PROCESS OPTIMIZATION OF FRUIT BLENDED BOBA TEA PEARLS FROM CASSAVA (*Manihot esculenta*)

by

GAYATHRI D

(2020-16-005)

THESIS

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF SCIENCE IN COMMUNITY SCIENCE
(Food and Nutrition)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF COMMUNITY SCIENCE

COLLEGE OF AGRICULTURE

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DECLARATION

I, hereby declare that this thesis entitled **"Process Optimization of fruit blended Boba Tea pearls from Cassava (*Manihot esculenta*)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma,associateship, fellowship or other similar title, of any other University or Society.

Place: Vellayani

Date: 11 - 09 - 2023

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Certified that this thesis, entitled **"Process Optimization of fruit blended Boba Tea pearls from Cassava (*Manihot esculenta*)"** is a record of research work done independently by **Ms. GAYATHRI D (2020-16-005)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

CTCRI	Central tuber crops research institute
ANOVA	Association of Official Agricultural Chemists
CD(0.005)	Critical difference at 5% level
Cfu	Colony Forming Units
CRD	Completely Randomized Design
^{0}B	Degrees Brix
EMP	Eosin Methylene Blue
et al	Co workers /Co-authors
Fig	Figure
FP	Fruit Pulp
g	Gram
kg	Kilogram
mg	Milligram
ml	Milliliter
No.	Number
PCA	Plate Count Agar
PDA	Potato Dextrose Agar
%	Percent
ppm	Parts per million
Rs	Rupees
TAA	Total Soluble Solids
TSS	Total Soluble solids

LIST OF PLATES

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ABSTRACT OF THE THESIS

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INTRODUCTION

In tropical and subtropical regions, Cassava *(Manihot esculenta Crantz*) is a staple food .and the third most significant source of calories in the tropics crop and a valuable food source. It is s a perennial shrub which was orginated in Southern Brazil which comes under the family Eurphorbiceae. As the sixth-most significant food crop in the world, cassava is widely known for generating calories (Pujol *et al* ., 2002 , Silva *et al* ., 2003)

Cassava was introduced as the dominant staple food crop in Kerala due to its abundant staple crop.Cassava is the second most important source of starch (Stapleton *et al*.,2012) It is referred to as poor man's food throughout the world since it is the least expensive form of human sustenance. Rapid post-harvest deterioration in cassava necessitates value enhancement. It is urgently necessary to develop new processed root crop products in light of the anticipated rise in worldwide demand. (Moorthy, 2006; Padmaja *et al.,* 2006).Cssava was also used as a significant raw material used to make starch, bioethanol, and other bio-based goods like feed, medication, cosmetics, and biopolymers and is superior to other starchy crops in terms of its capacity to accumulate starch, tolerance to drought, and resistance to low soil nitrogen levels.

Tapioca is a very good source of carbohydrates and has recently gained popularity as a wheat and grain substitute that is also gluten free. According to Ojo *et al.,(*2017), it is a good source of protein, dietary fibre, and other minerals The cassava root typically contains 70% moisture, 24% starch, 2% fibre, 1% protein, and 3% other compounds, including minerals. The primary source of carbohydrates in foods is starch, and the thickening, stabilising, gelling, and binding abilities of cassava and its compounds are gaining industrial importance (Singh *et al.,* 2003). In some conventional cuisines, it can also be used as a thickener. Cassava starch is a great source in cassava since it is readily available and affordable, especially for the food and feed industries.

Recently bubble tea is a popular culinary item consumed all over the world and is in high demand. This product has a chewy bubble, which improves the product's acceptance and palatability(Moorthy *et al*.,2015).Buble tea which is a cold tea-based beverage with milk and flavourings that originated in Taiwan in the 1980s is also known as boba tea in which chewy bubles called boba pearls or tapioca pearls are incorporated. These Chewy "bubbles" are created by violently shaking the liquid in a cocktail shaker. The drink is then topped with more pearl jelly, which are black tapioca balls that resemble "bubbles". The term "bubble" encompasses both the bottom of the drink and the bubbles that form on top of it (Teo and Khoh, 2015).

Boba pearls or tapioca pearls improves the visual appeal of beverages like tea, cold coffee, juice, etc. A variety of pearls are added to bubble tea, which can be made hot or cooled, with or without milk, and with or without fruit flavouring and other fluids. Typically, bubble tea is served in a cup and consumed with a sizable straw while slurping up tapioca pearls and tea. According to a survey conducted by market research company Nielsen, Generation Z enjoys going to bubble tea shops as a hobby. One of the main uses for cassava starch in cuisine is the creation of tapioca pearls. (Bulathgama *et al*.,2010)). According to Bulgathama *et al.* (2020), the approximate composition of tapioca pearls is as follows: protein 1.43 percent, carbohydrate 79.35 percent, total fat 0.96 percent, and crude fibre 0.2%. According to Ojo *et al.*, (2017), tapioca pearls at an 8.79% moisture content include 0.55% protein, 0.345 lipids, 0.32% ash (minerals), 0.10% crude fibre, and 89.62% carbohydrates.

Currently around the globe, Boba pearl beverages are a popular trend all over the world and are in high demand among consumers. Since brown sugar is just used as the liquid to activate the tapioca starch in the creation of a typical brown sugar boba pearl. In most cases, they are flavourless. As a result, tapioca pearls are typically preserved in a sugar syrup to prevent them from sticking to one another. Tapioca pearls are made sweeter with this technique (Kester *et al*., 2021).So The addition of fruits during the manufacturing of tapioca pearls helps to give boba drinks a fruit flavour, texture, and appearance because boba pearls lack any specific flavour and texture extended shelf life while also making it more appealing and artistic. Additionally, fruits offer a variety of antioxidants that promote health, such as flavonoids. Cassava starch pearls will lessen the post-harvest as well as to improve this's use while reducing losses untapped food source.

New interventions that enhance its properties are required to improve the physiological and nutritional qualities of boba pearls. Without using any artificial colourants or flavours, the addition of fruits will improve the nutritional value and sensory appeal of boba pearls. Therefore, the goal of the current study is to standardise and develop a process protocol for fruit-infused cassava boba pearls using underutilised and widely accessible fruits like mango, pineapple, passion fruit, jackfruit, and dragon fruit as well as to assess their organoleptic, nutritional, textural, and shelf-life qualities. As part of the One District One Product plan, cassava producers and microbusinesses will gain from the creation of process protocols for cassava boba pearls and the transfer of related technology(Dubrin *et al.*,2019)Hence the present study aims to develop fruit blended tapioca pearls from fruits like dragon fruit, passion fruit, mango, pineapple and jackfruit.

Review of Literature

2. REVIEW OF LITERATURE

The relevant literature available on the study Process Optimization of fruit blended Boba Tea Pearls from Cassava have been briefly reviewed here.

2.1 Cassava- Orgin , geographical distribution and production

2.2 Nutritional benefits of cassava

2.3 Starch and its different types

2.4 Value added products of cassava starch powder in food industry

2.5 Nutritional significance of fruit incorporated tapioca pearls

Cassava (*Manihot esculenta Crantz*) is a perennial shrub which comes under the family Euphorbiaceae.) It is a staple food for over 800 million people in the tropics. Cassava ranks fourth among food staples with worldwide production. Among starch producing botanicals, including main cereal crops, cassava is the highest producer of carbohydrates per hectare and can be grown at considerably lower cost. Cassava is a perennial shrub which comes under the family Euphorbiaceae..Due to the abundant availability of tapioca, cassava was introduced as a dominant staple food crop in Kerala. Cassava is the second most important source of starchworldwide (Stapleton et al., 2012). Its roots are one of the most important source of commercial starch (Moorthy.,2004). Forty percent of total cassava production is used for starch extraction (Onwueme, 2002; Fuglie et al.,2006). The waxy starches from root and tuber crops mainly cassava, offer the advantage of clearer gels, neutral flavour and taste (Wijesinghe, 2010). It also possess higher viscosity and different gel textures compared with those from cereals. This property of cassava starch is very useful in the food industry.

2.1.CASSAVA- ORGIN ,GEOGRAPHICAL DISTRIBUTION AND PRODUCTION

Cassava (*Manihot esculenta Crantz)* plays a considerable role in the global agricultural economics and trade among tuber crops and thus cassava is known as the king of tropical tuber crops. Cassava is the starchiest root crop grown in the tropics which is primarily grown in southern peninsular India. For more than 500 million people, its starchy roots provide a significant source of dietary energy. It is well known as the staple crop with the largest production of carbs. After rice, maize, and wheat, cassava is the fourth most important food crop in developing nations, according to the Food and Agriculture Organisation of the United Nations (FAO).

North eastern Brazil is said to be the origin of cassava. Portuguese traders from Brazil introduced it in the seventeenth century to nations including Indonesia, Singapore, Malaysia, and India. Nigeria, which accounts for 50% of global output and area growth among the global economy. The southern peninsular region of India, particularly Kerala, Tamil Nadu, and Andhra Pradesh, contributes 93% of the nation's land and 98% of its production to agricultural cultivation. The crop played a significant role to overcome food shortage among the low income group of people in Kerala. (Srinivas *et al*. 2005) .

Around the globe, Nigeria has the highest area under cultivation (22.25%), producing 38.18 million tonnes of the root every year. 10% of the world's cassava production comes from the second-placed Congo. India leads the world in cassava productivity, with a rate of 27.92 t/ha compared to the global average of 10.76 t/ha. India is ranked third in Asia and seventh in the globe for the output of cassava roots, while it is ranked fourth in Asia and fourteenth overall for area. However, India only makes up 1.30 percent of global production space. Although it is grown in 13 states in India, much of the country's southern peninsula and, to a lesser extent, its north east are where it is concentrated.

2.2.NUTRITIONAL BENEFITS OF CASSAVA

With a rapid growth rate under ideal conditions, cassava is currently the largest source of carbohydrates for human consumption in the world. The tuberous roots are also utilised as animal feed and an ingredient in various industrial products (Mann, 1997; El-Sharkawy,2004; Sheffield *et al.*,2006;Gbadesgesin *et al.*,2008) The Green Revolution and rising living standards among Indians, particularly in Kerala, have caused a slow change in the way that cassava is used. Even though India has the highest cassava yield in the world, the crop's value for ensuring food security is being replaced by its function as a raw resource for industry. A study conducted by Tewe and Lutaladio (2004) reported that the nutritional content of the roots is significant because they are the primary plant component eaten in underdeveloped nations. The nutritionally significant sections of the plant, which make about 50% of the mature plant, are the cassava roots.

After rice and maize, cassava is third in the tropical food chain. Its value as a cheap source of calories, particularly in underdeveloped nations where malnutrition and calorie deficiency are pervasive, stems from the starchy, tuberous roots of the plant. About 500 million people get the majority of their calories from cassava alone. (Yeoh *et al* .,1998) Prathibha *et al* (1995) reported that despite having a high calorie content and a high concentration of certain vitamins, minerals, and

dietary fibre, as well as the lack of a trypsin inhibitor, it has been observed that cyanide is present in cassava roots. This can be removed by heating and postharvest treatments.

According to a study, the cassavas edible starchy flesh makes up about 80% to 90% of its overall weight, with water making up the majority of the root. Between 60.3% and 87.1% of cassava is water, and between 9.2% and 12.3% and 11% to 16.5% of cassava flour is moisture. (Padonou *et al.,* 2010 ; Zvinavashe *et al.*,2011; Charles *et al* .,2005; Shittu *et a*l.,2007)

On a fresh weight basis, the lipid content of cassava roots ranges from 0.1% to 0.3%; on a dry weight basis, it ranges from 0.1% to 0.4% and 0.65%. (Padanou *et al*., 2005; Charles *et al* ., 2005). Mainly galactose diglyceride makes up the glycolipids. Palmitate and oleate are the main types of fatty acids present in cassava roots. (Hudson *et al* ., 1974)

2.2.1.Macronutrients

In a study conducted by Okigbo(1980) cassava has a high calorific value of 250 cal/ha/day, placing it higher than foods like rice, wheat, maize, and sorghum, which have calorific values of 176 cal/ha/day, 110 cal/ha/day, 200 cal/ha/day, and 110 cal/ha/day, respectively. According to Montangac et al. (2019) and Zvinavashe et al. (2011), the root is a physiological energy store with a high carbohydrate content that varies from 80% to 90% on a dry matter basis and 32% to 35% on a fresh weight basis. Cassava contains trace amounts of sucrose, glucose, fructose, and maltose, according to Tewe (2004).

Gil *et al* ., (2004) stated that stated that the cassava variety and age determines its fiber content in the root. Usually its content does not exceed 1.5% in fresh root and 4% in cassava flour.

In the study conducted by Sanni *et al* (2002) According to a study, the root of the cassava plant contains very little methionine, cysteine, or tryptophan and is rich in important amino acids including arginine, glutamic acid, and aspartic acid. The crude protein in the roots is made up of roughly 50% entire protein, 50% free amino acids (mostly glutamic and aspartic acids), and the remaining 10% is made up of non-protein substances like nitrite, nitrate, and cyanogenic chemicals.

2.2.2.Vitamins and minerals

According to Okigbo (1980), with the exception of soybeans, cassava roots have high levels of calcium, iron, potassium, magnesium, copper, zinc, and manganese that are comparable to those of many other legumes. When compared to other staple crops, which typically contain between 15 and

35 mg of calcium per 100 g of edible portion, this crop has a relatively high calcium concentration. The amount of vitamin A is also considerable, ranging from 15 to 45 mg/100 g.

2.2.3.Proteins and amino acids

Cassava tubers have low protein content (0.7%-1.3%) (Ngiki *et al*.,2014)A study conducted by Iyayi and Losel (2001) reported that the protein content of cassava flour was 5.5% . As reported by Nagib and Sousa,2007 the total amino acid content of cassava is approximately 0.254 g per 100 g and lysine content is approximately 0.010 g per 100 g. The protein in cassava has a high arginine content but low methionine, threonine, cysteine, phenylalanine, isoleucine and proline content

The Green Revolution and rising living standards among Indians, particularly in Kerala, have caused a slow change in the way that cassava is used. Even though India has the highest cassava yield in the world, the crop's value for ensuring food security is being replaced by its function as a raw resource for industry. A study conducted by Tewe and Lutaladio (2004) reported that the nutritional content of the roots is significant because they are the primary plant component eaten in underdeveloped nations. The nutritionally significant sections of the plant, which make about 50% of the mature plant, are the cassava roots.(Prado *et al*.,2019)

After rice and maize, cassava is third in the tropical food chain. Its value as a cheap source of calories, particularly in underdeveloped nations where malnutrition and calorie deficiency are pervasive, stems from the starchy, tuberous roots of the plant. According to a study, the cassavas edible starchy flesh makes up about 80% to 90% of its overall weight, with water making up the majority of the root. Between 60.3% and 87.1% of cassava is water

2.3.STARCH AND ITS DIFFERENT TYPES

Starches are complex carbohydrates that are primarily present in grains, roots, and tubers but also occur in many plant-based sources. They improve the texture, look, and flavour of many meals by acting as thickeners, stabilisers, and binders. Potato, corn, cassava, rice, and wheat starches are some of the more popular kinds of starches. Additionally, starches can be divided into three classes based on how easily they can be digested: Slowly Digestible Starch (SDS), Resistant Starch (RS), and Rapidly Digestible Starch (RDS)

Because of this, starch's fundamental structural characteristics can be altered in order to functionalize it and satisfy particular needs. Chemical, physical, enzymatic, and genetic modification are the four fundamental forms of starch modifications.(Potty *et al.*,1985)

The molecules of amylose and amylopectin make up the starch granules. It is known that the composition and arrangement of both molecules in the starch granules affect the usefulness of starch in foods. For some applications, native starches don't always have the right physical, chemical, and rheological characteristics.(Hossain *et al.*,2016) Because of this, starch's fundamental structural characteristics can be altered in order to functionalize it and satisfy particular needs. Chemical, physical, enzymatic, and genetic modification are the four fundamental forms of starch modifications.

2.3.1. Rice starch

Nearly 80% of the dry weight of rice is made up of carbohydrates, which make up the majority of its composition. Starch makes up the majority of the carbohydrates in rice1. Long glucose chains termed amylose and amylopectin make up starch.(Santos,2002) These substances are present in variable concentrations in different species of rice, which has an impact on the texture of the grain. For instance, sticky rice, or glutinous rice, is low in amylose and high in amylopectin, making it sticky after cooking, whereas Basmati rice is rich in amylose, meaning it does not cling together after cooking (Akpa,2012). The body's ability to digest rice is likewise impacted by these substances. Because amylose slows down starch digestion, the body takes longer to digest rice with a high amylose content. Sticky rice, on the other hand, is incredibly simple to digest(Charles *et al*.,2005)

Rice starch is a highly digestible starch that can be used in a broad range of food applications . Food starch functions as a thickening agent, aids in product stability, and aids in the binding of water.(Ancos *et al.*,2016) Amylose branching in rice starch is distinct; higher branching means more amylose stays in the granules. Rice starch granules are important ingredients in many food applications since they are non-GMO, allergen-free, and entirely natural.

2.3.2. Corn starch

The starch generated from corn grain is known as corn starch, maize starch or cornflour the kernel's endosperm is where the starch is found. A common food ingredient, maize starch is used to manufacture corn syrup and other sugars, as well as to thicken sauces and soups.(Amuah *et al*.,2019) Corn starch is adaptable, simple to modify, and has a wide range of industrial applications, including the production of textiles, paper goods, adhesives, and anti-sticking agents. Additionally, it has medical applications, such as providing glucose to sufferers of diseases of glycogen storage.(Braantia *et al.*,2015)

One of the least nutritionally rich parts of maize is its starch, which is high in carbs but low in vitamins, proteins, fibre, and minerals. However, because cornflour absorbs moisture, it can be used in food items as a thickening and anticaking agent.(Ismail *et al.*,2018) It is employed in several oral treatments to aid in the dissolution of capsules and tablets. It can be used as a replacement for baby powder and wheat flour in gluten-free dishes. Other uses include the manufacture of paper, acrylic paint products, and adhesives (Kragutkar *et al*.,2018).

2.3.3. Potato starch

Potato starch is a type of starch extracted from crushed potatoes. It has a neutral flavor and high thickening capability, making it a desirable product in the food industry. It's also gluten-free (Nand *et al.*,2008) Potato starch is the extracted starch from potatoes. The starch turns to a light, powdery, flour-like consistency once it has dried out, and it is a common ingredient that features in several recipes (Mann *et al.*,2013). To make potato starch, a person crushes raw potatoes, which separates the starch grains from the destroyed cells. The starch is then cleaned and left to dry. Once dry, the potato starch forms a white, powdery, flour-like consistency(Khalid *et al.*,2016).

A versatile ingredient, potato starch is used by both professional chefs and home cooks to enhance the texture of a variety of cuisines. It is preferred in the food business because of its great thickening capability and neutral flavour (Prado *et al.*,2019) Crushed potatoes are used to extract potato starch, which is then removed, cleaned, and dried. It is a raw ingredient and a thickening agent used in the food and beverage industries. Instant noodles, soups, puddings, and other food items all contain potato starch powder. Potato starch, as well as other starches like corn flour, expands and ruptures when it comes into contact with heat and moisture (Priyadarshini *et al*.,2019)

2.4. VALUE ADDED PRODUCTS OF CASSAVA STARCH POWDER IN FOOD INDUSTRIES

Starch in cassava is the major source of carbohydrate in foods, and its products is also receiving industrial importance due to its thickening, stabilizing, gelling and binding properties (Singh *et al.*, 2003). It can also be used as a thickening agent in some traditional cuisines. Due to high availability and its cheaper cost cassava starch is a very good source especially in the food and industry.

2.4.1.Bubble tea and tapioca pearls.

Bubble tea a trending food product around the globe also known also as boba tea or black pearl tea, bubble tea is a concoction of tea, milk, and chewy, gelatinous candies made of tapioca or

fruit jelly known as "bubbles". In the middle of the 1980s, it first appeared in Taiwan'. A businessman and former barman named Chang Fan Shu invented a tea that was shaken in a martini mixer to produce a foamy surface in 1949, which is when bubble tea first appeared. Before Taiwan's economic growth in the 1980s, this was initially a luxury good and was not easily available to the majority of Taiwanese.

The culinary product bubble tea, also known as Boba (Bubble in Chinese), is currently popular everywhere and is also quite popular in the affluent Asian market. It is a milk tea beverage that also contains chewy bubbles known as tapioca pearls or boba pearls, which improves the final bubble tea product's acceptance and taste (Shikaghi, 2016). When making bubble tea, several sorts of bubbles are added along with fruit flavouring and many other fluids, typically with or without milk. Typically, bubble tea is served in a cup and consumed with a big straw, slurping up the tapioca pearls while sipping the tea. (Dubrin,2015)

Tapioca boba pearls are a food item that improves the visual appeal of beverages like tea, cold coffee, juice, etc. With or without milk, fruit flavouring, a variety of liquids, and various sorts of pearls, bubble tea can be made hot or cold. Typically, bubble tea is served in a cup and consumed with a sizable straw so that the tapioca pearls can be slurped up together with the tea.

2.4.2.Sweetners

The main component used to make liquid glucose and dextrose is cassava starch. The most popular method for converting starch into glucose is to utilise hydrochloric acid. Fructose syrup has gained importance due to the variable price of sugar and the potential health risks of artificial sweeteners. Maltose is created from starch for commercial purpose after being processed with enzymes. The three types of commercial maltose syrups are high maltose syrup, extremely high maltose syrup, and high conversion syrups. Cassava starch palys a major role Brewing, baking, making soft drinks, canning, and candy manufacturing in food industries. (Moorthy and Balagopalan,1996).

