PROCESS OPTIMIZATION AND STUDY ON STORAGE STABILITY OF DRAGON FRUIT [*Hylocereus Undatus*] AND PINEAPPLE [*Ananas Comosus*] MIXED JELLY

by

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Process Optimization and Study on Storage Stability of Dragon Fruit [*Hylocereus undatus*] and Pineapple [*Ananas comosus*] mixed Jelly

A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfilment of the requirements for the degree of B. Tech. in Food Technology.

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Approval Letter

This ***dissertation*** entitled ***Process Optimization and Study on Storage Stability of Dragon Fruit and Pineapple mixed Jelly*** presented by **Pooja Pokhrel** has been accepted as the partial fulfilment of the requirement for the **B. Tech degree in Food Technology.**

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Abstract

The main aim of the work was to optimise the process of dragon fruit and pineapple mixed jelly and study its storage stability at two different temperatures; room and refrigeration. Dragon fruit and pineapple were brought from the local market of Dharan and juice was obtained by the following process. The juices were analysed for TSS, pH, titratable acidity and juice yield. Dragon fruit and pineapple jelly was prepared with the extraction of their respective juices. Firstly, dragon fruit and pineapple were selected, washed, peeled off, and cut. Pineapple slices were grinded for juice extraction and filtered through muslin cloth whereas dragon fruit slices were cooked with equal amounts of water until soft and juice was extracted with muslin cloth. For optimization of dragon fruit juice and pineapple juice, seven sample were prepared as A (50:50), B (62.5:37.5), C (66.67:12.5), D (75:25), E (83.33:16.67), F (87.5:12.5), and Control (100:0) and jelly was prepared maintaining 68 ºBx TSS, 0.8% acidity and 1% pectin content. Sensory attributes of the jelly were evaluated using a nine point Hedonic scale rating test to identify the best product. The sample F was best and used for further analysis in two different temperatures, room (27±3°C) and refrigeration (7±1°C).

The jelly was filled in pre-sterilized glass bottles, capped and covered with aluminium foil and stored in two temperatures as room and refrigeration for the period of 45 days and analysed in an interval of 15 days for chemical and microbiological changes. From statistical analysis, it was found that the storage period had significant effect ($p < 0.05$) in change in reducing sugar, non-reducing sugar, total sugar and vitamin C and no significant effect in TSS, titratable acidity, pH and moisture content of dragon fruit and pineapple jelly. The production cost was found to be NRs. 493.68 per 500 g bottle.

Contents

List of Tables

List of Figures

List of Plates

List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of Variance
CCT	Central Campus of Technology
DM	Degree of Methyoxylation
DPPH	2,2- Diphenly-1-picrylhydrazyl
FAO	Food and Agriculture Organization
HMP	High Methoxy Pectin
LMP	Low Methoxy Pectin
LSD	Least Significance Difference
PCA	Plate Count Agar
PDA	Potato Dextrose Agar
RIRDC	Rural Industries Research and Development Corporation
TPC	Total Plate Count
TSS	Total Soluble Solid
US	United States

Part I

Introduction

1.1 General introduction

Historically, jams and jellies might have started out as an early attempt to preserve fruit for use during the off-season. These fruit treats became more widely available and popular as the cost of producing sugar decreased. The simplest citrus fruit by products are possibly jams in all of their forms. The latter half of the 18th century marked the publication of the first recorded account of jelly production (Vibhakara and Bawa, 2006). Jelly is an intermediate food made by boiling fruit juice, sugar, acid, pectin, and additional colouring, flavouring, and preservative-containing substances until the mixture has a thick consistency and hardness that allows the fruit tissues to be held in place.

An intermediate moisture (semi-solid) food product called jelly is made by boiling fruit juice with sugar (with or without the addition of pectin and acid) until the total soluble solids (TSS) content reaches at least 65%. Fruits generally have adequate levels of pectin (which is extracted during heating) and acidity, which contribute to the texture development in jelly. However, external pectin and acids are sometimes added to achieve a minimum pectin requirement of 1% and pH 3.0 since pectin with a particular TSS and pH forms a gel network (Shinwari and Rao, 2018). The sugar imparts weight and sweetness to the jelly, while acid contributes to the taste and texture of jelly, pectin has the jellifying quality. Colour and flavour are added at the individual's discretion. It is put into the bottle and chilled once the necessary concentration has been reached.

Pitahayas, sometimes known as dragon fruit, are indigenous to southern Mexico and Central America. The world's supply of these fruits is rising swiftly due to their alluring color and flavour, and new fruit crops are being developed in arid regions (Tel-Zur *et al.*, 2004). A pitaya must be cut open to reveal the flesh before it can be consumed. Due to the presence of dark, crunchy seeds, the texture of the fruit is occasionally compared to that of the kiwifruit. The flesh is pleasantly sweet and low in calories, and it can be eaten uncooked. The flesh and seeds are consumed simultaneously, and the seeds have a nutty flavour and contain a lot of lipids (Ariffin *et al.*, 2009). Dragon fruit has a mouth-wateringly light sweetness to it, as well as a vivid shape and color and stunning blooms. This lovely fruit is not only delicious and refreshing, but it also contains a lot of water, other essential minerals, and a variety of nutritional components. The availability of processed dragon fruit goods is extremely rare in our marketplaces.

Dragon fruit is a widely available commercial fruit that may be used in culinary and confections as well as eaten raw. In order to extract useful enzymes, it can also be fermented to produce wine. Though the frozen pulp can be used to produce yoghurt, sweets, ice cream, marmalade, jelly, juice, and pastries, the fruit is typically eaten fresh. Vegetables can be made from unopened flower buds. The oil in the dragon fruit's seeds accounts for some of its moderate laxative properties. Its compounds are beneficial as thickening agents, colouring agents, have a high antioxidant activity, and include dietary fibre, among other things (Le Bellec *et al.*, 2006).

One of the most significant commercial fruit crops in the world is the pineapple (Ananas comosus (L.) Merr. Family: Bromeliaceae). Its exceptional flavour and taste have earned it the title "queen of fruits" (Baruwa, 2013). After bananas and citrus, pineapples rank third among the world's most significant tropical fruits. Pineapples can be eaten or served raw, cooked, juiced, or preserved. This is a seasonal fruit that is extremely perishable. Mature fruit contains 14% sugar, as well as significant amounts of citric acid, malic acid, vitamin A, and B, and the enzyme bromelain, which breaks down proteins. The content of pineapple juice varies according to harvest time, location, season, and method. Changes in the skin colour from green to yellow at the base of the fruit, a minimum soluble solids content of ~12% and maximum acidity of 1 % will assure a baseline flavour that is acceptable to the consumer. The fruit's refreshing flavour is a result of its acidic and sugary balance (Lobo and Paull, 2017).

Thailand, the Philippines, Brazil, and China are the world's top pineapple producers, accounting for almost half of the crop's total production. India, Nigeria, Kenya, Indonesia, Mexico, and Costa Rica are among the other major growers; they supply the majority of the remaining fruit. Pickles can also be made from green pineapple. The remaining material after the juice is extracted is fed to cattle, and the delicate leaves are also utilised for this purpose. Pineapple is used to make a variety of foods, including jelly, syrup, and squash. Pineapples are also used to make vinegar, alcohol, citric acid, and calcium citrate.

Pineapple fruits have low crude fibre content, high sugar content, soluble solid content, and high moisture content. Thus, pineapple can be consumed as an additional fruit with nutrients for overall well-being. Additionally, some diseases may benefit from a pineapple-based medicinal diet as it supports the immune system, alleviates symptoms of common cold and strengthens bones. Bromelain is listed as a proteolytic digestive enzyme by the US National Library of Medicine. Bromelain breaks down proteins into amino acids to aid in protein digestion when taken with meals (Debnath *et al.*, 2012).

1.2 Statement of the problem

Dragon fruit is highly sought after and valuable on the global market because of its unique taste and exotic appearance that is also aesthetically pleasing. Due to which reason its framing has been growing widely all over the world. The high water content of dragon fruit could contribute to some deterioration. This reason leads to post harvest processing as soon as possible and converting it to some value added product. As a result of increased product knowledge and awareness in the market today, consumers are now more concerned about their health than the cost of the products they use (Moshfeghi *et al.*, 2013). In Asian nations, where traditional healers use herbal remedies to both prevent and treat illnesses, dragon fruit is also regarded as a medicinal plant (Sofowora *et al.*, 2013). The peels and pulp both contain a lot of nutrients, including a lot of vitamins, minerals, and antioxidants, as well as a lot of fibre and water (Guo *et al.*, 2003; Perween *et al.*, 2018). Making processed product is one method of extending the shelf life of dragon fruit.

The tropical fruit that is farmed commercially for its nutritional value is the pineapple. Due to the fact that the flavour and texture of dragon fruit are not exactly to the liking of the Nepalese people, Pineapple, a popular and nutrient-dense fruit, was used to create a blended fruit juice that addressed the disadvantage of dragon fruit and enhanced the nutritional value of the jelly. Foods of today are meant to do more than just fill us up and give us the nutrients we need; they should also protect us from diseases linked to nutrition and enhance our physical and mental health. Since fruits and vegetables are living entities, they continue to breathe for a while after being harvested. Between the time of harvest and consumption, wilting happens as a result of water loss, and texture changes as a result of shrivelling. As the produce is carried from harvest to consumer, the losses accumulate over time. Collectively, these losses result in poor economic returns for the growers, which eventually has an impact on all consumers. Therefore, by upgrading facilities, the loss of fruits can be overcome. Hence, for the above reasons, the research on the "Process optimization and study on the storage stability of dragon fruit and pineapple mixed jelly" was carried out.

1.3 Objectives of the study

The objectives of the research can be divided into two parts:

1.3.1 General objective

The general objective of this study was to prepare and study the storage stability of dragon fruit and pineapple jelly.

1.3.2 Specific objectives

The specific objective of the study are as follows:

1. To determine the physico-chemical characteristics of dragon fruit and pineapple juices.
2. To optimise the jelly formation by varying juice content in recipes on the basis of sensory analysis.
3. To study the physico-chemical properties of optimised best product.
4. To study the change in physico-chemical properties during the storage of the jelly.
5. To study the microbiological changes occurring during the storage of jelly.
6. To evaluate the cost of the product.

1.4 Significance of the study

The production aims to contribute valuable insight into the development of a commercially viable dragon fruit and pineapple jelly, capitalising on the increasing demand for the innovative and health conscious food products. The outcome of the study will not only benefit consumers but also provide a foundation for local food industries seeking to diversify their product lines. The study provides an opportunity to diversify the range of jelly product by introducing a novel combination of dragon fruit and pineapple. This can attract consumers seeking unique and exotic flavours.

The nutritional content of dragon fruit and pineapple jelly can highlight the potential health benefits of these fruits. Understanding the nutritional profile contributes to the development of healthier food options, enhancing the competitiveness of the food industry and aligns with the growing consumer demand for novel and health conscious food products.

Also, promoting the use of dragon fruit and pineapple in food products encourages sustainable agricultural practices and contributes to environment friendly and economically viable farming practices.

1.5 Limitation of the work

The limitations of the work were as follows:

1. Study on only one packaging material was carried out.
2. Optimization was limited to sensory test.
3. Storage stability was carried out only for 45 days due to time scarcity.
4. Only a specific variety of fruit was studied.
5. Hand pulping was practised for pulping the fruits.
6. The sensory panellists were all semi-skilled.
7. Pectin content in the final product was not analysed.

Part II

Literature review

2.1 Dragon fruit

2.1.1 Origin and distribution

The scientific name of the dragon fruit is derived from the Greek words hyle (woody), cereus (waxen), and undatus, which alludes to the wavy edges of its stem. Although its origin is unknown, the dragon fruit is most likely a native of Central America (Blancke, 2016). Pitahaya is another name for it, as is pitaya roja in Central and northern South America. Over a century ago, the fruit was brought to Vietnam by the French. It is a climbing cactus vine that thrives in dry environments. Because it is an epiphyte, it thrives in soil that contains a lot of organic matter. The fruits have red or pink thorn less skins, while the juicy flesh can range from white to magenta. Each plant yields 40 to 100 fruits annually, with a weight range of 300 to 800 g. A single plant typically produces 15 to 25 kg of fruits. Its peel accounts for more than 20 % of the fruit weight. Both stem cuttings and seeds can be used to propagate it (Thulaja and Abd Rahman, 1999).

As a fruit export, dragon fruit is now widely grown in Southeast Asia, primarily in Thailand and Vietnam, and Nepal is becoming more and more interested in it. With more recent cultivation in Australia, Israel, Japan, New Zealand, Philippines, Spain, Reunion Island, and the southwest of the United States, the *Hylocereus* species is currently grown for fruit in Cambodia, Colombia, Costa Rica, Ecuador, Guatemala, Indonesia, Malaysia, Mexico, Nicaragua, Peru, Taiwan, and Vietnam (Valiente-Banuet *et al.*, 2007). Right now, Vietnamese farmers' most lucrative harvest is this fruit. Vietnam is home to the largest pitaya growing area in Asia, where it is grown in 63 of the country's 65 cities and provinces (Ghorai, 2023; Luu *et al.*, 2021).

The plants are able to have up to 4-6 blooming flushes per year in a tropical climate (Jiang *et al.*, 2012). Known as "Noble Woman" or "Queen of the Night," this plant has a long day and a magnificent blossom that blooms at night. The huge, creamy white flowers (25 cm in diameter) that bloom at night give it its beautiful significance. The main benefit of this crop is that, once planted, it will continue to grow for over 20 years, with 800 dragon fruit plants being able to be grown on 1 hectare. After planting, it bears fruit in the second year and reaches full production in five years, at which point yields of 20 to 30 tonnes per hectare can be predicted (Choo and Yong, 2011). The dragon fruit is eaten by cutting it, and because of its crunchy, black seeds, some people compare its texture to that of kiwis (Tripathi *et al.*, 2014).

