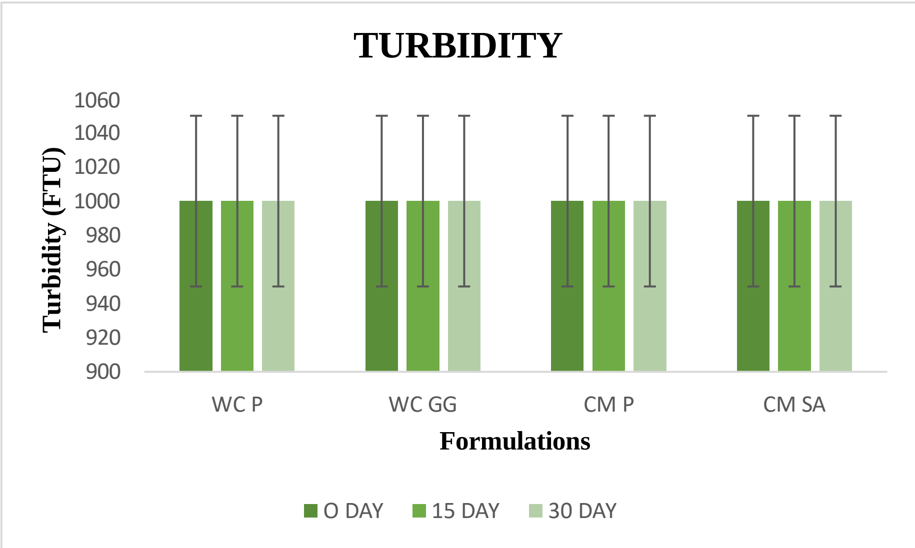


Figure 50: Turbidity (FTU) variations in coconut crush beverage during 0-30 days

4.8 EFFECT OF SUGARS

4.8.1 REDUCING SUGAR

The changes in reducing sugar of concentrated and reconstituted samples over 0-30 days are illustrated in **Table 32 & Figure 51**. Reducing sugar content increased steadily over 30 days in both concentrated and reconstituted samples. The increase is more pronounced in concentrated samples, likely due to hydrolysis of complex sugars or degradation of polysaccharides. CM SA had the highest reducing sugar content throughout, indicating potential enzymatic or preservative effects. WC GG had the lowest values, suggesting less hydrolysis or slower sugar conversion possibly due to ingredient interactions. Reconstituted forms had lower reducing sugar values compared to their concentrated forms as dilution reduces sugar concentration. **Table 33** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various concentrated and reconstituted coconut crush beverages was significantly different from each other at p value ≥ 0.05.

Table 32: Reducing sugar (%) of Concentrated and Reconstituted crush beverage during 0-30 days

PRODUCT VARIANT	COCONUT CRUSH (CONCENTRATED)			COCONUT CRUSH (RECONSTITUTED)		
	0 DAY	**15 DAY**	**30 DAY**	**0 DAY**	**15 DAY**	**30 DAY**
WC P	23.45	34.06	36.52	3.7	4.1	4.4
WC GG	21.36	30.23	35.63	2.2	3.02	3.6
CM P	24.39	27.34	30.24	3.45	3.82	4.21
CM SA	30.86	33.45	38.78	3.51	4.1	4.9

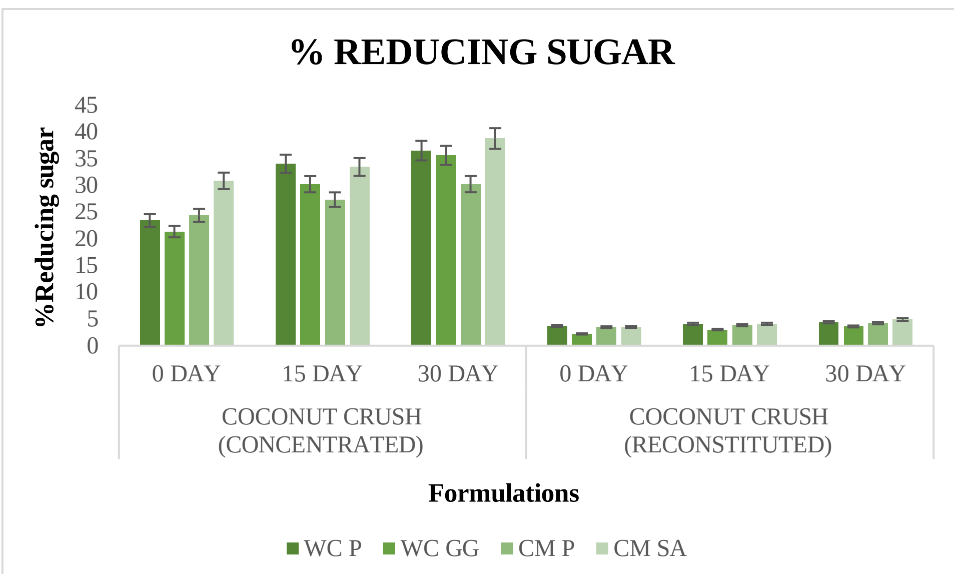


Figure 51: Reducing sugar (%) variations in coconut crush beverage during 0-30 days