2.4.3.Modified starch

Cassava starch is changed physically or chemically to make it more usable for industrial uses. Cassava starch that has been transformed for commercial use has undergone acid modification, oxidation, and dextrinization. The undesirable properties of cassava starch, such as a major breakdown in viscosity and cohesiveness of starch paste, can be modified through physical and chemical changes. Modified starches are used in the food sector for dusting powders, freezing, and

canning. Cross-linking aids in viscosity stabilisation and offers many types of starch for usage in food and industries. CTCRI has developed technology for each of these goods that can be expanded for future applications. These products can be used in the food, paper, and textile sectors as a starch alnernative.(Potty *et al*., 1982).

2.5.NUTRITIONAL SIGNIFICANCE OF FRUIT INCORPERATED TAPIOCA PEARLS

The nutritional qualities of dragon fruit juice are highly diverse, according to an analysis of juice from several species and crops (Ruzainah *et al.,* 2009; Ramli and Rahmat 2014; Jerônimo *et al.,* 2015). Accordingly, depending on the species and provenance, 100 g of fresh dragon fruit pulp includes about 80% moisture, 0.4 to 2.2 g of protein, 8.5 to 13.0 g of carbs, and 6.0 g of total sugar. Young stems of pitayas, another component with great nutritional value, also contain raw protein (10.0–12.1) and raw fibre (7.8–8.1 g 100 g-1). A notable amount of fatty acids can be found in the dragon fruit's flesh, especially in the seeds.

The identification of the phytochemical components found in dragon fruit as well as the possible medical benefits of these substances have attracted growing interest in recent years. The bioactive substances betalains, flavonoids, polyphenols, terpenoids, steroids, saponins, alkaloids, tannins, and carotenoids may be extracted from all portions of the pitaya (Ramli *et al*., 2014b; Jerônimo *et al*.,2015; Moo-Huchin *et al.* 2017; Kanchana *et al.* 2018; Mahdi et al. 2018). Because the waste sections of the dragon fruit, such as the peels, are similarly rich in phytochemicals, they could be used as herbal medicines or natural dyes in addition to the edible parts, which include the pulp.

In order to assess the worth of this species as a source of antioxidants and its potential role in the prevention of degenerative diseases linked to oxidative stress, such as cancer, Wu et al. (2006) measured for the first time the phenolic content and antioxidant activity of peel and flesh of red dragon fruit pulp.

The antimicrobial activity of plant extracts and their bioactive compounds involves a variety of mechanisms, including promoting microbial cell wall disruption and lysis, inducing the production of oxygen species to kill microbes, preventing the formation of bacterial biofilms, inhibiting cell wall construction, blocking a number of enzymes involved in the replication of microbial DNA, preventing microbes from generating energy, and preventing bacteria from producing toxins for the host (Mickymaray., 2019). Chang et al. (2020) conducted a recent study on the antiviral activity of betacyanin, a red-violet pigment from the betalains, from red pulp pitaya against dengue virus type 2 .

The Passifloraceae family includes the nourishing tropical fruit known as the passion fruit (Passiflora edulis). There are two different varieties of passion fruit: the traditional yellow and the purple.While the purple is less acidic and more starchy, the yellow is more acidic and less starchy. The two varieties of passion fruit, purple and yellow, are both valuable commercially. These two's hybrids have also been created for cultivation. The most well-liked varieties of passion fruit are those grown for their edible fruits, which can vary in size and colour. Passion fruit is a good source of nutrients, especially fiber, vitamin C and vitamin A. Raw passion fruit is 73% water, 22% carbohydrates, 2% protein and 0.7% fat (Rowe, 1985).In a 100 gram amount, fresh passion fruit supplies 97 calories, and contains 36% of the Daily Value of vitamin C, 42% dietary fiber, B vitamins riboflavin and niacin 12% iron and 10% phosphorus (Shyamalamma,2008) It's also rich in beneficial plant compounds, including carotenoids and polyphenols(Loizzo, 2010). Passion fruit is a high acid food with pH 3.2 due to the predominance of two acids, citric and malic acid. It is also rich in minerals like zinc, copper, potassuim , iron, magnesium .and protein

Based on the quantity of nutrients it contains, passion fruit is sometimes referred to as a fruit that is nutritionally dense. The main factor influencing such nutritional rankings is the high concentration of vitamins A, C, and B2 in passion fruit. The fruit possesses a high concentration of phenolic acids, which are considered nutraceuticals. Anthocyanins and flavonoids make up the majority of these chemicals, and carotenoids and -carotene appear to be the main constituent, leading to increased pro-vitamin A activity. These nutritional supplements operate as mutagens and carcinogens, have biological effects on health, and guard against chronic and degenerative diseases. This fruit is advantageous for the treatment and prevention of disorders like anxiety, diabetes, cardiovascular diseases, sedative, convulsive, asthma, osteoarthritis, and cancer due to the presence of pythoconstituents such alkaloids, phenols, glycosylic flavonoids, and cyanogenic chemicals. (Padanou *et al*.,2005)

Jackfruit is a tropical climacteric fruit, belonging to Moraceae family, is native to Western Ghats of India and common in Asia, Africa, and some regions in South America. It is known to be the largest edible fruit in the world. It is a nonseasonal fruit and had a major contribution to the food supply of the people and their livestock when there were short supplies of staple food grains (Sim *et al*.,2003) Therefore, it is referred to as poorman’s food (Singh 1963According to several chemical and histological research, Rahman et al. (1995) found that the jackfruit perianth and seed contain a significant amount of starch. As the fruit ages, its starch and dietary fibre content rises. (Rahman *et al* , 2009)

According to Pavanasavimam *et al.* (1973), jackfruit includes the amino acids arginine, cystine, histidine, leucine, lysine, methionine, threonine, and tryptophan. 100 grams of ripe jackfruit flesh provides 1.9 g of protein. The jackfruit seeds' protein content can range from 5.3% to 6.8%. The protein content of the flesh of various types of ripe jackfruit has been reported to range from 0.57 to 0.97% by Goswami et al. (1925).

Compared to fruits, cassava is low in dietary fibre, vitamin C, flavonoids potassium etc (Beth *et al*., 2019). Addition of fruit based boba pearls in bubble tea not only give an additional texture and flavour , but also provide very high nutritional value compared to the pearls. Fruits contain several bioactive phytochemical com- pounds, namely polyphenols, carotenoids,

flavonoids, tannins, and vitamins (Schreinemachers *et al.*, 2018). The growing economic recession in many parts of the world aggravates the state of food insecurity especially among the poor, hence, there is need to establish feasible models through which the low income group can be able to attain food security even amidst global economic meltdown (Herbert *et al*., 2013

To increase the physiological and nutritional characteristics of boba pearls, there is a need for new interventions which increases its properties. Addition of fruits will increase the quality of boba pearls with respect to its nutritional qualities and sensory appeal without adding any artificial colour or flavours. Hence, the present study is proposed to standardize and develop process protocol for fruit blended cassava boba pearls utilizing, under exploited and easily available fruits like mango, pineapple, passion fruit, jackfruit and dragon fruit as well as to evaluate their organoleptic, nutritional, textural and shelf-life qualities.

The characteristics of food, water, or other substances that a person perceives through their senses, including taste, sight, smell, and touch, are referred to as organoleptic properties. The taste and smell of dried cassava chips should be representative of the product, as stated in the Codex Standard for Edible Cassava Flour. Edible cassava flour should be free from unusual flavours and odours. The chips colour should reflect the variety, which is typically white, creamy, or yellow. Additionally, cassava flour needs to be stored in containers that maintain its sanitary, nutritive, technical, and gustatory qualities (Onwueme , 1978)

Materials and methods

3. MATERIALS AND METHODS

The present study entitled **"Process Optimization of fruit blended Boba Tea Pearls from Cassava (*Manihot esculenta*)** is a comprehensive study carried out with an objective of Standarization of fruit incorporated cassava boba tea pearls and evaluation of its quality attributes.

The methodology of the present study is explained by the following headings.

3.1 Selection and collection of raw materials

3.2 Development of cassava starch powder

3.3 Assessment of physical qualities of powder

3.4 Development of Plain and Fruit blended Tapioca pearls

3.5Quality evaluation of developed tapioca pearls.

3.6 Storage study of the developed fruit blended tapioca pearls

3.7 Cost analysis of the developed products

3.8 Statistical analysis.

3.1 SELECTION AND COLLECTION OF CASSAVA

3.1.1 Selection and collection of cassava

The first and foremost step in the present study was the selection and collection of matured M4 cassava. Fresh matured M4 cassava were selected and collected from CTCRI, Sreekaryam.

3.1.2 Selection and collection of Fruits

Then fully ripened and matured fruits viz., Mango (Neelam), Pineapple, passion fruit, dragon fruit (magenta colour), and jackfruit (Varikka) were selected and collected from the local market for the development of fruit blended tapioca pearls. Fruits selected for the present study were given in the following table.

3.2 DEVELOPMENT OF CASSAVA STARCH POWDER

The first and primary step in the study was the preparation of fresh tapioca starch which is the main ingredient in the preparation of tapioca pearls. Cassava starch was extracted primarily by wet milling of fresh cassava using the standard procedure. (Akpa and Dagde.2012) . Preparation of fresh tapioca starch was carried out by the following methods.

3.21 Cleaning and washing of Cassava

After the collection of fresh matured cassava, it was properly cleaned and washed to remove soil and mud with running water.

3.2.2 Cutting and slicing

The washed cassava was properly peeled using a knife to remove the outer skin .After peeling , it was cut down into smaller cubes or slices. The sliced cubes are again washed in water.

3.2.3 Filtration

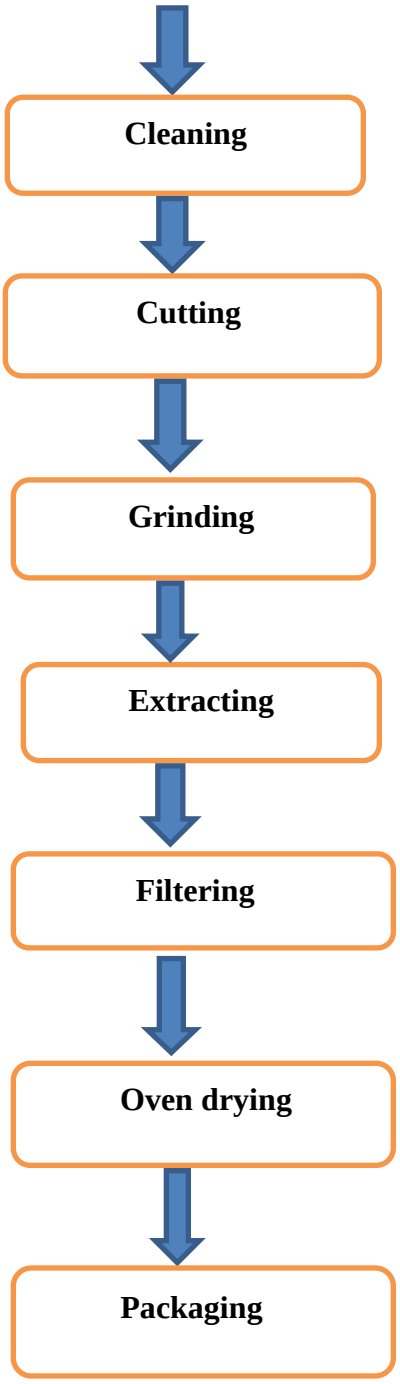
The third step carried out in the preparation of cassava starch was the extraction and filtration of tapioca juice. The cut out cubes was grinded well in a mixer using small amount of water into a paste form .The grinded paste of cassava was poured on a cleaned muslin cloth for filtration. The poured cassava paste was well filtered using the muslin cloth and the cassava residue was separated in different vessels. This procedure was carried out several times . The extracted juice was then kept for sedimentation for 5-6 hours by adding half litre of water. The decanted liquid was removed. This procedure was repeated for 3-4 times till the upper portion of the liquid becomes clear. The weight of the extracted residue was also noted down.

3.2.4 Oven drying

The sediment residue was poured on trays for drying. The trays were kept on hot air oven at a temperature of 80-90 degree for 2-3 days till the moisture content of the powder was totally reduced. The dried tapioca starch were properly packed in food grade covers at room temperature for further studies.

Flow chart-1 Flow chart for preparation of tapioca starch.

Collection of cassava



3.1.3 Extraction of fruit pulp

Fresh and fully ripened fruits were washed properly. Peels were removed with the help of a sharp knife and seeds were removed manually. For the extraction of fruit pulp, fruits except dragon fruit and jackfruit were properly blended using a mixer. Dragon fruit and jackfruit were blended using an electric blender because of their constinecy compared to other fruits.

3.3. DEVELOPMENT OF PLAIN AND FRUIT BLENDED TAPIOCA PEARLS

Plain and fruit blended pearls were developed using gelling method using the standard procedures (Bulgathama *et al.*,2020) . Plain tapioca pearls were developed by gelatinizing tapioca starch with sugar and water in the proportion 90:10 . Then it were rounded up into small balls which was oven dried at a temperature of 60^0C till the moisture content of the balls were reduced to 5-7 percent. The dried balls were packed and stored at food grade HDPE covers (250 guage) for sensory valuation and further studies.

Table:1 Varieties of fruits selected for the study

Sl. No	**Name of the fruits selected**
1	Dragon fruit(majenta colour)
2	Passion fruit
3	Mango(Neelam)
4	Jackfruit
5	Pineapple

Table:2 Proportions of ingredients used for different fruit blended tapioca pearls

SLNo	**Treatments**	**Ingredients**	
1		**Cassava starch powder(gm)**	**Fruit pulp(gm)**
2	T_1D	60	40
3	T_2D	75	25
4	T_3D	70	30
5	T_4D	65	35
6	T_5D	80	20
7	T_1P	60	40
8	T_2P	75	25

9	T_3P	70	30
10	T_4P	65	35
11	T_5P	80	20
12	T_1J	60	40
13	T_2J	75	25
14	T_3J	70	30
15	T_4J	65	35
16	T_5J	80	20
17	T_1PI	60	40
18	T_2PI	75	25
19	T_3PI	70	30
20	T_4PI	65	35
21	T_5PI	80	20
22	T_1M	60	40
23	T_2M	75	25
24	T_3M	70	30
25	T_4M	65	35
26	T_5M	80	20
27	T_6	100	0

D-Dragon fruit , P-Passion fruit, J- Jackfruit, PI-Pineapple , M- Mango, T- Plain blended tapioca pearls.

Fresh and fully ripened fruits were washed properly. Peels were removed with the help of a sharp knife and seeds were removed manually. For the extraction of fruit pulp, fruits except dragon

fruit and jackfruit were properly blended using a mixer. Dragon fruit and jackfruit were blended using an electric blender because of their constinecy compared to other fruits.

Fruit blended tapioca pearls were developed by mixing fruit pulp with cassava starch powder at a proportion of 40:60,25:75,30:70,35:65,20:80 and 100 g as T_1,T_2,T_3.T_4.T_5 and T_6(control)respectively. The mixed proportion was well kneaded into a dough like form and rounded up into small pearl like balls. The rounded balls were oven dried at a temperature of 60 degree Celsius till the moisture content were reduced to 5-7 percent. The well dried tapioca pearls were well packed at food grade HDPE covers and stored for sensory valuation and further studies.

3.4. QUALITY EVALUATION OF FRUIT BLENDED TAPIOCA PEARLS

The organoleptic characteristics of tapioca pearls significantly impact their popularity among consumers, and the composition plays a crucial role in their practical application, particularly for processing industries. In this study, various parameters of selected fruit varieties of tapioca pearls were examined, including physical, chemical, and organoleptic qualities. Several indicators were evaluated to determine the quality of fruit-blended tapioca pearls under each parameter. The following are the indicators analysed for each quality parameter.

3.4.1.Sensory Evaluation of the developed products

Pizani *et al* (2014) reported that sensory preferences have a major impact on food choice and food intake. This property of the food decide the amount of food to be consumed. Sensory analysis is a multidisciplinary science that uses human panellists and their senses of sight, smell, taste, touch and hearing to measure the sensory characteristics and acceptability of food products. There is no one instrument that can replicate or replace the human response, making the sensory evaluation component of any food study essential. Sensory analysis is applicable to a variety of areas such as product development, product improvement, quality control, storage studies and process development

3.4.1.1. Preparation of Score Cards

Acceptability trails on five fruit blended tapioca pearls were carried out by a panel of 10 judges and score cards were distributed .Sensory parameters like colour, appearance, taste, flavour, and texture of cooked tapioca pearls were studied by selected panel members. This was done using hedonic rating scales. Score cards were prepared using a 9-point hedonic rating scale. This scale ranges from 1=extremely unpleasant, 2=Moderately unpleasant, 3= Slightly un pleasant , 4=

Unpleasant ,5=Neither like or dislike, 6=Less liked,7=Good, 8=Very good and 9=Extremely good (Lawless&Heyman,2013) The 5 samples were tasted and valued by the judges and their respective scores were marked. The overall acceptability was also computed based on the scores for quality attributes.

3.4.1.2. Selection of best proportion

Different proportions for the standardization of fruit blended tapioca pearls in 100g was presented in Table 2. The proportions of cassava starch powder was 60g,65g,70g,75g , 80g for treatments T_1,T_2,T_3,T_4,T_5 and T_6 which was used as control. The proportions of added fruit pulps(Dragon fruit, passion fruit, jackfruit, pineapple and mango) was 40g,35g,30g,25g,and 20 g and 0 in T_1,T_2,T_3,T_4,T_5 and T_6 respectively. From the standardized five proportions of each fruit blended tapioca pearls, one best proportion from each fruit blended tapioca pearls were selected organoleptically by a panel of judges. Thus, five fruit blended combination which found superior in sensory qualities was selected for further studies. The selected best proportion from each fruit blended tapioca pearls along with control was subjected to sensorial, nutritional and shelf life studies.

3.5.Nutritional and chemical composition of fruit blended tapioca pearls

Nutrient and chemical composition is a major parameter influencing the quality of tapioca pearls. In the present study different nutritional and chemical parameters were studied using the methods specified on Table 2A and Table 2B. The different indicators ascertained under nutritional composition are:

Table 3. **Methods of analysis of nutrient composition of fruit blended tapioca pearls**

Nutrient components	**Methods adopted**
Protein	AOAC(1980)
Carbohydrate	Ranganna(2001)
Energy	AOAC
Fat	Sadasivam and Manikkam(1992)
Fibre	AOAC(2005)

Calcuim	Sadasivam and Manickam(2008)
Phosporus	Hseu(2004)
Iron	AOAC(1990)
Soduim	AOAC(1990)
Potassuim	Harway and Heidal(1952)
Magnesuim	Piper(1996)
Copper	Sadasivam and Manickam(2008)
Zinc	Sadasivam and Manickam(2008)
Vitamin-C	Sadasivam and Manickam(2008)

Table 4. Method of Analysis of Chemical components of fruit blended tapioca pearls

Chemical components	**Components**
Moisture	AOAC(2000)
Total soluble solids or TSS	Masunder and Majumdar(2003)
Reducing sugar	Rannganna(1986)
Total sugar	Ranganna (1986)
Fiber	AOAC(2005)
Total ash	AOAC(1994)
Total Soluble Solids(TSS)	Masunder and Majumdar(2003)
Cyanide	Bradbury *et al*.,1999.
Oxalates	Judprasong *et al*.,2012
Peroxide value	Cox and Pearson(1962)

Total phenol	Slinkard and Singleton(1997)
Acidity	AOAC(2005)
Total Antioxidant activity	Prieto,1999

3.6.ASSESSEMENT OF PHYSICAL QUALITIES OF CASSAVA STARCH POWDER

Quality studies are very important parameters for rating a product. Tapioca starch powder were evaluated for its functional , chemical , nutritional and shelf life qualities.

3.6.1. Functional quality studies of Cassava starch powder

Functional qualities like water absorption index, swelling power, and yield were studied to test its suitability in product development.

3.6.1.1.Water absorption index

A known volume of sample (1g) and distilled water (10 ml) were mixed in a centrifuge tube. The suspension was allowed to stand at room temperature and was centrifuged for 30 minutes. The volume of drained water and sediment was measured.

$$\text{Water absorption Index} = \frac{\text{Weight of water absorbed (g)} \times 100}{\text{Weight of the powder}}$$

3.6.1.2. Swelling Power (SP)

A known volume of Cassava starch powder (1gm) and distilled water(10ml) was heated at 80^0C. The resulting mixture was centrifuged and the weight of paste obtained was recorded after the supernatant was decanted(Leach *et al.*,1959). Formula used for calculating swelling power was

$$\text{Swelling power} = \frac{\text{Weight of the paste}}{\text{Weight of the dry sample}}$$

3.6.1.3. Yield(Weight)

Yield of Cassava starch powder obtained after all the preliminary processing was calculated from a known volume of sample (100g).

3.7.Storage stability of the products

For assessing keeping qualities of fruit blended tapioca pearls , the selected pearls were stored separately at HDPE covers ain both ambient and refrigerated temperature. In order to observe the parameters which determines the keeping qualities of the product- moisture, acidity, pH, peroxide value, insect infection and microbial count were analysed at monthly intervals and will be compared with the FSSAI specifications of cassava sago. Microbial count were assessed by pour plate method based on the standard serial dilution procedure. Bacterial growth, total viable count and microbial profile (cfu g-1)were also assessed periodically for 3 months.