In the family Cactaceae's subfamily Cactoideae, the genus *Hylocereus* is a member of the vine cactus. It is a native fruit that comes from Mexico, Central America, and South America, and has been grown in Vietnam for at least 100 years (Mizrahi *et al.*, 2010). According to a 2013 research by the Rural Industries Research and Development Corporation (RIRDC), *Hylocereus undatus* is the tropical exotic fruit crop with the highest documented yield, with 34,150 locations out of 50,100 planting sites, or 62.2% of all plantings, in Australia's Northern Territory (Fanning and Diczbalis, 2013). Three major countries, Vietnam, China and Indonesia, provide over 93% of the world's dragon fruit production. Vietnam alone provides more than half (51.1%) of the world production. It has almost 55,419 ha devoted to dragon fruit farming with a volume of production more than 1 million metric tons (MT) valued at US$ 895.70 million (2018). The average productivity is 22-35 metric tonnes/hector/yr (Sharma *et al.*, 2021). It is the fifth most famous tropical crop fruit from Asia behind lychee, longan, banana and mango (Chen and Paull, 2019).

2.1.2 Classification

There are five major varieties of *Hylocereus* species, which are mostly distinguished by the features of their fruits. *Hylocereus undatus* is distinguished by its white pulped fruits and pink skin; similarly, *Hylocereus polyrhizus* has red pulped fruits and pink skin; *Hylocereus costaricencis* has violet-red pulp and pink skin; *Hylocereus guatemalensis* has red pulp and reddish-orange skin; and *Hylocereus megalanthus* has white pulp and yellow skin (Arivalagan *et al.,* 2021). The *H. megalanthus* was previously categorized in genus *Selenicereus* and later by updating its taxonomy, Bauer (2003) gave the *Selenicereus megalanthus* species the name *H. megalanthus* and moved it into the *Hylocereus* genus. *Hylocereus polyrhizus* has also been renamed to *Hylocereus monacanthus.*

The plant is a climber cacti. Within the classifications of *Hylocereus megalanthus* (yellow skin and white flesh), *Hylocereus undatus* (red skin and white flesh fruit), and *H. monacanthus* (red skin and red flesh), there are 18 species (Gunasena *et al.*, 2007). All generate huge flowers and fruit as well as aerial roots that make it easier to anchor in trunks.

Between May and October, several pitahaya bloom flows take place in the northern hemisphere, and the daily floral opening timing varies by region. The remarkable ability of the dragon fruit to adapt to various pressures is linked to its high capacity for growth in many conditions. Self-compatible or self-incompatible pollination may be a part of a plant's reproductive system, and it may also be able to perform crosses within a species (inter-clonal hybrids), between species (interspecific hybrids), or even between different genera (inter-generic hybrids). This enables the creation of very productive hybrids (Cohen and Tel-Zur, 2012).

<u>Scientific classification</u>

Kingdom –Plantae

Subkingdom-Trachebionta

Division-Magnoliophyta

Class-Magnoliopsida

Order-Caryophyllales

Family-Cactaceae

Sub family-Cactaceae

Genus-*Hylocereus*

Species- *Undatus*

Source: Elmarzugi *et al.* (2016); (Le Bellec *et al.*, 2006a)

2.1.3 Soil and climatic requirement

In many soils the dragon fruit can grow, but because water logging impedes its growth and causes bacterial rot it needs to be well drained. The loamy soil, rich in organic matter, is good for its commercial cultivation. It is optimal for dragon fruit to grow in the soil pH 5.5-6.5. It's a very shallow root crop; most of the roots are confined to the ground, the soil depth of 40 cm may not be an issue for the cultivation of this fruit crop. It can withstand certain salts in the soil and favours slightly acidic conditions (Kakade *et al.*, 2022).

Dragon fruit is grown commercially in countries with adequate rainfall because it is native to tropical rainforests. However, with the aid of micro-irrigation, this fruit crop can now be grown in dry locations where rainfall is insufficient because it has become well adapted to those environments over time. Its growth is good for rainfall of approximately 500 to 1500 mm, with a proper distribution. A surplus of water will lead to dehydration of flowers and young fruits. The ideal temperature to grow dragon fruit is between 20 and 30 ◦C (Gunasena *et al.*, 2006). Higher temperatures cause cladodes to become yellow and a succulent stem to dry out and droop. It should be planted with the best possible shade in drier and warmer climates. The dragon fruit may be grown up to 1700 metres above sea level.

2.1.4 History of dragon fruit development in Nepal

The white skinned dragon fruit (*Hylocereus undatus*), which originated in Vietnam, was introduced to Nepal in the year 2000 AD by an American engineer who was working in Nepal. Only around 2014 AD did its commercial plantations begin in the Kabhre district (Atreya *et al.*, 2020). Many farmers from all across the country have started planting white fleshed and red fleshed cultivars on a trial basis in modest or even commercial scale as a result of the successful outcomes of these commercial farms by a few enthusiastic persons including ex Minister Mr. Lokendra Bist in Dang district. As a result, dragon fruit is now a promising new fruit crop for the country's warmer regions.

Currently, this fruit sells for about Rs 350 per kg in Nepal. But in the early days of its introduction, a kg of dragon fruit cost about Rs 800-1000. At an elevation of 1500 metres above mean sea level, this fruit can be grown in an area with less rainfall. There are countless acres of marginal and fallow land in the Terai, Bhitri Madhes, valley, and lower mountain range that is appropriate for farming. Dragon fruit requires less chemical fertiliser, so we can grow it organically using our local manures, such as FYM, compost, and vermicompost, leading to cost-effective and environmentally responsible production (Rijal, 2019).

2.1.5 Nutrient composition

The nutritional composition of dragon fruit (Hylocereus spp.) varies depending on a variety of factors, including species, geographic location, and cultivation techniques, reflecting an ever-evolving landscape of innovation (Le *et al.*, 2021).

The composition of dragon fruit is given in a table below:

Table 2.1 Composition of dragon fruit

Nutrient	Amount per 100 g
water	87 g
Protein	1.1 g
Fat	0.4 g
Carbohydrate	11.0 g
Fibre	3.0 g
Ash	0.8 g

Source: Charrondière *et al.* (2013)

2.1.6 Health benefits of dragon fruit

The health advantages of dragon fruit's flesh, peel, and edible seeds have been documented by numerous researchers. Thus, this review outlined some of the health benefits of dragon fruit, including its antibacterial, anticancer, and anti-diabetic qualities.

1) Antioxidant activity

It is well recognised that the human body experiences oxidative stress due to reactive oxygen species, or ROS. These free radicals have the potential to harm cellular proteins through oxidative damage and to harm genes as well. This raises the chance of developing numerous deadly degenerative illnesses, including Alzheimer's, cancer, and cardiovascular conditions. The body's natural antioxidants might not always be enough to counteract the produced ROS. Antioxidant supplementation is therefore advised to reduce the risk of numerous chronic illnesses. Concerns regarding toxicity and carcinogenicity have been raised about synthetic antioxidants such butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). Consequently, their application in food and medicinal goods is limited. A less expensive and secure substitute is to employ natural antioxidants (Gülcin, 2012). Naturally occurring antioxidants are mostly found in fruits, vegetables, and whole grains. Dragon fruit contains phenolic compounds, carotenes, vitamin C, vitamin E, and betanin, all of which have strong antioxidant qualities.

2) Antimicrobial activity

Infectious disease rates are rising in the twenty-first century, and concerns over antibiotic resistance are intensifying. Few, if any, of the medications now on the market can treat some infectious disorders. The creation of fresh antibacterial substances can address this issue. Considering treatment resistance and the expense of synthetic medications, natural antimicrobial agents can be quite important. An ethanolic extract from the flesh of white dragon fruit was found to contain about 85% of mixed oligosaccharides. These oligosaccharides were more resistant to human salivary α-amylase than inulin. Although not broken down in the stomach, they act as prebiotics to support the digestive system (Wichienchot *et al.*, 2010).

3) Anti-diabetic activity

One of the main causes of death worldwide is metabolic disease diabetes mellitus, or diabetes. The study of using herbs or natural therapies to treat diabetes is expanding. According to reports, H. undatus has CAMP phosphodiesterase inhibitory action, which helps the body hold onto insulin for a longer period of time (Prabhakar and Doble, 2008). White dragon fruit's phytoconstituents are useful in lowering blood sugar levels. According to Ajie (2015), there are three ways that flavonoid content mediates hypoglycaemic action: Specifically, lowering oxidative stress through the antioxidant impact, blocking GLUT 2 in the intestinal mucosa, and blocking phosphodiesterase to increase insulin retention (Ajie, 2015).

4) Anticancer activity

According to some research, dragon fruit may have anti-cancer properties. This fruit can significantly limit the growth of MCF-7 breast cancer cells, according to research by (Divakaran *et al.*, 2019) who evaluated the fruit's capacity to create nanoparticles. Faecal fermentation of pitaya oligosaccharides has been shown in another study to produce lactic, acetic, propionic, and butyric acids that can inhibit Caco-2 cells and may reduce the risk of colon cancer. The fermentation process also increased the populations of Lactobacillus and decreased those of Bactericides and Clostridium. Methanol extracts of H. undatus have good anti-cancer activities against human liver cancer (HepG-2) cells, as shown by (Padmavathy *et al.*, 2021) in a very intriguing study. Pitaya is linked to multiple bioactive substances that have anti-cancer properties.

5) Anti-inflammatory activity

Dragon fruit has anti-inflammatory properties in addition to antioxidant ones. Research revealed that pro-inflammatory enzymes like cyclooxygenase-2 lipoxygenase and acetylcholinesterase were inhibited by the extract from dragon flesh and peel and the isolated squalene. It was concluded that this fruit had a significant potential for the control and management of inflammatory processes through a variety of pathways, including prostaglandin, leukotriene, and cholinergic pathways (Amin *et al.*, 2022).

6) Anti-Lipedemic effect

In individuals who are normocholesterolemic, pre-diabetic, or have type 2 diabetes, pitaya can help improve lipid profiles, lower total cholesterol, LDL-c, and triglyceride levels, and raise HDL-c levels (Akhiruddin, 2013). In dyslipidemic C57BL/6 mice, pitaya intake also improved lipid levels, which may help prevent cardiovascular illnesses (Holanda *et al.*, 2021).

2.1.7 Uses of dragon fruit

Because of its vibrant exterior, deep red interior and tasty black seeds embedded in white flesh, dragon fruit is a great choice for salads. Dragon fruit pulp can be used to make wine, juice, jam, jellies, and candies. Fruit peels have a high pectin content, and several techniques have been shown to extract 7.5% of pectin from fruit peels. It can be used to make food colourants and to give food colour. Pitaya seeds have half of the necessary fatty acids that are challenging to synthesise in vivo, specifically linoleic and linolenic acid(Ariffin *et al.*, 2009). The use of dragon fruit peel as a natural colour has a lot of possibilities (Rebecca *et al.*, 2009). Dragon fruit skins are a natural thickening and colouring factor in cooking since they are strong in pectin and betalains when they are fresh or dried. DFCP, or Dragon Fruit Colouring Powder, is a natural food ingredient made from the peel of the fruit and is used as "albedo." The natural advantages of dragon fruit are therefore unaffected. The "albedo" of dragon fruit is traditionally used to colour pastries, rice, milk, yoghurt, and juice. Its medicinal qualities include the reduction of blood pressure and diabetes.

2.2 Pineapple

The pineapple's scientific name is *Ananas comosus*. It is regarded as a perennial monocot herbaceous tropical plant. The plant grows to a maximum height and width of between 75 and 150 cm and can extend its reach to 90-120 cm. It features spiral-shaped leaves with flowers at the ends that later bear tasty fruit. Around 25 to 50 cm long make up the stem at its middle. About 60–80 sword-shaped leaves, which are present on a mature pineapple plant. From a crown cutting of the fruit, pineapples can be grown; they may flower in 20–24 months and bear fruit in the subsequent six months. Pineapple ranks third in terms of global fruit production, behind bananas and citrus fruits (Wali, 2019).

2.2.1 Origin and distribution

Many experts contend that pineapple originated in South American nations like Columbia, Brazil, and Paraguay and that it was introduced to other regions of the world by travellers and historians who spread knowledge of the fruit, particularly the Portuguese and Spanish. Since their discovery, pineapple trees have undergone mutations that have increased the size of the fruits, made them seedless, and made them sweeter. The majority of the world had already experienced pineapple by the sixteenth century, including the Philippines, China, India, the African coasts, Holland, and England. Because of the pineapple's natural ability to endure a variety of environmental factors, including droughts, and because it can easily generate propagules in uncultivated areas, the plant has spread around the world (Wali, 2019).

Currently, pineapple agriculture is mostly concentrated in the tropical parts of the world. With fruit in over 82 countries, it is planted on over 2.1 million acres. In terms of cultivation, pineapple ranks twelfth with slightly over 27,402,956 tons produced in 2017, according to data from the Food and Agriculture Organisation of the United Nations (FAO). The Philippines and Brazil are the next two countries in the world that produce the most pineapples after Costa Rica (Mohsin *et al.*, 2020).

A total of 974 hectares of land are used to grow pineapple in Nepal, where 13300 metric tonnes are produced annually. The Terai region produces about 58% of all pineapples. The central development zone encompasses the majority of the pineapple production and area. In 2015–16, the country's average productivity was 13.7 MT/ha, with the Eastern Development Region having the highest productivity (21.6 MT/ha). Jhapa, Sindhuli, and Kaski districts have the highest production and area of pineapples (Pandey *et al.*, 2017).

