PROCESS OPTIMIZATION AND CHARACTERIZATION OF ARROWROOT BASED FUNCTIONAL HEALTH BEVERAGE

BY,

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KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND FOOD TECHNOLOGY

TAVANUR-679573, MALAPPURAM

KERALA, INDIA

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PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree of

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Department of Processing and Food Engineering

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND FOOD TECHNOLOGY

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DECLARATION

I hereby declare that this thesis entitled "**PROCESS OPTIMIZATION AND CHARACTERIZATION OF ARROWROOT BASED FUNCTIONAL HEALTH BEVERAGE"** is a bonafide record or research work done by us during the course of research and the project report has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date: 17/01/2025

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CERTIFICATE

Certified that this project report entitled "**PROCESS OPTIMIZATION AND CHARACTERIZATION OF ARROWROOT BASED FUNCTIONAL HEALTH BEVERAGE"** is a bonafide record of research work done independently by **Lesna V L (2021-06-020), Asna T A (2021-06-022), Sravya C (2021-06-023), Muhsin (2021-06-024), Binsiya (2021-06-027)** under any guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associate ship.

Place: Tavanur
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LIST OF SYMBOLS AND ABBREVIATIONS

$	:	Dollar
%	:	Per cent
&	:	And
/	:	Per
+	:	Plus
=	:	Equal to
±	:	Plus or minus
°C	:	Degree Celsius
3D	:	Three-Dimensional
a*	:	Greenness or redness
ANOVA	:	Analysis of variance
AOAC	:	Association of official analytical chemists
a_w	:	Water activity
b*	:	Blueness or yellowness
CAGR	:	Compound annual growth rate
CFU	:	Colony forming units
Cfu/g	:	Colony-forming unit per gram
Cm	:	Centimeter
$CUSO_4$	:	Copper sulphate
DPPH	:	2, 2-Diphenyl-1-picrylhydrazyl
et al.	:	And others
etc	:	Etcetera
Fig	:	Figure
g	:	Gram
g/ml	:	gram per millilitre
GC- MS	:	Gas Chromatography- Mass Spectrometry
GI	:	Glycemic index
gm	:	Gram
h	:	Hours
H_2SO_4	:	Sulphuric acid

HCl	:	Hydrochloric acid
Hrs	:	Hours
i.e	:	That is
Inc.	:	Incorporation
KAU	:	Kerala Agricultural University
KCAEFT	:	Kelappaji College of Agricultural Engineering and Food Technology
KMS	:	Potassium meta bisulphate
kWh	:	Kilowatt hour
L*	:	Lightness or darkness
Min	:	Minute
N	:	Normality
NaOH	:	Pottasium hydroxide
nm	:	Nanometer
PET	:	Polyethylene Terephthalate
ppm	:	Parts per million
rpm	:	Rotation per minute
RSM	:	Response surface methodology
RTS	:	Ready to serve
t ha $^{-1}$	:	Tonnes per hectare
TPC	:	Total plate count
TSS	:	Total soluble solids
USA	:	United states of America
USD	:	United States Dollar
viz.,	:	Namely
WHO	:	World Health Organisation

CHAPTER I
INTRODUCTION

Food is a vital component of the human diet. When consumed daily, it helps to reduce the risk of various diseases by providing essential nutrients such as vitamins, minerals, energy and fiber. Over the past decade, there has been a growing interest in the food sector in incorporating antioxidant substances of plant origin for the functionalization of a wide range of food products. Alongside this trend, the demand for health drinks has also increased, as individuals strive to maintain a healthy and balanced lifestyle. Health drinks are specially formulated beverages that offer a variety of essential nutrients, vitamins and minerals, making them an appealing choice for those seeking to enhance their overall well-being. These drinks may or may not contain added ingredients, and their primary function is generally to support overall health and wellness rather than provide targeted therapeutic benefits (Vilas-Boas et al., 2021).

The World Health Organization (WHO) has emphasized the health benefits of functional foods and beverages, contributing significantly to their growing global popularity. In addition to this, consumers have become increasingly aware of the importance of food composition and nutrition in maintaining overall health. Among the fastest-growing segments within the functional food industry is the functional beverages market, which focuses on fortified beverages or novel products designed to enhance the bioavailability of bioactive compounds and deliver targeted health benefits. The bioactive ingredients in functional beverages include phenolic compounds, minerals, vitamins, amino acids, peptides, unsaturated fatty acids, etc. which can be obtained from plant, animal and microorganisms. The types of functional beverages which are globally intensifying the markets are pre-/pro-biotics, beauty drinks, cognitive and immune system enhancers, energy and sports drink produced via several thermal and non-thermal processes (Gupta *et al*., 2023). The modern era has witnessed a significant shift in dietary preferences, with consumers seeking healthier alternatives that combine nutrition, taste, and convenience. Functional beverages, designed to offer nutritional and health benefits beyond basic sustenance, have become a focal point of innovation in the food and beverage industry. Among the many plant-based ingredients gaining attention for their health-promoting properties, arrowroot **(***Maranta arundinacea***)** holds particular promise.

Owing to its versatility and nutrient-dense composition, arrowroot presents a valuable potential for the formulation of wholesome and palatable health beverages.

Arrowroot (*Maranta arundinacea*), including the Marantaceae family, meaning plants that have rhizome roots (tubers) shaped like arrows, is an herbaceous plant, perennials have a height of 60-80 cm. The plant has a perennial fibrous starchy rhizome producing numerous fusiform fleshy, scaly tubers from its crown. The fleshy, white and cylindrical rhizome is covered with regular scale leaves and grows approximately 2.5 to 5.0 cm thick and 20-45 cm in height. It is used for the extraction of a very fine easily digestible starch known as the arrowroot starch. Yields of rhizomes normally average about 12 to 31 t ha-1 depend on the land condition and the normal commercial yield of starch is 8-16 % (Qodliyati & Nyoto, 2018).

The arrowroot is native to Mexico, Central America, the West Indies and South America. It is originated from tropical America, or precisely from West Indians, and spread to tropical regions where these plants would grow and adapt. This plant can grow and develop easily in even less fertile soil types (Djaafar *et al*., 2010).

The starch content in the rhizome of arrowroot varies depending on the plant's age, comprising around 20% and in this starch content, approximately 20–30% is composed of amylose. The tuber can be consumed directly or processed into semi-finished form of arrowroot flour (Anggun *et al*., 2017).

In 2024, India continued to be the world leader in arrowroot production and exports, accounting for 52% of global arrowroot powder exports with 1,383 shipments. The country’s export industry is robust, comprising 173 manufacturers and exporters, and its arrowroot products reached 18 different countries during this period. The United States was the largest importer, receiving 70% of India’s shipments, followed by the United Kingdom and the United Arab Emirates, which together accounted for 84% of India’s total arrowroot powder exports. Other notable export destinations included Canada, Australia, Kuwait, Qatar, Malaysia, and the Netherlands. Despite its strong position, India experienced a decline in export growth, with an 8% decrease in shipments from October 2023 to September 2024.

Globally, over 28 countries contributed to the export of arrowroot powder in 2024. After India, Thailand and Vietnam were significant exporters, holding 23% and 9% of the market share, respectively. In the broader arrowroot market, the United States and

China also played key roles, with the United States accounting for 18% and China for 9% of global arrowroot exports. The global arrowroot flour market was valued at approximately USD 875 million in 2024, reflecting steady demand and a diverse international trade network.

These figures highlight India's dominance in the arrowroot sector and the importance of the United States and other developed markets as primary destinations for arrowroot products. While the industry faced some short-term challenges in export growth, the overall global market for arrowroot remained strong and diversified in 2024.

Arrowroot is beneficial for health because it is low in calories compared to the other tubers such as potatoes, yams, cassava, and so forth. Arrowroot starches contain amylopectin (80%) and amylose (20%) (Priadi *et al*., 2000). Arrowroot is used externally as well as internally because the starch contains alternative sources of carbohydrate, it is widely used as a stabilizing agent in food, condiments, soup, candy, pudding and ice cream. Arrowroot also contains more protein compared to other tropical food sources such as the sweet potatoes, potatoes, cassava, bananas and so forth. The other advantage of arrowroot tubers is that they are gluten-free as in other roots and tubers. Gluten-free starch is used for patients with celiac disease (Setyowati *et al*., 2011).

Moreover, the natural antioxidant compounds of polyphenols can be found in arrowroot tubers that are used to make starch and contains high carbohydrates (Priadi *et al*., 2000). The arrowroot bulbs can also be used to treat ulcer peptic. It is also reported to treat diarrhea, pain and as antioxidant. The tuber has the properties of anti-cholesterol and anti-ulcer since they have 32 glycemic index (GI) which belongs to the food category with low glycemic index. The arrowroot plants also have phenolic, flavonoid, alkaloids and saponin compound that are potential as antioxidants. According to the literature (Ramadhani *et al*., 2017), the antioxidant activity of fresh tuber extract (1.78 µg ml^{-1}) is higher than fresh leaf extract (0.27 µg ml^{-1}).

Arrowroot is a tuberous plant celebrated for its high starch content, easy digestibility, and suitability for individuals with dietary restrictions, such as gluten intolerance or food allergies. Traditionally used as a natural remedy for gastrointestinal disorders and as a source of nutrition during recovery from illness, arrowroot is valued for its hypoallergenic properties and high bioavailability of nutrients. It is rich in essential

minerals like potassium and calcium, as well as vitamins such as B-complex, making it a functional ingredient with significant health potential.

Combining arrowroot with milk and sugar creates a nutritionally balanced and appealing beverage that caters to a wide demographic. Milk provides a rich source of protein, calcium and other essential nutrients, complementing the starch and minerals in arrowroot. The addition of sugar enhances the drink's palatability, making it an accessible choice for both children and adults. Furthermore, this combination leverages the natural thickening property of arrowroot starch, resulting in a creamy, smooth texture that is both satisfying and nourishing.

This project work aims to explore the development and evaluation of an arrowroot-based healthy drink using milk and sugar. The research focuses on optimizing the formulation to balance nutritional value, sensory appeal, and consumer acceptability. By incorporating traditional knowledge of arrowroot's therapeutic benefits with modern food science techniques, this study seeks to highlight its potential as a base for functional beverages.

The proposed beverage aligns with global trends favoring natural, minimally processed, and nutrient-dense products. It also addresses the growing demand for convenient and healthful dietary options that provide both energy and essential nutrients. This research contributes to the broader discourse on sustainable food innovation, advocating for the revival and mainstreaming of traditional ingredients like arrowroot in contemporary diets.

In this background the project entitled “Process optimization and characterization of arrowroot based functional health beverage” was undertaken at Kelappaji College of Agricultural Engineering and Food Technology (KCAEFT) Tavanur, Kerala, India with the following objectives:

a) To determine the physio-chemical properties of arrowroot powder
b) To optimize the process parameters for the production of arrowroot-based health beverage
c) Characterisation and shelf-life studies of optimized health beverage

CHAPTER II

REVIEW OF LITERATURE

A brief review of the earlier researchers releated to agronomical characteristics, composition, processing and uses of the East Indian and West Indian varieties of arrowroot, characterisation and shelf-life study of arrow root based functional health beverage are presented in this chapter.

2.1 ARROW ROOT

Arrowroot (*Maranta arundinacea*e L.) is an herbaceous perennial, growing usually about 3ft and bearing oval leaves. The rootstock forms cylindrical rhizome below the soil surface. It is this rhizome, which are about 9-12 inches long 1 inch thick, that provide the starch that has made cultivation of the crop commercially feasible. West Indies particularly in St. Vincent, there are native varieties of arrowroot, namely: "Banana" and "Creole variety". The Creole variety has long thin rhizome, which spread more widely and penetrate more deeply into the soil. The Banana variety has shorter, thicker, less fibrous rhizomes, and produced near the soil surface. These two varieties do not seed, and propagation has so far by means of rhizome bits. The plant is extremely resistant to adverse weather conditions and has hitherto been subjected to only one disease, the "Arrowroot burning disease" (*Rosillinea bunodes*) and one pest, the "Arrowroot Leaf roller" (*Calpodea ethleus*): even these have been relatively minor in their effect (Martin *et al*., 1967).

2.2 GLOBAL SCENARIO

Global Arrowroot Powder Market is expected to grow at a compound annual growth rate (CAGR) of 5.5% during the forecast period, to reach USD 1.2 billion by 2030. The market is driven by the increasing demand for arrowroot powder in food and cosmetics applications, which are anticipated to be the fastest-growing segments of this market during the forecast period.

The global arrowroot powder market has been segmented on the basis of type (pure and mixture), application (food and cosmetics) and region (North America, Latin America, Europe, Asia Pacific and Middle East & Africa). The pure segment accounted for a share of over 50% in 2017 owing to its high demand in food applications such as bakery products, confectionery items such as biscuits or cookies; it also finds use in cosmetic products such as face masks or hair care products.

2.3 PRODUCTION STATUS OF WORLD AND INDIA

The global production of arrowroot powder is largely concentrated in St. Vincent and the Grenadines, about 95% of the world's demand for arrowroot is met by this Caribbean Island nation. While arrowroot is native to Tropical America, and cultivation occurs in other regions like Florida, Australia, South Asia, Brazil, and Thailand, St. Vincent and the Grenadines dominates global supply. Global arrowroot powder market was valued at $155 million in 2022 and is expected to grow at a CAGR of 4.5% from 2023 to 2030. This growth is driven by the increasing demand for food products and gluten-free foods, as well as the increasing awareness of the health benefits associated with arrowroot powder. The growth of the market is supported by the diversity of the powder in food applications, such as thickening soup, sauce, and baby food, as well as its use in personal care and pharmaceutical products. The North American and European regions have the largest market shares, driven by consumer trends towards health, plant-based ingredients and increasing adoption in the food processing industry.

The Indian starch and starch derivatives market is segmented such as maltodextrin, cyclodextrin, glucose syrups, hydrolysates, modified starch, and others; and its wide application in different end-user industries such as food and beverage, feed, paper industry, pharmaceutical industry, bio-ethanol, cosmetics, and others. In India, starch is produced in 3,75,000 tonnes. Out of which 1,87,000 tonnes used by the food sectors and the remaining goes to non-food sectors. In India, starch and starch derivative market is projected to grow at a CAGR of 5.1% during the forecast period 2020-2025.

2.4 VARIETIES

In India, three types of arrowroots are cultivated for starch purposes. They are West Indian arrowroot (*Maranta arundinacea* L.), East Indian arrowroot (*Curcuma angustifolia* L.) and Queensland arrowroot (*Canna indica* L.). The starch is extracted by traditional methods from the above three arrowroot crops by the farmers as an off-seasonal activity and marketed locally (Nedunchezhiyan *et al*., 2023).

2.4.1 West Indian Arrowroot

West Indian arrowroot (*Maranta arundinacea* L.) is grown for its edible rhizomes and starch extraction. High quality starch content of arrowroot is used as food for infants. Arrowroot biscuits are known in every corner in India. Its starch is also used as special glue and paste as a base for face powder and ice-cream stabilizer. Generally yellow-

coloured local cultivars are grown. However, cultivars having blue rhizomes give higher yield of starch than yellow colour cultivars (Nedunchezhiyan *et al*., 2023).

2.4.2 East Indian Arrowroot

East Indian arrowroot (*Curcuma angustifolia* L.) is a perennial herb and grown for its starchy rhizomes. In India, it is locally known as 'Shoti'. About 30 Curcuma species occurs in India, of which Curcuma angustifolia Roxb. and Curcuma zedoaria Rosc. are useful in the production of starch (Kundu, 1967). The 'Shoti' starch of commerce is a product extracted from the tubers and is used as substitute for arrowroot and barley (Kundu, 1967). It is highly valued as an article of diet, especially for infants and convalescents.