3.7.1 Moisture

Moisture content was determined according to AOAC (2000). In this case, the sample materials were taken in a flat- bottom dish (pre-weighed) and stored overnight in an oven at 100 to 110℃ and weighed. Weight loss is considered as a measure of moisture , which was calculated using the following formula.

$$\text{Moisture (\%)} = \frac{\text{Weight of fresh sample - Weight of dried sample}}{\text{Weight of fresh sample}} \times 100$$

3.7.2.Acidity

Titratable acidity in terms of % lactic acid was measured by titrating 10 g of sample mixed with 10 ml of boiling water against 0.1 N NaOH using a 0.5% phenolphthalein indicator to an end point of faint pink colour

$$\text{Acidity} = \frac{\text{Titre value} \times \text{Normality} \times \text{Eq.Wt.} \times V1 \times 100}{\text{Weight} \times V2 \times 1000}$$

V1= Volume made up

V2= Volume of aliquot

Equivalent weight of lactic acid = 90.08

3.7.2.1.pH

The pH samples were measured using a digital pH meter

3.7.2.2. Microbial profile

The composition and variety of the microorganisms found in a certain food item are referred to as the food's microbial profile. It includes microorganisms such as bacteria, yeasts, moulds, and others that may be naturally present or may be added during food processing, handling, or storage. In order to evaluate food safety, quality, and shelf life, it is critical to know the types and quantities of microorganisms present in the food. In order to monitor and manage potential hazards related to foodborne pathogens, spoilage microorganisms, and the overall microbiological stability of the food product, it is helpful to understand the microbial profile.

The developed fruit blended tapioca pearls along with the control were stored and analysed for their microbial load for bacteria ,fungus ,E-Coli and insect infection and number of individual colonies were counted. In the analysis of microbial profile of the developed products, growth of bacterial colonies was assessed using plate Count Agar(PCA)and growth of E-Coli was assessed by using Eosin Methylene Blue(EMB) agar by pour plate method based on the standard serial dilution procedure. Colonies appearing in the plates after 24 hours were recorded and the microbial load of the products were expressed as CFU/g.

3.8. COST ANALYSIS OF THE STANDERDIZED PRODUCTS

Economic analysis of the developed fruit blended tapioca pearls were assessed by taking into consideration of variable cost and fixed costs. Variable costs included cost of food ,materials, electricity, packaging charge and labour cost whereas the fixed cost of the developed products included the cost of utensils, equipment and other materials. To sell the product in the market , the total cost of the product was calculated by assessing the fixed cost and variable cost.

TCP (Total cost of product) = FC(Fixed cost)+ VC(Variable cost)

3.9. STASTICAL ANAYSIS OF DATA

For obtaining suitable interpretations, the generalized data was subjected to statistical analysis. ANOVA was used. The different preferences given by the 10 judges in the sensory pannel

during sensory evaluation were analysed using the Kruskal-Wallis test to get the mean values for all the treatments. Graphical interpretation of analysed data was also presented.

Results

4.RESULTS

The results of present study entitled “Process optimization of fruit blended boba tea pearls from cassava (*Manihot esculenta)* are explained in this chapter under the following headings.

4.1. Selection and collection of raw materials.

4.2. Preparation of cassava starch powder

4.3..Functional properties of cassava starch powder

4.4. Development of plain and fruit blended tapioca pearls

4.5.Quality evaluation of plain and fruit blended tapioca pearls

4.6. Nutrient and chemical composition of plain and fruit blended tapioca pearls

4.7. Storage study of plain and fruit blended tapioca pearls

4.8. Cost analysis of developed products

4.1. SELECTION AND COLLECTION OF RAW MATERIALS

Cassava or tapioca (*Manihot esculenta Crantz*) a perennial tuber crop is a member of the Euphorbiaceae family. Cassava is a staple food for more than 800 million people in the tropics and ranks fourth among food staples in terms of global production (Uchechukwu-Agua et al. 2015). Cassava is the plant that produces the most carbohydrates per hectare among those that make starch, including the major cereal crops, and it can be produced for a lot less money. The Food and Agriculture Organisation (FAO) claims that consumers' preferences are shifting away from processed foods and towards natural foods of the highest quality that satisfy their nutritional needs while enhancing health (Mahmood et al., 2008).Fruits and vegetables are packed with nutrients and frequently improve human health as it is filled with immense amount of vitamins and minerals. Citrus, watermelon, banana, apple, grape, and mango are the most popular fruits produced in the world (Shabong *et al* .,2021). Because they include a variety of nutrients and calories, fruits can reduce the risk of obesity and cardiovascular disease. In addition to providing vitamins and minerals, fruits and vegetables also include phytochemicals, which act as anti-oxidants, phytoestrogens, anti-inflammatory agents, and through other protective processes.

Fresh matured M4 cassava were collected from Central Tuber Crops Research Institute (CTCRI) For the development of fruit blended tapioca pearls fruit varieties like *Mango(Neelam),passion fruit, pineapple ,jackfruit (varika) and dragon fruit(majenta)*collected from the local market which have a high economic and nutritive value among fruits (Table 1).

4.2. DEVELOPMENT OF FRESH TAPIOCA STARCH POWDER.

4.2.1. Preliminary Processing

After collection of *M4 matured cassava* , the mud and dirt were properly cleaned used running water. The physical characteristics of Cassava were ascertained. After removing mud, the outer peel was properly removed till the outer skin become pure white. All the outer brown coat was removed. The weight obtained for outer coat of cassava was 272.73 g/kg. Weight obtained for starch powder after all the preliminary processing was 727.27g/kg.

4.3.FUNCTIONAL PROPERTIES OF CASSAVA STARCH POWDER

Functional properties are the fundamental physicochemical characteristics of foods that reflect the intricate relationships between food component composition, structure, and molecular conformation as well as the environment in which these characteristics are measured and correlated**.** (Suresh and Samsher, 2013; Kaur and Singh, 2006; Siddiq et al., 2009).

Functional qualities also refer to how components behave during preparation and cooking as well as how they influence the final product's appearance, texture, and flavour. Functional qualities include gelatinization, bulk density, dextrinization, preservation, denaturation, coagulation, gluten formation, jelling power, and water and oil absorption capacities. They also include emulsion activity, stability, foam capacity, and stability.

Table 5. Functional properties of cassava starch powder

Functional qualities	**Cassava starch powder**
Water absorption capacity(%)	13.08
Swelling power(g)	4.02
Yield(g)	727.73

Table 5 represents the functional qualities of cassava starch powder.

Water absorption capacity

Water absorption, also known as water absorbing capacity, is the term used to describe a material's capacity to absorb water while submerged in it. The weight of water absorbed by a material in its saturated state divided by the weight of the dry material is known as the water

absorption capacity. In the present study water absorption capacity of cassava starch powder was found to be 13.08 percent.

Swelling power

Swelling power, which measures a starch's ability to hold water, has typically been used to highlight the distinctions between different types of starches (Crosbie 1991). The ratio of the sedimented gel to the dry weight of starch is known as the swelling volume. Swelling power of cassava starch powder was found to be 4.02 g/g.

4.3. DEVELOPMENT OF FRUIT BLENDED TAPIOCA PEARLS

Bubble tea is popular and trending food product all over the world which have a significant demand in the affluent Asian market. Tapioca pearls are chewy bubbles that improve the flavour and acceptability of cassava starch-based bubble tea. Different proportions of tapioca starch powder and fruit pulp were formulated to standardize fruit blended tapioca pearls. Five fruit blended tapioca pearls were developed using fruits like Passion fruit, Dragon fruit (majenta colour), Mango (Neelam), Jackfruit (Varika) and Pineapple. Different proportions of fruit pulp *viz*., 20g, 25g , 30 g, 35g and 40g were standardized along with tapioca starch powder in the ratio 80g, 75g,70g,65g and 60 g for the development of fruit blended tapioca pearls.The proportion with 40 g fruit pupl and 60 g cassava starch powder was not applicable in passion fruit and pineapple blended tapioca pearls since the moisture content of the fruits were 82.5% and 81.33% respectively compared to other selected fruits. The moisture content was reduced to 30%. The standardised proportions were kneaded properly and rounded up into small balls and oven dried at a temperature of 60^0 C for 7-8 hours till the moisture content of the fruit blended tapioca pearls reaches at a range of 5-7 percent. The dried products were stored in food grade HDPE covers (250 gauge) at ambient temperature for 3 months for of storage study and further studies.

Plates 1 to 6 shows the various treatments selected for the formulation of fruit blended tapioca pearls.

The treatments of fruit blended tapioca pearls was hedonically rated using a nine point hedonic rating scale by a panel of judges and the best proportion from each treatment was taken based on these sensory scores. The developed five fruit blended tapioca pearls were compared with the plain tapioca pearls as control.

4.4. QUALITY EVALUATION OF THE FRUIT BLENDED TAPIOCA PEARLS

The concept of food quality is frequently focused on the nutritional value and organoleptic properties of food. It typically indicates the totality of a food item's qualities and

characteristics that the consumer finds acceptable. These food quality characteristics include visual aspects such as size, shape, colour, gloss, and texture consistency**.**

Table 6. Sensory Evaluation of Dragon fruit blended tapioca pearls

Treatment	Colour	Taste	Texture	Flavour	Overall
T_1D	8.62^{a}	7.54^{ab}	7.99^{a}	7.53^{a}	8.31^{a}
T_2D	8.16^{ab}	7.22^{a}	8.01^{a}	7.54^{a}	8.03^{a}
T_3D	7.83^{bc}	8.62^{b}	8.82^{a}	7.86^{a}	8.41^{a}
T_4D	7.04^{cd}	6.82^{ac}	6.91^{b}	7.02^{a}	7.02^{b}
T_5D	6.33^{de}	6.12^{cd}	6.24^{bc}	6.07^{b}	6.39^{bc}
T_6	5.00^{e}	4.91^{d}	5.05^{c}	5.17^{b}	5.04^{c}
X^2	67.009	60.795	67.044	55.334	66.122
p-value	0	0	0	0	0

4.4.1. Sensory evaluation of dragon fruit blended tapioca pearls.

Since the inception of the food industry, the sensory quality of food products has been regarded as a crucial component because of its impact on the overall quality of the product. Sensory evaluation is a scientific discipline which is an important part in food industry mainly used to evoke, measure, analyse and interpret results of those characteristics of foods as they are perceived by the senses of sight, smell, taste, and touch. Here sensory evaluation was done by a panel of judges which includes 10 members using a 9 point hedonic rating scale. Parameters like appearance, taste, colour , flavour and overall acceptability of dragon fruit blended tapioca pearls was scored and the mean rank value for each parameters were evaluated. Sensory scores of dragon fruit blended tapioca pearls and control were given in Table 6.

Colour

In food industry consumers are mainly interested in many aspects related to the quality of food such as appearance, freshness, taste, nutritional value and food safety. The appearance of a food is the most salient feature which mainly determines the quality of a food. Appearance includes all visible attributes and derives from the interactions between a food and its environment as perceived by the human observer. The most important attribute of any foods appearance is its colour. Colour plays an essential role in food appearance and acceptability.

For selecting the best proportion, five proportions of dragon fruit blended tapioca pearls along with control were scored. From analysing the data obtained from sensory evaluation it was observed that the mean rank value of dragon fruit blended tapioca pearls ranged from 5.30-8.62.The highest mean rank value for appearance was obtained for treatment T_1D with a mean rank value of 8.6 2while lowest mean rank value was obtained for the treatment T_6 (control) with a mean score of 5.00using the Kruskal- Wallis test. The mean rank value of T_1D(8.62) was on par with T_2D (8.1) and treatment T_6(5.0) was on par with mean rank value of treatment T_5D(6.3).

Taste

Taste is the sensation or perception of flavours. It is the ability which helps to know the difference between flavours in our mouth.

From the sensory evaluation of dragon fruit blended tapioca pearls, it was observed that the mean rank values for taste ranged between 4.9- 8.6. From the data obtained it was revealed that the most favourable taste was obtained for the treatment $T_3D$with a highest mean (8.6) and the lowest mean score 4.9 was obtained for the treatmentT_6. The mean rank value of T_3D(8.6) was on par with treatment T_1D(7.5) and also the treatment T_6(control) with a mean score of 4.9 was on par with treatment T_5 D(6.1).

Texture

Texture of food is defined as those properties of a food that are sensed by touch in the mouth and with the hands. We use many words to describe food texture such as foods can be soft or hard, mushy or crunchy, or smooth or lumpy. Texture plays an important role for the enjoyment and acceptability of foods.

The mean rank value for texture ranged between 5.0 - 8.8. Treatment T_3D (8.8) was statistically superior than other treatments and it was on par with treatment T_2D (8.0) and T_1D(7.9).The lowest mean rank value was obtained for $T_6$and it was on par with T_5D (6.2)

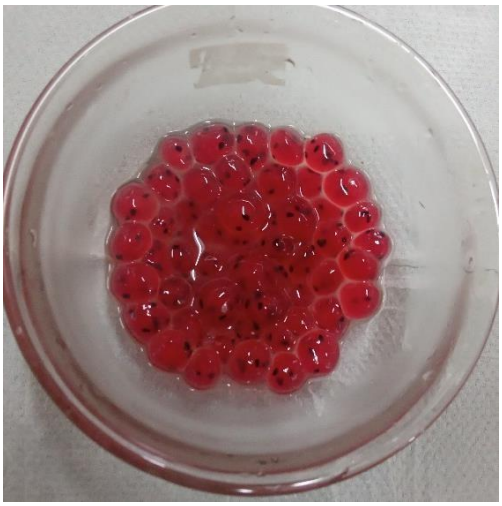
Flavour

Flavours are the sensory impressions which we experience when consuming foods. Perception of the flavour of foods is a complex process which mainly involves the senses of smell and taste. Each sense contributes special characteristics to a flavour through its ability to interact with different types of chemical stimuli, or through neural interactions that may modulate the responses of the other senses.

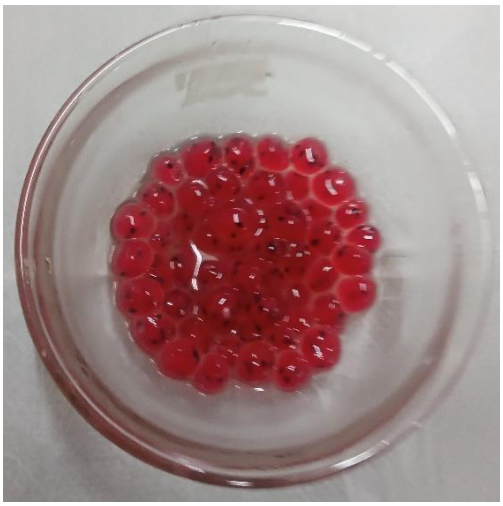
The flavour of six treatments ranged between 5.1- 7.8. Among these treatments , T_3Dwas observed with the highest mean rank value (7.8) in texture of Dragon fruit blended tapioca pearls It was on par with treatments T_1D (7.5) and T_2D (7.5).The lowest mean value was noted for T_6(5.1) and it was on par with T_5D(6.0)

Overall acceptability

Overall acceptability can be describe as the total quality of food, including look, colour, texture, taste, and flavour which is used to assess how acceptable a food product is in its entirety. Overall acceptability of dragon fruit blended tapioca pearls ranged between5.0 - 8.4. From the evaluation of overall acceptability, it was found thatT_3D obtained the highest mean rank value(8.4) and it was on par with T_2D(8.0) and T_1D(7.9) .While T_6got the lowest rank value of 5.0 and it was on par with T_5D(6.3)



T_1D



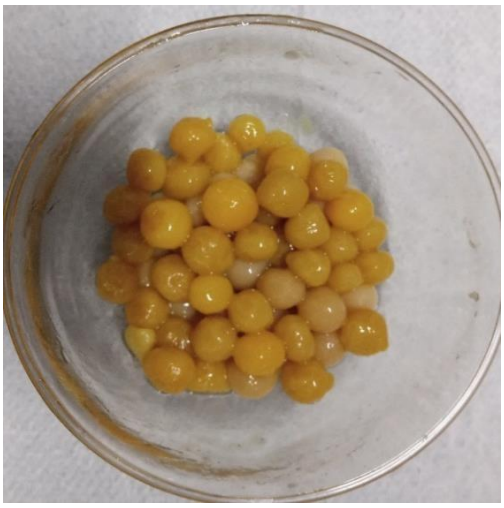
T_2D

T_3D

T_4D

T_5D Control

Plate 1: Dragon fruit blended tapioca pearls

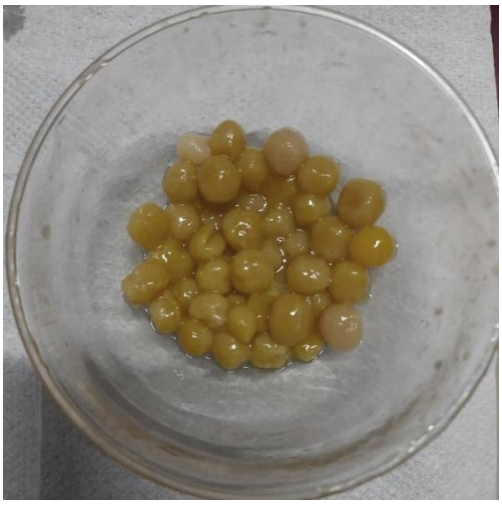


T_1M

T_2M

T_3M

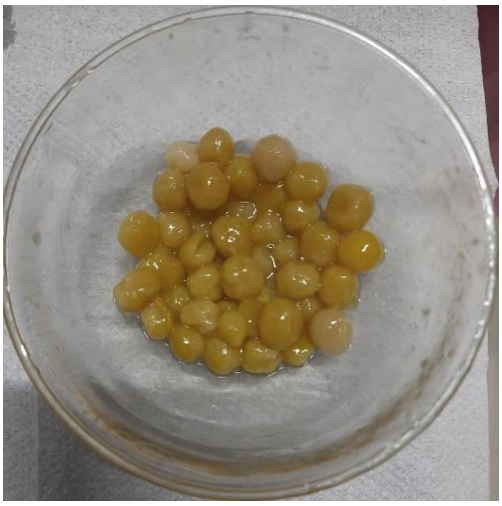
T_4M



T5M

Control(T6)

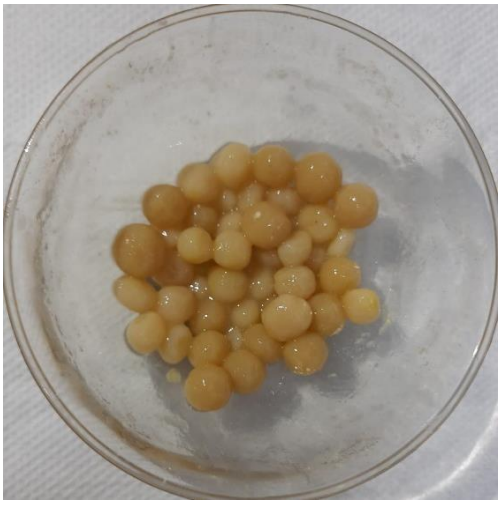
Plate 3: Mango blended tapioca pearls



T_1J

T_2J

T_3J



T_4J

T_5J

Control

Plate 4: Jackfruit blended tapioca pearls

T_1PI

T_2PI

T3PI

T4PI

T5PI

Control

Plate 5: Pineapple blended tapioca pearls

T1P

T2P

T3P

T4P

T5P

T6

Plate 2: Passion fruit blended tapioca pearls

Table 7. Sensory evaluation of Passion fruit blended tapioca pearls

Treatments	Colour	Taste	Texture	Flavour	Overall Acceptability
T_1P	8.71^{a}	5.45^{a}	7.03^{bc}	6.02^{a}	7.45^{ab}
T_2P	7.73^{ab}	6.07^{ab}	7.47ab	6.21^{a}	7.27^{ab}
T_3P	7.08^{bc}	6.69^{bc}	7.05^{bc}	6.72^{a}	6.85^{b}
T_4P	6.86^{c}	6.77^{c}	6.68^{c}	6.67^{a}	6.71^{b}
T_5P	6.75^{c}	8.73^{bc}	7.61^{a}	8.05^{b}	7.63^{a}
T_6P	4.14^{d}	3.87^{d}	4.08^{d}	3.81^{c}	4.08^{c}
χ^2	47.904	46.397	40.199	41.101	33.749
p-value	0	0	0	0	0

4.4.2. Sensory evaluation of Passion fruit blended tapioca pearls.

Colour

The most important attribute of any food's appearance is its colour. The hue of a food is the most crucial aspect of its appearance, especially when it is directly linked to other food-quality characteristics, such as when fruit changes its colour throughout ripening or when food loses colour quality due to spoilage or staleness. So colour plays an important role in determining food quality.

From the sensory evaluation of passion fruit blended tapioca pearls it was observed that the mean rank values for colour ranged between 4.1- 8.7. It was analysed that T_1P (8.7) got the highest mean score and it was on par with T_2P(7.7). The lowest mean value was observed for P6 and it was control.

Taste

One sense that both humans and other animals have is taste. The tongue feels it during eating and uses it to detect the flavour of the food that is currently in the mouth. The five tastes that humans can detect are sweet, sour, bitter, salty, and umami.

From the analysis of texture it was revealed that the mean rank value for passion fruit blended tapioca pearls ranged between 3.8-8.7.It was noted that P_5 obtained the first rank for

taste with a mean rank value of 8.7 and it was on par with treatments T_4P(6.7) and T_3P(6.6)and the lowest rank was observed for T_6(3.8).