2.2.2 Classification

A.comosus is a member of the family Bromeliaceae, which is further divided into the subfamilies Tillandsioideae, Bromeliodeae, and Pitcarniodeae (Bartholomew *et al.*, 2003; Elfick, 2007). The Bromeliodeae subfamily is where *A. comosus* resides. There are 56 genera and roughly 2794 species in this subfamily, the Bromeliaceae. It is able to adapt to a variety of climatic circumstances, including sun and shade, humidity and severe dryness, as well as hot tropical and cold subtropical climates. The fruits are composed of bared, plumose seeds and are berry-like or capsule-shaped (Purseglove, 1972).

Due to its traits, the Ananas genus is thought to be a member of the Bromeliaceae family. Its broad leaves and fruits, which range in size from medium to enormous, give it a highly distinctive shape and structure. The pineapple stands apart from other monocots due to its distinctive traits. The taxonomic categorization of pineapple underwent various stages and adjustments throughout time, but Coppens' proposed taxonomy from 2003 is now widely accepted (Bartholomew *et al.*, 2003; Gilmartin and Brown, 1987).

<u>Taxonomic classification of pineapple</u>

Kingdom: Plantae

Division: Magnoliophyta

Class: Liliopsida

Order: Bromeliales

Family: Bromoliaceae

Genus: *Ananas*

Species: *Comosus*

Source: M. F. Hossain *et al.* (2015)

Pineapple has been classified numerous times on the basis of different parameters since its introduction. But the classification on the basis of isozyme analysis is the most widely accepted one. This divides pineapple into five groups of cultivars; Cayenne, Queen, Spanish, Abacaxi and Maipure. ‘Smooth Cayenne’ is the standard for processing because of its cylindrical shape, shallow eyes, yellow flesh colour, mild acid taste and high yields. Queen group generally produces smaller plants and fruit with spiny, shorter leaves than the ‘Cayenne’ group. The plants of Spanish group are generally small to medium, spiny leaved, vigorous and resistant to mealybug wilt, but susceptible to gummosis caused by the larvae of the Batrachedra moth. Abacaxi group is not considered suitable for canning or for fresh fruit export, but the juicy, sweet flavour of the fruit is favoured in the local markets. The Maipure group is cultivated in Central and South America as fresh fruit for the local markets. Their clones may be of interest to breeders in the western hemisphere as they constitute a gene pool of adapted forms almost unused in breeding programmers (Joy and Anjana, 2016).

2.2.3 Nutrient composition

Table 2.2 Main constituent of pineapple (per 100 g).

Constituents	Pineapple pulp	Pineapple juice
Protein	0.5	0.4
Carbohydrates	11.7	12.1
Fat	0.5	0.1
Total sugars	10.5	12.1
Fibre	1.2	0.2
Ash	0.3	0.4

Source: Ali *et al.* (2020)

The main nutrients found in pineapple are carbohydrates and water, which are also important sources of dietary fibre, sugars, organic acids, ascorbic acid, niacin, and thiamine, as well as minerals including magnesium, manganese, and copper (de Ancos *et al.*, 2017). Additionally, bromelain, a proteolytic enzyme found in pineapple fruit, is crucial for bromelain's therapeutic actions as well as for aiding in digestion (Zdrojewicz *et al.*, 2018). The ripening process and cultivar type are two important aspects that affect the pineapple's chemical

2.2.4 Health benefits of pineapple

Human health is believed to depend on consuming enough nutrients. It has long been known that pineapple contains beneficial bioactive substances with potential medical use. As per M. Hossain and Development (2016), the fruit has the ability to eliminate intestinal worms and acts as a diuretic and contraceptive. Furthermore, pineapple is frequently utilised to promote meal intake and enhance fat excretion for topical debridement. To substitute proteolytic enzymes as an anti-inflammatory for soft tissue, pineapple is employed as a source of bromelain. Bromelain, a proteolytic enzyme found in pineapple fruit, aids in digestion by dissolving proteins (Hale *et al.*, 2005). When taken with food, bromelain helps break down proteins into their component amino acids, facilitating better protein digestion. Bromelain has anti-inflammatory effects on an empty stomach.

1) Antioxidant effect

According Zdrojewicz *et al.* (2018), half a glass of pineapple juice (28 mg) has roughly 16% of the daily requirement for vitamin C, which can be obtained in one ripe pineapple. Being a potent antioxidant, vitamin C protects cells from free radical damage and is particularly useful in slowing the ageing of osteoblasts and tracking the advancement of diabetes.

2) Healing bowel movement and gastrointestinal function

Pineapple is useful for treating constipation, gastrointestinal issues, and bowel movements as a possible source of dietary fibre (Dittakan *et al.*, 2018). In a similar vein, M. A. Hossain and Rahman (2011) showed that the functional dietary fibre in pineapple has a critical role in mitigating the risk of colon cancer, diabetes, and cerebro vascular illnesses in addition to alleviating the symptoms of diarrhoea.

3) Regulating emotional stability and strengthening the bone growth

Manganese, which is essential for the creation of energy and constitutes 73% of the daily need intake, is one of the most significant trace elements found in pineapples. Blood glucose management, skeletal deficiencies, insulin resistance, and Type 2 diabetes have all been linked to manganese's benefits. The presence of trace elements allows oxidant enzymes, such as ligases and transferases, to have a major effect on the breakdown of cholesterol by free radicals. These advantageous effects were critical for maintaining emotional stability and bolstering mature bone growth.

4) Monitoring nervous system function

Furthermore thought to be crucial in regulating nervous system activity is pineapple's thiamine content. Adequate thiamine intake helps prevent metabolic changes brought on by diabetes and high blood sugar, as well as aid in the formation of red blood cells, especially in individuals with nervous system disorders (Cannon *et al.*, 2018).

5) Digestion improvement and cardioprotective agent

Given its nutritional makeup, pineapple has one of the most complicated bioactive chemicals for improving digestion, acting as a cardioprotective agent, and acting as an antioxidant: bromelain (Asim *et al.*, 2015).

6) Other effects

In addition, it has been shown that the malic acid included in pineapple promotes immunity, keeps teeth healthy, and inhibits the development of dental plaque.

2.2.5 Uses of pineapple

The majority of pineapple is canned and eaten by people all around the world. In addition, it's processed into jams, vinegar, alcohol, citric acid, calcium citrate, juices and concentrates. After freezing, pineapple slices have also been kept fresh. Furthermore, pineapple stems contain the proteolytic enzyme bromelain, which is widely used in culinary and medicinal purposes. The stems and leaves of pineapples are a great source of fibre that may be processed to produce paper and textiles with remarkable thickness, smoothness, and pliability. Plant fragments are used to create silage and hay, which are then fed to cattle. Centrifuged juice production and processing waste particles are also used to make animal feed. The nutrient-rich pulp or juice of the pineapple core can also be used to make alcoholic beverages.

2.3 History and general overview of jelly

Since the dawn of time, fruit has been a staple of human nutrition. Jams and jellies are significant preserved fruit items that provide a way to use a lot of fruit that would otherwise be unusable for other uses, such as baking or eating fresh. Unlike canning and freezing, it is an older technique (Peckham, 1964; Thakur *et al.*, 1997a). In the past, jams and jellies may have been an early attempt to preserve fruits for use during the off-season. The popularity and accessibility of these fruit items expanded as sugar production became more economical (Vibhakara and Bawa, 2006). The simplest by-product of citrus fruit production is undoubtedly jams in all their varieties. In the latter half of the 18th century, the first recorded instance of jelly production was printed.

The technique of making jams and jellies was created by housewives as a way to preserve fruit at the precise moment when it was being harvested. The general public appears to frequently equate science with sophistication when it comes to the production of jam. Homemade jam, for example, is not required to adhere to certain criteria and regulations, but factory-made jam is; it must have a consistency that is solid enough to meet the needs of confectioneries and to endure handling during shipment. The amount of pectin determines the consistency. The precise application of pectin knowledge and the principles guiding the creation of the pectin-sugar-acid gel is thus a key component of scientific jam production. In order to prevent fermentation, jam and jelly products are made with high dissolved solids concentrations. Only pectin and sugar, however, are insufficient for the products' synthesis. Equally significant is the fruit's acidity, which creates a clear equilibrium in the "pectin-acid-sugar" system (Vibhakara *et al.*, 2006).

Jam is a semi-solid food item that is made by wisely combining sugar with fruit or vegetable pulp, pectin, acid, and other components. Jam should have at least 45% pulp and 65% or greater TSS. There are typically two varieties of jams: one is made from the pulp of a single fruit, and the other is made by combining the pulp of two or more fruits. Sugar in jam suppresses microbial development and prevents spoiling in jam. Because sugar absorbs water, products have a longer shelf life (Clarke, 1997). According to American definitions, jam is a semi-solid meal produced with at least 45 parts by weight of fruit and 55 parts by weight of sugar. For the appropriate quality, this combination is concentrated to a total of 68 percent soluble solids. It is possible to add flavourings and coloring additives (Awulachew, 2021).

Standards for jams and preserves are similar to those for jelly, with the exception that fruits are used as ingredients as opposed to fruit juice and that mint taste and green coloring are required ingredients. Heat is used to concentrate the fruit mixture so that, for some of the specified fruits, the total soluble solids content must be at least 65% and, for other fruits, at least 68% (Pilgrim, 1991).

2.3.1 Product type and recipes

The U.S. government standard specifies that a jam must have a minimum of 45 parts of prepared fruit and 55 parts of sugar, concentrated to 65% or higher solids and yielding a semi-solid product. When 45 parts of clarified fruit juice and 55 parts of sugar are combined to make jelly, the resulting minimum solids content is 65%. Jellies are similar to jams. For the required gelling texture in both categories, a maximum of 25% corn syrup as a sweetener, pectin, and acid may be used (Baker *et al.*, 2005).

It can be observed that the completed jam or jelly, regardless of grade, will include roughly the amount of sugar required to give the Pectin-sugar-acid gel the maximal strength, based on specifications and the allowance for soluble solids like acids and pectin. It is safe to assume that between 3 and 5 percent of the jam's total weight is made up of fruit-derived sugar, meaning that the remaining 65% is added sugar. Therefore, this figure will depend on the type of jam or jelly the manufacturer intends to produce. If the fruit being used is lacking in pectin, acid, or both, or if there isn't enough fruit in the recipe, it won't set

The following list includes several standard jam-making recipes by (Giridhari *et al.*, 1986) that have been proven effective on a big scale:

- A total of 75 kg of pulp, either fresh or in a can, together with 75 kg of sugar, 35 g of citric acid, 565 g of pectin of 150-grade pectin, and 75 ml of pineapple essence are needed to make jam.
- 50 kg of lye-peeled orange segments call for 50 kg of sugar, 250 g of citric acid, 375 g of pectin 150 grade, and 50 ml of sweet orange essence to make orange jam.
- 40 kg of mango pulp, 40 kg of sugar, 500 g of pectin of 150 grade, 400 g of citric acid, and 70 ml of mango essence are all needed to make mango jam.
- For every 40 kg of apple pulp, 44 kg of sugar, 400 g of pectin (150 grade), 500 g of citric acid, and 60 ml of apple essence are needed to make apple jam.

Depending on the fruits used, mixtures of mango, pineapple, orange, apricots, papaya, guava, etc. are needed to make mixed fruit jam, as well as sugar in an amount equal to the weight of the blended pulp taken, citric acid to the extent of about 0.75-1.0% by weight of the blended pulp, and pectin to the extent of 0.5-1.0% by weight of the blended pulp. In order to achieve the correct level of color, a mixture of primarily red food grade pigments and an acceptable essence may be added (Barwal, 1999). The same method can be used to make jam from cherries, mulberries, strawberries, muskmelons, jackfruit, cashew apples, etc. However, it could be essential to slightly alter the fruit sugar ratio and the amount of acid applied. In some circumstances, it could be advantageous to enhance the jam's flavour by including additional fruit flavour (Garcıia-Viguera *et al.*, 1997).

2.3.1.1 Gelling agent

With the rise of convenience meals, the use of gelling agents in the food business is expanding quickly in both classic and novel items. An optimal gelling ingredient shouldn't affect the product's aroma, flavour, or taste (Fishman and Jen, 1986). A fundamental understanding of gelatine processes and the molecular characteristics of gels is necessary for improving existing systems and developing new ones (Michel *et al.*, 1984).

Gels are a type of material that exists somewhere between a solid and a liquid. They are made of polymeric molecules that have been cross-linked to create a tangled molecular network that is submerged in a liquid media (Vibhakara *et al.*, 2006). The water is held by the polymer network, which prevents it from running away. As a solvent, water affects the type and strength of the intermolecular forces that preserve the integrity of the polymer network; the polymer network retains the water, preventing it from evaporating in an acidic environment; and pectin with sugar affects the pectin-water equilibrium and creates a network of fibres throughout the jelly (Mitchell and Blanshard, 1979; Thakur *et al.*, 1997). Liquids can support this structure. Hydrogen bonds, electrostatic forces, Vander Waals forces, and hydrophobic interactions are just a few of the weak intermolecular forces that hold the molecules in gels together. There are extended portions from two or more polymer molecules involved in the cross-linkages, which are not point contacts but are typically found in distinct structures called junction zones (D. A. Rees, 1969). In essence, these connection zones are created during the gelation process (fig 2.4.1).