2.4.3 Queensland Arrowroot

Queensland arrowroot (*Canna indica* L.) is a perennial herb and grown for the branched fleshy rhizomes (Joseph and Peter, 1985). The plant is hardy and in view of the low incidence of pests and diseases and wind resistance of the crop in the typhoon prone regions, it is considered easy to grow (Kurtia, 1967). The tuber and top of the plant are used as livestock feed. The starch extracted from the Queensland arrowroot is easy to digest and hence used as a food for children and invalids. The young rhizomes are eaten as vegetable. The cooked tubers are delicious whereas the young shoots and petioles are used as fodder (Nedunchezhiyan *et al*., 2023).

2.5 AGRONOMICAL CHARACTERISTICS

East Indian Arrowroot encompasses the rhizomes from *Zingiberecae* family. *Curcuma angustifolia* (Manjakoova) and *Curcuma leucorrhizza* (Neelakoova) are used for the starch extraction. Arrow root is an attractive ginger with stout underground rhizomes which lie dormant in winters. In early spring the flowers are produced before the leaves. Very colourful bracts make this a showy species. The shape and colour of the bracts are very variable. The inflorescence lasts in full bloom on the plants for about three weeks and more. Good for cut flower use with a vase life of 10 days and more for fresh cut blooms. Leaves grow to about 2ft tall and die down in autumn. This species is found in the Eastern Himalayas and inhabits bright open hillsides and woods. In Manipur, pakodas made using these flowers, are considered a delicacy. East Indian Arrowroot is found in the Himalayas, from Kumaon to NE India and SE Asia, at altitudes of 900-1210m. This is cultivated from its tubers containing starch. Moist and cool situation at

altitudes of 450m are suitable for the crop. Planted in late autumn and watered occasionally during the dry period. The plant, which is generally ratooned is easily propagated by cuttings from the rhizomes or young offshoots; one crop per year is harvested, 9 to 12 months after planting and maximum starch yields are usually obtained when 5 the plants are about a year old. Compared to other tropical starches, arrow root produces a low yield, but the starch has a high maximum viscosity and yields a very smooth jelly or paste which is of particular value for infant foods. Harvesting season extends from October to May. On the larger estates, the harvesting of the rhizomes usually proceeds from the base of a hill towards the top. Harvesting involves breaking of the rhizome from the shoot. Planting and harvesting are inter-relate in that when the rhizomes are harvested the shoot is replanted at the same time. The curcuma sp. which are grown in temperature ranging from 11 to 40ºC which are also suitable from the hilly area for their growth and development as the region receives a well distributed rain fall during the growing season and also the sloppy well drained land with good organic matter content (Pemba H Bhutia, 2017).

2.6 COMPOSITION

Table 2.1 Chemical composition of East Indian arrow root rhizome

Sl. No.	Constituents	Amount (%)
1	Moisture	69-70
2	Starch	25-30
3	Crude protein	1.6
4	Fat	0.2
5	Sugar and dextrin	2.1
6	Crude fibre	3.9
7	Ash	0.9

(Deshpande, 2008)

Rewa Kumari and Shrivastava SL (2017) analysed for the proximate composition of Curcuma angustifolia. The starch contained 32.30±0.44% amylose, 2.72±0.36% moisture, 0.30±0.04% ash, 97.43±0.52% carbohydrate as starch and negligible amount of fat and protein.

Srivastava AK *et al.* (2006) estimated the volatile composition of Curcuma angustifolia rhizome. The rhizome essential oils of Curcuma angustifolia from Central

and Southern India were subjected to GC/MS analysis, which resulted in the identification of 81 and 78 constituents, accounting for more than 95 and 99% of the oil contents, respectively. The major constituents in the rhizome oil from Central India were xanthorrhizol isomer (12.7%), methyl eugenol (10.5%), palmitic acid (5.2%) and camphor (4.2%), while the rhizomes oil from Travancore (Southern India) had germacrone (12.8%), camphor (12.3%), isoborneol (8.7%), curdione (8.4%) and 1,8-cineole (4.8%) as major constituents.

Table 2.2 Chemical composition of West Indian arrow root rhizome

Sl. No.	Constituents	Percentage (%)
1	Moisture	63
2	Starch	27.17
3	Albumin	1.56
4	Fat	0.2
5	Sugar and dextrin	4.17
6	Crude fibre	0.26
7	Ash	1.23

(Grieve,1970)

Functional properties of Arrowroot starch were evaluated by (Charles *et al*., 2016) and found out that the composite flour/starch gelatinize at relatively low temperatures and uniform swelling of granules occurs. They exhibit a high viscosity profile compared to cereal starches. Addition of Arrowroot starch to Cassava and Sweet potato starches improved gel stability and may find use in modulating gelling properties of these starches in commercial products.

2.7 PROCESSING METHOD

2.7.1 Traditional processing method of arrowroot powder

In traditional practice, fresh rhizome bulbs were separated, cleaned thoroughly and dipped in water for one night. The rhizomes were rubbed on a rough surface stone or sieve. The obtained paste was added with water in the ratio of 1:2 to make solution and passed though muslin cloth. Supernatant part of the solution remained on the cloth was thrown away as the waste. The filtered solution of arrow root powder was collected in an

earthen pot. This solution was kept for about 4 to 6 hours to allow settling of the powder particles. Powder mass was settled down in earthen pot as sediment. The decanting of water was done initially after 6 hours. The process of decanting was repeated 6-8 times till the bitterness taste was not experienced.

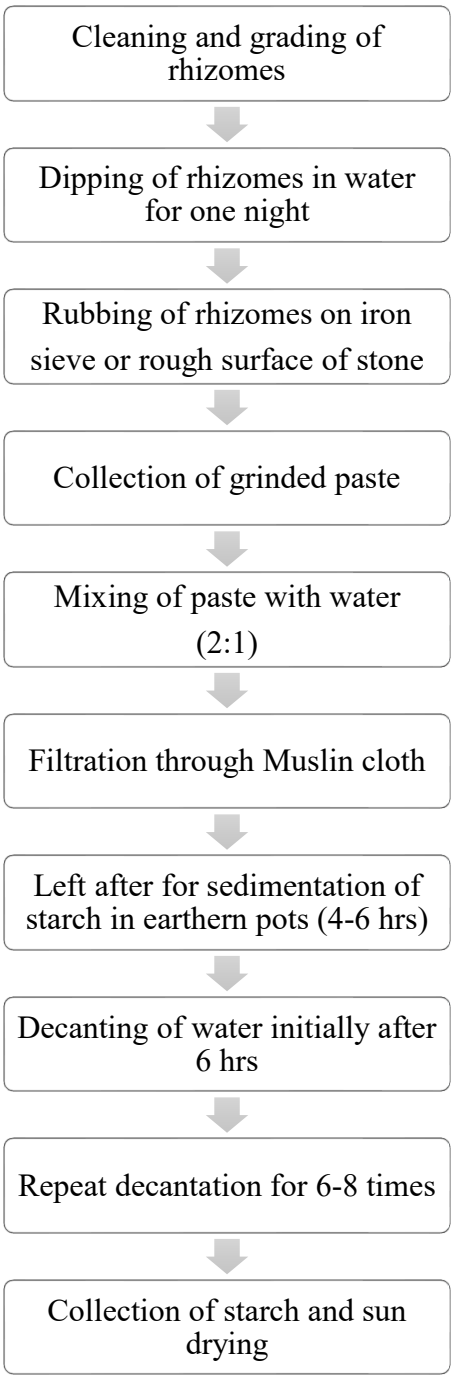

Fig 2.1 Traditional processing method of arrowroot powder (Faris *et al*., 2018)

2.7.2 Partially mechanized method of arrowroot powder

All the process was similar to that of traditional method except the size reduction of rhizomes by motorized wet grinder and drying by tray drying. All other steps were repeated as in case of traditional method.

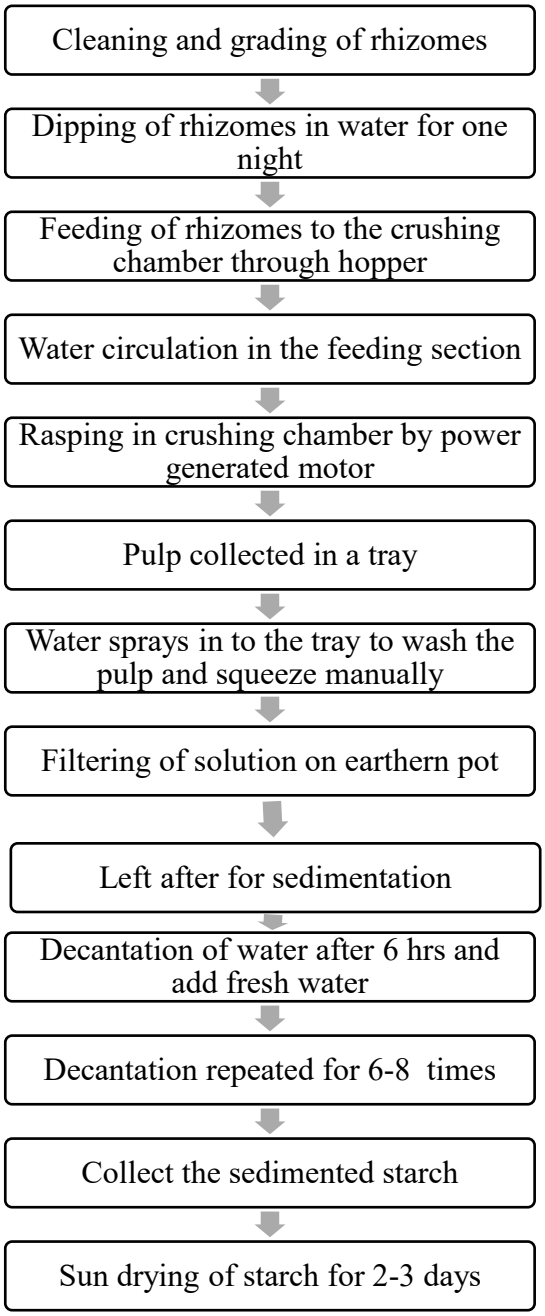

Fig. 2.2 Partially mechanized processing method of arrowroot powder (Faris *et al.,* 2018)

2.8 APPLICATIONS

2.8.1 Flour products

Flour products from arrowroot plant have special features, which are easy to digest because the content of the glycemic index is low so it is very good for health (Damat *et al*., 2019).

2.8.2 Boosting immunity

Arrowroot may contain bioactive compounds like flavonoids that may help in boosting immunity. It may also increase the level of antioxidants and may help in fighting against diseases (Damat *et al*., 2019).

2.8.3 Oral hygeine

Studies reported that arrowroot may be useful for relieving oral pain such as gum inflammation. Arrowroot may have anti-inflammatory properties that might be useful for inflammatory diseases of the mouth. It may also have antibacterial and antifungal properties (Damat *et al*., 2019).

2.8.4 Source of dietary fiber

Arrowroot flour is a good source of dietary fiber that may benefit the digestive and immune systems. Research indicates that arrowroot has fewer calories and more protein than other tuberous vegetables such as potatoes, yams, and cassava. Therefore, arrowroot may be beneficial in helping people to manage their weight and for those with digestive disorders. (Jayatilake *et al.,* 2020)

2.8.5 Gluten-free diet

Arrowroot is a naturally gluten-free food. Studies suggest that arrowroot flour may be helpful for those who are sensitive to gluten or people with celiac disease. People can make many food items and incorporate arrowroot flour into recipes for baked goods as an alternative to other flours, such as wheat, that contain gluten, the resistant starch in arrowroot may improve gluten-free products' texture, flavor, and mouthfeel (Nedunchezhiyan *et al*., 2023).

2.8.6 Industrial applications

In the Caribbean, Indonesia, Sri Lanka, and other areas in the tropics. People in the food industry use the starchy rhizomes of arrowroot to make thickeners and stabilizers. Additionally, manufacturers use the fibrous waste to make paper products and other items.

Arrowroot powder has a potential role in cosmetics as it has the capability of absorbing extra oil from the skin which in turn enhances skin rejuvenation (Indrasari *et al.,* 2021)

Arrowroot powder is rich in vitamins and minerals, including vitamin B6, iron, and calcium. The arrowroot plant is mainly found in the West Indies (Jamaica), Indonesia, Philippines, India, and Sri Lanka. About 95% of the world's demand for arrowroot is fulfilled by St. Vincent (West Indies). The arrowroot is a high starch content rhizome. The extracted starch is known to be easily digested and it also has an excellent gelling property (Indrasari *et al.,* 2021).

It has a high content of amylose (35.20%) which makes it suitable for the production of films. The technical properties of films, in particular when it comes to mechanical strength and barrier properties, are usually stronger than those of amylopectin. Recently, there has been a growing interest in the use of rigid nanoscale particles as reinforcement materials in polymeric matrices, composites, and nanocomposites (Indrasari *et al.,* 2021).

2.9 PRODUCTS FROM ARROWROOT

The various products that can be prepared out of koova starch are cookies, dessert, kanji, cake, payasam, halwa, jam, thickener in yogurt, pancakes etc. The commercially available arrowroot starch brands are Redmill and Koova. As we know that arrowroot powder has several health benefits, we can make cookies which can be applied as alternative snack for diabetic people. It is suitable as morning, afternoon, or evening snacks (Indrasari *et al.,* 2021).

Arrowroot starch is alternative flour which can be used for producing functional food like cake. modified arrowroot starch is useful for enhancing functional food production. Arrowroot is a well-known thickening agent. It stands up to acidic mixtures such as Asian sweet and sour sauce. Using it for thickening fruit sauces like cranberry sauce or really any slightly acidic sauces like sweet teriyaki sauce. And then there is the whole savory world of sauces, soups, and gravy. It will not make the sauce go cloudy, such as cornstarch, flour, or other starchy thickening agents would. It’s commonly used as an alternative to corn starch which is usually more expensive. When using arrowroot powder as a thickener for sauces and gravy, there are a couple of things which has to be remembered. Arrowroot powder is twice the thickening power of wheat flour and is

gluten free. Unlike cornstarch, arrowroot powder creates a perfectly clear gel and does not break down when combined with the acidic ingredients like fruit juices. Arrowroot also stands up to freezing, whereas mixtures thickened with corn starch tend to break down after freezing and thawing. Arrowroot powder is great as a thickener for everything from gravy to puddings and soups. Naturally gluten-free, arrowroot starch is an excellent thickening agent in puddings, sauces and stews, and makes a great binder in meat loaf and veggie burger mixtures (Indrasari *et al.,* 2021).