Texture

From the evaluation of texture , it was noted that T_1P(7.6) got the highest mean rank value and T_6(4.0) got the lowest mean value.

Flavour

The sensory impressions which we get during eating and drinking are called flavours. The chemical perceptions of taste and smell help to create these impressions. The mean rank values for Passion fruit blended tapioca pearls ranged between 3.8- 8.0. The highest mean rank value is obtained for T_5P(8.0) and T_6(3.8) got the lowest mean value.

Overall acceptability.

The interaction a food item with a consumer at any given time immediately affects how acceptable it is. The sensory qualities of food are the primary determinants of food acceptability because consumers choose foods with particular sensory qualities**.**

From the analysis of overall acceptability of Passion fruit blended tapioca pearls it was noted that the mean rank value ranged between 4.0-7.6 and the highest rank value was observed for T_5P(7.6) and it was on par with T_1P(7.4) and T_2P(7.2).The lowest mean value was observed for T_6(4.0).

Table 8. Sensory evaluation of Mango blended tapioca pearls

Treatments	**Colour**	**Taste**	**Texture**	**Flavour**	**Overall Acceptability**
T_1M	8.95^{a}	8.76^{a}	8.65^{a}	8.71a	8.32^{a}
T_2M	8.06^{b}	8.04^{ab}	8.03^{ab}	8.06^{ab}	7.83^{ab}
T_3M	8.06^{b}	7.93^{ab}	8.05^{ab}	7.98^{ab}	7.35^{bc}
T_4M	7.91^{b}	7.65^{bc}	7.68^{bc}	7.66^{bc}	7.68^{ab}
T_5M	6.95^{c}	6.98^{cd}	6.84^{cd}	6.99^{cd}	6.81^{cd}
T_6M	4.10^{c}	4.17^{d}	4.17^{d}	4.12^{d}	4.01^{d}
χ^2	56.146	50.918	42.185	50.918	33.536
p-value	0	0	0	0	0

4.4.3. Sensory evaluation of Mango blended tapioca pearls.

Colour

In food products, especially meats, fruits, and vegetables, the consumer often assesses the initial quality of the product by its colour and appearance. The appearance and colour of these products are thus the primary indicators of perceived quality. Scientific studies have also shown that the colour of the product affects our perception of other attributes such as aroma, taste, and flavour. From the sensory analysis of Mango blended tapioca pearls it was noted that the mean rank value for colour and appearance ranged between 4.1- 8.9. From the data it was noted that the highest mean value is for treatment T_1M (8.9) and it was significantly different from all other treatments. Treatments T_2M (8.0), T_3M (8.0) and T_4M (7.9) was on par. The lowest mean value was observed for T_6 (4.1).

Taste

Taste is one of the most important senses which helps us to evaluate food and drinks and also helps to determine what's safe to eat. It also prepares our body to digest food. The taste of food is caused by its chemical compounds. These compounds interact with sensory (receptor) cells in our taste buds. The cells then send information to our brain, which helps us to identify the final taste of a food product. From the analysis of taste, it was noted that the highest mean rank value was obtained for T_1M (8.7) and it was significantly different from other treatments. The lowest mean value was obtained for T_6 (4.1).

Texture

Food acceptance and pleasure are largely influenced by texture. Texture is also an index of food quality. According to texture food product can be described in a variety of ways, such as soft or hard, mushy or crunchy, smooth or lumpy. From the analysis, it was observed that the mean values ranged between 4.1- 8.6.The highest mean score was obtained for the treatment T_1M (8.6) and it was on par with T_2M (8.0) and T_3M(8.0).The lowest mean score was obtained for T_6(4.1)which was the control among the treatments.

Flavour

Taste, odour or fragrance, heat and cold, and texture or "mouthfeel" are all components of flavour which is an important sensory phenomenon in food industry. Although food's look is significant, its flavour ultimately decides acceptability and quality of a food product. It was

noted that T_1M(8.7)has the highest mean rank value and it was on par with T_2M(8.0)and T_3M(7.9).The lowest mean rank value was observed for T_6(4.1)

Overall acceptability

Food acceptability is influenced by a variety of variables. Acceptability is a hedonic or pleasure based subjective measure that is influenced by a variety of factors, including the food's sensory qualities, previous exposure to it and subsequent expectations, contextual considerations, a person's culture, physiological status such as hunger, thirst, and the presence or absence of illness, among many others. The measuring of food acceptability is quite complex and depends on behavioural models such as food-choice models or psychometrics or scales.

From the analysis of overall acceptability of Mango blended tapioca pearls it was observed that the mean rank values ranged between 4.0-8.3.Treatment T_1M (8.3) scores the highest position in overall acceptability and it was on par with T_2M (7.8).Treatment T_6 (4.0) scores the lowest score among other treatments.

Table 9. Sensory evaluation of Jackfruit blended tapioca pearls

Treatments	Colour	Taste	Texture	Flavour	Overall Acceptability
T_1J	6.92^{c}	7.02^{bc}	7.06^{bc}	7.02^{bc}	7.08^{bc}
T_2J	7.96^{ab}	7.65ab	7.64^{ab}	7.63^{ab}	7.72^{ab}
T_3J	7.13^{bc}	7.07^{bc}	7.09^{bc}	7.13^{bc}	7.04^{bc}
T_4J	8.65^{a}	8.17a	8.04a	7.92^{a}	8.18^{a}
T_5J	6.23^{cd}	6.29^{cd}	6.23^{cd}	6.27^{cd}	6.28^{cd}
T_6	4.34d	4.24^{d}	4.13^{d}	4.39^{d}	4.22d
χ^2	50.678	4 6.924	46.903	45.918	49.14
Pvalue	0	0	0	0	0

4.4.4.Sensory evaluation of Jackfruit blended tapioca pearls

Colour

One of the most crucial indications customers use to judge the quality of a food product is its colour . It might be explained as a person's reaction to the visual signals produced by the light on a product. From the analysis of Jackfruit blended tapioca pearls, the mean rank values for colour and appearance ranged between 4.3-8.6.It was noted that T_3J got the highest mean rank value (8.6) and it was on par with T_2J (7.9) .The lowest mean value was noted for T_6(4.3)and it was on par with T_5J(6.2)

Taste

From the data obtained from the analysis of taste, it was revealed that the highest mean rank value for taste was observed for treatment T_3J (8.1) and it was on par with T_2J (7.2).Treatments T_1J(7.0)and T_4J(7.0) was also on par. Treatment T_6 was observed with the lowest mean rank value (4.2) and it was on par with T_5J(6.9).

Texture

Texture plays a very significant role in food industry. It is the term which is used to describe the characteristic of the finished food product. Every food product has a distinct texture so that we can see , feel and eat it. From the analysis of texture it was observed that the highest mean rank value was obtained for T_1J(8.0) and it was on par with T_2J (7.6).The lowest mean rank value was obtained for T_5J (6.2)

Flavour

Flavour is the quality produced by the sensation of taste and smell in a combined effect. From the analysis it was observed that the mean rank values for flavour ranged between 4.3-7.9.The highest mean rank value was observed for T_3J(7.9) and it was on par with T_2J(7.6).Treatments T_1J(7.1) and T_4J (7.0)was also observed to be on par. The lowest mean value was observed for treatment T_6(4.3).

Overall acceptability

Overall acceptability of a food product can be judged through its appearance, colour. texture and taste of the product. From the statistical analysis for overall acceptability, it was noted that T_4J got the highest mean rank value (8.1)).The lowest mean rank value was obtained for T_6(4.2) and it was on par with T_5J(6.2).

4.4.5.SENSORY EVALUATION OF PINEAPPLE BLENDED TAPIOCA PEARL

Table 10. Sensory evaluation of pineapple blended tapioca pearls.

Treatments	Colour	Taste	Texture	Flavour	Overall
T_1PI	8.72^{a}	7.48^{a}	7.08^{a}	7.37^{a}	7.28^{a}
T_2PI	7.74^{ab}	7.42^{a}	7.14^{a}	7.21^{a}	7.21^{a}
T_3PI	7.02^{bc}	7.07^{a}	7.08^{a}	6.98^{a}	7.04^{a}
T_4PI	6.83^{c}	8.73^{b}	8.44^{b}	8.84^{b}	8.83^{b}
T_5PI	6.78^{c}	6.61^{a}	6.29^{a}	6.48^{a}	6.61^{a}
T_6	4.19^{d}	4.26^{c}	4.23^{c}	4.21^{c}	4.20^{c}
χ^2	47.904	40.94	42.661	45.676	44.317
Pvalue	0	0	0	0	0

Colour

Consumers frequently judge the initial quality of food products by their colour and appearance. Thus, appearance and colour serve as the main gauges of perceived quality of the food product. From the sensory evaluation, it was observed that the highest mean value for colour and appearance was observed for T_1PI (7.8) and lowest for T_6 (4.1).

Taste

The sensory evaluation revealed that the mean rank value for taste ranges between 4.1-8.6.The highest mean value was obtained for T_4PI (8.6) and lowest for T_6(4.1)

Texture

Food texture is characterised as the characteristics of a food that can be felt in the mouth and with the hands. Foods can be described as being soft or hard, mushy or crunchy, smooth or lumpy, or any number of other ways. The enjoyment and acceptance of food are both influenced by texture. From the analysis table 10. It was observed that the highest mean rank score was obtained for T_4PI(8.4) and T_6PI(4.3).

Flavour

Flavour is the sensory phenomenon which is a combination of the sensations of taste, odour or aroma, heat and cold, and texture or "mouthfeel". The appearance of food is important, but it was observed that the flavour that ultimately determines its quality and acceptability. From the above table it was evident that the highest mean value for flavour is for T_4PI (8,8) and lowest for T_6(4.2)

Overall acceptability

Overall acceptability of a food product is a subjective measure based on hedonics or pleasure, which in turn is influenced by the sensory properties of the food. From the above table it was evident that the highest mean value obtained for T_4PI(8.8) and lowest score obtained for T_6(4.1).

4.5.Selection of best proportion

Table 11. Best proportions of fruit blended tapioca pearls selected for the study

Treatments	Proportion	Fruit pulp(g)	Cassava starch powder (g)
T_3D	35:65	35	65
T_5P	20:80	20	80
T_1M	40:60	40	60
T_3J	35:65	35	65
T_4PI	30:70	30	70

From the sensory evaluation of fruit blended tapioca pearls from Dragon fruit, passion fruit, mango jackfruit and pineapple , it can be concluded that T_3D from dragon fruit blended tapioca pearls, T_5P from passion fruit tapioca pearls,T_1M from mango blended tapioca pearls,T_3J from jackfruit blended tapioca pearls and T_4PI were selected as the best combinations based on parameters like colour and appearance, taste, texture, flavour and overall acceptability These treatments scored maximum mean rank values in all aspects.

T_3D- Dragon fruit blended tapioca pearls, T_5P-Passion fruit blended tapioca pearls, T_1M-Mango blended tapioca pearls, T_3J-Jackfruit blended tapioca pearls and T_4PI – Pineapple blended tapioca pearls.

4.5. NUTRIENT AND CHEMICAL COMPOSITION OF PLAIN AND FRUIT BLENDED TAPIOCA PEARLS.

Nutrient composition of food refers to the specific types and amount of nutrients present in a particular food item. Nutrients are essential substances needed for the growth, development and maintenance of the human body, providing energy and supporting varouis bodily functions. The major nutrients available food are carbohydrates, proteins, fats, vitamins and minerals and water. In the present study nutrient contents of the developed products were analysed using standard procedures as given in table 3

The types and quantities of nutrients, such as carbohydrates, proteins, fats, minerals, vitamins, and fibre, that are present in a certain food are referred to as the chemical composition of that food. A vital component of human life is nutrition, and a proper nutritional balance is essential for maintaining good health. Moisture, ash, fat, protein, and carbohydrate contents are all part of the food's immediate composition. These food ingredients may be useful to the food business for developing new products, doing quality control or meeting regulatory requirements. Table 8 represents the proximate composition of plain and fruit blended tapioca pearls.

Table 12. Proximate composition of fruit blended tapioca pearls

Treatments	Carbohydrate (g/100g)	Protein (g/100g)	Fibre (g/100g)	Vitamin C (mg/100g)	Fat
T_3D	2.49^{b}	0.85^{c}	1.65^{b}	0.03^{e}	-
T_5P	2.56^{a}	1.62^{a}	2.79^{a}	12.05^{c}	-
T_1M	2.24^{c}	0.66^{d}	1.12^{c}	15.01^{b}	-
T_3J	2.09^{d}	1.13^{b}	1.63^{b}	10.07^{d}	-
T_4PI	2.62^{a}	0.63^{d}	0.95^{d}	17.08^{a}	-
T6	2.04^{e}	0.13^{e}	0.80^{e}	0.0^{e}	-
SE(m)	0.016	0.024	0.009	0.007	-
CD%	0.082	0.075	0.029	0.021	-

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Carbohydrate

Carbohydrate is the most significant source of food energy among the micronutrients. which contributes about 40 - 80 per cent of total energy intake.. Sugars, starches, and dietary fibre are the major forms of carbohydrate mainly present in plant meals and dairy products. These are transformed by the body into glucose which is a necessary energy source. Cereals are the main sources of food carbs, which accounts for about 50% of all carbohydrates consumed worldwide. From the nutrient analysis of carbohydrate, it was observed that the carbohydrate content was higher in T_4PI(2.62mg/g) and was lower in T_6 or control(2.04 g/100g)

Protein

Proteins are highly complex molecules that are actively involved in the most basic and important aspects of life. These include metabolism, movement, defence, cellular communication, and molecular recognition. They are essential for the structure, function and control of the body's tissues and organs and carry out the majority of the work done within the cells. Protein helps repair and build your body’s tissues. It triggers metabolic processes, preserves fluid and pH equilibrium, and supports our immune system. Additionally, it also serve as an energy source and transports and store nutrients .From the analysis table it was revealed that the protein content was higher in T_5P(1.62g/100g)and lower in control (0.13g/100g).

Fibre

Dietary fibre which is also known as roughage mainly found in plants such as legumes, whole grains, vegetables, and fruits. Fibres can offer significant health advantages for sustaining proper bodily functions. Its primary role in the body is to affect how the gastrointestinal tract works. Soluble fibre can emulsify with bile acids in the small intestine, preventing them from entering other body organs. This ultimately has an impact on lowering blood cholesterol levels and maintaining heart health. Since fruits are the higher source of crude fiber, from table 8a it was evident that the fiber content was higher in T_5P(2.79g/100g) and lowest in T_6(0.80g/100g).

Vitamin-C

Vitamin C, also known as ascorbic acid, which is a water-soluble which is an essential nutrient which helps to repair damaged tissue and in the generation of essential neurotransmitters that are crucial for the immune system's normal operation. It is a natural antioxidant that is

essential for eliminating free radicals from the body, minimising oxidative and inflammatory damage, wound healing and protecting against infections and a wide range of pathological disorders. Results showed that Vitamin C content was higher in T_4PI(17.08mg/100g)and lowest in T_1D(0.01mg/100g)

Fat

Fats are a group of macronutrient which are involved in the metabolism of triglycerides. Due to its high capacity of storing energy and high level of chemical stability, fats are considered as the most vital macronutrient. From the table, it was evident that fat content was not present in the developed products.

Table 13. Macro mineral composition of plain and fruit blended tapioca pearls

Treatments	Calcuim (mg/100g)	Phosphorus (mg/100g)	Iron (mg/100g)	Magnesuim (mg/100g)	Maganeese (mg/100g)
T_3D	1.00^{b}	0.23^{d}	0.72^{b}	1.16^{b}	-
T_5P	2.00^{ab}	0.02^{d}	1.33^{a}	1.13^{b}	-
T_1M	3.00^{a}	0.53^{b}	0.17^{e}	1.20^{b}	-
T_3J	1.33^{b}	0.98^{a}	0.53^{c}	1.16^{b}	-
T_4PI	1.00^{b}	0.02^{d}	0.27^{d}	1.80^{a}	-
T6	2.00^{ab}	0.01^{e}	0.01^{e}	1.20^{b}	-
SE(m)	0.043	0.032	0.007	0.041	-
CD%	1.326	0.103	0.021	0.126	

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 13 represents the macro mineral composition of plain and fruit blended tapioca pearls

Calcuim

Calcium is an essential macro mineral which plays a vital role in our body in order to fortify our bones, teeth and connective tissues, control the contraction and relaxation of muscles, monitor heart activity, normalize blood clotting processes as well helps in smooth transmit of nerve impulses between cells in the body. Calcium is present in the body in the form of calcium ions, aids in biochemical signalling processes, facilitates the pain-free passage of nerve impulses, and upholds overall health and harmony. Calcium content was higher in T_1M(3.0mg/100g) followed by T_5P(2.0mg/100g) and T_6(2.0mg/100g)

Phosphorus

After calcium, phosphorus is the mineral that is most prevalent in the human body. Its primary function is to support the structural integrity and strength of the bones and teeth by collaborating with blood calcium deposits. The body needs phosphorus to properly utilise fats and carbohydrates**.** It is also needed for the body to make protein for the growth, maintenance, and repair of cells and tissues. Results showed that phosphorus content was highest in T_3J(0.98mg/100g) and was lowest in T_6(0.01mg/100g)

Iron

In contrast to zinc, iron is an abundant element on earth and it is a biologically essential component of every living organism. As a key mineral iron has many functions such as electron transport and cellular respiration, cell proliferation and differtiation and regulation of gene expression. The main function of iron is the synthesis and transport of red blood cells to various tissues and organs in our body. From table it was evident that the iron content was higher in T_6P(1.39mg/100g)followed by T_4J(0.45 mg/100g).Lowest content was obtained for T3PI(0.007mg/100g)

Magnesuim

Magnesium is a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body, including protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation. It contributes to the structural development of bone and is required for the synthesis of DNA, RNA, and the antioxidant glutathione. Magnesium also plays a role in the active transport of calcium and potassium ions across cell membranes, a process that is important to nerve impulse conduction, muscle contraction, and normal heart rhythm (Rude,2012).From table 13, it was observed that magnesium content was highest in T_4PI (1.8mg/100g)

Maganeese

Manganese is a trace mineral that is essential to our bodies in small amounts. Manganese is a coenzyme which assists many enzymes involved in breaking down carbohydrates, proteins, and cholesterol. It also assists enzymes in building bones and keeping the immune and reproductive systems running smoothly. Manganese works with vitamin K which helps in wound healing by clotting the blood. From table 13 , it was observed that maganeese content was absent in the developed products.

Table 14. Micro mineral composition of plain and fruit blended tapioca pearls

Treatments	Copper (mg/100g)	Zinc (mg/100g)	Soduim (mg/100g)	Potassuim (mg/100g)
T_3D	0.02^{d}	0.08^{d}	1.85^{c}	0.01
T_5P	0.43^{b}	0.13^{c}	4.21^{a}	0.01
T_1M	0.18^{c}	0.20^{b}	1.34^{d}	0.01
T_3J	0.76^{a}	0.02^{e}	2.96^{b}	0.01
T_4PI	0.02^{d}	0.27^{a}	1.50^{d}	0.02
T_6	0.01^{e}	0.10^{d}	0.86^{e}	0.01
SE(m)	1.872	0.006	0.071	0.004
CD%	0.031	0.020	0.220	0.005

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Copper

From table 14, it was evident that the copper content was highest in jackfruit blended tapioca pearls (0.76mg/100g) and was lowest in plain blended tapioca pearls(0.01mg/100g).

Zinc

Zinc plays a crucial role in the production of DNA, cell proliferation, the synthesis of proteins, the repair of damaged tissue, and the maintenance of a strong immune system. A sufficient amount of zinc is needed during periods of rapid growth, such as childhood,

adolescence, and pregnancy, as it aids in cell growth and multiplication. From Table 14,it was evident that zinc content was highest in T_4PI(0.27 mg/100g)and lowest in T_3J(0.0mg100g)

Soduim

Sodium is an essential nutrient involved in the maintenance of normal cellular homeostasis and in the regulation of fluid and electrolyte balance and blood pressure . Its role is crucial for maintaining ECF volume because of its important osmotic action and is equally important for the excitability of muscle and nerve cells and for the transport of nutrients and substrates through plasma membranes (Seldin, 1990). Soduim content was observed to be in highest in T_5P(4.21mg/g)and lowest in T_6(0.86 mg/g).

Potassuim

Table 14 represents the potassuim content of plain and fruit blended tapioca pearls.

Potassium is found naturally in many foods and as a supplement. Its main role in the body is to help maintain normal levels of fluid inside our cells. Potassium reserves are primarily present in cells, of which at least 80% of the mineral is found in muscle cells, while the remaining 20% is stored in bone tissue, liver as well as red blood cells. Potassium also helps muscles to contract and supports normal blood pressure. Potassium rich foods that have an alkalizing effect include fruits, vegetables, almonds and lentil. From the analysis table 14, it was observed that potassium content was highest in T_6(0.02mg/100g) and all other treatments was on par.