Table 33: ANOVA for reducing sugar (%) of coconut crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3149.849	5	629.9697	142.9019	2.91E-10	3.105875
Within Groups	52.90087	12	4.408406			
Total	3202.75	17				

4.8.2 TOTAL INVERT SUAGR

The changes in reducing sugar of concentrated and reconstituted samples over 0-30 days are illustrated in **Table 34 & Figure 52**. Invert sugar levels increased over time in both concentrated and reconstituted crush, suggesting sucrose hydrolysis during storage. WC P and WC GG showed the highest increase in concentrated form reaching 81.57% by 30 day, indicating higher sucrose breakdown. CM P and CM SA had lower values (71.23%) in concentrated form, possibly due to stabilizing additives that slow hydrolysis. Reconstituted samples showed minimal increase as dilution reduces sugar concentration. **Table 35** shows Statistical analysis of variance (ANOVA) which revealed that the data analysed for various concentrated and reconstituted coconut crush beverages was significantly different from each other at p value ≥ 0.05.

Table 34: Total Invert sugar (%) of Concentrated and Reconstituted crush beverage during 0-30 days

PRODUCT VARIANT	COCONUT CRUSH (CONCENTRATED)			COCONUT CRUSH (RECONSTITUTED)		
	0 DAY	15 DAY	30 DAY	0 DAY	15 DAY	30 DAY
WC P	57.7	71.4	81.57	11.47	11.56	11.58
WC GG	57.14	71.4	81.57	11.41	11.56	11.58
CM P	69.44	69.44	71.23	10.48	11.36	11.38
CM SA	69.44	69.44	71.23	10.48	11.36	11.38

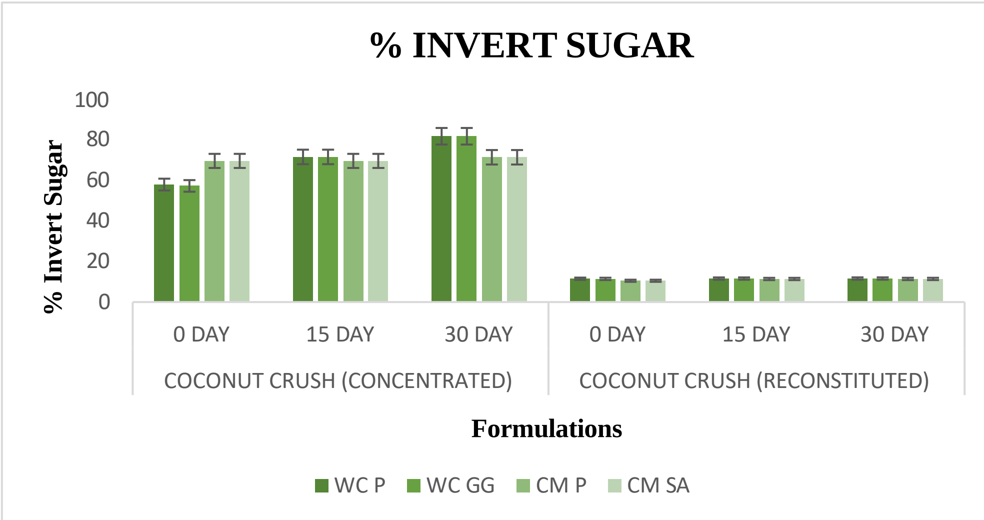


Figure 52: Invert sugar (%) variations in coconut crush beverage during 0-30 days

Table 35: ANOVA for invert sugar (%) of coconut crush during storage

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21075.48	5	4215.095	297.3028	1.22E-16	2.772853
Within Groups	255.2001	18	14.17778			
Total	21330.68	23				

4.9 ESTIMATION OF FAT

Table 36 & Figure 53 provides the details of fat conent estimated in the crush. Fat content varies among the samples with CM SA having the highest (5.08%) and WC GG the lowest (3.31%). This indicates differences in formulations, possibly due to the type of coconut used or the presence of additives. Higher fat content can enhance texture and mouthfeel, while lower fat may improve stability and shelf life.