2.10 Development of health beverages

According to Bolarinwa *et al.* (2018) the development and quality evaluation of soy-walnut milk beverages shows that every citizen of developing nation should have right to optimal nutrition, which guarantee daily intakes of energy, nutrients and bioactive and other compounds to improve some body functions and reduce the risk of some diseases (Ashwell *et al.,* 2005). Optimal nutrients could be made available to the poor and low income earners in developing countries through the incorporation of walnut in their frequently consumed foods. Previous studies have reported the development of nutritious and health supporting beverage from soymilk and sea buckthorn syrup (Maftei *et al*., 2013), soymilk and carrot (Banigo *et al*., 2015) and soy-mushroom beverage (Farzana *et al.,* 2017). The objectives of this study are therefore to produce soy-walnut beverages from the blends of walnut milk and un-malted or malted soymilk and to determine the proximate and mineral content, physicochemical properties, and consumer acceptability of the milk beverages**.**

2.11 Characterization of health beverages

In this study, soy-walnut milk beverages were produced from various proportions (0:100; 10:90; 30:70; 50:50) of un-malted or malted soymilk and walnut milk blends. The proximate composition, mineral content, physicochemical properties and sensory attributes of the soy walnut beverages were evaluated. The range of the proximate composition of the soy-walnut milk beverages were 86.93-90.67%, 1.96-2.87%, 3.08-5.09% ,0.14-0.30%, and 2.18-6.89%, for moisture, proteins, fat, ash and carbohydrate, respectively. The mineral content of the soy-walnut milk beverages ranged from 0.97-2.38 ppm for iron, 22.13- 59.51 ppm for magnesium, 26.08-35.08 ppm for calcium, 2.71-3.25 ppm for sodium and 1.38-2.14 ppm for zinc. The physicochemical contents ranged

from 4.95 -5.36%, 9.34-13.17%, 3.4-3.9% and 0.25 – 0.42%, for pH, total solid, total soluble solid, and total titratable acidity, respectively.

2.12 Shelf-life study of health beverages

Effect of temperature on physicochemical properties of Aloe vera-mango RTS beverage was studied by Jakhar *et al*. (2012) during storage periods. Colour and appearance Temperature plays an important role in biochemical changes that leads to development of off flavor as well as discolorations in the beverages during storage. The effect of two different temperature 10^{o}C and 25^{o}C on colour and appearance of Aloe vera-mango RTS beverage during storage. It is explicit that the score for colour and appearance decreased significant during that storage period from 0 to 60 days. The maximum decreased was observed in sample (A25m) stored under 25^{o}C, which decreased from 8.1 ± 0.36 To 6.73 ± 0.14. Minimum decreased was observed in sample (A10m) stored under 10^{o}C, which decreased from 8.1 ± 0.36 to 7.4 ± 0.057. Reduction in organoleptic quality obtained in present study is in correlation to previous report of effect of storage temperature on pomegranate juice (Jakhar *et al*., 2012)

CHAPTER III

MATERIALS AND METHODS

This chapter presents a detailed investigation into the potential of arrowroot as a functional ingredient for developing a health beverage, physicochemical analysis of arrowroot to assess its suitability for food applications is explained in this chapter. And formulation and development of a healthy beverage using arrowroot powder, followed by the optimization of process parameters to ensure the best quality and nutritional value of the beverage are included. Furthermore, the characterization of the optimized arrowroot drink and its storage study to determine the stability and shelf life under different storage conditions are also included in this chapter.

3.1 COLLECTION OF RAW MATERIALS

Raw materials for the preparation process involves sourcing high-quality arrowroot powder and fresh milk. The arrowroot powder is procured from Kuttippuram, known for its premium-grade produce, ensuring the best texture and nutritional value. The milk, sourced from a nearby shop, is of the trusted Milma brand, guaranteeing freshness and quality. Together, these carefully selected ingredients form the foundation for creating a product that meets high standards of taste and quality.

Plate 3.1 Arrowroot powder

3.2 PREPARATION OF ARROWROOT POWDER

The tubers were undergone a series of steps, including thorough washing to remove dirt and impurities, peeling to eliminate the fibrous outer layer, and subsequent grinding

or pulping to extract the starch-rich content. The extracted pulp was then mixed with water, strained and allowed to settle, separating the starch from other fibrous components. The settled starch was dried to produce the fine, white arrowroot powder used in culinary, medicinal, and industrial applications.

3.3 PROXIMATE AND QUALITY ANALYSIS OF ARROWROOT POWDER

Arrowroot powders are the edible starch which is extracted from arrowroot tubers, which are the raw material for the development of healthy beverage which is shown in plate 3.1. Prior to the development of healthy beverage, the proximate analysis and quality parameters of arrowroot powder were studied. Proximate analysis and quality parameters refer to the physical and chemical characteristics of materials which are useful and necessary in the analysis, design and development of machines.

The various proximate analysis and quality parameters selected for the study are furnished below.

1) Quality parameters
    a) Moisture content
2) Optical properties
    a) Color
3) Proximate components
    a) Water activity
    b) Protein content
    c) Carbohydrate content
    d) Fat content
    e) Crude fibre
    f) Ash content

3.4 DETERMINATION OF PHYSICOCHEMICAL PROPERTIES OF ARROWROOT POWDER

3.4.1 Quality parameters of arrowroot powder

3.4.1.1 *Moisture content*

The moisture content of arrowroot was determined using an infrared moisture meter. This device works by emitting infrared radiation onto the surface of the sample and the moisture content is measured based on the interaction between the infrared radiation and the sample. Before beginning the actual measurement, the infrared moisture

meter must be properly calibrated. The sample should then be prepared by finely grinding or homogenizing it to ensure uniformity and consistent results. Once the sample is ready, the infrared moisture meter should be turned on and allowed to warm up according to the manufacturer's instructions. It is essential to ensure that the instrument is clean and free from any contaminants that might affect the accuracy of the readings. The prepared sample was uniformly spread in the sample holder provided with the instrument. After setup, the moisture meter was activated to start the measurement process. The instrument digitally displayed the moisture content value on the screen. The measurement was repeated multiple times and the average value was noted.

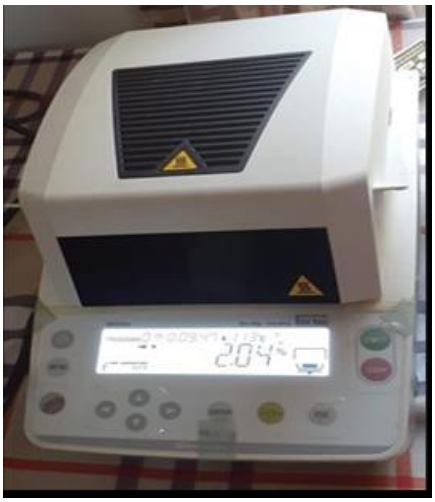

Plate 3.2 Infrared moisture meter

3.4.2 Optical properties

3.4.2.1 *Colour*

The colour of arrowroot powder was determined by optical density value using a Hunter lab colorimeter - Colour Flex EZ diffuse model, as shown in Plate 3.3. A beam of light was passed to the sample and the energy reflected from the sample across the entire visible spectrum was measured. The standard observer curves of the colorimeter are red, green and blue. The three-dimensional scale L*, a* and b* values were used to express the colour on the basis of lightness black/ white coordinate 0 to 100, red/ green coordinate 100 to –100 and yellow/ blue coordinate 60 to – 60, respectively (Reddy *et al*., 2014). Before starting the analysis, the colorimeter was calibrated by placing black and white tile. The sample was filled in transparent glass jar and was placed over the port and the colour values viz., L*, a* and b* were recorded.

Plate 3.3 Colorimeter

3.4.3 Proximate components

3.4.3.1 *Water activity*

Water activity (a_w) is the amount of free moisture available for chemical and biological reactions. Water activity meter works on the principle of measuring the relative humidity at head space, when liquid phase water in the sample reaching equilibrium with the vapour phase water in the headspace. The water activity of arrowroot powder was observed with a water activity meter (Model: Aqua Lab, Decagon Devices Inc., Pullman, USA) as shown in Plate 3.5. The sample was filled in cup which was provided along with water activity meter. The drawer knob was first turned to OPEN position and opened the sample port by pulling the handle. The sample was then placed in sample port and sealed the chamber and turned the knob to READ position. The water activity of the sample was shown in the display screen with respect to atmospheric temperature (Kha *et al*., 2010).

Plate 3.4 Water activity meter

3.4.3.2 *Protein content*

The crude protein content in the arrowroot powder was determined using Kjeldahl method (AOAC, 2005). The experiment was conducted using a protein analyzer (M/s. Pelican Equipments, model: KEL PLUS). The sample of 0.5 g was taken into the

digestion tube. The digestion mixture was prepared by mixing 2.7 g of potassium sulphate (K_2SO_4) and 0.3 g of copper sulphate ($CuSO_4$). Add 0.5 g to the digestion mixture and add 10 ml of concentrated sulphuric acid (H_2SO_4) to the sample. The sample was digested in the digestion unit (400°C for 1-2 h) till it became colourless. After completion of digestion, the tubes were cooled and transferred into distillation unit. 40 per cent NaOH solution was allowed in to the tube. Liberated ammonium was absorbed in boric acid (4 per cent) solution containing mixed indicator (10 ml bromocresol green and 7 ml of methyl red). The colour of boric acid (pink) solution was turned to green colour in the distillation unit and the obtained solution was titrated against 0.1 N hydrochloric acid (HCL) until pink colour will be obtained.

$$\text{Protein (\%)} = \frac{14 \times (normality\ of\ acid\ ) \times (Titrant\ value\ burette\ reading) \times 100}{Sample\ weight \times 1000} \times 6.25 \quad \ldots. (3.1)$$

3.4.3.3 ***Total Carbohydrate***

Total carbohydrate present in arrowroot powder was determined by anthrone reagent. Principle of the analysis is hydrolyzation of carbohydrates into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose is dehydrated to hydroxyl methyl furfural. This compound forms green coloured product with anthrone reagent with an absorption maximum at 639 nm. The sample (100 mg) was taken in a boiling tube. It was hydrolyzed by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N hydrochloric acid and cool to room temperature. Neutralize with solid sodium carbonate until the effervescence ceases. Made up volume to 100 ml and centrifuged. Supernatant was collected and 0.5- and 1-ml aliquots were taken for analysis. Standard glucose (stock) solution was prepared by dissolving 100 mg in 100 ml distilled water. The working standard was made by diluting 10 ml stock in 100 ml distilled water. After adding few drops of toluene stored at refrigerated condition. Standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard ("0" serves as blank). By adding distilled water, volume was made up to 1 ml in all the tubes including the sample tubes. Then 4 ml of anthrone reagent (200 mg anthrone in 100 ml ice cold 95 per cent sulphuric acid) was added and is heated for 8 minutes in a boiling water bath. Cooled rapidly and read green to dark green colour at 630 nm using spectrometer. Concentration of the

standard versus, absorbance graph was plotted. From the graph, amount of carbohydrate present in the sample was calculated by the equation given below (Nithya *et al*., 2014).

$$\text{Carbohydrate present in 100 mg of sample} = \frac{mg\ of\ glucose}{volume\ of\ test\ sample} \times 100 \quad \ldots. (3.2)$$

3.4.3.4 ***Fat content***

The fat content of the arrowroot powder was determined by using AOAC standard procedure (AOAC, 2005) with Soxhlet extraction method (M/s.Pelican Equipments, SOCS 06, India). The Soxhlet apparatus was shown in Plate 3.6. The sample of 2 g was weighed and taken into thimble. Take the weight of empty beaker. The petroleum ether was poured into the beaker and all the beakers were loaded into the system. The petroleum ether was boiled for about 30 min at 80°C. After completion of the process time, the temperature was doubled at 160°C for 15-20 min to collect the petroleum ether. All the beakers from the system were removed and placed in the hot air oven for 100°C for 1 h. Take out the sample from the hot air oven and cooled in the desiccator and again weight was noted. The final weight of the beaker was recorded and fat content was determined by using the following equation:

$$\text{Fat content}(\%) = \frac{W_2 - W_1}{w} \times 100 \quad (3.3)$$

Were,

W- Weight of sample taken, g

W_1- Initial weight of beakers, g

W_2- Final weight of beaker, g

Plate 3.5 Soxhlet apparatus

3.4.3.5 *Fibre content*

Crude fibre consists of cellulose, variable proportion of hemicellulose and high variable proportions of lignin with some minerals. It was estimated by following the method suggested by AOAC, (2005). About 2 g of dried sample (W) was ground and boiled with 200 ml of H_2SO_4 for 30 min. Then the sample was filtered through muslin cloth and washed with hot water for 2-3 min so that the washings were not acidic. The residue obtained was boiled with 200 ml NaOH and filtered through muslin cloth and again washed with 25 ml of 1.25 per cent H_2SO_4, 350 ml of water and 25 ml of alcohol. Then the residue was transferred to ashing dish (W_1) and dried for 2h at 130°C.Weight of the dish and the residue (W_2) was taken after the cooling in the desiccator. Again, the dish was ignited for 30 min at 600°C and weighed after cooling (W_3).

$$\text{Crude fibre content (\%)} = \frac{(w_2 - w_1) - (w_3 - w_1)}{w} \quad (3.4)$$

3.4.3.6 *Total Ash*

The total mineral content or crude ash of arrowroot powder was determined by muffle furnace method described in AOAC, 2005 (Method No.930.30). Platinum crucible was heated to 600°C in muffle furnace for 1 h. Cooled in desiccator and weighed. 2 g of accurately weighed sample was taken in crucible. Crucibles along with weighed samples were loaded into muffle furnace and heated about 5 h at 550°C to greyish white ash. After cooling in desiccators take the weight. Difference in weights taken as the total ash content and is expressed in percentage.

$$\text{Total ash (\%)} = \frac{weight\ of\ ash\ (g)}{weight\ of\ sample\ (g)} \times 100 \quad (3.5)$$

3.5 DEVELOPMENT OF ARROWROOT BASED HEALTH BEVERAGE

3.5.1 Preparation of health beverage

Preparing an arrowroot powder drink involves a straightforward process that begins with carefully mixing arrowroot powder with regular milk to ensure a smooth, lump-free solution. Pour the mixture into a saucepan and heat it over a low flame, stirring occasionally to prevent scorching. Continue stirring until the mixture achieves a smooth consistency. Allow it to cook for 5–7 minutes on low to medium heat until it thickens, as the arrowroot gelatinizes. Sweeten the drink by adding sugar to adjust the total soluble solids (TSS) to your preference. Once prepared, the drink can be served warm or chilled. This beverage is rich in nutrients—arrowroot provides easily digestible carbohydrates,

milk contributes protein and calcium, and sugar offers quick energy in moderation. It is an excellent gluten-free and nutritious option suitable for all age groups.

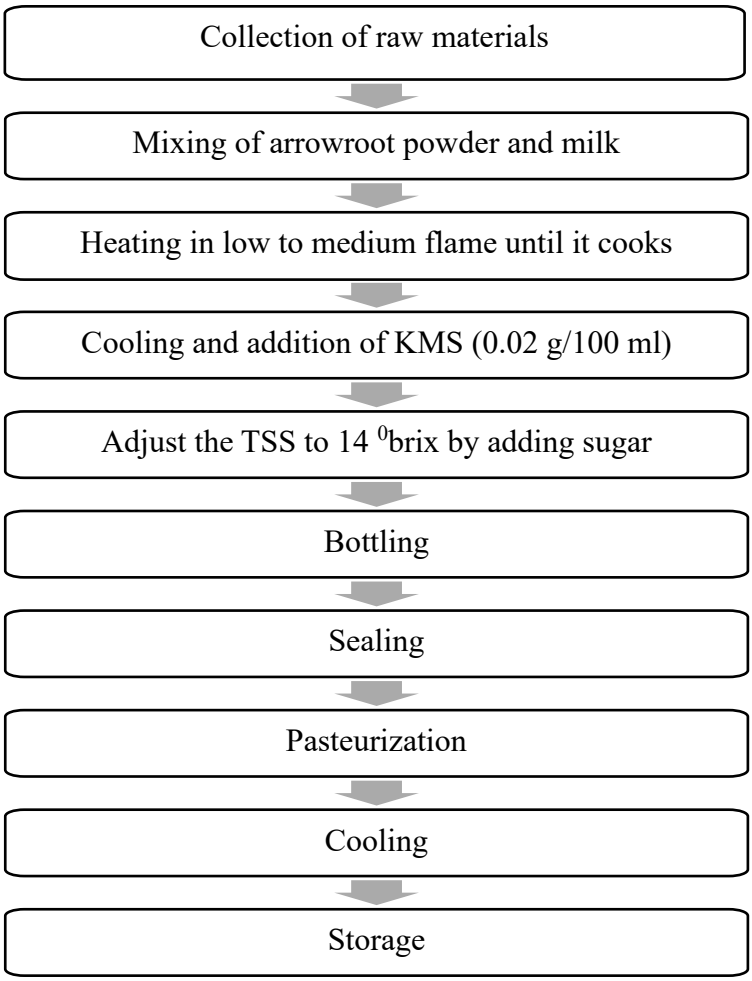

Fig. 3.1 Process flowchart of arrowroot based health beverage

3.6 PROCESS PARAMETERS FOR THE DEVELOPMENT OF ARROWROOT BASED HEALTH BEVERAGE

3.6.1 Optimisation of process parameters

The process parameters for the developed arrowroot healthy beverage were optimized based on sensory and proximate analysis. Sensory evaluation was conducted to assess the drink's appearance, colour, taste, flavour and overall acceptability. Proximate analysis included the assessment of water activity, moisture content, pH and microbial count to determine the drink's physicochemical and microbiological stability. The experimental design involved three independent variables:

1. Arrowroot powder concentration (%)
2. Pasteurization temperature (°C)

3. Milk to water ratio

These variables were systematically varied to identify the optimal combination for producing a nutritious, palatable, and microbiologically safe arrowroot based healthy beverage.