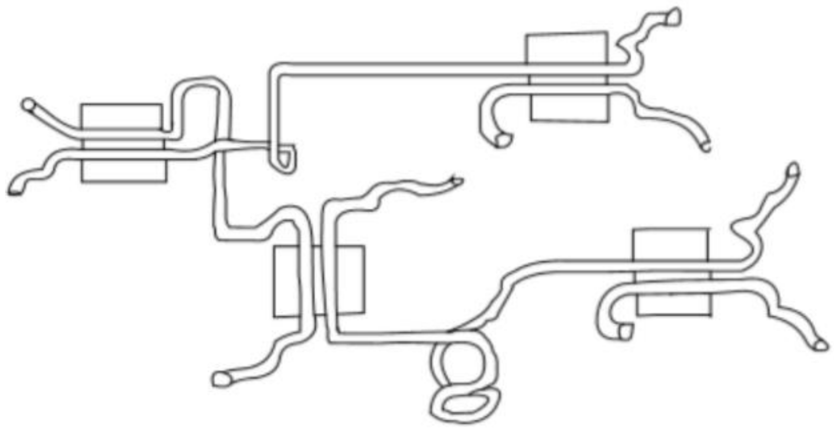

Fig 2.1 Gel network

Source: Mitchell *et al.* (1979)

The creation of a continuous three-dimensional network of cross-linked polymer molecules on a molecular level is what leads to the physical characteristics of gel; an aqueous gel is made up of three components (M. C. Jarvis, 1984).

1. Zones of junction where molecules of polymers are connected.

2. Polymers with inter-junction segments that are reasonably mobile.

3. The polymer network trapped water.

Aqueous conditions are required for gel formation. Consequently, the interactions between protein and polysaccharides and water are crucial elements in the gelation process (D. A. J. A. i. c. c. Rees and biochemistry, 1969). In aqueous solutions, both types of polymers are highly hydrated, and as a result, certain water molecules are so securely bound that they do not freeze even at – 60 ºC (Eagland, 1975). Although a stable intermolecular junction must exist in order for gelation to occur, inter-chain association must also be limited in order to produce a hydrated network rather than an insoluble precipitate (Axelos and Thibault, 1991).

In technological procedures that gel food products, it is crucial to understand the circumstances that cause gelation to begin. This decrease in consistency is described using a variety of techniques. Physically, it is possible to monitor the critical stage of gelation by observing the decrease in fluidity or the increase in the elastic property of the expanding network (Shomer, 1991). The various kinds of gelling agents used in the production of jellies are listed in Table 2.3.

Table 2.3 Different types of gelling agent used in the manufacturing of jellies

Type of gelling agent	Origin	Uses
Gelatin	An animal protein that has been refined from bones	Not to be boiled in general. To be added to warm syrup for setting on cooling
Agar/ alginates	Extracted from various sea weeds	Several items, including neutral jellies, are weakened by boiling in an acid solution
Gum Arabic/ Acacia	Exudates from trees	Used as a thickener and extender in items like Marshmallow and to make hard gums
Starch/ modified starch	Seeds and various roots	Other gelling agents in gums have partially and fully taken their place.- Turkish delicacy Glazer
Pectin	Fruits residues particularly citrus and apple pomace	Utilised primarily in sour fruit jellies but also in neutral jellies due to its low melting point

Source: Vibhakara *et al.* (2006)

2.3.1.1.1 Pectin

The hydrocolloid that is utilized in processed fruits the most frequently is pectin. The primary food type that uses more pectin than other types is jams and jellies. Pectin is a group of intricate heteropolysaccharides that are present in the cell walls of higher plants. They serve as a hydrating agent and a cement for the cellulose network (Mualikrishna and Tharanathan, 1994).

The main component of pectin is d galacturonic acid polymer (homopolymer of [1→4] α-Dgalacto pyranosyluronic acid units with different amounts of methylation esterified carboxyl groups). The molecule is made up of l-1, 4-glycosidic bonds between the pyranose rings of Dgalacturonic acid units. Due to the axial positioning of the D-galacturonic acid hydroxyl groups at carbon atoms 1 and 4, a 1, 4-polysacchariderhamnogalacturonan polymer is created, which is a heteropolymer consisting of repeated [1→2] α-l-rhamnosyl [1- l] α-D-galactosyluronic acid disaccharide units (Mualikrishna and Tharanathan, 1994).

Pectin's capacity to form gel in the presence of Ca^{2+} ions in a sugar and acid solution is by far it's most exceptional and distinctive quality (Halliday and Bailey, 1924). The texture of pectin gels is additionally influenced by acetylation, cross-linking, attached chains of neutral sugars, esterification, and neutral sugar chains. Pectin chains have a negative charge, and the density changes more when the pH is greater and the degree of methoxylation (DM) is lower (Gross *et al.*, 1980).

Depending on the DM, pectin are classified into:

1. Low Methoxy (25–50%) Pectin
2. High Methoxy (HM) (50–80%) Pectin

In HM pectin, the effect of sugars is particularly dependent on the sugar's molecular shape and interactions with nearby water molecules. The development of gel in HM pectin is thought to be caused by non-covalent forces, specifically hydrogen bonding and hydrophobic interactions. Gel develops in LM pectin in the presence of Ca^{2+}, which serves as a link between the pairs of carboxyl groups on the pectin molecules. At the low pH values found in jams and jellies, the two types of pectin are comparatively stable (Pilgrim, 1991). In acid medium with a high sugar concentration, HM pectin is used to create gels, and LM pectin is utilized in products with a reduced sugar content (Axelos *et al.*, 1991). Depending on how quickly the gel sets, pectin can also be categorized into rapid-set, medium-set, and low-set varieties. DM and molecular size are two variables that affect how well pectin molecules work (Michel *et al.*, 1984).

Guichard *et al.* (1991) analysed the flavour and flavour features of jams created with various pectin, looking at the headspace composition, consistency, and taste. In contrast to low methoxylated pectin, which induced minor alterations, larger concentrations of methoxylated pectin caused an unfavourable modification of the normal flavour and intensity of flavour. A major disease in consistency and observable alterations of the flavour perception were induced by a disease in degree of esterification with fixed concentration and molecular weight, but no change in taste. Only the consistency was considerably altered when the pectin molecular weight was mechanically reduced.

Pectin comes in grades ranging from 100 to 500. Their primary basis for use as a food hydrocolloid is their gelling characteristics(Voragen *et al.,* 1986).Pectin selection for a certain food is influenced by a variety of elements, such as the desired texture, pH, processing temperature, the presence of ions and proteins, and the anticipated shelf life of the finished product (Vibhakara *et al.*, 2006). Combinations of gelling agents are frequently employed because they produce a texture that is preferable. Mixed systems are therefore quite important in terms of technology. Physical chemistry in mixed systems is undoubtedly extremely complex. However, there has lately been a substantial advancement in the creation of an appropriate theoretical framework, at least for two component systems (Morris, 1986).

2.3.1.2 Sweetening agent

In addition to adding sweetness, sweeteners are utilized in fruit processing for a variety of functional purposes. They improve texture and guard against spoiling by adding taste, body, bulk, and viscosity control. It binds moisture in fruits that harmful microorganisms need. Insufficient sugar can cause yeast and mold to thrive while preventing gelling. Sugar facilitates gelling and acts as a preservative. All sweeteners are evaluated for their quality, flavour, and taste profile against sucrose, also referred to as table sugar (or refined sugar). However, in recent years, the usage of glucose syrups as a source of sugar has grown significantly. To stop sucrose from crystallizing during storage in high-solids jellies and jams, an invert sugar component is required. In goods with less than 68% solids, such crystallization is uncommon. If the sugar concentration is high, the jelly retains less water, resulting in a rigid jelly, presumably as a result of dehydration (Vibhakara *et al.*, 2006).

The ideal range for invert sugar in a jam's sugar content is between 35% and 40%. Because molecular water is absorbed into the sugars during the inversion process, 95 parts of sucrose result in 100 parts of invert sugar (Hyvönen and TÖRMÄ, 1983). Desrosier and Desrosier (1977) studied the rate of inversion is influenced by three factors:

1. Hydrogen ion concentration
2. Boiling temperature
3. Boiling time

During the boiling process, sucrose goes through a chemical transformation. Sugars from cane and beets are not reducible. However, sucrose is split into two reducing sugars, dextrose and levulose, in equal amounts when it is heated with acid or treated with certain enzymes. Sucrose has a molecular weight of 342 and invert sugar has a molecular weight of 360; the 18-fold discrepancy is due to the water molecule added during inversion (Vibhakara and Bawa, 2006). The characteristics of jelly with respect to different ºBx values are shown in Table 2.4.

Table 2.4 Characteristics of jelly with respect to different ºBx value.

ºBx	Characteristics of jelly
70 ºBx	Crystallization may occur
68 ºBx	Good texture jelly
65 ºBx	Legal minimum
62 ºBx	Weak gel
60 ºBx	No gel, viscous liquid

Source: Vibhakara and Bawa (2006)

In LM pectin gels, adding sugar can strengthen the gel and lessen syneresis (Axelos and Thibault, 1991). A variety of different sugars, alcohols, and polyols will allow gelation for HM pectin gels. From a practical standpoint, it might be desirable to swap out other sugars for sucrose, either for cost reasons, to lessen the chance of crystallization, or to change the flavour (Ahmed, 1981). The rheological characteristics and setting times of model gels were changed when sucrose was partially substituted with different sugars such maltose, glucose, syrups, or high fructose corn syrup (May and Stainsby, 1986). In contrast to fructose, the inclusion of maltose slowed setting time and increased the gelation pH range. Changes in the system's water activity and the hydrophobic interactions that contribute to gelation can result from partially or completely replacing sucrose with other sugars (Baker *et al.*, 2005).

Only when the sugar concentration is at least 55% and the environment is acidic does HM pectin gel develops. When the pH is low, unbound carboxylic acid groups are less likely to dissociate and repel one another electrostatically, whereas sugars prevent hydrophobic connections between the methyl ester groups. Since junction zone size and the standard free energy of gelation are related to the square of esterification, they grow as esterification increases. Jelly strength increases as the amount of pectin ester is reduced to 50%, but only at steadily lower pH levels. The flavour perception of the jellies can also be influenced by pectin esterification levels. An object must come into contact with the taste buds in order to be tasted (M. C. J. P. Jarvis, Cell and Environment, 1984). As a result, if a gel slows down the substance's diffusion to the taste buds, diffusion may control surface perception rather than the taste reaction. High methoxyl pectin diminishes flavour intensity more than low methoxyl pectin does for similar gel consistencies (SMIT and BRYANT, 1968).

2.3.1.3 Acidulant

The acids that are naturally present in the fruits and vegetables or are used as additives in food processing are acidulants. They serve many functions in food processing. The primary function being acidifier, pH regulator, preservative and the other being curing agent, flavouring agent, chelating agent, buffering agent, gelling/ coagulating agent, and antioxidant synergist (Board, 2002).

The choice of the specific acid for every given food application depends on a number of variables. Because each acid has a distinct combination of physical and chemical properties, the selection should be based on the attributes needed (Watase and Nishinari, 1993). A food acid can only be used to reduce pH, which is its most basic usage. For instance, where pH alterations are all that are needed, it may be desirable to just acidify the solution. The choice is frequently made based on the acid's capacity to highlight and improve the flavor of the food. Compatibility and mixing are crucial considerations when selecting an acid for these uses. The behaviour of each acid varies slightly depending on pH, and one acid is not always preferable over another. Thus, tartaric acid for grapes, citric acid for most fruits, and malic acid for apples are favoured. Since taste stability cannot always be foreseen, when blending or substituting the employed acids, the result should be evaluated both before and after storage (Viberg *et al.*, 1997).

2.3.1.2.1 pH of the mixture

The characteristics of the Jam/jelly with respect to the pH variation is shown in the table 2.5.

Table 2.5 Characteristics of jelly

pH	Gel property
3.6	No gel
3.4	weak gel
3.0	Good form gel
2.6	Weak gel, syneresis may occur
2.4	No gel

Source: Desrosier and Desrosier (1977)

Fruits of the same type might differ not just in quantity but also in the type of acid they contain. When it comes to fruit preservation and a decisive factor in the creation of the pectin-sugar-acid gel, buffering substances like organic bases and inorganic and organic salts have a significant impact on the H+ ion concentration (Desrosier and Desrosier, 1977).

It has been discovered that gel formation only takes place within a specific range of hydrogen ion concentration, with pH 3.0 being the ideal acidity figure for ions and jellies. When the pH value rises, the gel strength fouls quickly. The typical soluble solid range has no gel formation beyond pH 4.0. The temperature at which jams and jellies set is also greatly influenced by the pH value. One of the frequent causes of jelly failure is insufficient acidity. When the jam or jelly is sufficiently concentrated to pour, the pH value should be measured. Depending on the juice's initial acidity and buffering capacity, different juices will need varying quantities of extra acid. The pH can be changed to achieve the best flavour, to regulate or alter the rate of setting, and to alter the degree of sugar inversion (SMIT and BRYANT, 1968).

In the case of HM pectin in particular, pH control is essential for optimal gel formation with pectin. Low pH reduces electrostatic repulsion between neighbouring pectin chains by increasing the proportion of unionized carboxyl groups. The slowest pectin, which has the most degree of esterification, will gel at a lower pH than the rapid-set pectin with the highest degree of esterification; nevertheless, this difference is minimal, with the optimum pH for rapid-set pectin being approximately 3.4 and for slow-set pectin being about 3.1 (Crandall and Wicker, 1986). Gels can form at somewhat higher pH levels by substituting different sugars for sucrose and changing the hydrophobic contacts between chains. Low methoxyl pectin can produce gels at higher pH than high methoxyl pectin because they depend on calcium bonding to cause gelation. Gels can be created at pH levels close to neutral (Chang and Miyamoto, 1992) which is beneficial for making dairy-based products (Baker *et al.*, 2005).