Table 15. Chemical composition of plain and fruit blended tapioca pearls

Treatments	Moisture (%)	Acidity (%)	Reducing Sugar (g/100g)	Total sugar (g/100g)	TSS (^{0}B)	TAA (g/100g)
T_3D	3.27^d	1.32^d	4.91^e	12.65^e	11.23^c	2.75^c
T_5P	3.57^c	1.48^b	5.03^d	28.23^a	14.72^a	9.15^a
T_1M	4.01^b	1.42^c	5.86^c	18.98^c	13.56^b	1.92^e
T_3J	4.21^a	1.36^d	7.24^b	24.42^b	13.40^b	2.05^d
T_4PI	4.25^a	1.65^a	9.46^a	15.74^d	9.23^d	7.22^b
T6	1.13^e	1.23^e	1.37^f	3.31^f	6.60^e	1.08$_f$

SE(m)	0.020	0.014	0.011	0.564	0.061	0.013
CD%	0.062	0.044	0.035	1.738	0.189	0.049

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Moisture

The water content in a product is known as its moisture content. Weight, density, viscosity, conductivity, and other physical characteristics of a substance are affected by its moisture content. Typically, weight loss after drying is used to determine it. From table 15 it was observed that T_3J(4.25%)which was on par with T_4PI(4.21%)and lowest moisture content was observed for T_6(1.13%).

Acidity

Table 15 represents acidic content of plain and fruit blended tapioca pearls. Acidic content was highest in pineapple blended tapioca pearls(1.65%) and was lowest in plain blended tapioca pearls(1.23%).

Reducing sugar

Reducing sugars are carbohydrates that can oxidize other substances by contributing electrons while being reduced. These are group of carbohydrate or natural sugar which consists of either a free aldehyde group or a ketone group. Monosaccharides, disaccharides, oligosaccharides, polysaccharides, are the major reducing sugars. Reducing sugar was highest in T_4PI(9.46g/100g) and lowest in T_6(1.37g/100g).

Total sugar

Total sugar was highest in passion fruit blended tapioca pearls(28.23 g/100g)and lowest in plain blended tapioca pearls(3.31g/100g)(Table 15).

Total antioxidant activity

Total antioxidant activity in food refers to a food's overall ability to combat damaging free radicals in the body and neutralise their effects. Antioxidants are molecules that shield cells from the harm oxidative stress does to them. Oxidative stress is associated to a number of

diseases, such as cancer, cardiovascular disease, and ageing. Vitamins minerals (like phenolic compounds and carotenoids are some examples of antioxidants that are found in the body. From table 15, it was evident that totat antioxidant content was highest in T_5P(9.15g/100g)

Table 16. Phytochemical composition of plain and fruit blended tapioca pearls

Treatment	Total Phenol (g/100g	Total Ash (g/100g)	Oxalate (g/100g)	Cyanide	Peroxide value
T_3D	0.82^{f}	4.23^{d}	0.46^{b}	-	-
T_5P	3.30^{c}	4.87^{b}	0.44^{b}	-	-
T_1M	1.18^{d}	3.46^{c}	0.22^{d}	-	-
T_3J	3.45^{b}	4.92a	0.55^{a}	-	-
T_4PI	1.08^{e}	4.82^{ab}	0.33^{c}	-	-
T_6	5.27^{a}	3.09^{e}	0.44^{b}	-	-
SE(m)	0.017	0.093	0.012	-	-
CD%	0.052	0.156	0.036	-	-

Total phenol

The term "total phenols in food" describes all of the phenolic compounds that are contained in a certain food product as a whole. Phenolic compounds are a large class of chemical substances that are found in plants naturally and have been shown to have anti-inflammatory and antioxidant properties. Depending on the food product, its type, ripeness, processing, and storage circumstances, the total phenol concentration in food might vary greatly.

Table 16 represents the total phenol content of plain and fruit blended tapioca pearls. From the above analysis table it showed that the total phenol content ranged between 0.8-5.27.It was noted that the highest phenol content was obtained for T_6 (5.27g/100g) which was the control and lowest for T_4D(0.82g/100g).

Total ash

Table 16, depicts the total ash content of plain and fruit blended tapioca pearls.The ash content in food refers to the minerals and inorganics left after the food sample has been heated to a very high temperature removing moisture, volatiles, and organics It is a widely accepted index

of refinement of foods. From the analysis table, it was evident that T_4PI(2.82) got highest ash content and lowest was observed for T_3J(4.92g/100g) and was lowest in T_6(3.09g/100g)

Oxalates

Oxalates,also known as oxalic acid are naturally occurring compounds found in many plant based foods. They belong to a group of chemicals called organic acids. Oxalates are commonly found in certain vegetables , fruits, nuts and seeds. From Table 16, it was observed that the oxalate content of plain and fruit blended tapioca pearls ranged between 0.22-0.55g/100g.The highest oxalate content was observed for T_4J(0.55g/100g).Treatments T_4D(0.46g/100g),T_5P(0.44g/100g) and T_6(0.44g/100g) was on par . The lowest oxalate content was obtained for T_1M(0.22g/100g).

Cyanide

From Table 16, it was evident that cyanide content was not present in the developed products which shows the quality of the developed products.

Peroxide value

The peroxide value of food is a measure of the degree of oxidation or rancidity of fats and oils present in the food. It indicates the amount of peroxides formed in the fat or oil due to oxidative reactions. When fats and oils are exposed to oxygen, they undergo oxidative reactions, leading to the formation of peroxides. These peroxides contribute to the development of off-flavors, odors, and a decrease in the nutritional quality of the food product. From the analysis table, it was evident that peroxide content was not present in the developed products.

4.7.STORAGE STABILITY OF THE PRODUCTS

Food's shelf life, which is determined by four primary aspects including formulation, processing, packing, and storage conditions, is the amount of time that it will be safe to eat and organoleptically pleasing**.**

Table 17. Microbial Profile of plain and fruit blended tapioca pearls

Treatments	**Time interval**	**Bacteria(CFU/ml)**		**Fungi(CFU/ml)**		***Escherichia coli*(CFU/ml)**	
	Dilution	10^{-3}	10^{-4}	10^{-3}	10^{-4}	10-^{3}	10^{-4}
T_4D	Fresh	ND	ND	ND	ND	ND	ND
	After one	ND	ND	ND	ND	ND	ND

	month						
	After 2 month	ND	ND	ND	ND	ND	ND
	After 3 month	ND	ND	ND	ND	ND	ND
T_5P	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND
	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND
T_1M	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND
	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND
T_4J	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND
	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND

.
ND - Not detected
T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 18: Microbial profile of plain and fruit blended tapioca pearls

Treatments	**Time interval**	**Bacteria(CFU/ml))**		**Fungi(CFU/ml)**		***Escherichia coli*(CFU/ml)**	
	Dilution	10^{-3}	10^{-4}	10^{-3}	10^{-4}	10^{-3}	10^{-4}
T_3PI	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND
	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND
T_6	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND
	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND

ND - Not detected

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 19: Microbial profile of plain and fruit blended tapioca pearls

Treatments	Time interval	Bacteria(CFU/ml))		Fungi(CFU/ml)		*Escherichia coli*(CFU/ml)	
	Dilution	10^{-3}	10^{-4}	10^{-3}	10^{-4}	10^{-3}	10^{-4}
T_3PI	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND

	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND
T_6	Fresh	ND	ND	ND	ND	ND	ND
	After one month	ND	ND	ND	ND	ND	ND
	After second month	ND	ND	ND	ND	ND	ND
	After third month	ND	ND	ND	ND	ND	ND

ND - Not detected
T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

In the study , microbial profile of the developed products was conducted to determine the keeping qualities and thus the rate of contamination with bacterial colonies, fungal colonies and coli forms were analysed to ascertain the microbial profile.

The analysis report of the microbial profile of fruit blended tapioca pearls is shown in table. During the analysis conducted at monthly intervals at dilutions $1x10^{-3}$ and $1x10^{-4}$, there was no detection of bacterial, fungal, and coliform colonies, up to three months of storage. From Tables 17,18,19 , it was evident that there was no detection of bacterial fungal and coliform colonies upto three months of storage.

Table 20: Moisture content of plain and fruit blended tapioca pearls.

		Ambient temperature			Refrigerated temperature		
Treatments	Initial	Ist month	2nd month	3rdmonth	1st month	2ndmonth	3rdmonth
T_3D	3.27	3.27	3.28	3.29	3.27	3.27	3.28
T_5P	3.57	3.57	3.58	3.59	3.57	3.58	3.58
T_1M	4.01	4.02	4.03	4.04	4.01	4.01	4.03
T_3J	4.21	4.22	4.22	4.23	4.21	4.21	4.22

T_4PI	4.24	4.26	4.27	4.28	4.24	4.24	4.25
T_6	1.13	1.13	1.14	1.14	1.13	1.13	1.13
SE(m)	0.009	0.006	0.005	0.002	0.009	0.008	0.003
CD	0.027	0.019	0.014	0.007	0.028	0.027	0.010

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 21. pH content of plain and fruit blended tapioca pearls

Treatments		Ambient temperature			Refrigerated temperature		
	Initial	Ist month	2nd month	3rdmonth	1st month	2ndmonth	3rdmonth
T_3D	5.24	5.24	5.26	5.27	5.30	5.30	5.32
T_5P	4.79	4.81	4.82	4.79	4.85	4.85	4.92
T_1M	5.00	5.02	5.01	5.01	5.05	5.05	5.06
T_3J	5.12	5.14	5.15	5.11	5.18	5.18	5.22
T_4PI	4.19	4.20	4.22	4.22	4.26	4.28	4.28
T_6	5.28	5.29	5.31	5.31	5.35	5.35	5.37
SE(m)	0.013	0.018	0.005	0.009	0.009	0.028	0.032
CD	0.028	0.056	0.016	0.027	0.013	0.062	0.053

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 21 shows the pH content of the developed fruit blended tapioca pearls at ambient and refrigerated temperature during 3 months of shelf study at monthly intervals .From Table 14.,it reveals that at ambient temperature, pH content of developed fruit blended tapioca pearls

ranges from 4.22-5.29. During the initial month, the highest pH was found in T_6 which was the control (5.28) and lowest in T_4PI(4.19).pH of other fruit blended tapioca pearls were T_3D(5.24),T_5P(4.79),T_1M(5.00)respectively. During the first month, the highest pH was observed for T_6(5.29)and lowest in T_4PI(4.22).On the second month of storage, the highest pH was observed for T6(5.29) and the lowest was observed for T_4PI(4.22)On the third month of storage, pH content ranged between 4.22-5.27.The highest pH was observed for T_6(5.31)and lowest was observed for T_4PI(4.22)

From table 21, it was observed that at refrigerated temperature , pH ranges between 4.28-5.36 during the initial month. The highest pH was observed for T_6(5.36)and the lowest pH was observed for T_4PI(4.28).During the second month of storage, pH of the developed products found to be highest in T_6(5.36)and lowest in T_4PI(4.26).On the final month of storage pH content ranges between 4.28-5.37.The highest pH was found to be highest in T_6(5.37) and lowest in T_4PI(4.28).From the table it was observed that there was no much variation in pH content during the storage period on both ambient and refrigerated temperature.

Table 22: Acidity of plain and fruit blended tapioca pearls

Treatments		Ambient temperature			Refrigerated temperature		
	Initial	I^{s} month	2nd month	3rd month	1st month	2nd month	3rd month
T_3D	1.32	1.34	1.42	1.49	1.32c	1.33d	1.37
T_5P	1.58	1.61	1.64	1.69	1.43b	1.46b	1.48
T_1M	1.42	1.48	1.57	1.63	1.39bc	1.41b	1.44
T_3J	1.33	1.37	1.48	1.53	1.35bc	1.38c	1.40
T_4PI	1.61	1.66	1.71	1.73	1.61a	1.68a	1.71
T_6	1.17	1.20	1.23	1.26	1.20d	1.24	1.26
SE(m)	0.053	0.021	0.011	0.083	0.026	0.013	0.007
CD	0.098	0.065	0.035	0.029	0.081	0.048	0.056

(Results expressed are mean values of three replicates)*significant @5%

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 22 shows that acidity of plain and fruit blended tapioca pearls ranged between

At ambient temperature , the highest acidic content was observed for T_4PI(1.61%) and the lowest was observed for T_6(1.17%)or plain blended tapioca pearls during the intial month. On the first month of storage , acidity of six treatments ranged between 1-20%-1.66 %. T_4PI(1.66%) was noted with highest acidity and T_6(1.20%) shows lowest acidic content. During the second month of storage , the highest acidic content was observed for T_4PI(1.71%)and the lowest value was observed for T_6(1.23%).During the third month of storage , pH content was observed to be highest for T_4PI(1.73%) and lowest was observed for T_6(1.26%).

At refrigerated temperature, acidic content of plain and fruit blended tapioca pearls ranged between 1.20% -1.61% during the first month. On the second month of storage, highest acidic content was recorded for T_4PI(1.61%) and lowest was observed for T_6(1.20%)On the third month of storage, acidity ranges between 1.37%-1.71%.The highest acidic content was observed in T_4PI(1.71%) and lowest in T_6(1.26%)

The acidic content of the products were found to be decreased during each month of storage at both ambient and refrigerated temperature with a significant difference at 5% level during the storage period.

4.7.COST ANALYSIS OF PLAIN AND FRUIT BLENDED TAPIOCA PEARLS

The cost analysis of the developed products were worked out based on the price of the commodities such as cost of Cassava, fruits , sugar labour cost , etc.

Table 23: Cost analysis of plain and fruit blended tapioca pearls.

Treatments	**Total Cost(Rs)**
T_3D	440/-
T_5P	365/-
T_1M	350/-
T_3J	320/-
T_4PI	290/-
T_6	190/-

T_3D-Dragon fruit blended tapioca pearls, T_5P Passion fruit blended tapioca pearls, T_1M- Mango blended tapioca pearls, T_4PI - Pineapple blended tapioca pearls,T_6 control

Table 23 depicts the expenses obtained for the fruit blended tapioca pearls along with the control or plain blended tapioca pearls. From the table, it was reported that the highest cost was obtained for Dragon fruit blended tapioca pearls,T_3D (440/-) and the lowest cost was obtained for plain blended tapioca pearls(190/-)Therefore from the cost analysis of the developed products ,it can be concluded that the fruit blended tapioca pearls have comparatively highest cost compared to plain blended tapioca pearls may due to the higher cost of fruits selected in the study.

Discussion

5. DISCUSSION

The results of the following study entitled " Process Optimization of Boba Tea Pearls from Cassava (*Manihot esculenta*)"is discussed below ,under the following headings:

5.1. Selection and collection of raw materials

5.2. Development of cassava starch powder

5.3.Functional properties of cassava starch powder

5.3.Development of plain and fruit blended tapioca pearls

5.4.Quality evaluation of plain and fruit blended tapioca pearls

5.5. Nutrient and chemical composistion of plain and fruit blended tapioca pearls

5.6.Storage study of plain and fruit blended tapioca pearls

5.7.Cost analysis of developed products

5.1. SELECTION AND COLLECTION OF RAW MATERIALS

Cassava is a widely grown starchy root crop which is widely grown and consumed in many parts of the world particularly in tropical regions. It holds significant importance due to its various characteristics and uses.

In the present study , M4 matured cassava were selected from CTCRI, Sreekaryam which is a high yielding starch variety and a rich source of carbohydrate and energy. Fruits like dragon fruit, passion fruit, mango , jackfruit and pineapple were selected and collected from the local market which are also high source of dietary fibre, antioxidants, vitamins and minerals.

5.2. DEVELOPMENT OF TAPIOCA STARCH POWDER

5.2.1. Preparation of tapioca starch powder

Starch is the major food reserve of cassava.Fresh cassava contains approximately 21.5% of cassava starch(IITA,1990). Zhu(2015) stated that the end-use characteristics of cassava flour and starch, such as composition, physicochemical properties, and functional properties, govern their application in product development and food formulations.

Preliminary processing is the first and foremost step carried out in the development of a product. The primary step carried out was the cleaning and removal of the outer skin. The common practice and primary method of extracting starch from fresh cassava is wet milling (Nand *et al*., 2008).

The primary steps carried out in the extraction of tapioca starch was filtration, sedimentation, and decantation.The cut cubes of tapioca were washed in running water to remove all the mud and dirt. It was grinded well in a mixer with 20 ml of water into a slurry form. The slurry was extracted using a muslin cloth. The filterate was added with 50 ml of water and allowed to sediment for 6-7 hours. The supernatant was decanted and the slurry was taken for drying. In the present study, tapioca starch powder obtained was 7.27.27g/kg. In a study conducted by Chandra *et al*.,(2013) it was reported that cassava starch powder obtained was 11.56g/kg .

5.3.ASSESSMENT OF PHYSICAL QUALITIES OF POWDER

5.3.1Water absorption capacity (WAC).

From Table , it was evident that water absorption capacity of cassava starch powder was found to be 4.02 per cent . A study conducted by Butt and Batool (2010) reported that the observed variation in WAC of different foods/flours may be due to different concentrations of protein, conformational characteristics of flour and their degree of interaction with water.

According to Zghal *et al*., (2001) the increase in water absorption capacity of flour may also be due to the increase in the amylose solubility and leaching, as well as loss of the crystalline structure of starch. High WAC of composite flours suggests that the combination of different flours can be used in formulation of many foods such as processed cheese, bakery products, sausage, and dough.

In a study conducted by (Sugih *et al.*, 2015., Sugih *et al*., 2016) reported that Water absorption capacity (WAC) of native tapioca starch was 3.04 g/g which was higher compared to arrowroot and sweet potato starch (0.847-1.33 g/g respectively). Water absorption capacity is a significant functional property required in foods especially those involving dough handling (Iwe *et al*., 2016).

5.3.2.Swelling power

The swelling power is the measure of the ability of starch granules to absorb water and swell, and also reflects the extent of associative forces in the starch granules. Swelling capacity

(index) is considered a quality measure in some food products such as bakery products. The swelling capacity of flours are influenced by the particle size, species variety and method of processing (Suresh and Samsher, 2013)

In the present study, the swelling power of cassava starch powder was observed as 13.08%. Study conducted by Chandra *et al.,* (2015) reported that swelling power of cassava starch powder increased with the increasing temperature and the highest swelling power ranged between14.4 to 40.0 per cent 90 °C. A study conducted by Pino *et al*., 2013 reports that swelling power of corn starch ranged between 5.78-9.0 and swelling power of corn starch was lowest compared to cassava starch powder.

5.4.DEVELOPMENT OF PLAIN AND FRUIT BLENDED TAPIOCA PEARLS

Tapioca pearls also known as Boba pearls are translucent pearls prepared from cassava starch. In the study, plain tapioca pearls were prepared by gelatinizing cassava starch powder and sugar in the ratio 90:10.The developed tapioca pearls were cooked at 100^{o}C till it becomes chewy and jelly in appearance. According to research studies , the main purpose of the production of tapioca pearls is to improve the sensory experience of the food product when compared to comparable products like sago, which it has incorporated together with the bubble-like appearance, springiness, and chewiness. According to a study by Bulathgama *et al* .,(2018) these desirable properties of tapioca pearl were attained through "gelatinization" of starch, which can be accomplished with the proper heat-moisture treatment.

Fruits are relatively important due to their nutritional components and despite of their widespread popularity especially in food industries. In spite of their pleasant and appealing flavours, fruits are also high source of dietary fibre, vitamins, minerals and health boosting anti-oxidants including flavonoids. Compared to fruits, tapioca is low in dietary fiber, Vitamin C, B- Carotene, flavonoids etc. So fruits incorporated with boba pearls helps to increase its physiological and nutritional characterstics and also affects its sensory appeal without adding any artificial colour or flavour.

In the present study, fruit blended tapioca pearls were developed with fully ripened fruits like dragon fruit, passion fruit, jackfruit (varikka), pineapple and mango (neelam) Each fruit blended tapioca pearls were developed with five different proportions. From sensory analysis, the best proportion or combination from each treatment was identified using sensory scores which was

carried out using 10 semi-trained panellists. Sensory parameters like colour and appearance, taste, texture, flavour and overall acceptability was examined using 9 point hedonic rating scale.

5.5. QUALITY EVALUATION OF FRUIT BLENDED TAPIOCA PEARLS.

The sensory evaluation revealed that dragon fruit blended tapioca pearls (dragon fruit pulp – 35 per cent and cassava starch powder – 65 per cent T_3D) showed the best combination for the parameters like taste, flavour, texture and overall acceptability except colour. T_1D with 40 per cent of dragon fruit pulp and 60 per cent cassava starch powder scored the highest for colour, this is due to the highest proportion of dragon fruit pulp in T_1D. Putri *et al*., (2022), reported that increase in red dragon fruit peel extract concentration (200 ml) along with 270 g of cassava starch, increased the boba colour and in turn increased the preference among the panellists. Sari *et al.*, (2021) stated that the higher the concentration of dragon fruit peel extract, the higher the anthocyanin percentage, so the purplish red color will be more pronounced.

The sensory evaluation of passion fruit blended tapioca pearls showed that the best proportion was T_5P with 20 per cent fruit pulp and 80 per cent cassava starch powder than that of control. This proportion performed remarkably well in qualities viz., taste, texture, flavor and overall acceptability except colour. Proportion T_1P with 40% fruit pulp and 60% cassava starch powder scored the highest in colour.

Regarding the sensory analysis of Mango blended tapioca pearls (T_1M) with 40% mango pulp and 60% cassava starch powder showed the best proportion in all the attributes compared to all other treatments.

In the present study, jackfruit blended tapioca pearls and pineapple blended tapioca pearls with 35% fruit pulp and 65% cassava starch powder showed the best proportion with highest scores in all the parameters including colour, taste, texture , flavour and overall acceptability. Pineapple blended tapioca pearls with 30% pineapple pulp and 70% cassava starch powder showed the best proportion in all the treatments like colour, taste, texture , flavour and overall acceptability.