Arrowroot powder (%): 1, 2, 3

Pasteurisation Temperature (ºC): 60, 70, 80

Milk to water ratio: 30:70, 35:65, 40:60

Response surface methodology was made use of for optimising the process variables. Box Behnken design with three independent variables as described in section 3.3 and five dependent variables (responses) were employed for the purpose of optimisation. The optimization of the process parameters was based on various response variables are as follows: -

a) Water activity
b) Moisture content
c) pH
d) Microbiological analysis
e) Sensory analysis

Table 3.1 Experimental design

RUN	INDEPENDENT VARIABLES		
	CONCENTRATION (%)	MILK TO WATER RATIO (ml)	PASTEURISATION TEMPERATURE (°C)
1	2	30:70	60
2	3	35:65	60
3	2	40:60	80
4	2	30:70	80
5	1	35:65	80
6	2	35:65	70
7	2	35:65	70
8	2	35:65	70
9	3	40:60	70
10	2	35:65	70
11	2	40:60	60
12	2	35:65	70
13	3	35:65	80
14	1	40:60	70
15	1	30:70	70
16	1	35:65	60
17	3	30:70	70

3.7 EXPERIMENTAL PROCEDURE TO ESTIMATE RESPONSE VARIABLES

3.7.1.1 Water activity

The water activity of the arrowroot based health beverage samples was determined using water activity meter in the same way as per the procedure described in the section 3.4.3.1

3.7.1.2 Moisture content

The moisture content of the arrowroot beverage sample was determined using infrared moisture meter in the same way as per the procedure described in the section 3.4.1.1

3.7.1.3 pH measurement

The pH of the freshly prepared arrowroot samples was determined using a digital pH meter (M/s. Systronics; Model MK VI) shown in Plate 3.1. Initially, the pH meter was standardised with distilled water of pH 7.0 and standards of pH 4.0, 7.0 and 9.0. Samples was taken in a beaker and the electrode of pH meter was immersed in the sample. The reading was directly recorded from the pH meter. This procedure was repeated thrice for precision and the average value was noted (AOAC, 1990).

Plate 3.6 pH Meter

3.7.1.4 Microbiological Analysis

The microbiological quality characteristics of the arrowroot beverage samples were determined at different storage periods. The microbial growth was estimated

through standard plate count method and serial dilution agar plate technique. The bacterial population in arrowroot beverage samples were analysed by different microbiological methodologies, that includes enumeration of the microorganism in selective media for different dilutions of sample, incubation of plates and counting the number of colonies present. The media generally used for enumeration bacteria was nutrient agar medium. The arrowroot beverage sample of 1 ml was pipetted using a sterile pipette into a test tube containing 9 ml of sterile water which gave a l:10 (10) dilution. The test tubes were shaken well for 10-15 minutes for uniform distribution of microbial cell in the water blank. Then 10 dilution was prepared by pipetting out 1ml of (10) dilution to 9 ml of sterile water in test tube with a sterile 1 ml pipette, the process was repeated up to 10^{-6} dilutions with a serial transfer of the dilutants. One millilitre of aliquot from 10^{-5} dilution was transferred to the sterile petri dishes for the enumeration of bacteria. Approximately, 15-20 ml of molten and cooled (45°C) agar medium was added to each petri dish containing the sample dilutions and the plates were rotated in clockwise and anticlockwise direction for thorough mixing of the dilutants and the medium. The plates were then incubated at 35°C (room temperature) for 24-48 hours for bacteria. After the incubation period, the colonies were counted and the number of organisms (total bacteria) per gram of sample was calculated by using the equation

$$No.of\ Colony\ Forming\ Units\ (CFU) per\ gram\ of\ the\ sample = \frac{No.of\ colonies \times dilution\ factor}{Volume\ of\ sample\ taken} \quad \text{.... (3.6)}$$

3.7.1.5 Sensory analysis

Sensory analysis is a scientific study used to measure, analyse, and interpret reactions to those characteristics of foods as they are perceived by the senses of sight, smell, taste, touch, and hearing. In general, sensory quality of liquid food is the consumer's reaction to the physical nature and chemical constituents of the food in its prepared and formulated form. Organoleptic evaluation was carried out by a panel of ten untrained judges for appearance, colour, taste, odour, mouthfeel and overall acceptability using nine-point hedonic scale. Sensory analysis was conducted separately for carbonated and non- carbonated samples. Based on the sensory analysis four samples were optimized. These samples were only selected for further studies.

3.8 EXPERIMENTAL DESIGN FOR OPTIMISATION

A statistical software package Design expert 12 from a private company Stat-Ease Inc. specifically designed to perform the design of experiments was used in the optimisation of various process in the development of arrowroot based health beverage. The procedure of optimisation was conducted using Box-Behnken design which is a most efficient and economical way to estimate the first and second order coefficients of mathematical model (Bezerra *et al*., 2008). Further Box-Behnken design provides three levels for all given variables and contains a subset of the factorial combinations from the 3^k factorial design (Khuri and Mukhopadhyay, 2010). Besides providing optimised treatments response surface plots are also obtained using Design Expert software. The three-factor Box-Behnken design will present the optimised treatment with the values of independent variables in such a manner that they will yield a maximum value of sensory analysis, pH and minimal moisture content, water activity, microbial count.

3.9 CHARACTERISTIC STUDY OF OPTIMISED ARROWROOT BASED HEALTH BEVERAGE

Arrowroot based health beverage is a beverage obtained from arrowroot starch. It refreshes and nourishes the body. It is a rich source of calcium, potassium, manganese phosphorus etc. It cools the body, reduces urinary symptoms like burning micturition, dysuria etc. It prevents stone formation also. It is good for genital, urinary and reproductive systems. It improves quality and quantity of semen. Reduces dysuria and leucorrhoea, fever, vomiting, diarrhoea, measles, chickenpox, burns, post-surgical etc. As it belongs to curcuma family it has got a unique property of removing toxins from our body. Toxins accumulated in our body are metabolic by-products of alcohol and drugs, colouring agents and preservatives of packed food products, insecticides and pesticides in vegetables and fruits etc. detoxification process is being carried out in livers.

3.9.1 *Protein content*

The Protein contents of optimised arrowroot beverage were found out using the procedure illustrated in section 3.2.3.3

3.9.2 *Carbohydrate content*

The procedure for the determination of carbohydrate content of arrowroot beverage is same as elucidated in section 3.2.3.4

3.9.3 ***Fat content***

The Fat content of arrowroot beverage was estimated by the same procedure as in 3.2.3.5

3.9.4 ***Crude fibre***

The crude fibre content of arrowroot beverage was evaluated by the same method as in section 3.2.3.6

3.9.5 ***Ash content***

The ash content of the arrowroot beverage was determined in a similar manner as explained in 3.2.3.7

3.9.6 ***pH***

The hydrogen ion concentration of arrowroot beverage was found using a pH meter. The procedure for measurement is similar to that explained in section 3.4.1.3

3.9.7 ***Moisture content***

Moisture content of arrowroot beverage sample could be determined as described in section 3.2.1.1

3.6.8 ***Microbial analysis***

Microbial analysis of arrowroot beverage sample was determined as described in section 3.4.1.4

3.9.9 ***Total Soluble Solids (TSS)***

The TSS was found using hand refractometer. First, a small quantity of the test solution (2-3drops) was transferred to the surface of the fixed prism of the refractometer & immediately the movable prism was adjusted. Then, the field of view was illuminated suitably and readings were taken (Jiang, L. L. *et al*., 2016)

Plate 3.7 Refractometer

3.9.10 *Titrable Acidity*

For determining titrable acidity, first, 5 ml of sample was taken and it was made up to 100ml. Then, 10 ml solution was taken from the above sample and to that 2-3 drops of phenolphthalein indicator was added. 0.1 N NaOH was prepared by dissolving 0.4g NaOH in 100 ml distilled water and was taken in the burette. Then the blank and sample was titrated. The titre values were obtained. Titrable acidity was then found by substituting the values in the given equation. (George, D. S. and Patricia, A. M. 2010).

$$\% \, Acidity = \frac{volume \; of \; titrant \times Normality \; of \; titrant \times 0.067}{Sample \; weight \; (g)} \times 100 \qquad (3.7)$$

3.9.11 *Ascorbic Acid*

Ascorbic acid content in arrowroot beverage sample were estimated using the 2, 6-dichlorophenol indophenols titrimetric method as described by Sadasivam and Manickam (1992). Dye solution was prepared by dissolving 52mg of 2, 6 dichlorophenol indophenols, and 42 mg of sodium bicarbonate in 200ml distilled water. Standard solution was prepared by adding 100 mg of ascorbic acid to 100 ml of 4% oxalic acid. To prepare working standard solution, 10 ml of standard solution was pipetted out and was diluted to 100 ml using 4% oxalic acid. The 5 ml arrowroot beverage samples were made up to 50 ml using 4 percent oxalic acid. To find dye factor, 10 ml of working standard solution was pipetted out into a 50 ml conical flask and 10 ml of 4% oxalic acid was added and titrated against the dye. The end point was the appearance of pink colour which persisted for a few minutes. The titration was repeated to get concordant values. The amount of dye consumed was equal to the amount of ascorbic acid present in the working standard solution (V_1). Ten millilitre of sample extract was pipetted out to which 10 ml of 4% oxalic acid was added. It was then titrated against the dye. The titration was replicated for each sample until the concordant values were obtained (V_2).

$$\text{Dye factor} = \frac{0.5}{\text{Titrable value}(V_1)}$$

$$\text{Ascorbic acid} \frac{\text{mg}}{100\text{g}} = \frac{0.5\text{mg}}{V_1\text{ml}} \text{x} \frac{V_2}{5\text{ ml}} \text{x} \frac{100\ ml}{\text{Wt. of the sample}} \text{x}100 \qquad (3.8)$$

V_1 - Amount of dye consumed by ascorbic acid present in the working standard solution, ml.

V_2 - Amount of dye consumed by the liquid sample, ml.

3.9.12 *Measurement of Anti-oxidant Activity*

A spectrophotometer was used to measure the antioxidant capacity of the arrowroot beverage. A stock solution of DPPH (2, 2-Diphenyl-1-picrylhydrazyl) was prepared by dissolving approximately 15 mg DPPH in 100 ml methanol and stored at −20ºC until further use. The working solution was prepared by mixing 10 ml of stock solution with 45 ml of methanol to adjust absorbance at 517 nm wavelength to unity, which was then kept in dark. The change in colour of the DPPH solution from purple to yellow, resulting from the addition of different quantities of ascorbic acid standards was measured at 517 nm after allowing the solution to stand in the dark for 20 min. The decrease in absorbance of DPPH after 20 min was calculated and expressed as mg of ascorbic acid equivalents antioxidant capacity per 100 g. The control sample was prepared as above without any sample extract and methanol was used for the baseline correction.

$$\text{Percentage radical scavenging activity (\%)} = \frac{Absorbance\ of\ control - Absorbance\ of\ sample}{Absorbance\ of\ control} \quad \ldots. (3.9)$$

3.10 SHELF-LIFE STUDIES OF OPTIMIZED ARROWROOT BEVERAGE

Optimized sample was selected based on the results of sensory evaluation, microbiological quality and proximate analysis. The sample was then subjected to storage studies over a period of seven days to assess its shelf stability. A volume of 100 mL of the arrowroot drink was filled in PET bottles and glass bottles, which were subsequently stored under ambient and refrigerated conditions at 8 ± 1°C.

3.10.1 Ambient storage at room temperature

The samples were monitored at regular intervals to evaluate the changes in quality attributes during storage.

Table 3.2 Experimental details of treatments

Sl. No.	Notations	Details of treatments
1	T1	Optimised samples in glass bottles stored at refrigerated temperature (8 ± 2℃)
2	T2	Optimised samples with KMS in PET bottles stored at refrigerated temperature (8 ± 2℃)

3	T3	Optimised samples in PET bottles stored at refrigerated temperature (8 ± 2℃)
4	T4	Optimised samples with KMS in glass bottles stored at refrigerated temperature (8 ± 2℃)

The arrowroot beverage samples which were optimised were packed in two different materials viz. PET bottle and glass bottle with 500ml capacity. Moreover, the packed specimens were stored under refrigerated temperature (8 ± 2℃). Further, the samples were analysed continuously on a 7-day interval to examine the variations in different physio-chemical attributes. The experiment was carried out for a time period of 14 days in triplicates and the average was taken.

3.10.2 Quality evaluation of stored samples

Various quality attributes of stored samples like moisture content, pH, water activity, total soluble solids, microbiological analysis, etc were found out by employing the standard measurement methodologies as elucidated in 3.2.1.1, 3.4.1.3, 3.2.3.2, 3.6.9, and 3.4.1.4 respectively after every 7 days until the 14th day of storage.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the results of the physical properties of arrowroot powder, along with the development and optimization of process parameters for formulating an arrowroot based health beverage. Additionally, the results of characterization of arrowroot powder under optimized conditions and the storage studies of the optimized arrowroot based health beverage are included in this chapter.

4.1 PHYSICO-CHEMICAL PROPERTIES OF ARROWROOT POWDER

Arrowroot powder is the raw ingredient for arrowroot based health beverage and it has an important role in bringing the excellent qualities of the developed beverage. The proximate analysis of arrowroot powder was determined prior to the development of arrowroot drink. Various proximate analysis of arrowroot powder are tabulated in Table 4.1

The physicochemical as well as proximate components of arrowroot powder viz. moisture content, water activity, protein, carbohydrate, total fat, crude fibre and total ash were found to be 18.53%, 0.642, 11 g/100g, 76 g/100g, 0.55 g/100g, 0.77 g/100g, 1.2 g/100g, respectively.