2.3.1.4 Coloring agent

A very important consideration is the jam's color (Abers and Wrolstad, 1979). A excellent jam should be aesthetically pleasing in addition to tasty. Jams made from fresh fruit don't need to be colored, as long as the boiling process is quick and the heat isn't too high. However, presentation with SO2 and, in certain circumstances, boiling always alter the fruit's natural color, necessitating the addition of artificial color. Restoring the appearance's natural state of origin should be the goal. It is best to use only approved edible food colors. The most common color used, albeit to a lesser extent, is coal tar. The colors must be vibrant, easily soluble, and able to withstand high solution concentrations. Acid colors typically have more stability than basic colors. Colors need to be acid-proof because many are impacted by acids, in particular the sulphur dioxide found in fruit pulp and glucose. They need to be heated excessively as well, therefore they should be added at the very end of the boiling procedure (D. A. J. A. i. c. c. Rees and biochemistry, 1969).

Coal tar dyes have historically been used to create two-color jams and marmalades, especially those made with sulphated fruit. As artificial coloring are less popular with customers, color testing of jams using natural colorings—specifically anthocyanins from grape skins—is growing. Powdered colors should be prepared right before addition because many of them have a tendency to precipitate standing. When dissolving, the pigment is first combined into a paste with a little cold water before being added to the necessary amount of boiling water and thoroughly stirring (Abers and Wrolstad, 1979).

2.3.2 Effect of time, temperature during cooking of jam

One of the most crucial phases in creating jam or jelly is boiling because it dissolves the sugar and produces the union of the three ingredients—sugar, acid, and pectin—which results in jam or jelly. Typically, it results in the coagulation of some organic substances that may be skimmed off the top while boiling, and their removal makes the jelly clearer. Boiling is mostly used to make sugar more concentrated to the point where gelling occurs (Anjum *et al.*, 2000).

Even though it's typically a required stage in the creation of jam or jelly, the boiling process should be kept to a minimum. Long-term boiling causes the pectin to hydrolyse, which causes the loss of flavour and color as well as jelly failure (Lesschaeve *et al.*, 1991). Fruits that can withstand boiling are ideal for jam manufacturing because they can concentrate the finished product by evaporating extra moisture. Boiling in commercial practice is usually conducted in open steam jacketed stainless steel kettles (D. A. J. A. i. c. c. Rees and biochemistry, 1969).

Some cane sugar is inverted when the sugar solution is heated up in the presence of acid. As a result, a jam or jelly that is cooked for a long time is less likely to produce sucrose crystals than one that is cooked for a short time. Long-term boiling could cause flavour to be lost due to evaporation, hydrolysis, or other types of breakdown. At lower temperatures between 65 and 76 degrees Celsius, jam is occasionally boiled in a vacuum pan. The loss of vitamin C is prevented and unwanted color changes are minimized during vacuum boiling or heating. However, the lengthy boiling required to soften the fruit pieces in the jam combination results in some flavour loss that can be remedied by reclaiming the volatile esters and adding them back to the jam (Yadav *et al.*, 2019). To prevent excessive soluble solids concentration, excessive sugar inversion, and pectin hydrolysis, boiling must be properly controlled (Lund, 1975).

2.3.3 Packaging material used in jelly production

Jams are stored in a wide range of shapes and sizes of containers. Although enamel-lined tin cans and customised containers are occasionally utilised, glass is the most common material (Cruess and Sugihara, 1948). Glass jars with hermetically sealed lids are best for jam. A paraffin seal is insufficient to keep the product from spoiling. It is not necessary to pasteurise a container that has been filled with hot jelly that is over 83°C because the hot jelly will sterilise the container on its own. At least 90% of the jar should be filled, leaving no more than 1.25 cm of headspace. After filling, the scalded lids should be placed on the containers loosely and tightened tightly within two to three minutes. This gives the air in the head space enough time to exhaust. As the jelly cools, the steam in the head space condenses, sealing the vacuum. To create a hermetic seal, superheated steam injection capping is frequently utilised. A post-capping sterilisation procedure is utilised when the product is not filled hot enough to guarantee head space sterilisation, or when superheated steam injection is not utilised. Certain jellies develop when they boil and produce bubbles that cover the surface of the hot jelly jar. Before serving, quickly skim the jelly while it's still in the kettle. Clear jelly can be poured into the jars if it can be extracted from the kettle's bottom (Lal *et al.*, 1998).

To ensure that the jelly can be turned out without losing its structure or shape, glass jars with smooth edges are ideal for storing jelly. To ensure that there are no breakages, preheat the containers before adding the jelly. The jars need to be quickly chilled to around 21°C once they are filled. This temperature promotes a faster setting time for pectin jellies than lower ones. In order to remove any extra water and encourage setting, jelly that is weak or fails to set is put in a dryer (Lal *et al.*, 1998).

2.3.4 Defects in jellies

The next paragraphs provide an overview of the many jelly defects that might be found throughout the production process.

2.3.4.1 Failure of jams/jellies to set

2.3.4.1.1 Lack of acid or pectin

If the fruit from which the jam or jelly is made lacks pectin, acid, or both, the jam or jelly may not set. Insufficient fruit boiling, which results in insufficient pectin and acid extraction, may also cause it to fail to set (Giridhari *et al.*, 1986).

2.3.4.1.2 Addition of too much sugar

A syrupy or extremely soft jelly may result from the use of too much sugar. By including enough fresh juice that is high in pectin, this can be fixed (Raphaelides *et al.*, 1996).

2.3.4.1.3 Cooking below the end point

If the cooking is stopped before the concentration of sugar reaches 65%, the jam/jelly may fail to set and may remain syrupy and highly soft (Lal *et al.*, 1998).

2.3.4.1.4 Cooking beyond the end point

The jam or jelly will become tough owing to over-concentration if heating is carried past the termination point. When there is not enough sugar present and the juice is high in both pectin and acid, this typically occurs. If the acid is too strong, the pectin dissolves, and the result is ropy syrup or a jelly with a waxy consistency (Lal *et al.*, 1998).

2.3.4.1.5 Slow cooking for a long time

Prolonged heating should be avoided because pectin's coagulating function is lost when heated for a long time while being exposed to acid (Thakur *et al.*, 1997b).

2.3.4.2 Cloudy or foggy jam/jelly

2.3.4.2.1 Cloudy jam/jelly

If the juice or extract is not clarified, this type of jam or jelly is produced (Lal *et al.*, 1998).

2.3.4.2.2 Use of immature fruits

The jam or jelly formed from green, immature fruit has a murky appearance because it contains starch that is soluble in juice but not in the fruit's juice (Lal *et al.*, 1998).

2.3.4.2.3 Over-cooking

Jams and jellies that have been overcooked are gummy and sticky, and when they are put into a container, their high viscosity prevents them from becoming transparent (Lal *et al.*, 1998).

2.3.4.2.4 Over cooling

The jam or jelly gets thick and occasionally lumpy when it is overly chilled. This jam or jelly is virtually hazy (Lal *et al.*, 1998).

2.3.4.2.5 Faulty pouring into container

Because air is mixed into the mass and the created bubbles are difficult to clear, it is not recommended to pour jam or jelly into containers from a large height, especially if the jam or jelly is well-made and will set quickly. The pouring vessel's spout shouldn't protrude more than 2.5 cm from the container's top (Lal *et al.*, 1998).

2.3.4.2.6 Non removal of scum

If the scum is not eliminated before pouring, the jam or jelly also turns hazy (Lal *et al.*, 1998).

2.3.4.2.7 Premature gelation

The jam or jelly may become opaque if there is too much pectin in the juice, which could lead to premature gelation and air-entrapment problems. Premature gelation of the jelly can be prevented in four different methods. According to Voragen *et al.* (1986) they are:

a. To reduce the amount of time pectin, acid, and sugar are in contact with one another while the jelly is boiling, heat the solution to just below boiling before swiftly pouring it into containers.

b. The acid is removed from the cooking batch and added to the container in the form of a concentrated solution before the jelly batch is added.

c. Working with low sugar concentrations; and

d. Using pectin that has a slow rate of setting

2.3.4.3 Formation of crystals

When too much sugar is added to a jam or jelly, sugar crystals begin to form. Additionally, it is a sign that the jam or jelly has been over-concentrated. When preparing jam or jelly from fruits lacking in acid, the mixture should be heated for a short period of time after the sugar is added to ensure that the sugar is sufficiently hydrolysed and does not later crystallize. Cream of tartar crystals can occasionally form in grape jam or jelly. Even though they aren't harmful, they detract from the jam or jelly's appearance. By cooling and settling the grape juice, the cream of tartar should be removed. Only use the purified juice to make jam or jelly (Peckham, 1964).

2.3.4.4 Syneresis or weeping

Syneresis, often known as jelly or jam weeping, is the occurrence of fluid spontaneously escaping a gel. There are multiple causes for it.

2.3.4.4.1 Excess of acid

The hydrolysis and disintegration of pectin caused by an overabundance of acid is what causes the jelly's structure to break down. In tender jellies, syneresis is more apparent. It can be avoided by combining less acidic juice or more pectin to enable the addition of more sugar, which will increase the volume of the jam or jelly and lessen its (Moyls *et al.*, 1962).

2.3.4.4.2 Too low concentration of sugar or soluble solids

This makes the pectin network more capable of holding fluids than it would normally be able to (Lal *et al.*, 1998).

2.3.4.4.3 Insufficient pectin

This results in the formation of a pectin network which is not sufficiently dense and rigid enough to hold the sugar syrup (Lal *et al.*, 1998).

2.3.4.4.4 Premature gelation

When the jelly is poured into the containers, this breaks the pectin network, causing the jelly to weaken and continue to be broken. A tiny amount of buffer salts, such as sodium citrate, disodium hydrogen citrate, or even ordinary salt can be added to jams and jellies to check for syneresis (Lal *et al.*, 1998).

2.3.4.4.5 Fermented jams/jellies

While most jams and jellies have a high sugar content (65%), which is enough to stop all common kinds of formation, fermented jams and jellies are frequently encountered. Usually, fermentation occurs in these jams or jellies after syneresis has occurred (Smith, 1972). Mold growth is encouraged by moist storage conditions, even for jellies sealed with paraffin wax. Molding may be due to several factors such as:

a. Jam or jelly not completely covered
b. Failure to pour paraffin wax hot enough to destroy bacteria and mold that are present on the jam or jelly's surface, and
c. Cracking of the wax seal.

The ideal containers for storing jams and jellies that won't grow mold are glass jars and cans with hermetically sealed closures (Kratz, 1993).

2.3.4.5 Microbial spoilage of jam/jelly

In jams where syneresis has occurred, fermentation occurs. Jams sealed with paraffin wax are more likely to develop mold when stored in a moist environment. Several causes led to the development of mold in the jam (Board, 2002). *Torulopsis colliculosa* and *Torulopsis cantarellii* fermentation has been a recent cause of rotting issues in jams. The popularity of low-calorie foods has prompted the development of low-sugar jams. These are more vulnerable to deterioration by osmophilic yeast and xerophilic molds because their water activity increases from 0.08 to 0.94 (Peckham, 1964).

2.3.5 Physiochemical properties of jam

2.3.5.1 TSS

Sugar, a natural food preservative, is one of the most significant components of fruits. It is advised to use a Brix of 68±0.71 to slow down microbial development (Cruess and Sugihara, 1948). Desrosier and Desrosier (1977) claimed that the ideal range for solids is little over 65% and that, by adding more pectin and acid, gel may form at 60% solids.

2.3.5.2 Titratable acidity

The gelation property of pectin is significantly impacted by acidity. A variety of acidities with appropriate gelation qualities have been reported by several employees. Desrosier and Desrosier (1977) argued that the pH range required for gel formation should be maintained by adjusting the additional acid.

2.3.5.3 Ascorbic acid

Due to the antioxidant properties of vitamin C, also known as ascorbic acid, the quantity of this substance in a dish is a crucial factor in evaluating its quality (Siddiqui *et al.*, 2015). The heating process dramatically reduced the amount of naturally existing antioxidants (Anese *et al.*, 2002). Jawaheer *et al.* (2003) concluded that ascorbic acid was lost by 62.5% throughout the guava jam production.

2.3.5.4 pH

The most crucial parameter in jam processing that needs to be watched over and managed is the pH level. Gel production has been shown to only occur within a specific range of hydrogen ion concentration, with pH 3.0 being the ideal acidity figure for both ions and jelly. The gel's strength deteriorates gradually as the pH drops and quickly as it rises. No gel forms in the typical soluble solid range above pH 4.0 (SMIT and BRYANT, 1968). To prevent bacterial growth and contamination, food goods like jams must have a low pH (Siddiqui *et al.*, 2015).

2.3.6 Sensory properties of jelly

Sensory analysis evaluates the texture, flavour, taste, appearance, and aroma of a product or meal using the panelists' senses of sight, smell, taste, touch, and hearing. This type of research has been used to endorse or condemn food products since ancient times. It was formerly believed to be a process for assessing food quality that improves technological and microbiological safety. But because to its notable advancement and importance in recent decades, it has become one of the most important innovation and application strategies to ensure that the finished product is accepted by consumers (Ruiz-Capillas and Herrero, 2021).