Table 36: Fat (%) content of coconut crush beverage

SAMPLES	FAT (%)
WC P	4
WC GG	3.31
CM P	3.9
CM SA	5.08

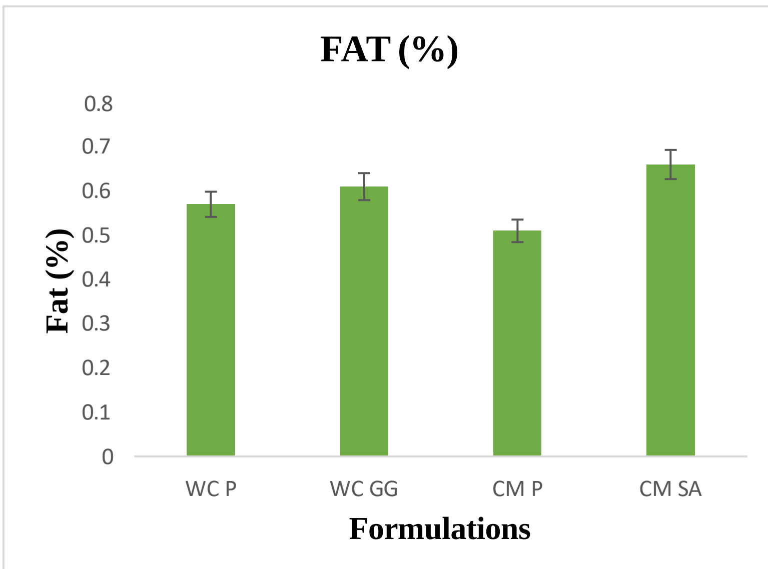


Figure 53: Fat (%) content in coconut crush beverage

4.10 ESTIMATION OF PROTEIN

Table 37 & Figure 54 provides the details of protein content estimated in the crush respectively. The protein content in the samples is relatively low with CM SA having the highest (0.66%) and CM P the lowest (0.51%). The variation suggests that certain additives or formulations might contribute slightly to protein retention. While coconut based beverages are not a significant protein source, higher protein content can enhance nutritional values.

Table 37: Protein (%) content of coconut crush beverage

SAMPLES	PROTEIN (%)
WC P	0.57
WC GG	0.61
CM P	0.51
CM SA	0.66

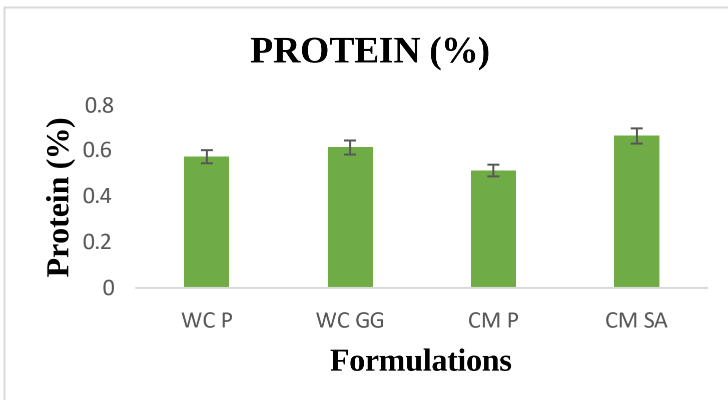


Figure 54: Protein (%) content of coconut crush beverage

4.10 SENSORY EVALUATION

A 9-point hedonic scale was used for quantitative research in order to assess the sensory qualities of coconut crush beverage. The evaluation was initially conducted to identify the best acceptable formulation. Evaluation criteria included general acceptability as well as appearance, color, flavor, taste, and texture. This is crucial for product development since the features and product should persuade potential buyers to purchase the product. **Figure 55** shows visual representation of sensory evaluation of coconut crush beverage.