Table 4.1 Physico-chemical properties of arrowroot powder

Sl. No.	Constituents	Value
1	Moisture, %	18.53
2	Water activity	0.642
3	Protein, g/100g	11
4	Carbohydrate, g/100g	76
5	Fat, g/100g	0.55
6	Crude fibre, g/100g	0.77
7	Total ash, g/100g	1.2

Table 4.2 Effect of process variables on various

Run	Concentration, %	Milk to water ratio	Pasteurisation temperature, °C	Sensory score	pH	Moisture content, %	Water activity, a_w	TPC, (CFU/ml)
1	2	30:70	60	7.325	6.7	84.8	0.991	1.6×10^1
2	3	35:65	60	7	6.68	85.12	0.991	2.5×10^1
3	2	40:60	80	7.25	6.64	84.86	0.991	1.0×10^2
4	2	30:70	80	7.05	6.69	84.59	0.989	1.3×10^2
5	1	35:65	80	7.075	6.68	86.7	0.991	2.0×10^1
6	2	35:65	70	6.55	6.66	85.37	0.99	4.0×10^2
7	2	35:65	70	6.55	6.66	85.37	0.99	1.3×10^2
8	2	35:65	70	6.55	6.66	85.37	0.99	1.3×10^1
9	3	40:60	70	6.975	6.68	85.05	0.991	2.5×10^1
10	2	35:65	70	6.55	6.66	85.37	0.99	1.3×10^2
11	2	40:60	60	6.975	6.71	90.32	0.988	3.2×10^1
12	2	35:65	70	6.55	6.66	85.37	0.99	1.3×10^1
13	3	35:65	80	7.2	6.71	85.31	0.989	2.0×10^1
14	1	40:60	70	7.075	6.7	84.82	0.988	1.6×10^2
15	1	30:70	70	7.225	6.82	86.5	0.989	1.3×10^2
16	1	35:65	60	6.8	6.74	87.83	0.989	1.3×10^1
17	3	30:70	70	6.8	6.68	85.15	0.986	1.0×10^2

4.2 OPTIMIZATION OF PROCESS PARAMETERS OF ARROWROOT BEVERAGE

The optimization process for the development of arrowroot based beverage involved three independent variables: arrowroot concentration (1%, 2%, 3%), milk-to-water ratio (30:70, 35:65, 40:60) and pasteurization temperature (60°C, 70°C, 80°C). These ranges were selected based on preliminary studies and existing literature. The process parameters were optimized based on dependent responses, including moisture content, water activity, pH, microbiological quality, sensory attributes, and overall beverage quality. The effects of process variables were individually analyzed using Design Expert software to determine the optimal treatment conditions. Analysis of variance (ANOVA) was employed to assess the significance of the independent variables on each dependent response.

4.2.1 Effect of process parameters on Water activity

The effects of process parameters on water activity are presented in Table 4.2 and the respective ANOVA tables are presented in Appendix- A.1. The 3D graphs

representing the response surface generated by the model (Equation. 4.1) are depicted in Fig.4.1.

Analysis of variance showed that, the process parameters viz. concentration, milk to water ratio and pasteurization temperature had a significant effect on arrowroot drink. The R- squared value of the model was 0.89.

From Fig 4.1, it was found that the water activity varied between 0.986 to 0.991. The maximum value was obtained at 80°C pasteurization temperature, 3% arrow root concentration, and milk to water ratio of 30:70 and whereas minimum obtained at 70°C temperature, 3% concentration, 30:70 milk to water ratio, respectively.

From the Equation 4.1, it was observed that the concentration, milk to water ratio and temperature was found to be a positive effect on water activity. As the pasteurization temperature increased from 60 to 80°C, milk to water ratio from 30:70 to 40:60 and concentration from 1 to 3%, the water activity increased from 0.986 to 0.991. It may be due to interaction of starch properties with moisture (Bolarinwa *et al.,* 2018).

A second-order quadratic equation was fitted between independent variables and water activity using the experimental values. Following regression model is obtained to predict the water activity of arrowroot beverage.

$$\text{Water activity} = 0.99 + 0.0A + 0.0004B + 0.0001C + 0.0015AB - 0.0010AC + 0.0013BC - 0.0006A^2 - 0.0009B^2 + 0.0006C^2 \qquad R^2 = 0.99 \quad (4.1)$$

Where,

A= Concentration (%)

B= Milk to water ratio (ml)

C= Pasteurisation temperature (°C)

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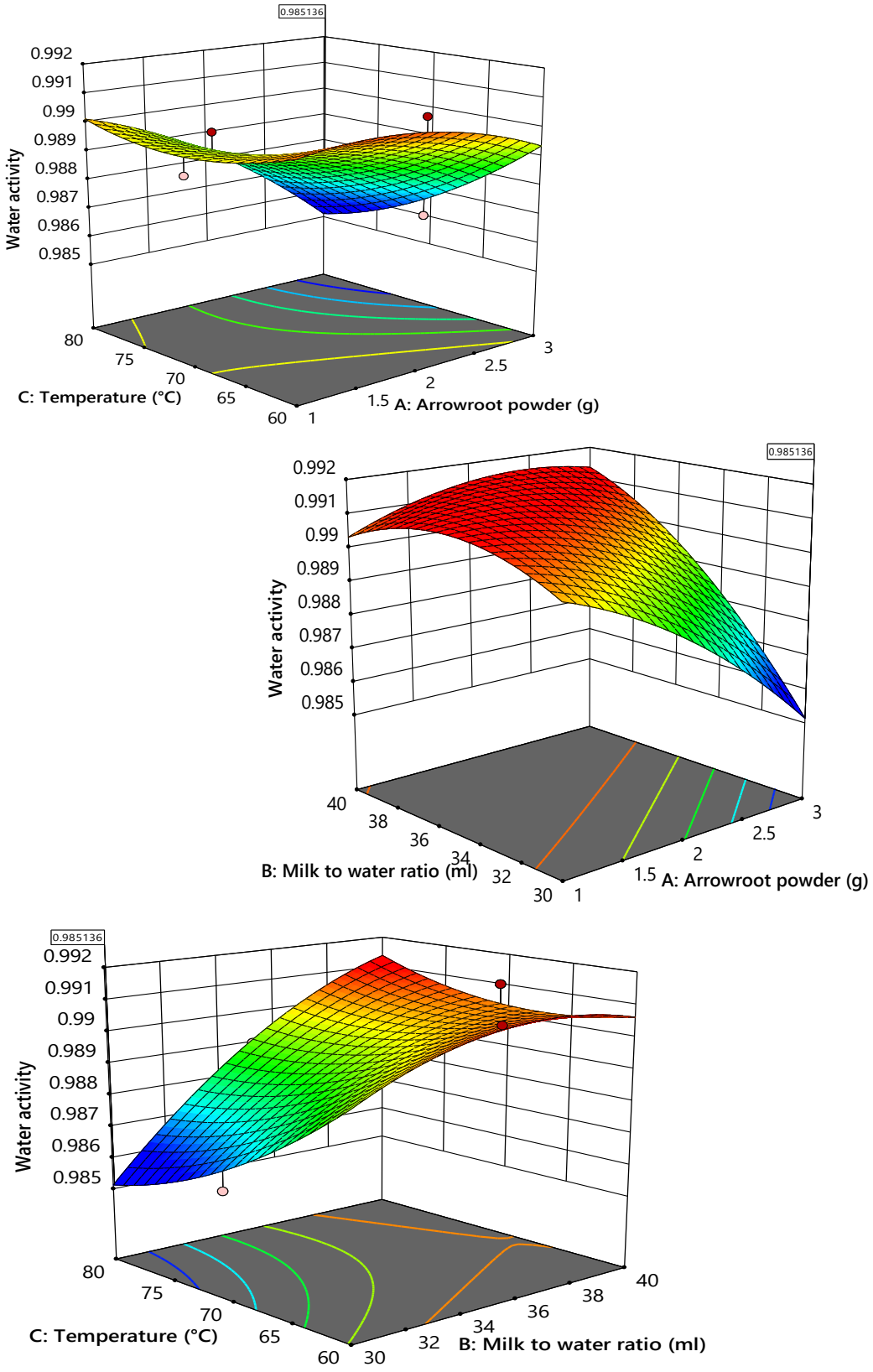

Fig 4.1 Effect of process parameters on water activity

4.2.2 Effect of process parameters on Moisture content

The 3D graphs representing the response surface generated by the model (Equation. 4.2) are depicted in Fig.4.2. Moisture content of arrowroot beverage at different operating conditions are tabulated in Table 4.2.

From the analysis of variance table (Appendix – A.2), it was understood that the process parameters viz. concentration, milk to water ratio, pasteurisation temperature had a significant effect on moisture content. The R- squared value of the model was 0.5750.

From Fig.4.2, it was observed that the moisture content of arrowroot beverage varied from 84.59 to 90.32 percent. The maximum moisture content of 90.32 percent was obtained at 60°C, 2% concentration and milk to water ratio of 40:60 whereas minimum obtained at 80°C, 2% concentration and milk to water ratio of 30:70, respectively.

From the Equation 4.2, it was observed that the milk to water ratio was found to be a positive effect on moisture content whereas reverse effect was found on concentration and temperature. This is due to the relatively high fat and protein content in milk, which enhances moisture retention. Conversely, increased concentration and temperature negatively affect moisture because higher concentrations can lead to reduced water availability, while elevated temperatures increase evaporation rates and disrupt water binding (Bolarinwa *et al.,* 2018).

The linear equation (4.2) explained the relationship between the process parameters and moisture content:

Moisture content = +85.76 – 0.6525A + 0.5013B – 0.8262C + 0.3950AB + 0.3300AC – 1.31BC $R^2 = 0.575$ (4.2)

Where,

A= Concentration (%)

B= Milk to water ratio (ml)

C= Pasteurisation temperature (°C)

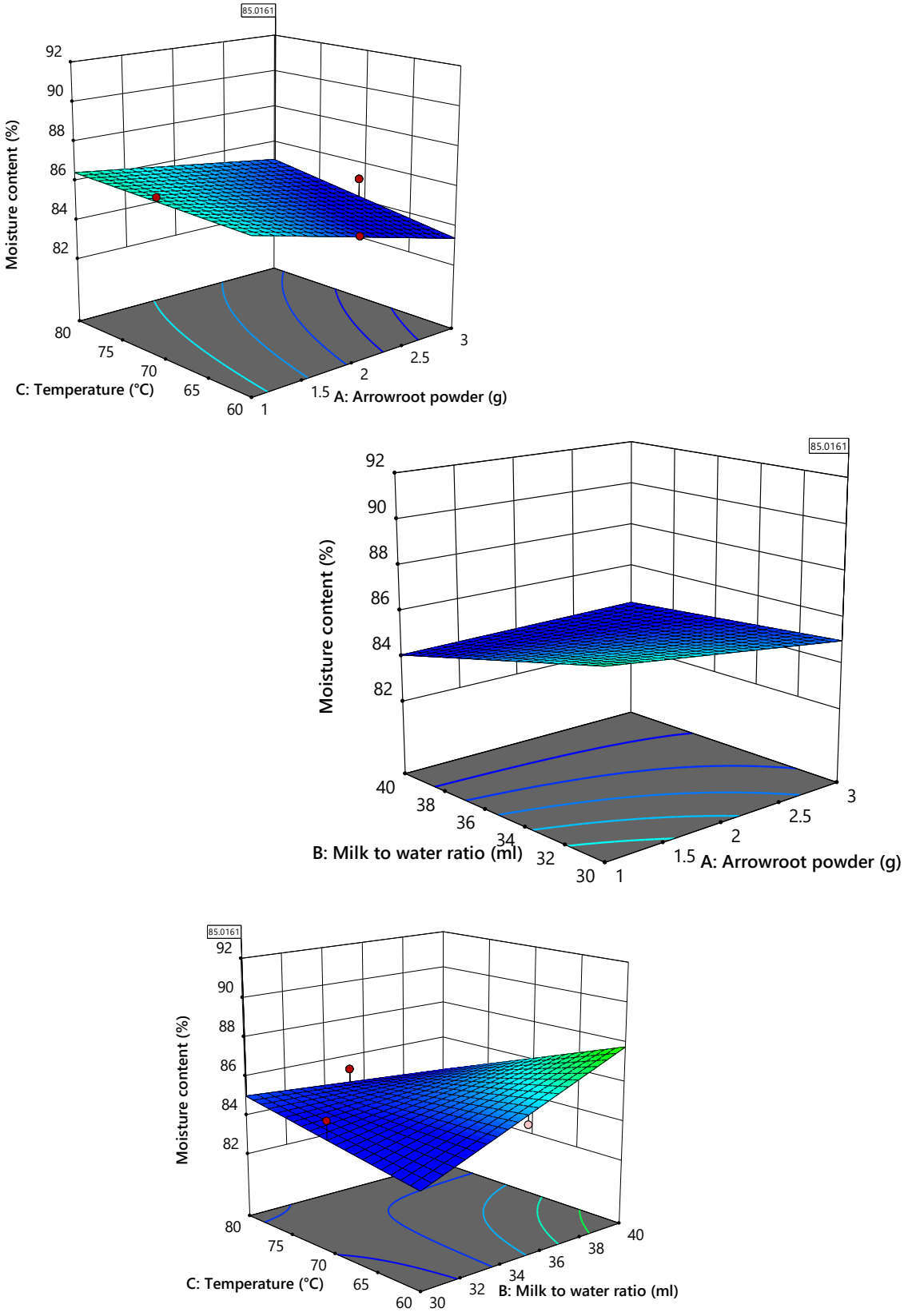

Fig 4.2 Effect of process parameters on moisture content

4.2.3 Effect of process parameters on pH

The pH of arrowroot beverage at different operating conditions are illustrated in Table 4.2. The 3D graphs representing the response surface generated by the model (Equation. 4.3) are depicted in Fig.4.3.

Analysis of variance table (Appendix – A.3) showed that the process parameters viz. concentration, milk to water ratio, pasteurization temperature had a significant effect on pH. The R- squared value of the model was 0.884.

From Fig 4.3, it was found that the pH varied between 6.64 to 6.82. The maximum value was obtained at 70°C, 1% concentration and milk to water ratio of 30:70 whereas minimum obtained at 80°C, 2% concentration and milk to water ratio of 40:60, respectively.

From Equation 4.3, it was observed that all process parameters had negative effect on pH. The presence of starch from arrowroot may also influence pH. As starch gelatinizes, it can interact with water and other components, potentially releasing acidic by-products (Belitz *et al*., 2013).