When fruit jelly is finished and put on the market, it needs to be transparent, have a gelatinous consistency, and taste, colour, and smell typical of the fruit juice it was created from. Apart from the physical-chemical qualities, sensory attributes play a crucial influence in the overall acceptance of food products. When shopping for food products, consumers typically have established a condition corresponding to the anticipated quality level, and when consuming, they contrast the anticipated and actual quality levels of the fundamental sensory quality attributes, such as form, colour, scent, flavour, aroma, consistency, or textural quality. Determining which sensory feature of a product most influences the assessment of its quality and the making of decisions connected to its actual quality is crucial (Costa and Jongen, 2006). In order to avoid inaccurate results from being accepted, precision, accuracy, and sensitivity are highly valued in the measurement-based science of sensory evaluation. A product is assessed using the senses of sight, smell, taste, and touch to determine its look, flavour, texture, and other qualities. This process is known as sensory analysis. Customer evaluation is a common tool in the field of investigation (Tan *et al.*, 2023).

2.3.7 Hedonic rating of sensory

Hedonic response emerged as a rapidly growing field in the 20th century, coinciding with the growth of the food processing industry. This encompasses an assortment of techniques required to obtain precise measurements of individuals' responses to food, which in turn shapes consumers' opinions about the items. A scientific method for measuring, assessing, deciphering, and interpreting responses to products as perceived by the senses of sight, hearing, touch, smell, and taste is called sensory evaluation, according to the Institute of Food Technologists. A product is evaluated using the senses of taste, smell, and touch to assess its appearance, flavour, and other quality attributes using sensory analysis (Sharif *et al.*, 2017).

Customers' responses to food are determined by sensory analysis, which is necessary to verify a new product's reactivity. It is the scientific measurement and assessment of food quality through the use of human senses. The hedonic scale is used to determine how acceptable one or more items are. This is a category scale with an odd number of categories—between one and nine—that span from "dislike extremely" to "like extremely." A compromise that isn't hated or adored is included. Customers rate the goods on a scale based on their feedback (Falade and Omojola, 2010).

Part III

Materials and methods

3.1 Materials

3.1.1 Dragon fruit

Dragon fruit (*Hylocereus undatus*) that were matured and ripe were bought from the local market of Dharan and taken to the laboratory of CCT on the same day. They were washed and peeled, sliced and cooked with same amount of water until soft texture and juice was extracted with the help of muslin cloth.

3.1.2 Pineapple

Pineapple (*Ananas Comosus*) of Giant kew variety that were matured enough to process were also bought from the local market of Dharan and taken to the laboratory of CCT the same day. They were washed and peeled, sliced and grinded and juice was extracted with the help of muslin cloth.

3.1.3 Sugar

Clean and crystalline cane sugar was used which was purchased from local market of Dharan.

3.1.4 Citric acid

The citric acid was obtained from the laboratory of Central Campus of Technology.

3.1.5 Pectin

The pectin was obtained from the laboratory of Central Campus of Technology and found to be of 150 grade as per information provided by the laboratory of CCT.

3.1.6 Packaging materials

Glass bottles were utilised for primary packaging, while metal caps wrapped with aluminium foil were used as cap-seals, which were bought from Bhatbhateni Super Market, Dharan.

3.1.7 Chemicals and equipments

All the equipments and chemicals required during the dissertation were provided by Central Campus of Technology. List of equipments and chemicals used for this work are mentioned in Appendix B.1 and B.2.

3.1.8 Other materials

Other materials were bought from local market of Dharan. List of materials used for this work is given as; muslin cloth, glass bottles, plastic cups, aluminium foil.

3.2 Methods

The production and stability of jelly utilising pineapple juice and dragon fruit under two distinct storage conditions was the main focus of the entire dissertation.

3.2.1 Preparation of dragon fruit juice

Fig 3.1 shows the process flowchart for the preparation of dragon fruit juice.

Dragon fruit

↓

Washing

↓

Peeling and cutting into slices

↓

Addition of water (1:1 slices: water)

↓

Boiling (for about 20 – 30 minutes)

↓

Straining the extract with muslin cloth

↓

Dragon fruit juice

Fig 3.1 Flowchart for preparation of dragon fruit juice

Source: Panchal *et al.* (2018)

The fully riped dragon fruit were washed and peeled, cut and sliced. The dragon fruit pulp were cooked with water in 1:1 ratio for few minutes until they became soft with conditional stirring. They were then strained through the muslin cloth and juice was extracted.

3.2.1.1 Extract recovery

The entire extract was measured and collected in a glass jar. The percentage recovery was computed and expressed against the total amount of materials consumed.

3.2.2 Preparation of pineapple juice

The fully riped pineapple were washed and peeled. They were cut and core was removed and slices were grinded in an electronic grinder. The juice was then extracted by filtration through muslin cloth. Fig 3.2 shows the process flowchart for the preparation of pineapple juice.

Selection of pineapple
↓
Washing
↓
Peeling and removal of core
↓
Cutting into slices
↓
Grinding
↓
Straining the extract with muslin cloth
↓
Pineapple juice

Fig 3.2 Flowchart for the preparation of pineapple juice

Source: Panchal *et al.* (2018)

3.2.3 Design of experiment

Table 3.1 Design of experiment

S.N.	Sample	Dragon fruit (%)	Pineapple (%)
1.	A	50	50
2.	B	66.67	33.33
3.	C	75	25
4.	D	83.33	16.67
5.	E	87.5	12.5
6.	F	100	0

Design expert 13 was used to create the recipe. Mixture design was used to formulate the recipe. The independent variable for jelly preparation were dragon fruit and pineapple concentration.

3.2.4 Preparation of dragon fruit and pineapple jelly

Jelly was prepared with the variation in pulp content. Fig 3.3 shows the process flowchart for the preparation of dragon fruit and pineapple jelly.

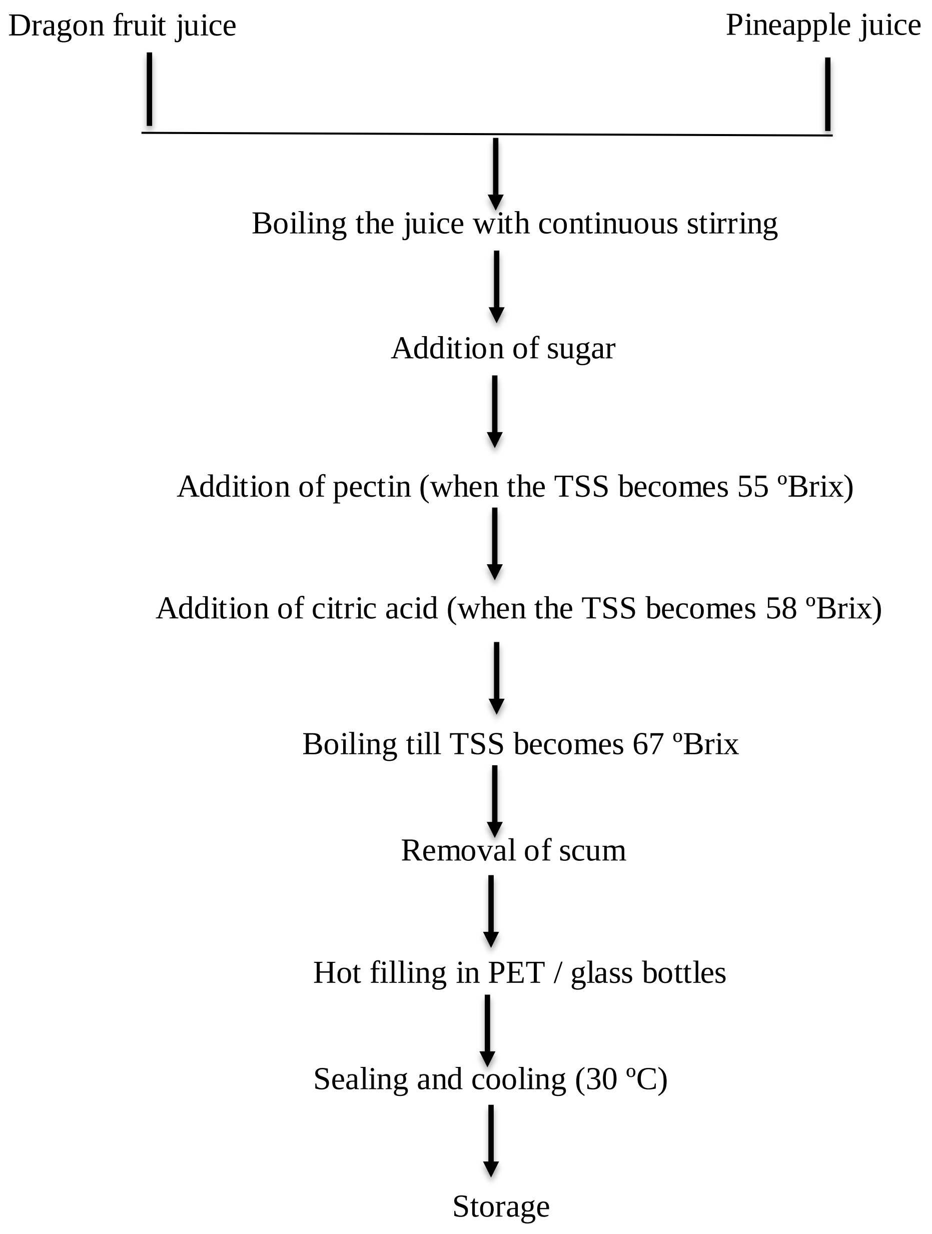

Fig 3.3 Flowchart for the preparation of dragon fruit and pineapple jelly

Source: Panchal *et al.* (2018)

3.2.5 Process optimization in the preparation of dragon fruit and pineapple jelly

Seven different samples of different proportion of dragon fruit and pineapple were taken and coded as A (50% dragon fruit pulp and 50% pineapple pulp), B (62.5% dragon fruit pulp and 37.5% pineapple pulp), C (66.67% dragon fruit pulp and 33.33% pineapple pulp), D (75% dragon fruit pulp and 25% pineapple pulp),E (83.33% dragon fruit pulp and 16.67% pineapple pulp), F (87.5% dragon fruit pulp and 12.5% pineapple pulp) and control (100%

dragon fruit). The acidity and pectin content was added in the amount of 0.8% and 1% respectively. The best quality jelly was selected on the basis of sensory evaluation (color, flavour, texture, taste, overall acceptability).

3.2.6 Filling, Sealing and cooling

Jelly were hot filled in the pre-sterilized glass bottles and were capped and sealed with aluminium foil and cooled. The best sample after sensory evaluation through 9 point hedonic scale rating were stored in two different storage conditions: refrigeration temperature and room temperature.

3.2.7 Physiochemical analysis

3.2.7.1 Total soluble Solid

A hand refractometer (0–30) was used to measure the total soluble solids, and the results were expressed as °Brix in accordance with Rangana (1986).

3.2.7.2 Titrable acidity

The titratable acidity was determined as per Rangana (1986).

3.2.7.3 Moisture content

The moisture Content was determined as per Rangana (1986).

3.2.7.4 Vitamin C

The 2-6-dichloro-indophenol visual titration method was used by Rangana (1986) to assess the amount of vitamin C, also known as ascorbic acid.

3.2.7.5 Reducing Sugar and total sugar

The Lane and Enyon method, as detailed in Rangana (1986), was used to calculate the reducing sugar and total sugar of jelly.

3.2.7.6 Non- reducing sugar

As stated in Rangana (1986), it was calculated using the Lane and Enyon method.

3.2.7.7 pH

It was directly measured by using pH meter. pH meter was standardized by using buffer solution of pH 7 and 4 at the room temperature.

3.2.7.8 Protein

Protein was determined by micro-kjeldahl method using conversion factor of 6.25 as described in Rangana (1986).

3.2.7.9 Ash content

Ash content was determined as described in Rangana (1986) by dry ashing method.

3.2.7.10 Crude fibre

Crude fibre content was determined as described in AOAC (2005).

3.2.7.11 Antioxidant

The antioxidant activity of dragon fruit and pineapple juice was determined as per (Panico et al., 2009) with slight modifications. The control sample (A control) was made by adding 0.28 mL of DPPH solution (0.1 mM, in 95% methanol) to a 10 mL conical flask, and then diluting it with methanol to the necessary volume. 0.28 mL of the DPPH solution and 0.28 mL of the test sample (A sample) were used in the preparation and poured into a 10 mL conical flask. The mixture was then diluted with methanol to the necessary level. Following repeated inversions, the mixture was incubated for 30 minutes at ambient temperature in a darkened area. The absorbance was calculated with the aid of a spectrophotometer set at 517 nm, in comparison to the control sample. The radical scavenging activity was estimated as a decrease in DPPH absorbance and was calculated using the following equation:

Scavenging effect (%) = [1-(A sample-A control)] ×100%

3.2.8 Statistical analysis

To ascertain whether the samples differed significantly from one another and which is better, the data were subjected to two way ANOVA, mean ANOVA (no blocking at 5% level of significance), LSD, and interaction effects using GenStat (GenStat Discovery Edition 12, 2009) at 5% significance level. The LSD method is used to compare the means. The same statistical method was also used to analyse the means and standard deviation.

3.2.9 Microbiological analysis

Plate Count Agar (PCA) medium was used to determine Total Plate Count (TPC) using the pour plate technique (incubated at 37°C/48 h). Using the pour plate technique on Potato Dextrose Agar (PDA) medium (incubated at 30°C/48 hours), the number of yeast and moulds was counted.

3.2.10 Storage stability of the jelly

Glass bottles that had been previously sterilised were aseptically filled with the jelly, which was then kept at room temperature (27±3°C) and refrigeration temperature (7ºC). Following 45 days of storage, the storage stability was then assessed at 15-day intervals based on changes in TSS, acidity, pH, reducing sugar, total sugar, vitamin C retention, moisture content and microbial alterations.