Figure 1: Sensory Evaluation of Dragon fruit blended tapioca pearls

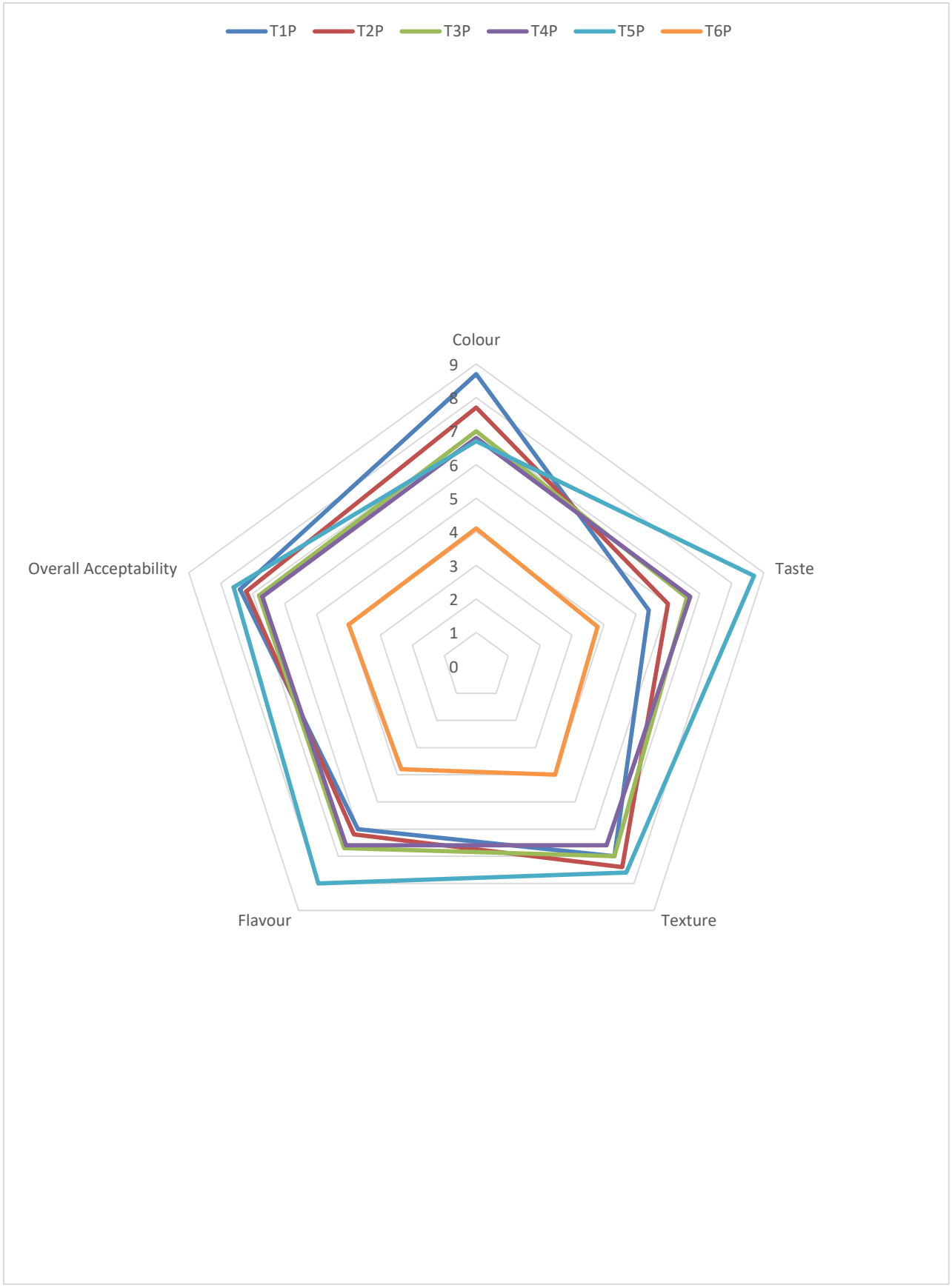


Figure 2: Sensory evaluation of Passion fruit blended tapioca pearl

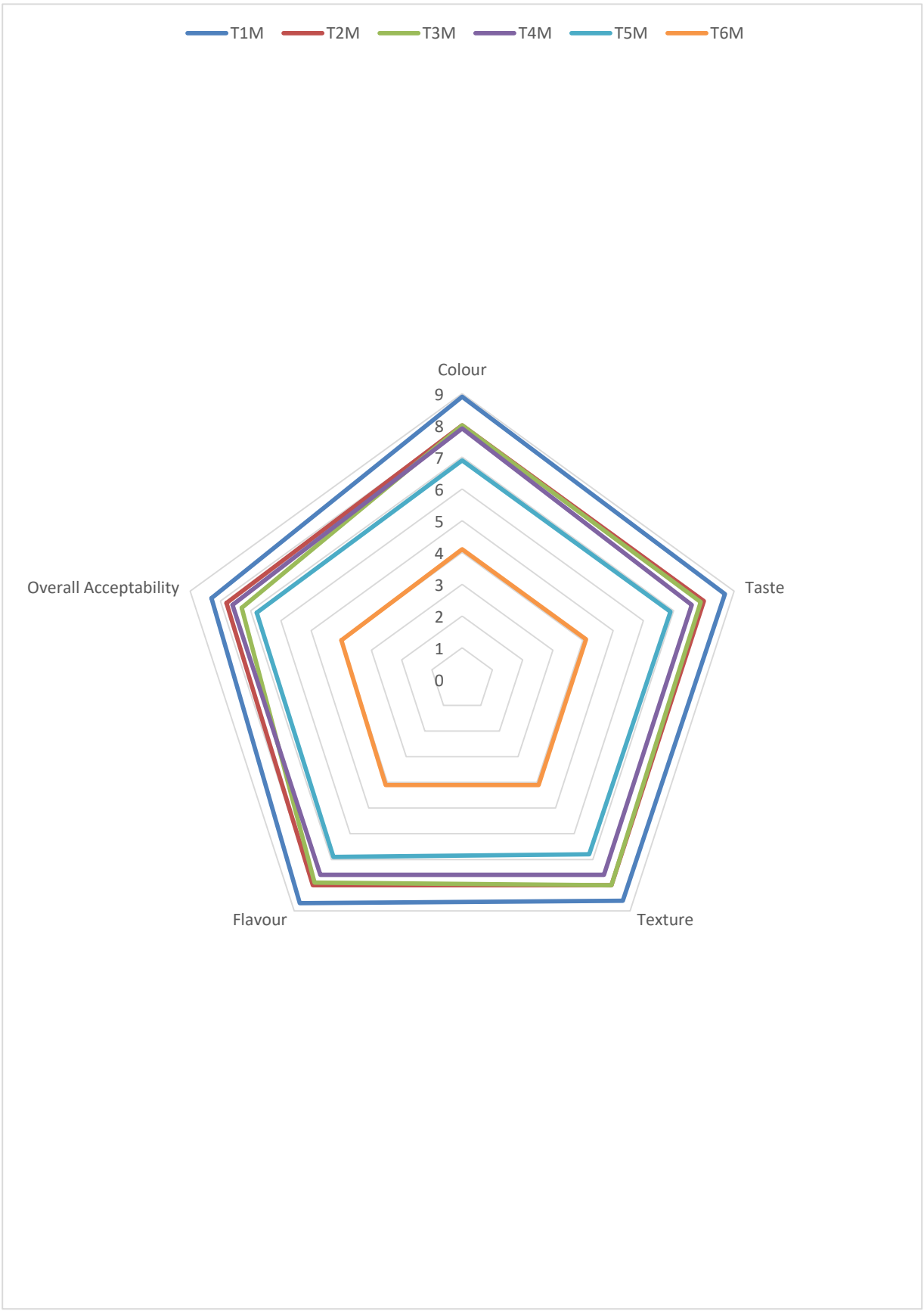
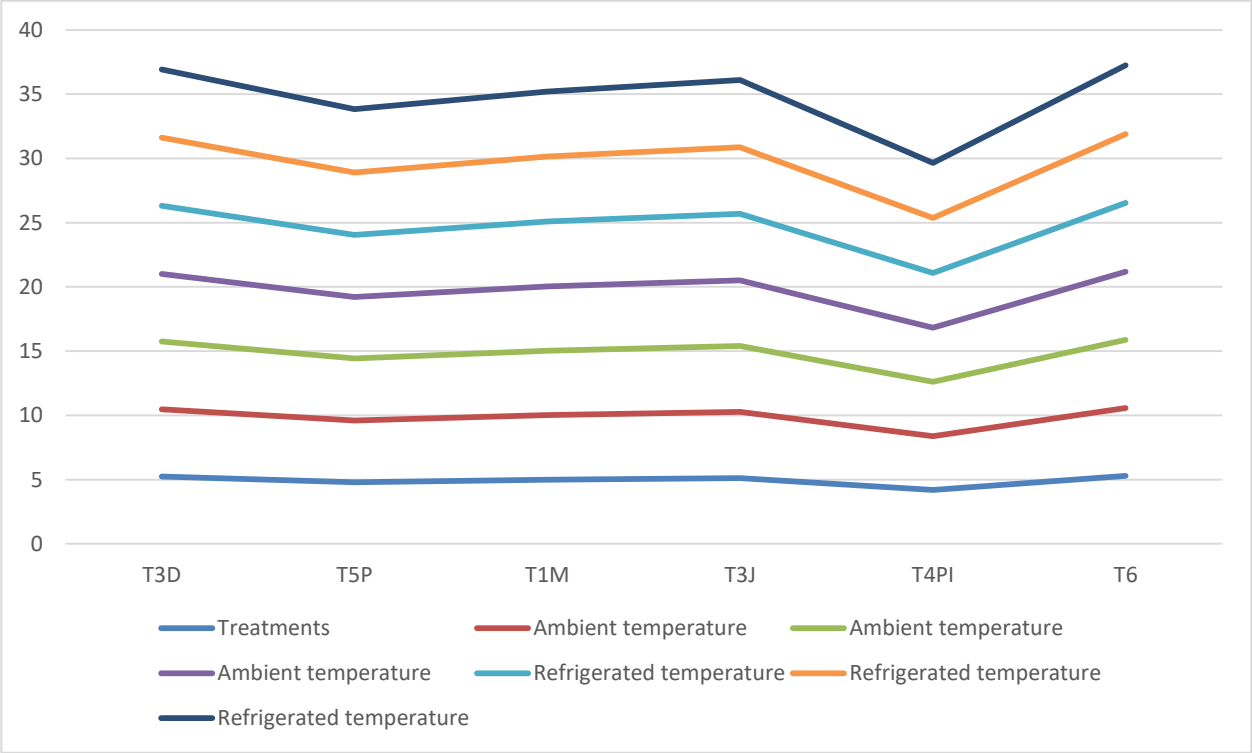

T1M
T2M
T3M
T4M
T5M
T6M
Colour
9
8
7
6
5
4
3
2
1
0
Taste
Texture
Flavour
Overall Acceptability

Figure 4: Sensory evaluation of Jackfruit blended tapioca pearls

Figure 5: Sensory evaluation of pineapple blended fruit blended tapioca pearl



5.6. NUTRIENT AND CHEMICAL COMPOSISTION OF FRUIT BLENDED TAPIOCA PEARLS

In the present study, nutritional parameters of the best proportions of plain and fruit blended tapioca pearls were studied.

From the nutrient analysis, it was observed that the carbohydrate content of plain and fruit blended tapioca pearls ranged between 2.04mg -2.56mg.Passion fruit blended tapioca pearls with 20% passion fruit pulp and 80% cassava starch powder showed highest carbohydrate content(2.56 mg/100g) than other fruit blended tapioca pearls. This may be due to the higher carbohydrate content in passion fruit compared to other fruits. According to a report by Santos (2002),

carbohydrate content in passion fruit found to be (23.38g/100g).The lowest carbohydrate content was observed for T_3J(2.04mg/g)

In the present study, the protein content was higher in jackfruit blended tapioca pearls (1.13 g/100g) than the control or plain tapioca pearls. According to Pavanasasivam and Sultanbawa, 1973 jackfruit was rich in amino acids like arginine, cystine, histidine, leucine, lysine, methionine, threonine, and tryptophan. Based on a study conducted by Chrips *et al*.,(2008) jackfruit pulp contains 1.9g/100g. So it can be concluded that since jackfruit is a rich source of amino acids among all other fruits , jackfruit blended tapioca pearls with 35% jackfruit pulp showed highest protein content compared to other fruit blended tapioca pearls. The lowest protein content was observed for T_6 or plain tapioca pearls (0.13g/100 g). Protein content of sago pearls was found to be 0.20mg.(Krishnakumar *et al*., 2020)

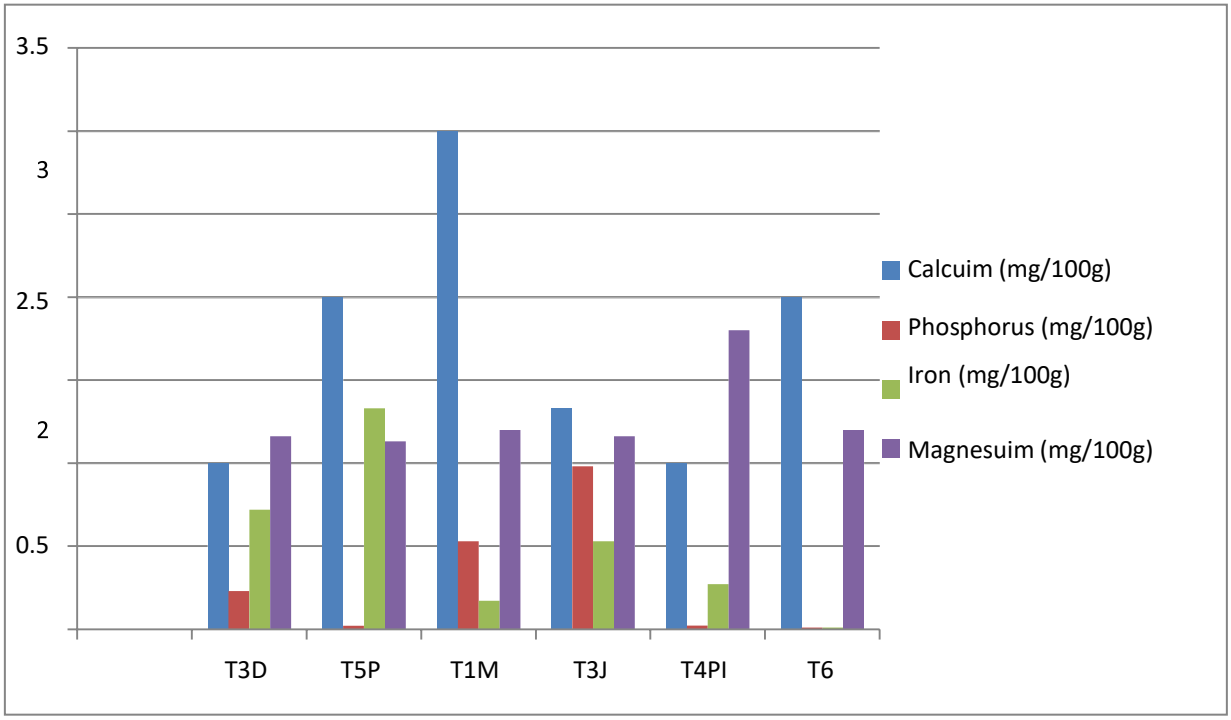
The findings of present study revealed that fibre content of fruit blended tapioca pearls along with the control ranges between 0.80g-2.79g.Passion fruit blended tapioca pearls (2.79g/100g) showed highest fibre content compared to other fruits. The lowest fibre content was observed in T_6 (0.80g/100g) or plain blended tapioca pearls. The increase in dietary fibre in fruit blended tapioca pearls compared to plain tapioca pearls may due to the addition of fruit pulps which is a rich of dietary fibre .Onibon *et al* ., 2007 stated that passion fruit is an immense source of dietary fibre , vitamins , minerals and flavonoids. The findings of USDA supports this statement. They reported that 100g of passion fruit pulp consists 46% of dietary fibre . So it can be concluded that T_5P with 80 g cassava starch powder and 20 g passion fruit pulp showed highest fibre content due to the passion fruit pulp present in the product compared to the plain tapioca pearls were cassava starch was the only ingredient .

Vitamin C content was found to be highest in pineapple blended tapioca pearls (17.08 mg/100g) with 30% fruit pulp and 70% cassava starch powder and the lowest vitamin C content was observed for plain blended tapioca pearls or T_6(0.02 mg/100g).Baretto *et al*.,2013 stated that pineapple can be considered as one of the most useful fruits for producing value-added compounds such as bromelain, antioxidants, organic acids, and phenolic compounds based on its physicochemical composition and nutritional qualities. George *et al* ., 2016 reported that vitamin C or ascorbic content of pineapple pulp was 51.97 mg/100 g. From the analysis report it was evident that Vitamin C content was not present in plain blended tapioca pearls. In a study conducted by Ogunjobi and Ogunwolu (2010) it was reported that vitamin C content was not found in cassava

flour. So it can be concluded that vitamin C content was present in all other treatments except plain blended tapioca pearls may due to the vitamin C content present in fruit pulps.

Calcium content was found to be higher in mango blended tapioca pearls or T_1M(3.00mg/100g). Richard(1997) stated that mango is a rich source of calcium among other fruits and mango pulp contains 10mg/100g calcium content. Phosphorus content was highest in T_3J(0.98 mg/100g) with 35% jackfruit pulp and 65% cassava starch powder and lowest content was observed in plain blended tapioca pearls or T_6.(0.01 mg/100g) . Samaddar (1998) has stated that the fakes of ripe jackfruit are high in nutritive value and reported that 100 g of ripe fakes contains 287-323 mg potassium. Iron content was found to be highest in T_5P or passion fruit blended tapioca pearls and lowest in T_6. A study conducted by Biswas *et al* .,(2012) depicts that passion fruit is a high source of dietary fibre, antioxidants and considerable amount of iron content. Passion fruit pulp contains 1.60mg/100g iron content (Kishore *et al* ., 2010). Copper content was highest in jackfruit blended tapioca pearls or T_3J and dragon fruit blended tapioca pearls and found to be lowest in plain blended tapioca pearls. Studies reported that copper content in jackfruit pulp was 0.24 mg/100g.(Manjeshwar *et al*.,2011; Srikanth *et al*., 2012 and Tang *et al*., 2013).

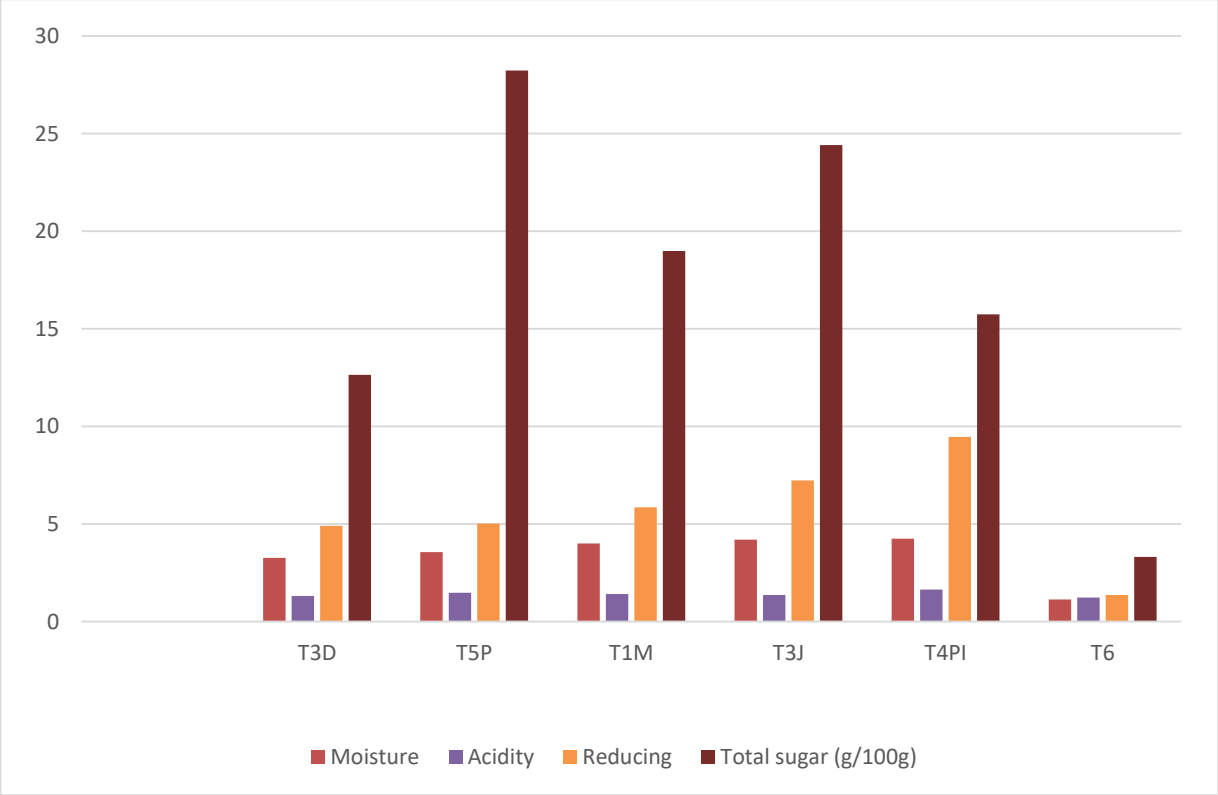
Figure 7 : Macro mineral composition of plain and fruit blended tapioca pearls



Fruits contribute significant amounts of minerals to the human diet. Minerals are required for normal cellular function, haemoglobin composition, gene expression and amino acid, lipid and

carbohydrate metabolism (Marisa, 2006). The results of the study showed that calcium , phosphorus, iron and copper content was highest in fruit blended tapioca pearls than plain blended tapioca pearls. This may due to the mineral content present in fruits compared to cassava starch powder which is a poor source of vitamins and minerals. Report by Montagnac (2009) stated that processing of cassava through peeling, chopping, and cooking will significantly reduces its content of vitamins, minerals, fiber, and resistant starch which supports this conclusion. Zinc content was found to be highest in pineapple blended tapioca pearls with 30% pineapple pulp and 70% cassava starch powder.