The relationship between the effect of process parameters and pH is shown in the second-order quadratic model and depicted by the equation 4.3:

$$\text{Extraction Time} = 6.66 - 0.0237A - 0.0200B - 0.0138C + 0.0300AB + 0.0225AC - 0.0150BC + 0.0387A^2 + 0.0212B^2 + 0.0038C^2 \qquad R^2 = 0.8840 \qquad (4.3)$$

Where,

A= Concentration (%)

B= Milk to water ratio (ml)

C= pasteurisation temperature (°C)

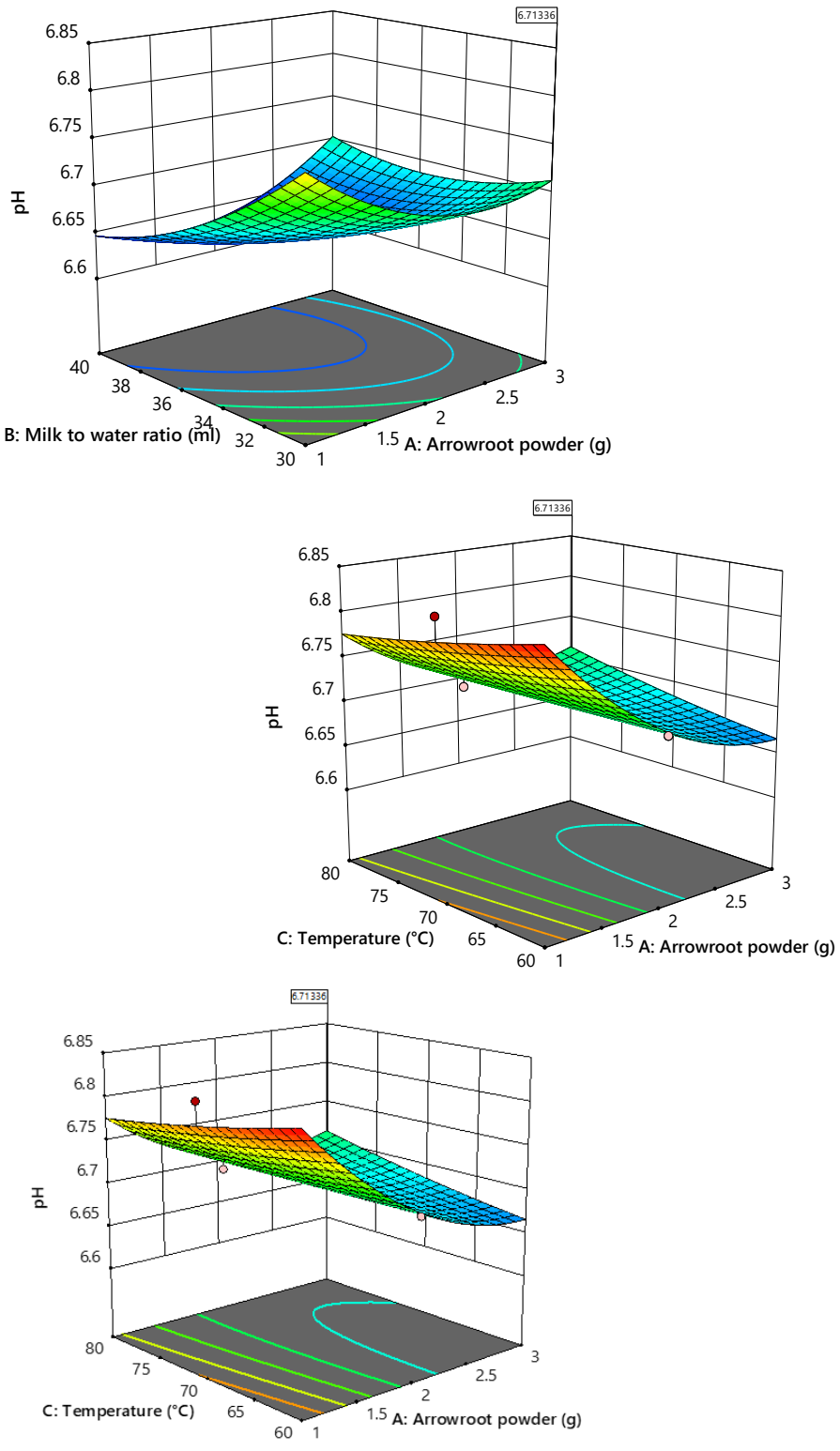

Fig 4.3 Effect of Process Parameters on pH

4.2.4 Effect of Process Parameters on Microbiological analysis

The surface plots for microbiological analysis of arrowroot at different processing conditions are shown in Fig. 4.4. Microbiological analysis of arrowroot at different operating conditions are depicted in Table 4.2.

Analysis of variance Table (Appendix – A.4) showed the process parameters viz. concentration, milk to water ratio had a significant effect whereas pasteurization temperature had insignificant effect on microbiological analysis. The R- squared value of the model was 0.6570.

From Fig 4.4, it was observed that the microbiological analysis varied between 0.5×10^5 to 3×10^5. The minimum value of microbial count was recorded at process parameters of 80°C, 1% concentration and milk to water ratio of 35:65 and the maximum value obtained at 70°C, 2% concentration and milk to water ratio of 35:65, respectively.

From Equation 4.4, it was found that the concentration and milk to water ratio had a positive effect on microbiological analysis, whereas pasteurization temperature had a negative effect on microbiological analysis. It is due to enhanced nutrient availability and prebiotic effects of arrowroot, which support probiotic growth. Higher concentrations and milk ratios provide more substrates for microbial activity, promoting the survival of beneficial bacteria like *Lactobacillus acidophilus*. Conversely, pasteurization temperature negatively impacts microbiological analysis because high temperatures can kill not only harmful bacteria but also beneficial probiotics, reducing overall microbial viability (Bolarinwa *et al.,* 2018).

$$TPC = 1.70 + 0.4375A + 0.0B - 0.1875C + 0.5AB - 0.3750AC + 0.0BC - 0.4125A^2 + 0.2125B^2 - 0.4125C^2 \qquad R^2 = 0.66 \qquad (4.4)$$

Where,

A= Concentration (%)

B= Milk to water ratio (ml)

C= pasteurisation temperature (°C)

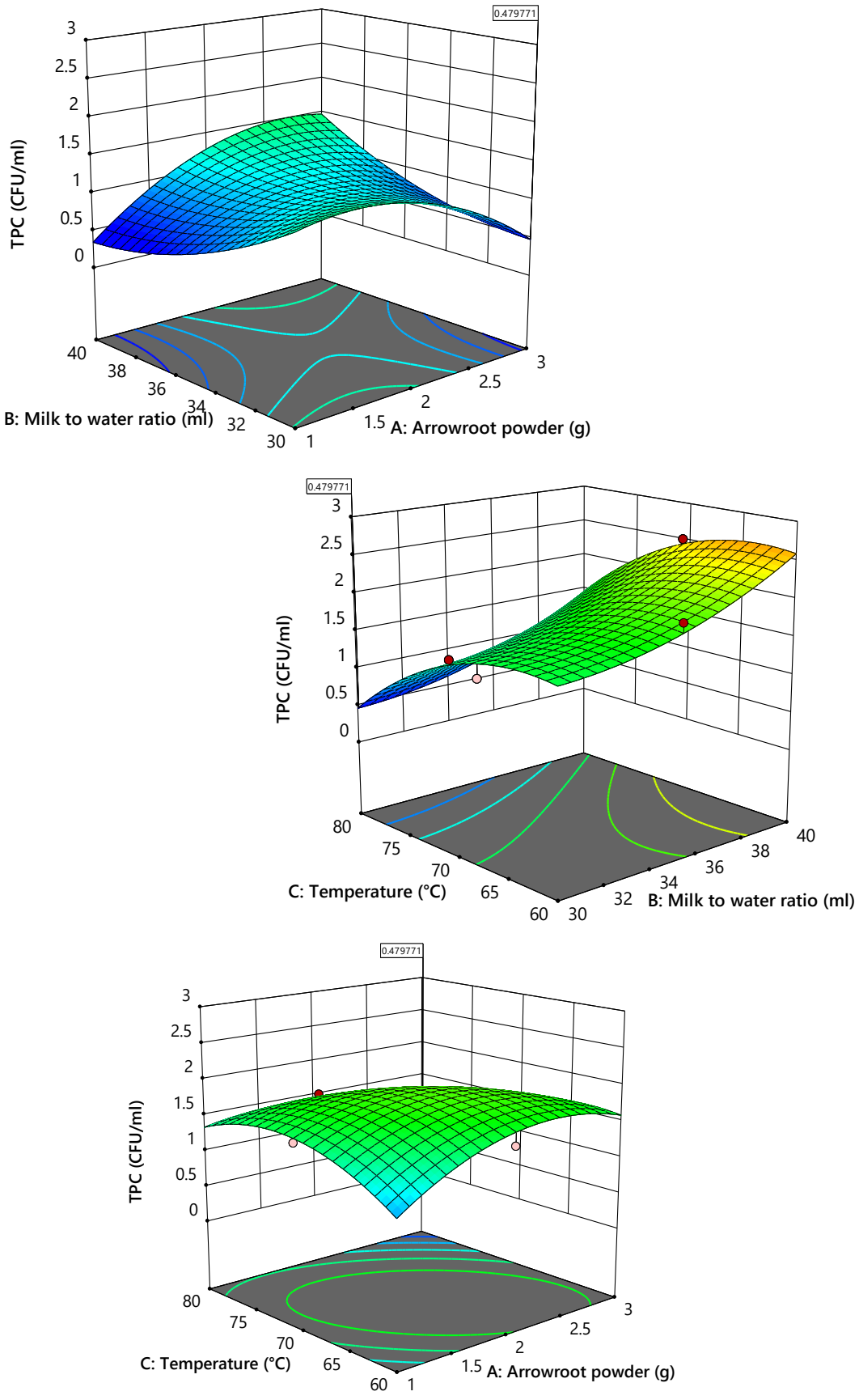

Fig 4.3 Effect of Process Parameters on Microbiological analysis

4.2.5 Effect of Process Parameters on Sensory analysis

The sensory analysis of arrowroot beverage at different process parameters are depicted in Table 4.2. Fig 4.5 shows the 3D surface plot for the sensory analysis of arrowroot beverage at different processing conditions.

Analysis of variance Table (Appendix – A.5) showed that the process parameters viz. pasteurization temperature had a significant effect whereas concentration, milk to water ratio had insignificant effect on sensory analysis. The R- squared value of the model was 0.90.

From the figure 4.5, it was found that the sensory analysis of arrowroot beverage ranged from 6.55 to 7.32 at different process parameters. The minimum value of sensory analysis was identified at operating conditions of 70°C, 2% concentration and milk to water ratio of 35:65 and maximum value was obtained at 60°C, 2% concentration and milk to water ratio of 30:70, respectively.

From the Equation 4.5, it was observed that the pasteurization temperature had a positive effect on sensory analysis while Concentration and milk to water ratio shows negative effect.

The changes in sensory analysis values with different processing parameters was determined by using the second-order quadratic model and represented by the equation 4.5:

$$\text{Sensory analysis} = 6.55 - 0.0250A - 0.0156B + 0.0594C + 0.0812AB - 0.0188AC + 0.1375BC + 0.1687A^2 + 0.3000B^2 + 0.3000C^2 \qquad R^2 = 0.9 \qquad (4.5)$$

Where,

A= Concentration (%)

B= Milk to water ratio (ml)

C= Pasteurisation temperature (°C)

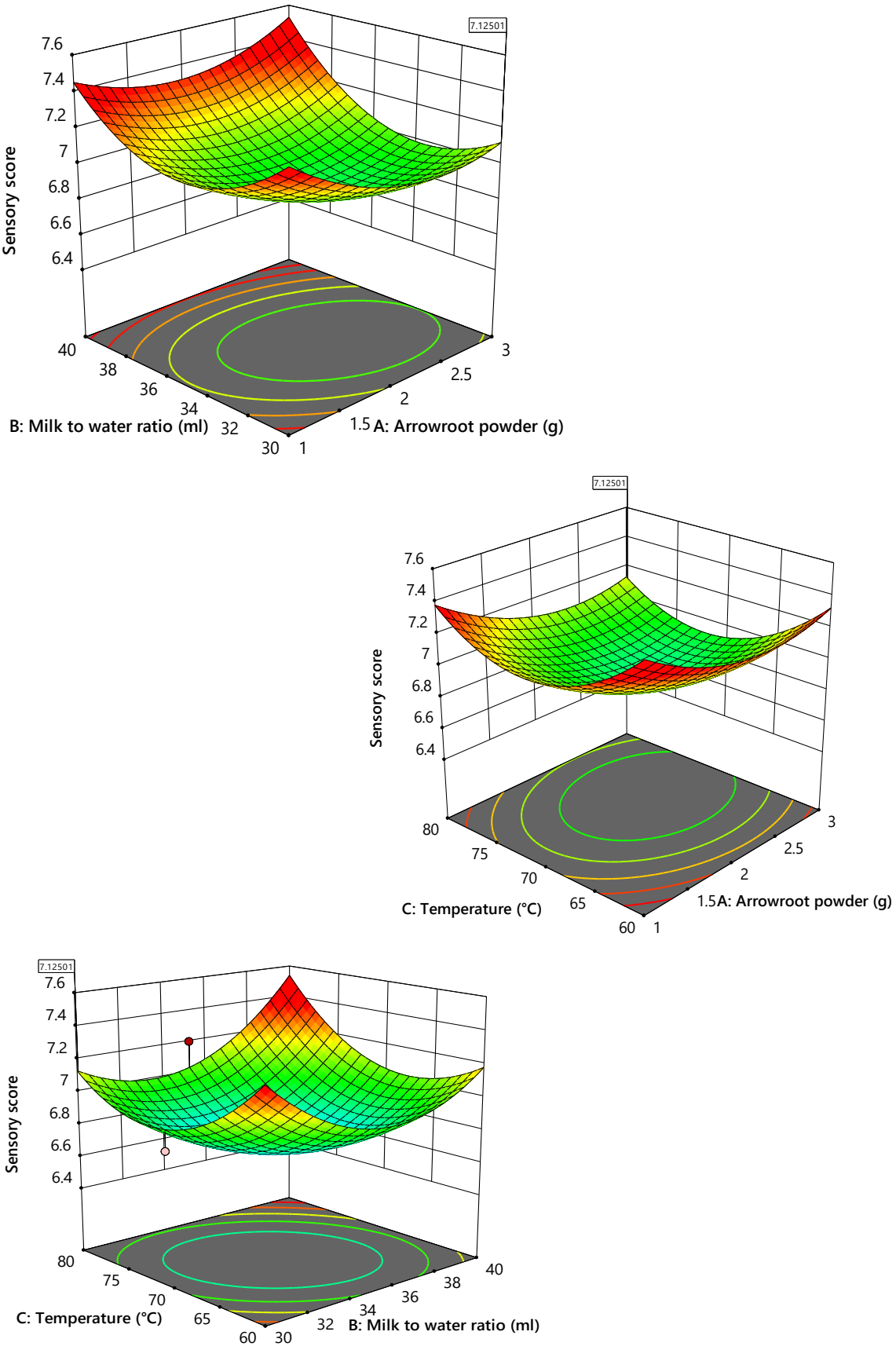

Fig 4.5 Effect of process parameters on sensory analysis

4.3 DEVELOPMENT OF ARROWROOT BASED HEALTH BEVERAGE

The process flow chart for the development of arrowroot based health beverage is shown in Fig. 4.6. Arrowroot powder having a concentration of 3% was prepared by mixing of 3g arrowroot powder with 30% milk and 70% water ensuring a smooth, lump-free solution. Heat the mixture in a saucepan over low flame, stirring occasionally to prevent scorching. Stir continuously to achieve a smooth consistency. Allow the mixture to cook for 5-7 minutes on low to medium heat until it thickens, as the arrowroot gelatinizes. Adjust the TSS to 14° Brix. Bottle the sample and pasteurize at 80°C. After cooling, stored it in a refrigerated condition.