3.2.11 Sensory evaluation

The sensory evaluation was done in nine point hedonic scale rating method. The sensory panellist members were the research students of Central Campus of Technology. The sensory score card is presented in Appendix A.

Part IV

Result and Discussion

The work was carried out to prepare dragon fruit and pineapple jelly and investigate how well they stored. The key ingredients were pineapple and dragon fruit juices, plus varying amounts of sugar, citric acid, and the necessary quantity of pectin while keeping the TSS at 67°Bx, 0.8% acidity, and 1% pectin. A sensory analysis was performed on the seven distinct dragon fruit and pineapple juice formulations. The best sample was chosen, and it was examine for storage stability during a 45-day period at room temperature and refrigeration.

4.1 Physiochemical Properties of fruit

4.1.1 Dragon fruit and pineapple

The result of the physiochemical analysis of the fresh dragon fruit and pineapple is shown in table 4.1

Table 4.1 Chemical composition of fresh dragon fruit and pineapple

Parameters	Dragon fruit	Pineapple
TSS	11.5±0.0	17±0.0
pH	5.15±0.15	3.31±0.1
Reducing sugar (mg/100)	4.49±0.37	4.01±0.23
Non reducing sugar (mg/100)	3.65±0.31	4.32±0.42
Total sugar (mg/100)	8.33±0.46	9.5±0.3
Vitamin C (mg/100)	7.31±0.14	10±0.5
Acidity (%)	0.18±0.01	0.98±0.02
Moisture content (%)	89.19±0.5	88.54±0.5

*Values are means of triplicates, figures in the parenthesis are the standard deviations

According to Arivalagan *et al.* (2021), dragon fruit showed pH in the range 4.8-5.4, TSS 9.1-10.9 ºBx reducing sugar 3.39-4.98%, total sugar 5.13-7.6%, acidity 0.1-0.23%, vitamin C 7.4-14.1 % and 86.32% moisture content. Similar findings were obtained during this study.

Similarly, the chemical composition of pineapple was found to be 85.77% moisture content, 3.59 pH, 14.7 ºBx TSS, 15.74 mg ascorbic acid/100 ml and 0.74% titrable acidity as per reported by Odeyemi and OJELEYE (2021). While presence of 5.41 mg/100 g dextrose reducing sugar, 4.5 mg/100g non- reducing sugar and 9.91 mg/100 g total sugar was mentioned by (Vishwokarma, 2019). Similarity in findings of the studies can be observed.

4.2 Optimization of proportion of Dragon fruit juice and Pineapple juice in jelly

A sensory evaluation was conducted on six distinct jelly samples that had varying ratios of pineapple and dragon fruit juice. Figure displays the findings from the sensory analysis.

4.2.1 Color

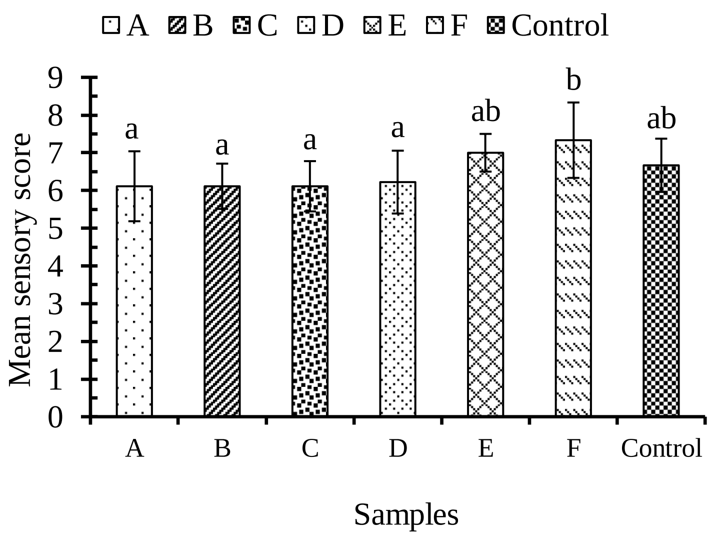

Fig 4.1 Comparison of the mean score of color among the jelly samples

The sensory score values of color for all the samples were subjected to two-way ANOVA (no blocking) at 5% level of significance using GenStat Release 12.1 (2012). The mean sensory score for color were 6.111, 6.111, 6.111, 6.222, 7.000, 7.333 and 6.667 for samples A, B, C, D, E, F and Control. The obtained means are represented as bar diagram in Fig. 4.1. Different letters on the top of the bar diagram in Fig 4.1 indicates that there is significantly difference between the samples with respect to color whereas the same letters at the top indicates that samples are not significantly different at 5% level of significance.

LSD indicated that there is a significant differences (p>0.05) between the mean scores. Sample F had the highest mean score with respect to color. Since no additional artificial color have been added to the products, the fluctuation in the color seen in the product is fully dependent on the pulp content, the different variation made in pulp part may be the reason that shows difference in color of different products.

4.2.2 Flavor

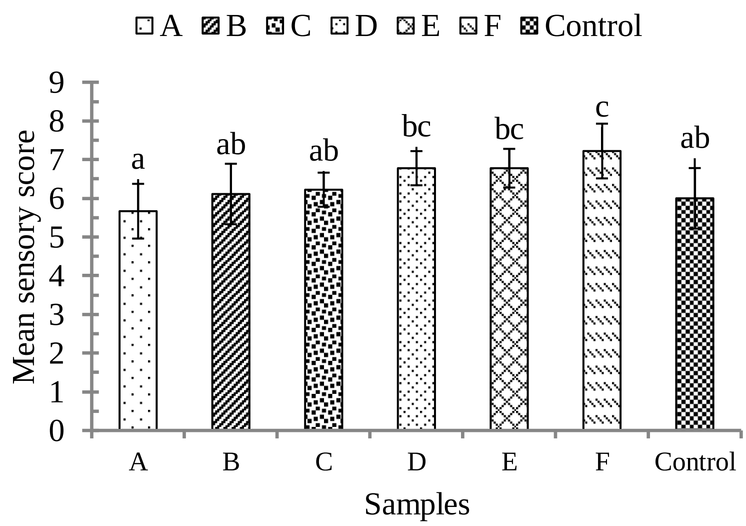

Fig 4.2 Comparison of the mean score of flavor among the samples

The sensory score values of flavor for all the samples were subjected to two-way ANOVA (no blocking) at 5% level of significance using GenStat Release 12.1 (2012). The mean sensory score for flavor were 5.667, 6.111, 6.222, 6.778, 6.778, 7.222 and 6.000 for samples A, B, C, D, E, F and Control. The obtained means are represented as bar diagram in Fig. 4.2. Different letters on the top of the bar diagram in Fig 4.2 indicates that there is significantly difference between the samples with respect to flavor whereas the same letters at the top indicates that samples are not significantly different at 5% level of significance.

LSD indicated that there is significant differences (p>0.05) between the mean scores. Sample F had the higher score in this work that might be due to good combination of pulps and cooking time. Food flavour is the result of the interaction between several ingredients. Since colour or flavour are not added during the jam-making process, the quality and type of fruit used determines the sensory attributes like look and taste. Fruit juice, fruit puree, frozen fruit, and fresh fruit are a few examples. Furthermore, fruit ripeness can vary, and overripe food loses its structure and flavour more readily when boiled. It is a good idea to mention that fruits with a high water content have fewer taste components (Javanmard *et al.*, 2010).

4.2.3 Taste

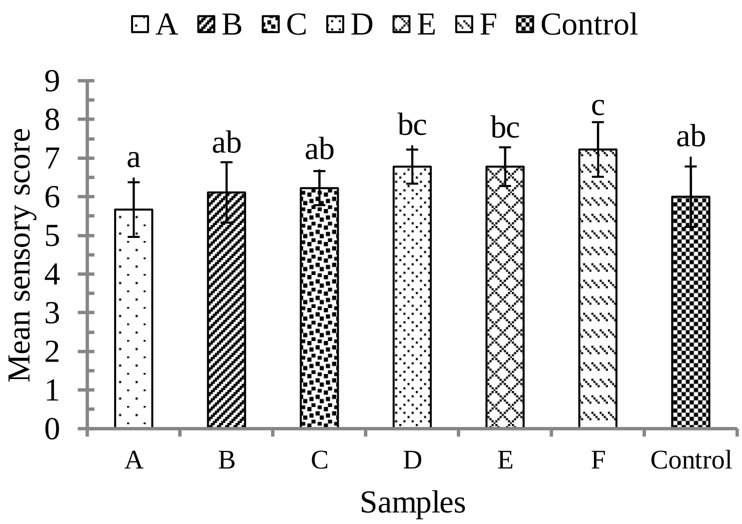

Fig 4.3 Comparison of the mean score of taste among the samples

The sensory score values of color for all the samples were subjected to two-way ANOVA (no blocking) at 5% level of significance using GenStat Release 12.1 (2012). The mean sensory score for taste were 5.667, 6.222, 6.333, 6.444, 7.111, 7.333 and 6.778 for samples A, B, C, D, E, F and Control. The obtained means are represented as bar diagram in Fig. 4.3. Different letters on the top of the bar diagram in Fig 4.3 indicates that there is significantly difference between the samples with respect to taste whereas the same letters at the top indicates that samples are not significantly different at 5% level of significance.

The samples were found to be significantly different from each other. LSD value showed that the sample F was the best with respect to taste with the highest mean score among all other samples.

4.2.4 Texture

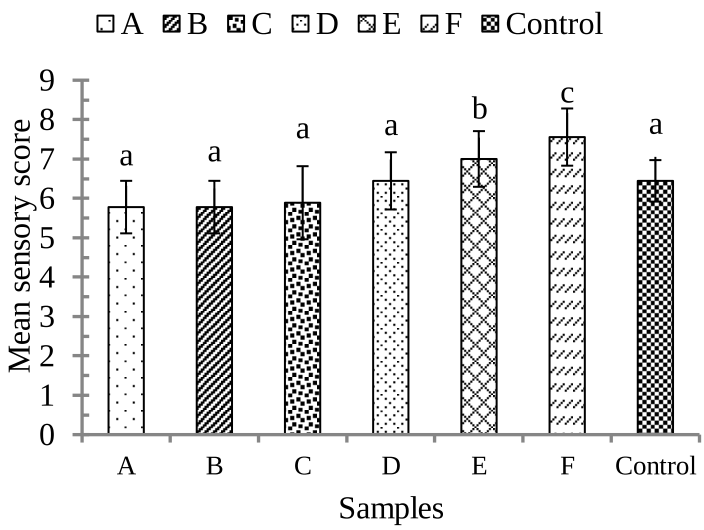

Fig 4.4 Comparison of the mean score of texture among the samples

The sensory score values of color for all the samples were subjected to two-way ANOVA (no blocking) at 5% level of significance using GenStat Release 12.1 (2012). The mean sensory score for texture were 5.778, 5.778, 5.889, 6.444, 7.000, 7.556 and 6.444 for samples A, B, C, D, E, F and Control. The obtained means are represented as bar diagram in Fig. 4.4. Different letters on the top of the bar diagram in Fig 4.4 indicates that there is significantly difference between the samples with respect to texture whereas the same letters at the top indicates that samples are not significantly different at 5% level of significance.

LSD indicated that there is a significant differences ($p>0.05$) between the mean scores. Sample F had the highest mean score in this work among all. Jam often has a smooth, velvety texture. The gel network that forms mostly determines the texture of jam. Gel production has been observed to occur only in a specific range of hydrogen ion concentration, with pH 3.0 being the ideal acidity figure for ions and jellies. As the pH level drops, the gel strength decreases gradually and increases quickly. In the typical soluble solid range, no gel formation happens beyond pH 4.0 (SMIT and BRYANT, 1968).

4.2.5 Overall acceptability

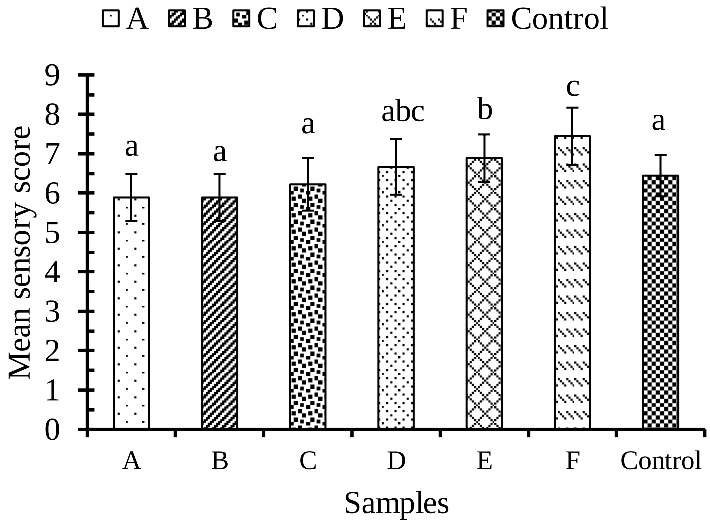

Fig 4.5 Comparison of the mean score of texture among the samples

The sensory score values of color for all the samples were subjected to two-way ANOVA (no blocking) at 5% level of significance using GenStat Release 12.1 (2012). The mean sensory score for overall acceptability were 5.889, 5.889, 6.222, 6.667, 6.889, 7.444 and 6.444 for samples A, B, C, D, E, F and Control. The obtained means are represented as bar diagram in Fig. 4.5. Different letters on the top of the bar diagram in Fig 4.5 indicates that there is significantly difference between the samples whereas the same letters at the top indicates that samples are not significantly different at 5% level of significance.