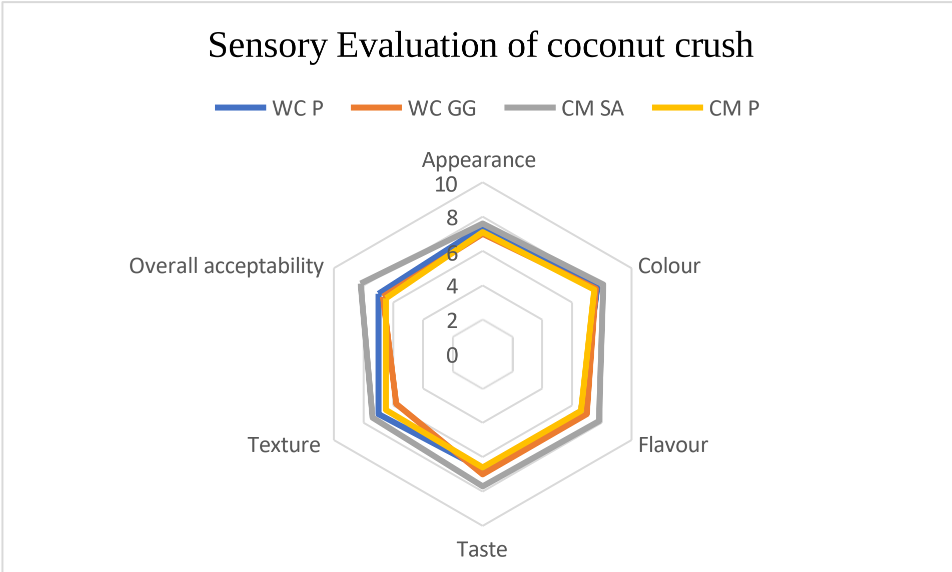


Figure: 55 Sensory evaluation of coconut crush beverage

4.10.1 EVALUATION OF APPEARANCE

The scores across panelists appear fairly consistent for all samples. CM SA (7.6) and WC P (7.4) seem to have higher appearance compared to CM P (7.1) and WC GG (7). Some variation exists among the panelists but overall, the scores range between 6 and 9, indicating good visual appeal across all variants.

4.10.2 EVALUATION OF COLOUR

The colour evaluation shows that all samples received moderate to high scores from the panelists. CM SA (8.1) and WC P (7.7) had slightly higher ratings, indicating better colour appeal.

4.10.3 EVALUATION OF FLAVOUR

Flavour was perceived by the panel members and CM SA (7.8)was most preferred in terms of flavour by the panelists followed by WC P, CM P and WC GG.

4.10.4 EVALUATION OF TASTE

According to taste evaluation data, CM SA(7.7) and WC GG (7) received the highest scores, suggesting they were the most preferred in taste. WC GG and CM P were less favored by panelist. Taste of the beverage was evaluated in terms of sweetness and sourness.

4.10.5 EVALUATION OF TEXTURE

Among the panelist, CM SA (7.7) had the best texture perception, WC P and CM P had moderate ratings while WC GG (5.8) had the lowest scores. Texture was analysed based on the thickness and consistency of the beverage.

4.10.6 EVALUATION OF OVERALL ACCEPTABILITY

According to the sensory analysis performed and the scores obtained CM SA (8.2) appears to have received the highest ratings overall suggesting it was the most preferred sample. WC P (7) and WC GG (6.7) followed closely, indicating moderate acceptability. CM P (6.5) had the lowest ratings, suggesting it was the least preferred.

CHAPTER 5
CONCLUSION

CHAPTER 5

CONCLUSION

The present study focused on the development of a novel coconut crush beverage using whole coconut, coconut milk and coconut fibre enhanced with various stabilizers such as pectin, sodium alginate and gellan gum. The primary aim was to improve the physiochemical properties, sensory attributes and storage stability of the beverage. Among the different formulations, fibre based coconut crush was rejected based on sensory evaluation due to its coarse particle size, highlighting the importance of texture refinement for consumer acceptability. As a result, the formulation excluding fibre were further optimized.

Physiochemical analysis indicated that additives influenced parameters like viscosity, pH, total soluble solids and acidity which in turn affected the sensory perception of the beverage. Protein estimation across all the formulations revealed negligible protein content. Fat analysis indicated the highest content in CM SA (5.08%) and the lowest in WC GG (3.1%). Turbidity remained stable throughout the storage period for all formulations, maintaining a value of 1000 FTU. Particle size analysis showed that CM SA exhibited superior stability, with particle size remaining relatively consistent (105.8-93.13μm), indicating minimal fluctuation during storage. Viscosity analysis demonstrated that WC GG maintained good viscosity retention, contributing to effective thickening and prevention of phase separation.

The sensory evaluation was carried out using 9 point hedonic scale which in particular, adds a consumer centric perspective to the research, ensuring that the developed beverage meet not only nutritional standards but also consumer preference in terms of taste, colour, and overall acceptability. CM SA emerged as the most preferred formulation due to its superior sensory attributes in terms of appearance (7.6), colour (8.1), flavour (7.8) and enhanced stability compared to others.

The optimized coconut crush beverage developed in this study is a unique and innovative product that offers potential health benefits due to the presence of natural coconut components, including dietary fiber, healthy fats, essential nutrients which aids digestion and provide hydration.

Furthermore, the incorporation of stabilizers contributed to improved texture, stability and overall sensory appeal, enhancing the product's market potential. As a novel addition to the beverage industry, this coconut crush can cater to health conscious consumers seeking natural and functional drinks. Future research can focus on refining the texture of fibre based formulations and evaluating their nutritional and functional properties to expand the product range.

CHAPTER 6
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