Figure 9: Phyto chemical composition of fruit blended tapioca pearl

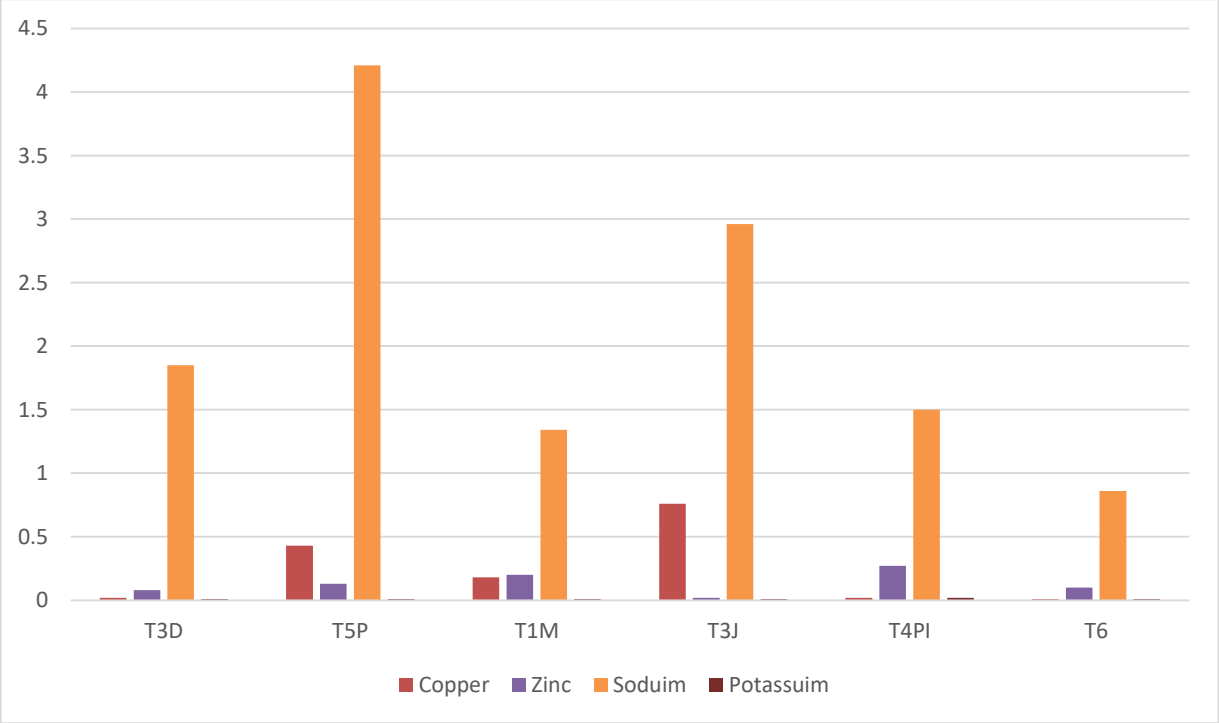


In the developed products moisture content was found to be highest for T_4PI or pineaaple blended tapioca pearls (4.25%) and jackfruit blended tapioca pearls (4.21%).Since the products are dried for 6-7 hours at 60^0C, the moisture content of the developed products was found to be below 5 percent. Excess moisture content in a food product can cause an increase rate of microbial growth, which results in the spoilage of the food products and thus affects the shelf life of the product. So it can be concluded that the the moisture content of the developed products in the present study was below 5 percent, it shows an highest shelf life for 3 months and therefore decreases the rate of spoilage of food.

Reducing sugar was found to be highest in pineapple blended tapioca pearls or T_4PI(9.46g/100g) and lowest in plain blended tapioca pearls(1.37g/100g). In a study conducted by

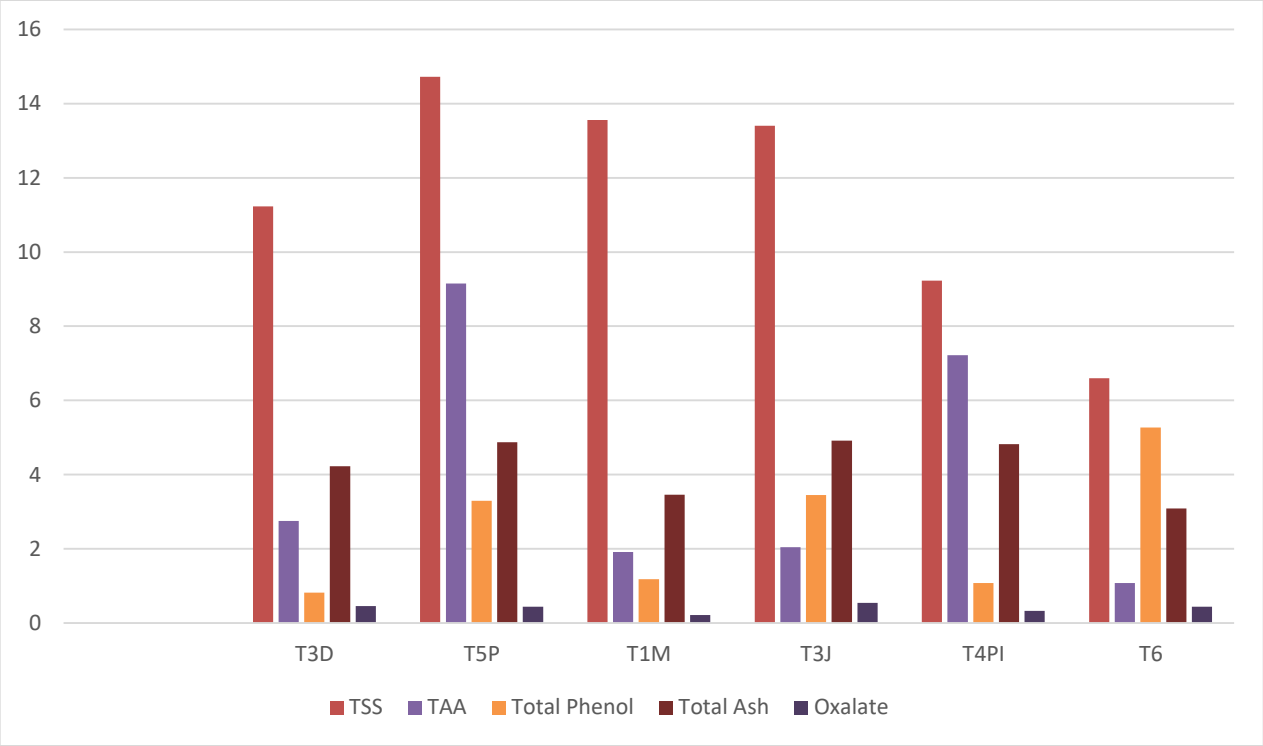
Achinewhu and Hart (1994) it was reported that the reducing sugar content of pineapple pulp was 12.5g/100g. Total sugar was highest in T_5P with 20% passion fruit pulp and 80% cassava starch powder.

Figure 8: Micro mineral composition of fruit blended tapioca pearls



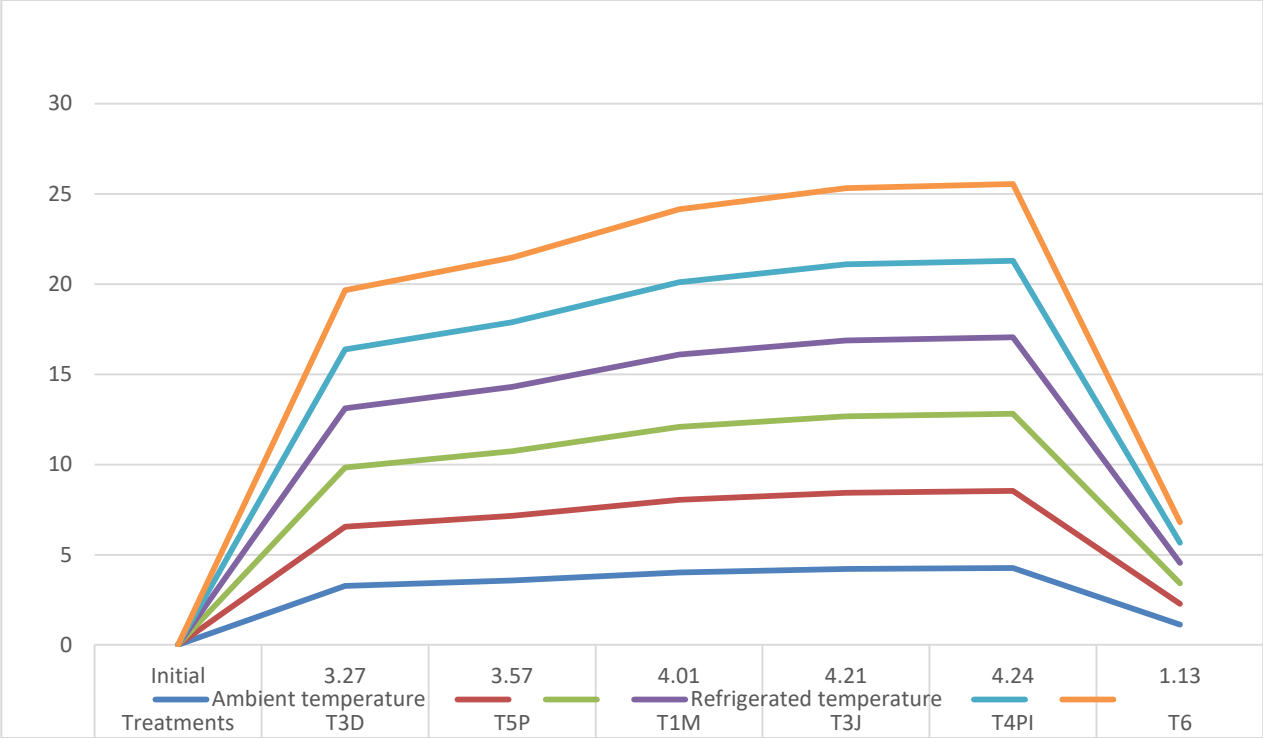
Mehta *et al*.,(2002) stated that total soluble solid in a food product is an important criterion which influences the total acceptability of the product. TSS was found to be highest in passion fruit blended tapioca pearls(14.7^0B) or T_5P and lowest in plain blended tapioca pearls(6.60^0B)

Figure 10: Chemical composition of plain and fruit blended tapioca pearls



In the present study , fat content and peroxide value was not present in the developed products which shows the shelf life and quality of the product. High fat content in food products can contribute to their susceptibility to rancidity and spoilage. The amount of oxidation in fats and oils that affects their quality and produces unappealing flavours and odours is measured by their peroxide value. Higher peroxide values indicate higher oxidation, which may indicate food spoilage or degradation. Additionally, essential elements like vitamins and antioxidants might be destroyed by oxidised lipids.

Figure 11: Moisture of plain and fruit blended tapioca pearls.



5.7. SHELF LIFE OF TAPIOCA PEARLS

5.7.1 Microbial profile.

In the present investigation, the presence of bacterial, fungal and E-coli colonies were not detected during 3 months of storage at both ambient and refrigerated temperature. This indicates that there was no bacterial , fungal or other microbial growth in the developed products which shows the quality of the product. A study conducted by Miyagi *et al*., 2000 reported that there was no microbial and fungal growth in orange flavoured boba pearls during 2 months of storage study.This may due to the lowest moisture content in the developed products because water serves as a medium for microbial growth. This conclusion was supported by the findings of Mallhi *et al*., 2019 reported that moisture content reduces the growth of microbial and fungal growth in dried products.

5.7.2.Evaluation of moisture content during storage

Moisture content in food can have a significant impact in determing the microbial profile and shelf life of the products. Haug (1993) reported that excess water content in food product's increase microbiological growth, which could shorten the product's shelf life as well as lead it to degrade before it even reaches the market. In the present study the moisture content of the developed products ranged between 1.13-4.25%. Since moisture content of fruits was high compare to cassava starch powder the developed products were dried for 7-8 hours till it reaches 4-5%of

moisture. As moisture content was less than 5 percent the growth of microbial was not detected in the developed products which increased the shelf life and qualiity of the products,

5.7.3.Evaluation of pH during storage

pH plays a crucial role in food safety. Microorganisms such as bacteria, yeasts, and molds, have specific pH requirements for growth. By measuring the pH of food, it is possible to assess the potential for microbial growth and spoilage.

In the present study, at ambient temperature, intially the pH content of the developed products ranged from 4.19-5.28. After the second month pH content ranged from 4.20-5.29. During the third month Ph content ranged between 4.22-5.31. At refrigerated temperature, initially the pH content ranged from 4.22-5.27 and during the final month the pH content of the developed products ranged from 4.28-5.27 . It was evident that there was no much variation in pH content during the storage period at both ambient and refrigerated temperature.

5.7.4.Evaluation of acidity during storage.

Food acidity functions as a barrier to the growth of deterioration and pathogenic bacteria, especially when paired with other barriers like low water activity or low temperature, and can significantly increase food safety and shelf life (Leistner and Gorris, 1995).

Figure 13: Acidity of plain and fruit blended tapioca pearls

In the present study, the acidic content of the developed products decreased with a slight variation during 3 months of storage at both ambient and refrigerated temperature. As the pH content increases acidity decreases. Microbial growth was not observed during 3 months of storage because moisture content of the developed products was below 5 per cent. As moisture content decreases acidic content also increases which shows the higher shelf life of the product. This findings is consistent with Finola et al., 2007 who reported that high microorganism count can increase the acidity in food products.

5.8.COST ANALYSIS OF THE DEVELOPED PRODUCTS

The cost analysis of the plain and fruit blended tapioca pearls was done on the basics on the basics of market value of ingredients and cost of production .The cost of dragon fruit tapioca pearls, passion fruit pearls, mango tapioca pearls , jackfruit tapioca pearls ,pineapple tapioca pearls and

plain blended tapioca pearls were Rs 440, 365,350,320,290 and 210 respectively. Dragon fruit tapioca pearls was observed with highest expense since dragon fruit is a highly expensive and nutritious fruit compared to other fruits. The current market price for dragon fruit was 290/kg. The lowest expense was worked out for plain blended tapioca pearls (190/-).The price of plain blended tapioca pearls 480/kg. As cassava is a cheaply available tuber crop, this is a posistive indication for large scale cassava growers as well as micro entreprenurs to strengthen entreprenurship under One district One product scheme.

Summary

SUMMARY

The study entitled “Process optimization of fruit blended Boba tea pearls from cassava (*Manihot esculenta)*” was carried out at the Department of Community Science , College of Agriculture, Vellayani during the period of 2020-2022 with the objective to develop fruit blended tapioca pearls and to evaluate its quality attributes. The study comprised of collection of raw materials, extraction and preparation of cassava starch powder, functional qualities of cassava starch powder, development of plain and fruit blended tapioca pearls , organoleptic qualities and selection of best proportion, assessment of nutrient and chemical profile of selected pearls shelf life parameters and cost of production .The important findings of the study are summarized here.

Matured M_4 cassava were collected from Central Tuber Crop Research Institute (CTCRI) Sreekaryam. For the development of fruit blended tapioca pearls fully ripened and matured fruits like dragon fruit, passion fruit , mango, jackfruit and pineapple were collected from local market. Extraction and preparation of cassava starch powder was the first experiment carried out in the study. After proper cleaning washing , and peeling cassava was cut into smaller cubes or slices. . The cut out cubes was grinded well in a mixer using 20 ml of water until it becomes into a paste form. After filtration, the extracted cassava juice was kept for sedimentation for 5-6 hours by adding half litre of water. The decanted liquid was removed. This procedure was repeated for 3-4 times till the upper portion of the liquid becomes clear. The sediment residue was kept for drying on hot air oven at a temperature of 80-90 degree for 2-3 days till the moisture content of the powder was totally reduced. The dried tapioca starch was packed in food grade covers at room temperature for further studies.

Development of plain and fruit blended tapioca pearls was the second experiment carried out in the study . Plain and fruit blended tapioca pearls were developed through gelling method using the standard procedures recommended by Bulgathama *et al.,* 2020 after some modifications. Fruit pulps were extracted using mixer. Plain tapioca pearls were developed by gelatinizing cassava starch with sugar in the proportion 90:10 and oven dried at 60^0 C until the moisture content of the pearls reached below 5 percent.The varouis proportions selected for the formulation of fruit blended tapioca pearls with fruit pulp and cassava starch powder were 40:60 (T_1) , 25:75 (T_2) , 30:70 (T_3), 35:65(T_4), 20:80 (T_5) and 100:0 (T_6 or control) respectively. The treatments were similar for all the individual fruit blended tapioca pearls.

The usuage of varouis fruits in fruit blended tapioca pearls resulted in variations in sensory preferences . Based on the sensory evaluation of fruit blended tapioca pearls , it was observed that dragon fruit blended tapioca pearls with 35% cassava starch powder and 65%

(T_3D)dragon fruit pulp scored the highest value for all the parameters except colour. The other treatments of dragon fruit blended tapioca pearls were significantly different at 5 % level. Among passion fruit blended tapioca pearls , 80% cassava starch powder with 20% passion fruit pulp (T_5P) scored the maximum score in all the parameters. In the case of jackfruit blended tapioca pearls 65% cassava starch powder and 35% fruit pulp was found to be the best proportion in all the parameters and all other treatments were significantly different. The treatment T_1M with 60% cassava starch powder and 40% mango pulp obtained the highest score in all the parameters. In pineapple blended tapioca pearls , T_4PI with 70% cassava starch powder and 30% pineapple pulp was found to be the best proportion in all the treatments.

The nutritional profile of the standardised fruit blended tapioca pearls differerd significantly when compared with fruit blended tapioca pearls. Carbohydrate content was found higher in T_4PI or pineapple blended tapioca pearls (2.62g/100g) and lowest value was noted for T_6 or control (2.04g/100g). The highest protein content was noted for passion fruit blended tapioca pearls (1.62g/100g)and lowest protein content was observed for plain blended tapioca pearls or the control(0.13g/100g).Highest amount of fiber content was reported in passion fruit blended tapioca pearls (2.79g/100g)and lowest fiber content was noted in plain blended tapioca pearls (0.80g/100g).The fiber content was found to be highest in fruit blended tapioca pearls when compared to plain blended tapioca pearls. Fruits are a rich source of dietary fiber when compared to cassava , so addition of fruit pulp results in an increase in dietary fibre in fruit blended tapioca pearls when compared to plain blended tapioca pearls. Vitamin C content were found to be increased in fruit blended tapioca pearls .Pineapple blended tapioca pearls was noted with highest amount of vitamin C content (17.08 mg/100g) and found to be lowest in dragon fruit blended tapioca pearls (0.03 mg/100g) among fruit blended tapioca pearls. Plain blended tapioca pearls lack vitamin C content since cassava is a poor source of vitamin C content compared to fruits.

Calcium content was found to be highest in mango blended tapioca pearls .Phosphorus content was noted highest in jackfruit blended tapioca pearls (0.98mg/100g) and least in control or plain blended tapioca pearls (0.01mg/100g). Iron content was found to be highest in dragon fruit blended tapioca pearls (0.72mg/100g) and lowest in plain blended tapioca pearls (0.01 mg/100g). Potassium content was noted highest in pineapple blended tapioca pearls (1.80 mg/100g) and lowest in passion fruit blended tapioca pearls (1.13 mg/100g) as potassium content was found to be highest in pineapple compared to other fruits.

Moisture content, acidity and reducing sugar was found to be increased in fruit blended tapioca pearls. Moisture content (4.25%), acidity (1.65%) and reducing sugar (9.46g/100g) was highest in pineapple blended tapioca pearls. Moisture content (1.13%), acidity (1.23%) and reducing sugar (1.37g/100g) was noted lowest in plain blended tapioca pearls or control. Total sugar (28.23g/100g) and total soluble solids (14.72^0B) was found highest in passion fruit blended tapioca pearls. Plain blended tapioca pearls was noted least score in total sugar (3.31g/100g).

Total antioxidant activity was found to be highest in passion fruit blended tapioca pearls (9.15 g/100g) and lowest in control (1.08g/100g). Total phenol content was observed to be highest for plain blended tapioca pearls or control (5.27g/100g) compared to fruit blended tapioca pearls since phenol content is less in fruits compared to cassava. Total ash content (4.92g/100g) and oxalate content (4.92g/100g) was found to be highest in jackfruit blended tapioca pearls. Total ash content (3.09g/100g) was found to be lowest in plain blended tapioca pearls and oxalate content (0.22g/100g) was least in mango blended tapioca pearls.

Best proportion of plain and fruit blended tapioca pearls were stored at ambient and refrigerated temperature for 3 months and parameters like pH, moisture, acidity total viable count and microbial profile were analyzed at monthly intervals.