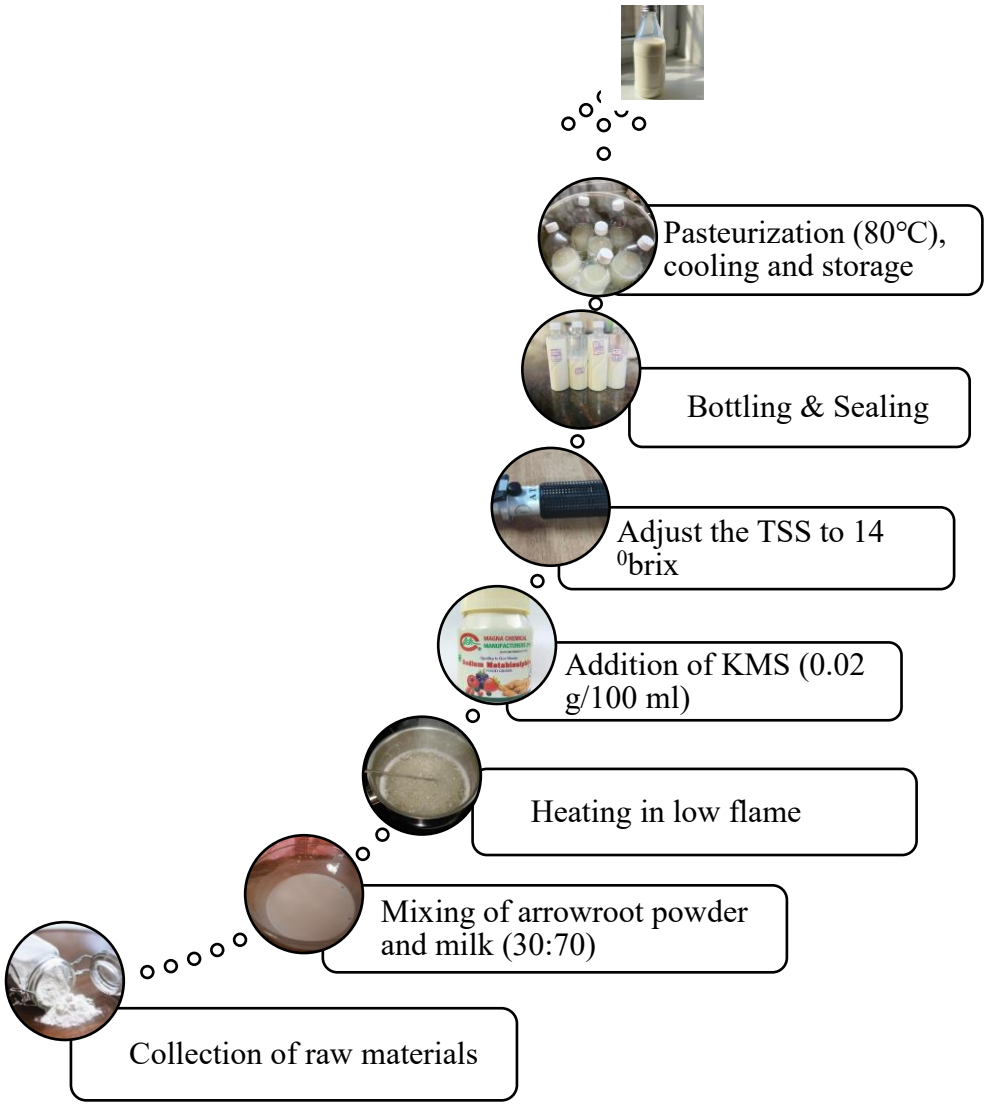

Fig. 4.6 Process flow chart for the development of arrowroot based health beverage

4.4 OPTIMISATION OF PROCESS PARAMETERS FOR ARROWROOT BEVERAGE

The optimization of process parameters was carried out using the Box Behnken design of the Design Expert software 12. Three independent variables viz. concentration (1, 2, 3 %), milk to water ratio (30:70, 35:65, 40:60) and pasteurization temperature (60, 70, 80 °C) were selected based on the study. Further, the quality of arrowroot beverage was analysed to decide the best treatment among the 17 trials provided by the software. In the optimization process, the three different independent variables were set in range whereas, the 5 response variables were kept either minimum or maximum based on the requirements of each dependent parameters. From the desirability analysis, the optimal level of various parameters were found and listed in Table 4.2. The optimal conditions obtained for arrowroot beverage was 3% concentration, 30:70 milk to water ratio and 80°C pasteurization temperature. Moreover, the desirability of the optimization was obtained as 0.823 and as the value is close to 1, the optimal values may be considered as ideal. The optimized conditions for the development of arrowroot beverage were tabulated in in Table 4.4.

Table 4.3 Multi response optimization process parameters for arrowroot beverage

Sl. No.	Parameters	Goal	Lower Limit	Upper Limit
1	Concentration	In range	1	3
2	Milk to water ratio	In range	30:70	40:60
3	Pasteurisation temperature	In range	60	80
4	Sensory analysis	Maximum	6.55	7.3
5	pH	Maximum	6.64	6.82
6	Moisture content	Minimum	84.59	90.32
7	Water activity	Minimum	0.988	0.991
8	TPC	Minimum	1.0×10^2	4.0×10^2

Table 4.4 Optimized process parameters for the development of arrowroot beverage

Sl. No.	Process parameter	Optimized Condition
1	Concentration	3%

2	Milk to water ratio	30:70
3	Pasteurisation temperature	80°C

4.5 CHARACTERISTIC STUDY OF OPTIMIZED ARROWROOT BEVERAGE

Arrowroot beverage was developed using arrowroot powder at optimal conditions of temperature preferred as 80 °C, milk to water ratio of 30:70 and concentration of 3%. Arrowroot beverage is found to be a nutritional beverage offering several health benefits.

Arrowroot beverage is one of the most nutrient-rich beverage, due to its unique healing properties. It is known for their nutritional benefits and digestive properties. They are made from arrowroot powder, which is a light, white starch that is extracted from arrowroot, aiding digestion and providing a soothing effect on the stomach. Arrowroot is rich in fiber, protein, and essential vitamins, making it beneficial for weight management and gastrointestinal health. Its unique properties also enhance the texture and moisture retention in food products. It offers several nutritional advantages compared to other popular health beverages. When considering its nutritional profile, arrowroot stands out for its high content of resistant starch. This type of starch acts as a prebiotic, promoting gut health by fostering beneficial bacteria and enhancing digestive function. In contrast, many fruit-flavored beverages are often high in sugars and low in fiber, which can lead to spikes in blood sugar levels and do not provide the same digestive benefits. For instance, while smoothies may offer a range of vitamins and minerals from fruits and vegetables, they often contain high amounts of sugar and calories. Similarly, energy beverages may provide quick energy boosts but often come with caffeine and artificial additives that can have negative health effects over time.

In summary, arrowroot beverage presents a compelling alternative to conventional health beverages due to its low calorie, high resistant starch content, rich nutrient profile, and digestive benefits. Its ability to promote gut health while providing essential vitamins and minerals makes it a valuable addition to a balanced diet. Similar results were obtained by Anvita *et al*., 2023.

Table 4.5 Characteristics of arrowroot based health beverage

Sl. No.	Parameters	Value
1	Carbohydrate, g/100ml	9.6

2	Protein, g/100ml	6.03
3	Fat, g/100ml	1.54
4	Crude fibre, g/100ml	0.1
5	Ash, g/100ml	0.096
6	Titrable acidity, percent	0.06
7	Antioxidant	41.11
8	Vitamin C	0.0513
9	Total soluble solids,°Brix	14
10	Total plate count, CFU/ml	1.0×10^2

4.6 STORAGE STUDIES

The analysis of shelf-life was carried out in optimized samples. The samples treated under optimal conditions viz. 3% concentration, 30:70 milk to water ratio and 80°C temperature were packed in two different packaging materials viz. PET bottles and glass bottles at refrigerated temperature (8 ± 2°C). Further, the samples were evaluated after every 7 days interval for about 14 days.

4.6.1 Effect of storage period on moisture content of arrowroot beverage

The amount of moisture content affects negatively the performance and shelf life of arrowroot beverage. Moisture may accelerate microbial count and the changes in the moisture content for arrowroot beverage sample during storage time, expressed in terms of per cent are shown in fig 4.7. The samples on the initial day had a moisture content for each treatment viz. T_1, T2, T3, T4 were 80.76, 80.190, 81.5, 83.2. Further, the values of moisture content on the 14th day storage for each treatment viz. T1, T2, T3, T4, were 83.58, 83.77, 84.17, 86.80, respectively.

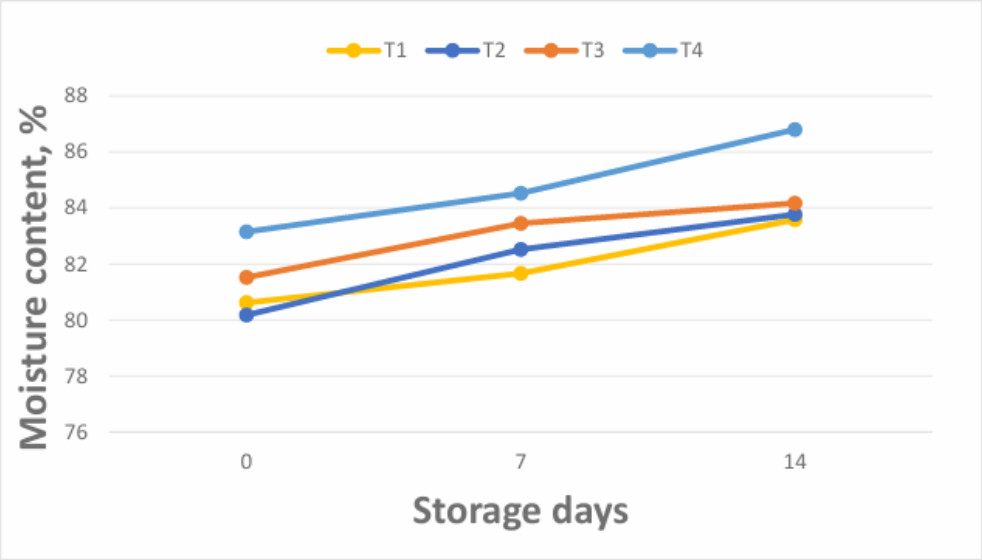

Fig 4.7 Change in moisture content of arrowroot based health beverage during storage

4.6.2 Effect of storage period on water activity of arrowroot beverage

The change in water activity of arrowroot beverage during storage is presented in the fig 4.16. From fig 4.8, it was observed that water activity of arrowroot beverage samples T1, T2, T3, T4, showed similar behaviour during storage. The samples on the initial day had a water activity for each treatment are 0.991, 0.981, 0.991, 0.986. Further, the values of water activity on the 14th day storage for each treatment viz. T1, T2, T3, T4, were 0.989, 0.989, 0.989, 0.988 respectively.

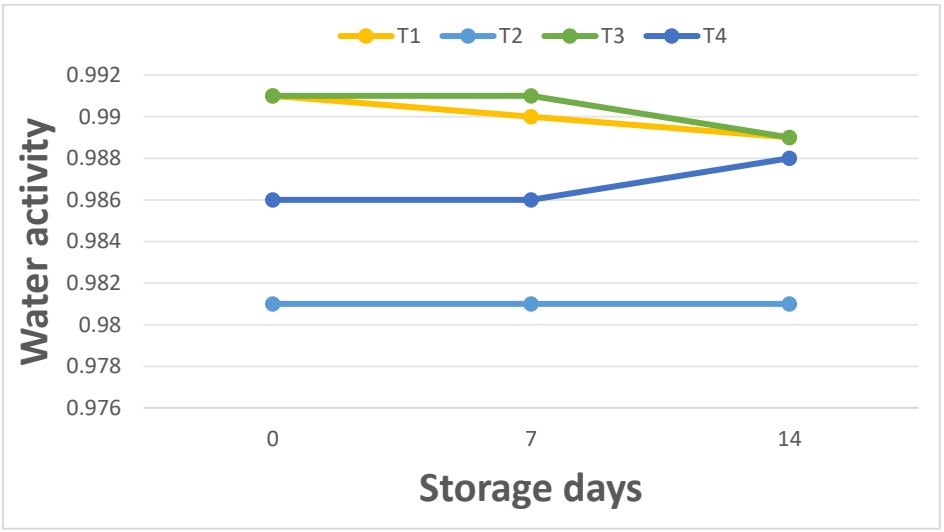

Fig 4.8 Change in water activity of arrowroot based health beverage during storage

4.6.3 Effect of storage period on TSS of arrowroot beverage

Organic acids, sugars, non-organic matter, proteins etc constitute total soluble solids (Panou *et al*., 2018). The variation of TSS values of arrowroot beverage during storage are presented in Fig 4.9. Initially, on the 0th day of packaging all the samples had a TSS value of about 14 °Brix which decreased during the course of storage. On the final day of storage i.e., on 14th day, the content of soluble solids in the different treatments viz. T1, T2, T3, T4, were 14, 13, 12.5, 13, respectively.

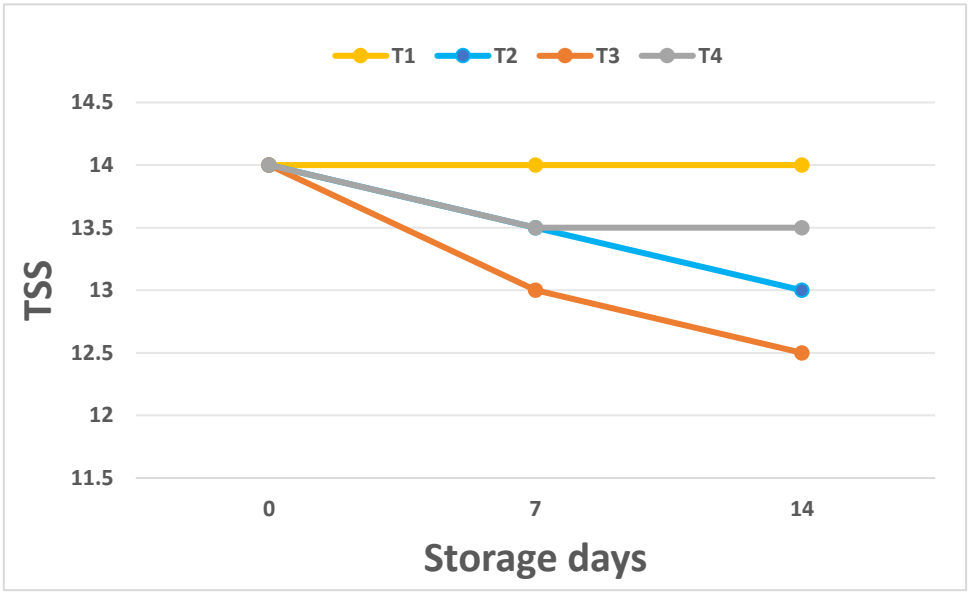

Fig 4.9 Change in TSS of arrowroot based health beverage during storage

4.6.4 Effect of storage period on TPC of arrowroot beverage

The amount of microbial load present in a product largely influences its keeping quality. The changes in microbial count of stored arrowroot beverage samples as affected by storage duration are presented in Fig 4.10. It was seen that as the storage time advances, microbial count also got increased resulting in value of 43×10^3, 50×10^3, 36×10^3, 12×10^3 CFU/ml on the 14th day of storage for each treatment viz. T1, T2, T3, T4, respectively.

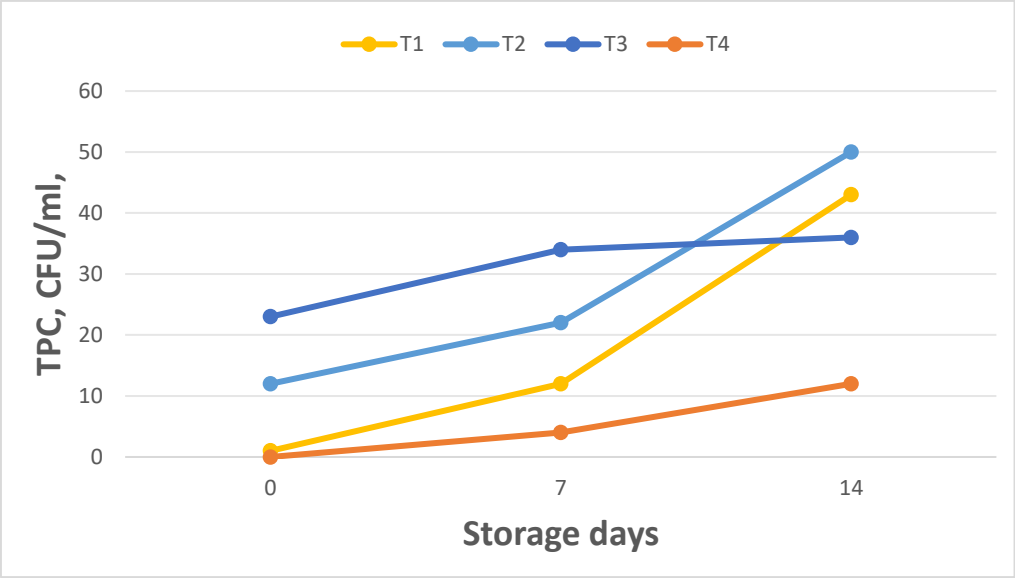

Fig 4.10 Change in TPC of arrowroot based health beverage during storage

CHAPTER V

SUMMARY AND CONCLUSION

Arrowroot is a low perennial herb found in rain forest habitats which is often cultivated for starch obtained from its rhizomes. It can grow two feet high, has a small white flowers and fruits. Arrowroot is indigenous in tropical America but has spread to other countries such as Brazil, Ceylon, and Indonesia. It is the only starch product with calcium ash which is important for the maintenance of proper acid and alkali balance in the human body. There are two varieties of Arrowroot in existence, Western Arrowroot which are the *Maranta aurundinacae* and Eastern Arrowroot which are *Curcuma leucorrhizza* and *Curcuma angustifolia* varieties, commonly known as white, blue and yellow Arrowroot (vella koova, neela koova and manja koova) respectively. The extraction of starch from koova is done traditionally by the method of stone scrubbing and grater scrubbing. The partially mechanised method which is in existence use rasper which have 31.01 kg/hr. at 1000 rpm rasper speed, which consumes minimum 15.5 kWh for 100 kg, the cost of the machine is 1 lakh rupees and the processing cost may range up to 100 rupees per kg starch powder per hour. The starch recovery was estimated as 10 to 20 % for arrow root (Chavindra kumar paikra, 2014).

The starch can be used in the development of products as a replacement of corn starch as well as to produce gluten free products like cookies, cake, barfi etc. The common use of Arrowroot starch is in the preparation of baby foods.

Arrowroot beverage is one of the most nutrient-rich beverage, due to its unique healing properties. It is known for their nutritional benefits and digestive properties. They are made from arrowroot powder, which is a light, white starch that is extracted from arrowroot, aiding digestion and providing a soothing effect on the stomach. Arrowroot is rich in fiber, protein, and essential vitamins, making it beneficial for weight management and gastrointestinal health. Its unique properties also enhance the texture and moisture retention in food products. It offers several nutritional advantages compared to other popular health beverages. When considering its nutritional profile, arrowroot stands out for its high content of resistant starch. This type of starch acts as a prebiotic, promoting gut health by fostering beneficial bacteria and enhancing digestive function. In contrast, many fruit-flavored beverages are often high in sugars and low in fiber, which can lead to spikes in blood sugar levels and do not provide the same digestive benefits.

Response surface methodology was made use of for optimising the three selected process variables viz. temperature (80 °C), milk to water ratio (30:70) and concentration (3%). Box Behnken design with three independent variables and eight different responses (Moisture content, water activity, ascorbic acid, TSS, titratable acidity, pH, sensory analysis and total plate count) were employed for the purpose of optimisation.

The sensory analysis of arrowroot beverage were conducted based on 9-point hedonic scale. The analysis was conducted to understand the consumer perception on the colour and appearance, flavour, taste and overall acceptability of the samples.

The arrowroot beverage samples which were optimised were packed in two different packaging materials (PET bottles and glass bottles) and they were stored under two different conditions say, room temperature (25±5°C) and at refrigerated temperature (8 ±2°C). Further, the samples were analysed continuously on a 7-day interval till 14 days to examine the variations in different physio-chemical attributes.

The results of the above experiments are summarized as following:

The chemical as well as nutritional characteristics of arrowroot beverage viz. moisture content, water activity, ascorbic acid, TSS, titratable acidity, pH, protein, carbohydrate, total fat, crude fibre, total ash were 86.80 %, 0.988, 0.0513 %, 13 °Brix, 0.062 %, 6.59 g/100ml, 6.03g/100ml, 9.6g/100ml, 1.54g/100ml, 0.1g/100ml, 0.096g/100ml respectively. Moreover, the microbial analysis of raw samples revealed a total plate count of 5 log cfu/ml.

The optimisation of process parameters was carried out using the Box Behnken design of the Design Expert software 12. Further, the characteristics of arrowroot beverage were vividly analysed to decide the best treatment among the 17 trials provided by the software. Optimal conditions obtained for arrowroot beverage was 3% concentration, 80°C pasteurization temperature and milk to water ratio of 30:70.

The arrowroot beverage samples under optimised conditions were analysed to understand the acceptability of the sample. Results on each quality and sensory parameter indicated that the optimised samples with KMS in glass bottles stored at refrigerated temperature retains all the quality parameters of food.

The analysis of shelf-life was carried out in the optimised samples treated under 3% concentration, 80°C pasteurization temperature and milk to water ratio of 30:70. The samples were packed in two different packaging materials viz. PET bottle and glass bottle.

The influence of two different packaging materials as well as the storage days on various quality indices of stored arrowroot samples were analysed on every 7th day of storage for a period of 14 days. During the course water activity, moisture content and total plate count of the samples increased whereas, TSS, titrable acidity and ascorbic acid decreased. However, arrowroot beverage samples stored in glass bottles stored at refrigerated conditions were acceptable till 14 days with better quality attributes and reduced microbial load.

Following conclusions were derived based on the findings:

- For a healthy nutrient diet, arrowroot beverage is a better alternative to other energy beverages.

- Arrowroot beverage within the threshold limit of the TSS does not significantly affect its physio-chemical as well as sensory attributes.

- KMS combined with packaging techniques are better preservation methods to extend the keeping quality of arrowroot beverage.

- An arrowroot concentration of 3%, 80℃ pasteurization temperature and milk to water ratio of 30:70 and low temperature storage (8±2℃) retained all the quality parameters of arrowroot beverage samples.

- Arrowroot beverage with packaging in glass bottles under refrigerated conditions extended the shelf-life of arrowroot based beverage to 14 days.

- The sensory and nutritional parameters of the stored arrowroot beverage at the end of storage were within the acceptable limits.

Scope of future work

- Explore the possibility of addition of flavour and colors.

- Explore the possibility of novel packaging technologies in arrowroot beverage.

- Shelf-life studies of arrowroot beverage can be conducted to a period of 1 year with different packaging materials and packaging technologies.

CHAPTER VI
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APPENDIX A

Appendix A.1. Analysis of variance (ANOVA) for Water activity

Source	Sum of squares	df	Mean square	F-value	p-value		a_w
Model	0.0000	9	2.985E-06	6.43	0.0113	significant	+0.9900
A-Arrowroot powder	0.0000	1	0.0000	0.0000	1.0000		+0.0000
B-Milk to water ratio	1.125E-06	1	1.125E-06	2.42	0.1635		+0.0004
C-Temperature	1.250E-07	1	1.250E-07	0.2692	0.6198		+0.0001
AB	9.000E-06	1	9.000E-06	19.38	0.0031		+0.0015
AC	4.000E-06	1	4.000E-06	8.62	0.0219		-0.0010
BC	6.250E-06	1	6.250E-06	13.46	0.0080		+0.0013
A^2	1.645E-06	1	1.645E-06	3.54	0.1018		-0.0006
B^2	3.224E-06	1	3.224E-06	6.94	0.0337		-0.0009
C^2	1.645E-06	1	1.645E-06	3.54	0.1018		+0.0006
Residual	3.250E-06	7	4.643E-07				
Lack of Fit	3.250E-06	3	1.083E-06				
Pure Error	0.0000	4	0.0000				
Cor Total	0.0000	16					

Std. Dev.	0.0007	**R^2**	0.8921
Mean	0.9896	**Adjusted R^2**	0.7533
C.V. %	0.0689	**Predicted R^2**	-0.7266
		Adeq Precision	9.3284

Appendix A.2. Analysis of variance (ANOVA) for Moisture content

Source	Sum of squares	df	Mean square	F-value	p-value		Moisture content
Model	18.83	6	3.14	2.26	0.1225	not significant	+85. 76
A-Arrowroot powder	3.41	1	3.41	2.45	0.1488		−0. 6525
B-Milk to water ratio	2.01	1	2.01	1.44	0.2571		+0. 5013
C-Temperature	5.46	1	5.46	3.93	0.0757		−0. 8262
AB	0.6241	1	0.6241	0.4485	0.5182		+0. 3950
AC	0.4356	1	0.4356	0.3131	0.5881		+0. 3300
BC	6.89	1	6.89	4.95	0.0502		−1. 31
Residual	13.91	10	1.39				
Lack of Fit	13.91	6	2.32				
Pure Error	0.0000	4	0.0000				
Cor Total	32.74	16					

Std. Dev.	1.18	**R^2**	0.5750
Mean	85.76	**Adjusted R^2**	0.3200
C.V. %	1.38	**Predicted R^2**	-1.0909
		Adeq Precision	5.6510

Appendix A.3. Analysis of variance (ANOVA) for pH

Source	Sum of squares	df	Mean square	F-value	p-value		pH
Model	0.0246	9	0.0027	5.93	0.0143	significant	+6.66
A-Arrowroot powder	0.0045	1	0.0045	9.79	0.0166		-0.0237
B-Milk to water ratio	0.0032	1	0.0032	6.95	0.0336		-0.0200
C-Temperature	0.0015	1	0.0015	3.28	0.1129		-0.0138
AB	0.0036	1	0.0036	7.81	0.0267		+0.0300
AC	0.0020	1	0.0020	4.40	0.0743		+0.0225
BC	0.0009	1	0.0009	1.95	0.2049		-0.0150
A^2	0.0063	1	0.0063	13.72	0.0076		+0.0387
B^2	0.0019	1	0.0019	4.13	0.0817		+0.0212
C^2	0.0001	1	0.0001	0.1285	0.7305		+0.0038
Residual	0.0032	7	0.0005				
Lack of Fit	0.0032	3	0.0011				
Pure Error	0.0000	4	0.0000				
Cor Total	0.0278	16					

Std. Dev.	0.0215	**R^2**	0.8840
Mean	6.69	**Adjusted R^2**	0.7348
C.V. %	0.3208	**Predicted R^2**	-0.8561
		Adeq Precision	9.5673

Appendix A.4. Analysis of variance (ANOVA) for Microbiological analysis

Source	Sum of squares	df	Mean square	F-value	p-value		TPC
Model	5.01	9	0.5561	1.49	0.3064	not significant	+1.70
A-Arrowroot powder	1.53	1	1.53	4.10	0.0825		+0.4375
B-Milk to water ratio	8.882E-16	1	8.882E-16	2.380E-15	1.0000		+0.0000
C-Temperature	0.2813	1	0.2813	0.7536	0.4141		-0.1875
AB	1.0000	1	1.0000	2.68	0.1457		+0.5000
AC	0.5625	1	0.5625	1.51	0.2592		-0.3750
BC	0.0000	1	0.0000	0.0000	1.0000		+0.0000
A^2	0.7164	1	0.7164	1.92	0.2084		-0.4125
B^2	0.1901	1	0.1901	0.5094	0.4985		+0.2125
C^2	0.7164	1	0.7164	1.92	0.2084		-0.4125
Residual	2.61	7	0.3732				
Lack of Fit	0.3125	3	0.1042	0.1812	0.9040	not significant	
Pure Error	2.30	4	0.5750				
Cor Total	7.62	16					

Std. Dev.	0.6109	**R^2**	0.6570
Mean	1.41	**Adjusted R^2**	0.2161
C.V. %	43.27	**Predicted R^2**	-0.1281
		Adeq Precision	4.6687

Appendix A.5. Analysis of variance (ANOVA) for sensory analysis

Source	Sum of squares	df	Mean Square	F- value	p-value		Sensory score
Model	1.11	9	0.1235	7.07	0.0086	significant	+6.55
A-Arrowroot powder	0.0050	1	0.0050	0.2861	0.6093		-0.0250
B-Milk to water ratio	0.0020	1	0.0020	0.1117	0.7480		-0.0156
C-Temperature	0.0282	1	0.0282	1.61	0.2446		+0.0594
AB	0.0264	1	0.0264	1.51	0.2587		+0.0812
AC	0.0014	1	0.0014	0.0805	0.7849		-0.0188
BC	0.0756	1	0.0756	4.33	0.0761		+0.1375
A^2	0.1199	1	0.1199	6.86	0.0344		+0.1687
B^2	0.3789	1	0.3789	21.68	0.0023		+0.3000
C^2	0.3789	1	0.3789	21.68	0.0023		+0.3000
Residual	0.1223	7	0.0175				
Lack of Fit	0.1223	3	0.0408				
Pure Error	0.0000	4	0.0000				
Cor Total	1.23	16					

Std. Dev.	0.1322	**R^2**	0.9008
Mean	6.91	**Adjusted R^2**	0.7734
C.V. %	1.91	**Predicted R^2**	-0.5864
		Adeq Precision	7.7050

APPENDIX B

SENSORY SCORE CARD

Department of Processing and Food Engineering,

KCAEFT, Tavanur

Name of the judge: **Date:**

You are requested to assess the product in terms of general acceptability on a 9- point hedonic scale.

Characteristics	Sample A	Sample B	Sample C	Sample D	Sample E
Appearance					
Colour					
Taste					
Flavour					
Overall acceptability					

Nine point Hedonic Scale

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

Comments if any :

Signature :

PROCESS OPTIMIZATION AND CHARACTERIZATION OF ARROWROOT BASED FUNCTIONAL HEALTH BEVERAGE

BY,

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ABSTRACT OF PROJECT REPORT

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In

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Department of Processing and Food Engineering

Faculty of Agricultural Engineering and Technology

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

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ABSTRACT

Arrowroot is a starchy root vegetable derived from several tropical plants, most commonly *Maranta arundinacea*. It is known for its fine, easily digestible starch, which is often used as a thickening agent in cooking and baking. Arrowroot powder is gluten-free and has a neutral taste, making it a popular substitute for cornstarch, especially in recipes for people with dietary restrictions. Traditionally, arrowroot has also been valued for its medicinal properties, including soothing digestive issues and aiding in recovery from illness. The present study was undertaken to develop and evaluate a nutritious health beverage using arrowroot powder to growing consumer preference for functional and plant-based beverages.

Arrowroot powder was blended with milk and sugar to formulate the beverage, and the process parameters viz. arrowroot concentration (3%), pasteurization temperature (80°C), and milk-to-water ratio (30:70) were optimized using Response Surface Methodology (RSM) based on Box-Behnken design. Proximate composition and quality attributes including moisture content, pH, water activity, crude fiber, protein, fat, carbohydrate content, total soluble solids (TSS), and titratable acidity were analyzed. Sensory evaluation was carried out using a 9-point hedonic scale to assess consumer acceptability in terms of color, taste, aroma, mouthfeel, and overall appeal.

The optimized arrowroot beverage was found to be highly acceptable and nutritionally beneficial, with favorable physicochemical and microbiological stability during refrigerated storage. After the storage study, we found that arrowroot beverage samples stored in glass bottles stored at refrigerated conditions were acceptable till 14 days with better quality attributes.

This study demonstrates the potential of arrowroot as a base ingredient for developing functional beverages, particularly suitable for health-conscious consumers and individuals with dietary sensitivities. The product aligns with current trends in sustainable food innovation and contributes to value addition in underutilized indigenous crops.