During the analysis conducted at monthly intervals at dilutions $1x10^{-3}$ and $1x10^{-4}$, there was no detection of bacterial, fungal, and coliform colonies, up to three months of storage

At ambient temperature, pH content of developed fruit blended tapioca pearls ranges from 4.22-5.29. During the initial month, the highest pH was found in T_6 which was the control (5.28) and lowest in T_4PI(4.19).pH of other fruit blended tapioca pearls were T_3D(5.24),T_5P(4.79),T_1M(5.00) respectively. During the first month, the highest pH was observed for T_6(5.29)and lowest in T_4PI(4.22).On the second month of storage, the highest pH was observed for T6(5.29) and the lowest was observed for T_4PI(4.22)On the third month of storage, pH content ranged between 4.22-5.27.The highest pH was observed for T_6(5.31)and lowest was observed for T_4PI(4.22)

At refrigerated temperature, pH ranges between 4.28-5.36 during the initial month. The highest pH was observed for T_6(5.36)and the lowest pH was observed for T_4PI(4.28).During the second month of storage, pH of the developed products found to be highest in T_6(5.36)and lowest in T_4PI(4.26).On the final month of storage pH content ranges between 4.28-5.37.The highest pH was found to be highest in T_6(5.37) and lowest in T_4PI(4.28). From the table it was observed that there was no much variation in pH content during the storage period on both ambient and refrigerated temperature.

At ambient temperature , the highest acidic content was observed for T_4PI(1.61%) and the lowest was observed for T_6(1.17%)or plain blended tapioca pearls during the intial month. On the first month of storage , acidity of six treatments ranged between 1-20%-1.66 %. T_4PI(1.66%) was noted with highest acidity and T_6(1.20%) shows lowest acidic content. During the second month of storage , the highest acidic content was observed for T_4PI(1.71%)and the lowest value was observed for T_6(1.23%).During the third month of storage , pH content was observed to be highest for T_4PI(1.73%) and lowest was observed for T_6(1.26%).

At refrigerated temperature, acidic content of plain and fruit blended tapioca pearls ranged between 1.20% -1.61% during the first month. On the second month of storage, highest acidic content was recorded for T_4PI(1.61%) and lowest was observed for T_6(1.20%)On the third month of storage, acidity ranges between 1.37%-1.71%.The highest acidic content was observed in T_4PI(1.71%) and lowest in T_6(1.26%)

The acidic content of the products were found to be decreased during each month of storage at both ambient and refrigerated temperature with a significant difference at 5% level during the storage period.

Cost of the developed products were calculated. The cost estimate of plain and fruit blended tapioca pearls ranged from Rs 190- Rs 440.The highest cost was obtained for Dragon fruit blended tapioca pearls,T_3D (440/-) and the lowest cost was obtained for plain blended tapioca pearls(190/-)

To increase the physiological and nutritional characteristics of boba pearls, there is a need for new interventions which increases its properties. Addition of fruits will increase the quality of boba pearls with respect to its nutritional qualities and sensory appeal without adding any artificial colour or flavours. Hence, the present study is proposed to standardize and develop process protocol for fruit blended cassava boba pearls utilizing, under exploited and easily available fruits like mango, pineapple, passion fruit, jackfruit and dragon fruit as well as to evaluate their organoleptic, nutritional, textural and shelf-life qualities. The development of process protocols for cassava boba pearls and its technology transfer will benefit cassava growers as well as micro-enterprises to strengthen entrepreneurship under One District One Product (ODOP) scheme, of Atmanirbhar Bharat.

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Abstract

ABSTRACT

The study entitled "**Process Optimization of fruit blended Boba Tea Pearls from cassava*(Manihot esculenta*)**"**was conducted at the department of Community Science, College of Agriculture, Vellayani during the period 202O-2022.The objective of the study was to develop fruit blended Boba tea pearls from cassava and to evaluate its quality attributes".

Matured M4 cassava was selected and collected from CTCRI, Sreekaryam. Five fruits like dragon fruit, passion fruit, pineapple, jackfruit and mango were selected to make fruit blended boba tea pearls. Cassava was properly cleaned, washed , cut into small cubes and grinded using water for extracting the starch content using a muslin cloth. The slurry was kept for 6-7 hours and the supernatant was discarded . The sediment was then oven dried at 60 C for 2-3 days until it reached moisture content between 5-7 per cent. Fruit pulp was taken after removal of seeds.

Fruit blended tapioca pearls was developed by gelatinizing cassava starch powder blended with fruit pulp in the proportions 40:60, 35;65, 70:30, 75:25 and 80: 20 with 10 gram of sugar and was oven dried until the moisture content of the pearls between 5-7 per cent. The dried pearls was then packed in HDPE covers for further sensory studies. For the selection of one best proportion from each fruit,100 grams of the developed fruit blended pearls was subjected to cook in 10 gram of sugar syrup in 100 ^{0}C till the pearls become transparent, chewy and jelly like form. Five proportions along with the control of fruit blended tapioca pearls were subjected to sensory evaluation and the best one from each fruit blended tapioca pearls was selected.

From the sensory evaluation it was found that T_1M(40 ; 60) was the best proportion for mango blended tapioca pearls, T_5P (20;80) for passion fruit tapioca pearls, T_4P(30: 70) for Pineapple blended tapioca pearls, T_3J(30: 70) for jackfruit tapioca pearls and T_3D(35:65)for dragon fruit tapioca pearls.

Nutritional analysis showed that Pineapple blended tapioca pearls T_3PI(2.62g/100g) contain highest carbohydrate content and the lowest carbohydrate content was observed for plain tapioca pearls(control).Phenol concentration was highest for control compared to fruit blended tapoca pearls. TAA content was observed highest for passion fruit (9.15g/100g) compared to other treatments and was low in mango blended tapioca pearls. Jackfruit blended

tapioca pearls have highest oxalate content compared to other fruit blended pearls and it low in mango and pineapple pearls. On mineral composition it was showed that Jackfruit blended tapioca pearls (T_4J) has more potasuim content and lowest for passion fruit tapioca pearls. Phosphorus content was highest in passion fruit blended tapioca pearls P6 (0.013g/100gm)and lowest for control. Calcuim content was highest in mango (3.1g/100gm)and was lowest in Pineapple and passion fruit. For magnesium it was observed that pineapple blended tapioca pearls have highest calcium content(1.8g/100gm). While analysing the PH of fruit blende tapioca pearls it was found that highest pH value is for passion fruit blended tapioca pearls(4.8g/100gm) and pineapple blended tapioca pearls(4.2g/100gm) and the lowest pH was observed for control or plain blended tapioca pearls. Physical properties like swelling power of tapioca starch powder and yield was analysed. Swelling power of tapioca starch powder was found to be 13.08. Total bacterial count, Total fungal count and total coliform count was assessed using microbiological methods under 1 month interval. The presence of bacteria , fungus and E-coli was not detected until 3 months of storage studies. It shows the quality and the shelf stability of the product.

To increase the physiological and nutritional characteristics of Boba pearls ,there is a need for new interventions which increases its properties Addition of fruits will increase its nutritive value along with sensory appeal without adding any artificial colours or flavours. Compared to fruits , cassava is low in dietary fiber, vitamins and minerals etc. So addition of fruit based boba pearls not only give an additional texture and flavour ,but also provide nutritive values compared to plain tapioca pearls. The development of process protocols for cassava boba pearls and its technology transfer will benefit cassava growers as well as micro-enterprises to strengthen enterprenurship under One District One product scheme.

സംഗ്രഹം

"പ്രോസസ് ഒപ്റ്റിമൈസേഷൻ ഓഫ് ഫ്രൂട്ട് ബ്ലെൻഡഡ് ബോബ ടീ പേൾസ് ഫ്രം കസവ (മണിഹോട്ട് എസ്കുലെന്റ)" എന്ന തലക്കെട്ടിലുള്ള പഠനം 2020-2022 കാലയളവിൽ വെള്ളായണിയിലെ കോളേജ് ഓഫ് അഗ്രികൾച്ചർ കമ്മ്യൂണിറ്റി സയൻസ് വിഭാഗത്തിൽ നടത്തി. കസവയിൽ നിന്ന് പഴങ്ങൾ കലർന്ന ബോബ ടീ മുത്തുകൾ വികസിപ്പിക്കുകയും അതിന്റെ ഗുണപരമായ ഗുണങ്ങൾ വിലയിരുത്തുകയും ചെയ്യുക എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യം.

പാകമായ M4 മരച്ചീനി തിരഞ്ഞെടുത്ത് ശ്രീകാര്യത്തെ CTCRI-യിൽ നിന്ന് ശേഖരിച്ചു. ഡ്രാഗൺ ഫ്രൂട്ട്, പാഷൻ ഫ്രൂട്ട്, പൈനാപ്പിൾ, ചക്ക, മാമ്പഴം തുടങ്ങി അഞ്ച് പഴങ്ങൾ ഫ്രൂട്ട് ബ്ലെൻഡഡ് ബോബ ടീ പേൾസ് ഉണ്ടാക്കാൻ തിരഞ്ഞെടുത്തു. മരച്ചീനി ശരിയായി വൃത്തിയാക്കി, കഴുകി, ചെറിയ സമചതുരകളാക്കി മുറിച്ച്, വെള്ളം ഉപയോഗിച്ച് പൊടിച്ച്, മസ്ലിൻ തുണി ഉപയോഗിച്ച് അന്നജം വേർതിരിച്ചെടുക്കുന്നു. സ്ലറി 6-7 മണിക്കൂർ സൂക്ഷിക്കുകയും സൂപ്പർനാറ്റന്റ് ഉപേക്ഷിക്കുകയും ചെയ്തു. അവശിഷ്ടം 60 ഡിഗ്രി സെൽഷ്യസിൽ 2-3 ദിവസത്തേക്ക് ഓവൻ ഉണക്കി, 5-7 ശതമാനം ഈർപ്പം എത്തും. വിത്തുകൾ നീക്കം ചെയ്തതിനുശേഷം പഴത്തിന്റെ പൾപ്പ് എടുക്കുന്നു.

40:60, 35;65, 70:30, 75:25, 80:20 എന്നീ അനുപാതങ്ങളിൽ ഫ്രൂട്ട് പൾപ്പിനൊപ്പം 10 ഗ്രാം പഞ്ചസാര ചേർത്ത് കസവ സ്റ്റാർച്ച് പൗഡർ ജെലാറ്റിനൈസ് ചെയ്താണ് ഫ്രൂട്ട് ബ്ലെൻഡഡ് മരച്ചീനി മുത്തുകൾ വികസിപ്പിച്ചെടുത്തത്. മുത്തുകളുടെ 5-7 ശതമാനം. കൂടുതൽ സെൻസറി പഠനങ്ങൾക്കായി ഉണക്കിയ മുത്തുകൾ HDPE കവറുകളിൽ പായ്ക്ക് ചെയ്തു. ഓരോ പഴത്തിൽ നിന്നും ഒരു മികച്ച അനുപാതം തിരഞ്ഞെടുക്കുന്നതിന്, 100 ഗ്രാം വികസിപ്പിച്ച പഴങ്ങൾ കലർന്ന മുത്തുകൾ 10 ഗ്രാം പഞ്ചസാര സിറപ്പിൽ 100 ഡിഗ്രി സെൽഷ്യസിൽ പാകം ചെയ്തു, മുത്തുകൾ സുതാര്യവും ചീഞ്ഞതും ജെല്ലി പോലെയുള്ള രൂപവും വരെ. ഫ്രൂട്ട് ബ്ലെൻഡഡ് മരച്ചീനി മുത്തുകളുടെ നിയന്ത്രണത്തോടൊപ്പം അഞ്ച് അനുപാതങ്ങളും സെൻസറി മൂല്യനിർണ്ണയത്തിന് വിധേയമാക്കി,

ഓരോ പഴം കലർന്ന മരച്ചീനി മുത്തുകളിൽ നിന്നും ഏറ്റവും മികച്ചത് തിരഞ്ഞെടുത്തു.

സെൻസറി മൂല്യനിർണ്ണയത്തിൽ നിന്ന്, മാങ്ങ കലർന്ന മരച്ചീനി മുത്തുകൾക്ക് T_1M (40; 60), പാഷൻ ഫ്രൂട്ട് മരച്ചീനി മുത്തുകൾക്ക് TP_5 (20;80), പൈനാപ്പിൾ കലർന്ന മരച്ചീനി മുത്തുകൾക്ക് T_4PI (30: 70), T_3JI (30: 70) ചക്ക മരച്ചീനി മുത്തുകൾക്കും T_3DI (35:65) ഡ്രാഗൺ ഫ്രൂട്ട് മരച്ചീനി മുത്തുകൾക്കും.

പൈനാപ്പിൾ കലർന്ന മരച്ചീനി മുത്തുകളിൽ T_4PI(2.620) ഏറ്റവും കൂടുതൽ കാർബോഹൈഡ്രേറ്റ് അടങ്ങിയിട്ടുണ്ടെന്നും സാധാരണ മരച്ചീനി മുത്തുകൾക്ക് (നിയന്ത്രണം) ഏറ്റവും കുറഞ്ഞ കാർബോഹൈഡ്രേറ്റ് ഉണ്ടെന്നും പോഷകാഹാര വിശകലനത്തിൽ കണ്ടെത്തി. TAA ഉള്ളടക്കം ഏറ്റവും കൂടുതൽ നിരീക്ഷിച്ചത്

പാഷൻ ഫ്രൂട്ട് (9.15g/100g) മറ്റ് ചികിത്സകളെ അപേക്ഷിച്ച് മാമ്പഴം കലർന്ന മരച്ചീനി മുത്തുകൾ കുറവാണ്. ചക്ക കലർന്ന മരച്ചീനി മുത്തുകളിൽ മറ്റ് പഴങ്ങൾ കലർന്ന മുത്തുകളെ അപേക്ഷിച്ച് ഏറ്റവും ഉയർന്ന ഓക്സലേറ്റ് അടങ്ങിയിട്ടുണ്ട്, മാങ്ങ, പൈനാപ്പിൾ മുത്തുകൾ എന്നിവ കുറവാണ്. ജാക്ക്ഫ്രൂട്ട് കലർന്ന മരച്ചീനി മുത്തുകളിൽ (ജെ4) പൊട്ടാസ്യത്തിന്റെ അംശം കൂടുതലാണെന്നും പാഷൻ ഫ്രൂട്ട് മരച്ചീനി മുത്തുകൾക്ക് കുറവാണെന്നും ധാതുക്കളുടെ ഘടനയിൽ തെളിഞ്ഞു. പാഷൻ ഫ്രൂട്ട് കലർന്ന മരച്ചീനി പേൾസ് P6 (0.013g/100gm) ലാണ് ഫോസ്ഫറസിന്റെ അളവ് കൂടുതലും നിയന്ത്രണത്തിന് ഏറ്റവും കുറവും. മാമ്പഴത്തിൽ (3.1g/100gm) കാൽക്കുയിം ഉള്ളടക്കം ഏറ്റവും കൂടുതലാണ്.

പൈനാപ്പിൾ, പാഷൻ ഫ്രൂട്ട് എന്നിവയിൽ ഏറ്റവും കുറവ്. മഗ്നീഷ്യം സംബന്ധിച്ചിടത്തോളം, പൈനാപ്പിൾ കലർന്ന മരച്ചീനി മുത്തുകളിൽ ഏറ്റവും കൂടുതൽ കാൽസ്യം അടങ്ങിയിട്ടുണ്ടെന്ന് നിരീക്ഷിക്കപ്പെട്ടു (1.8g/100gm). ഫ്രൂട്ട് ബ്ലെൻഡ് മരച്ചീനി മുത്തുകളുടെ പിഎച്ച് വിശകലനം ചെയ്യുമ്പോൾ, പാഷൻ ഫ്രൂട്ട് കലർന്ന മരച്ചീനി മുത്തുകൾക്കും (4.8 ഗ്രാം / 100

ഗ്രാം), പൈനാപ്പിൾ കലർന്ന മരച്ചീനി മുത്തുകൾക്കും (4.2 ഗ്രാം / 100 ഗ്രാം) ഏറ്റവും ഉയർന്ന പിഎച്ച് മൂല്യം ഉണ്ടെന്നും നിയന്ത്രണത്തിനോ സമതലത്തിനോ ഏറ്റവും കുറഞ്ഞ പിഎച്ച് നിരീക്ഷിക്കപ്പെട്ടു. കലർന്ന മരച്ചീനി മുത്തുകൾ.. മരച്ചീനി സ്റ്റാർച്ച് പൊടിയുടെ വീക്ക ശക്തി, വിളവ് തുടങ്ങിയ ഭൗതിക ഗുണങ്ങൾ വിശകലനം ചെയ്തു. മരച്ചീനി സ്റ്റാർച്ച് പൊടിയുടെ വീക്ക ശക്തി 13.08 ആണെന്ന് കണ്ടെത്തി. 1 മാസത്തെ ഇടവേളയിൽ മൈക്രോബയോളജിക്കൽ രീതികൾ ഉപയോഗിച്ച് മൊത്തം ബാക്ടീരിയകളുടെ എണ്ണം, മൊത്തം ഫംഗസ് എണ്ണം, മൊത്തം കോളിഫോം എണ്ണം എന്നിവ വിലയിരുത്തി. 3 മാസത്തെ സ്റ്റോറേജ് പഠനങ്ങൾ വരെ ബാക്ടീരിയ, ഫംഗസ്, ഇ-കോളി എന്നിവയുടെ സാന്നിധ്യം കണ്ടെത്താനായില്ല. ഇത് ഉൽപ്പന്നത്തിന്റെ ഗുണനിലവാരവും ഷെൽഫ് സ്ഥിരതയും കാണിക്കുന്നു.

ബോബ മുത്തുകളുടെ ശരീരശാസ്ത്രപരവും പോഷകപരവുമായ സവിശേഷതകൾ വർദ്ധിപ്പിക്കുന്നതിന്, അതിന്റെ ഗുണങ്ങൾ വർദ്ധിപ്പിക്കുന്ന പുതിയ ഇടപെടലുകളുടെ ആവശ്യകതയുണ്ട്, പഴങ്ങൾ ചേർക്കുന്നത് കൃത്രിമ നിറങ്ങളോ രുചികളോ ചേർക്കാതെ സെൻസറി ആകർഷണത്തോടൊപ്പം അതിന്റെ പോഷകമൂല്യവും വർദ്ധിപ്പിക്കും. പഴങ്ങളുമായി താരതമ്യപ്പെടുത്തുമ്പോൾ, മരച്ചീനിയിൽ നാരുകൾ, വിറ്റാമിനുകൾ, ധാതുക്കൾ മുതലായവ കുറവാണ്. അതിനാൽ പഴങ്ങൾ അടിസ്ഥാനമാക്കിയുള്ള ബോബ മുത്തുകൾ ചേർക്കുന്നത് ഒരു അധിക ഘടനയും സ്വാദും മാത്രമല്ല, സാധാരണ മരച്ചീനി മുത്തുകളെ അപേക്ഷിച്ച് പോഷകമൂല്യങ്ങളും നൽകുന്നു. കസവ ബൊബ മുത്തുകൾക്കായുള്ള പ്രോസസ്സ് പ്രോട്ടോക്കോളുകളുടെ വികസനവും അതിന്റെ സാങ്കേതിക കൈമാറ്റവും ഒരു ജില്ല ഒരു ഉൽപ്പന്ന സ്കീമിന് കീഴിൽ സംരംഭകത്വം ശക്തിപ്പെടുത്തുന്നതിന് കസവ കർഷകർക്കും ചെറുകിട സംരംഭങ്ങൾക്കും പ്രയോജനം ചെയ്യും.

Appendices

APPENDIX-1

Scorecard for quality evaluation of Dragon fruit blended tapioca pearls

Date:

Sign:

Parameters	T_1D	T_2D	T_3D	T_4D	T_5D	T_6
Colour						
Taste						
Texture						
Flavour						
Overall acceptability						

Please rate the scores hedonically to the developed to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like or dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX-II

Scorecard for quality evaluation of Passion fruit blended tapioca pearls

Date:

Sign:

Parameters	T_1P	T_2P	T_3P	T_4P	T_5P	T_6
Colour						
Taste						
Texture						
Flavour						
Overall acceptability						

Please rate the scores hedonically to the developed to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like or dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX-III

Scorecard for quality evaluation of Jackfruit blended tapioca pearls

Date:

Sign:

Parameters	T_1J	T_2J	T_3J	T_4J	T_5J	T_6
Colour						
Taste						
Texture						
Flavour						
Overall acceptability						

Please rate the scores hedonically to the developed to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like or dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX-IV

Scorecard for quality evaluation of Mango blended tapioca pearls

Date:

Sign:

Parameters	T_1D	T_2D	T_3D	T_4D	T_5D	T_6
Colour						
Taste						
Texture						
Flavour						
Overall acceptability						

Please rate the scores hedonically to the developed to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like or dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1

APPENDIX-V

Scorecard for quality evaluation of Pineapple blended tapioca pearls

Date:

Sign:

Parameters	T_1PI	T_2PI	T_3PI	T_4PI	T_5PI	T_6
Colour						
Taste						
Texture						
Flavour						
Overall acceptability						

Please rate the scores hedonically to the developed to the developed products from 1 to 9

Extremely good - 9

Very good - 8

Good - 7

Less liked - 6

Neither like or dislike - 5

Unpleasant - 4

Slightly unpleasant - 3

Moderately unpleasant - 2

Extremely unpleasant - 1