LSD indicated that there is a significant differences ($p>0.05$) between the mean scores and the sample F was the best sample with respect to overall acceptability with the highest mean score.

4.3 Physiochemical analysis of the best product

Physiochemical analysis of best product was carried out and found out to be as follow.

Table 4.4 Physiochemical analysis of best sample

Parameters	Best sample
Moisture (%)	29±0.6
TSS	68 ±0
Reducing sugar (mg/100)	27±0.2
Non reducing sugar (mg/100)	36.1±0.2
Total sugar (mg/100)	65±0.5
Vitamin c (mg/100)	2.9±0.1
Acidity (%)	0.8±0.02
pH	3.1±0.1

*The values are the mean ± standard deviation of triplicate analysis

4.4 Chemical analysis

The jelly after the preparation, maintaining the requirement of 68 ºBx TSS, 0.8% acidity and 1% pectin content were stored in sterilized glass bottles, in both room temperature and refrigeration temperature for a period of 45 days. The sample and control were analyzed for 15, 30 and 45 days for its TSS, acidity, reducing sugar, non-reducing sugar, total sugar, moisture, pH and vitamin C content. The effect of storage intervals on the physicochemical characteristics of jelly is presented in Appendix D.

4.4.1 TSS

The relationship between the TSS of sample and control with the storage period is shown in figure 4.6.

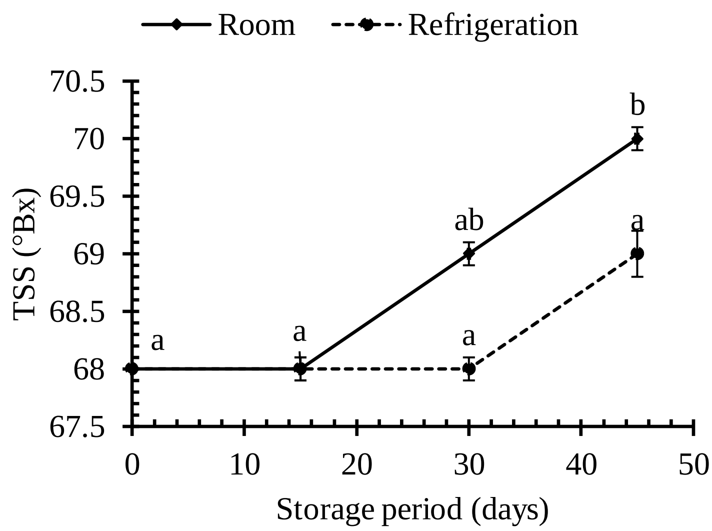

Fig 4.6 Effect of storage period on TSS of sample and control

The TSS of jelly stored at room temperature and refrigeration temperature were found to be 68, 68, 69 and 70 and 68, 68, 68 and 69 for 0, 15, 30 and 45 days respectively. The TSS of the jelly at room temperature increases from 68 ºBx to 70 ºBx whereas TSS of refrigeration stored jelly increased from 68 ºBx to 69 ºBx over 45 days of storage. The room sample TSS was statistically significantly impacted by the storage duration ($p<0.05$) and that of refrigeration was not. Both the room and the refrigeration sample showed an increase in TSS as the storage duration was extended. The presence of organic acids throughout the storage period likely caused the conversion of polysaccharides into sugars, which resulted in an increase in the total soluble solids content of the jelly (Kumar and Dee, 2017).

4.4.2 Titratable acidity

The relationship between the titratable acidity of sample and control with the storage period is shown in figure 4.7.

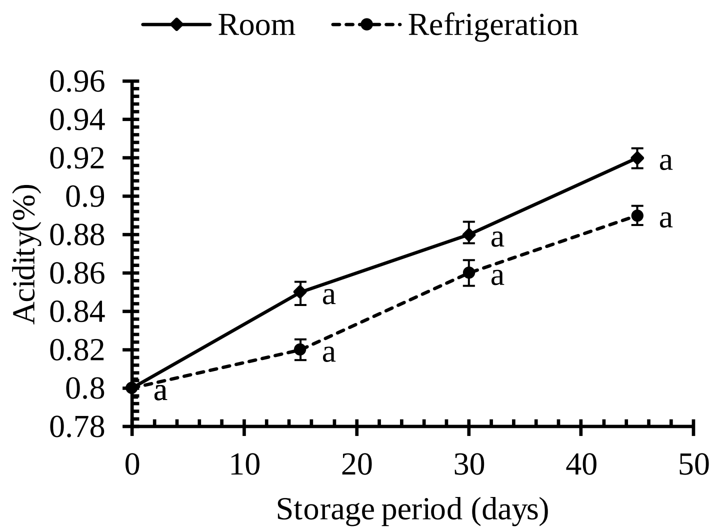

Fig 4.7 Effect of storage period on acidity of sample and control

The acidity of jelly stored at room temperature and refrigeration temperature were found to be 0.8, 0.85, 0.88 and 0.92 and 0.8, 0.82, 0.86 and 0.89 for 0, 15, 30 and 45 days respectively. The acidity of the jelly at room temperature increases from 0.8 to 0.92 whereas acidity of refrigeration stored jelly increased from 0.8 to 0.89 over 45 days of storage. The room sample and refrigeration samples' acidity was not statistically significantly impacted by the storage duration ($p<0.05$). Both the room and the refrigeration sample showed an increase in acidity as the storage duration was extended. The titrable acidity level increased significantly during storage, which could be the result of ascorbic acid breakdown into organic acids (Divyasree *et al.*, 2018).

4.4.3 Reducing sugar

The relationship between the reducing sugar of sample and control with the storage period is shown in figure 4.8

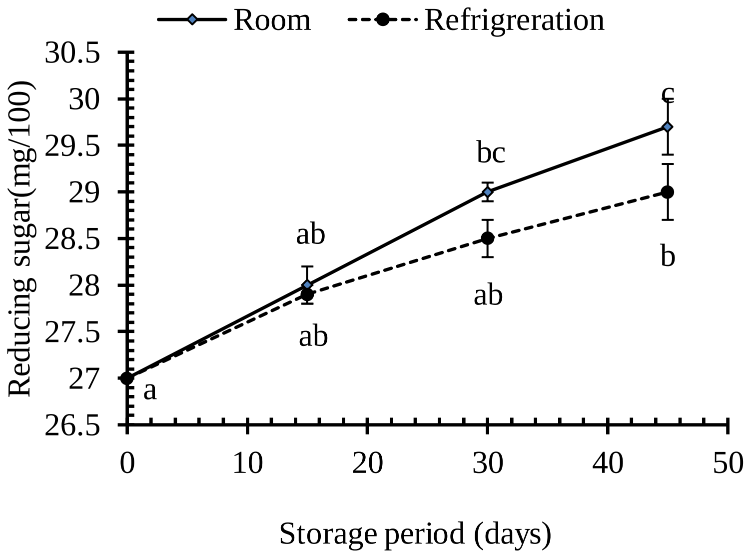

Fig 4.8 Effect of storage period on reducing sugar of sample and control

The reducing sugar of jelly stored at room temperature and refrigeration temperature were found to be 27, 28, 29 and 29.7 and 27, 27.9, 28.5 and 29 for 0, 15, 30 and 45 days respectively. The reducing sugar of the jelly at room temperature increases from 27 to 29.7 whereas reducing sugar of refrigeration stored jelly increased from 27 to 29 over 45 days of storage. The room sample and refrigeration samples' acidity was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed an increase in reducing sugar as the storage duration was extended. Reductions in non-reducing sugars correlated with increases in reducing sugar content, suggesting that the rise in reducing content of jelly may be the result of non-reducing carbohydrates being inverted into reducing sugars. Another explanation for the rise in sugar concentration could be the hydrolysis of polysaccharides like pectin and starch (Kumar and Deen, 2017)

4.4.4 Non-reducing sugar

The relationship between the non-reducing sugar of sample and control with the storage period is shown in figure 4.9

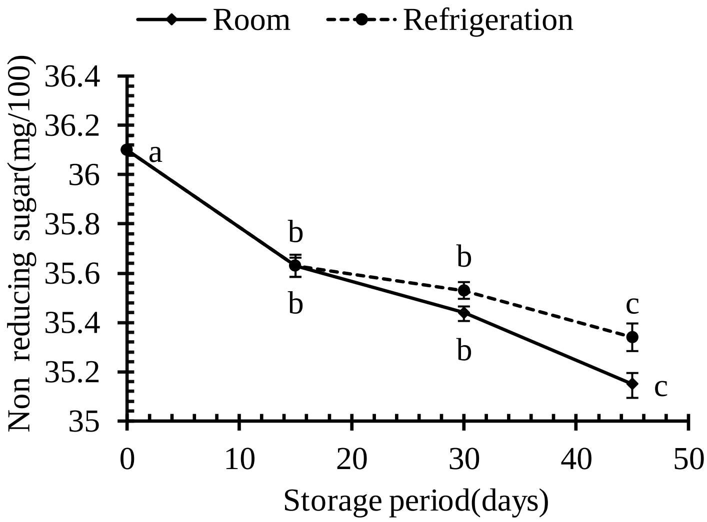

Fig 4.9 Effect of storage period on non-reducing sugar of sample and control

The non-reducing sugar of jelly stored at room temperature and refrigeration temperature were found to be 36.1, 35.63, 35.44, and 35.15 and 36.1, 35.63, 35.53 and 35.34 for 0, 15, 30 and 45 days respectively. The non-reducing sugar of the jelly at room temperature decreases from 36.1 to 35.15 whereas non-reducing sugar of refrigeration stored jelly decreased from 36.1 to 35.53 over 45 days of storage. The room sample and refrigeration samples' non-reducing sugar was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in non-reducing sugar as the storage duration was extended. There was an observed correlation between decreases in non-reducing sugars and increases in reducing sugar content. This implies that non-reducing carbs could be converted into reducing sugars, which could account for the decrease in non-reducing content of jelly (Kumar and Deen, 2017).

4.4.5 Total sugar

The relationship between the total sugar of sample and control with the storage period is shown in figure 4.10

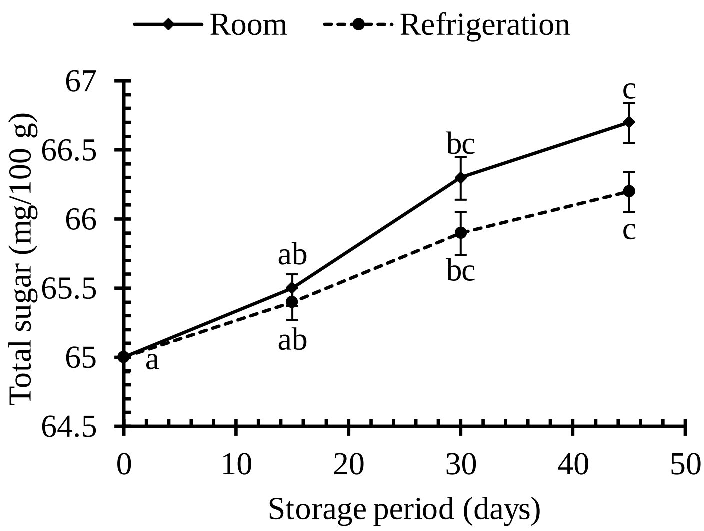

Fig 4.10 Effect of storage period on total sugar of sample and control

The total sugar of jelly stored at room temperature and refrigeration temperature were found to be 65, 65.5, 66.3 and 66.7 and 65, 65.4, 65.9 and 66.2 for 0, 15, 30 and 45 days respectively. The total sugar of the jelly at room temperature increases from 65 to 66.7 whereas total sugar of refrigeration stored jelly increased from 65 to 66.2 over 45 days of storage. The room sample and refrigeration samples' total sugar was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed an increase in total sugar as the storage duration was extended. One possible explanation for the increase in total sugars could be moisture loss during storage (Kumar and Deen, 2017).

4.4.6 Vitamin C

The relationship between the vitamin C of sample and control with the storage period is shown in figure 4.11.

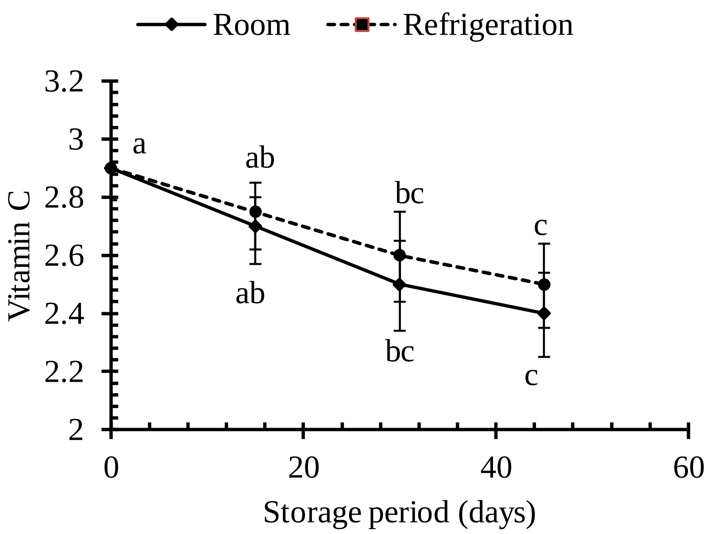

Fig 4.11 Effect of storage period on vitamin C of sample and control

The vitamin C of jelly stored at room temperature and refrigeration temperature were found to be 2.9, 2.7, 2.5, and 2.4 and 2.9, 2.75, 2.6, and 2.5 for 0, 15, 30 and 45 days respectively. The vitamin C of the jelly at room temperature decreases from 2.9 to 2.4 whereas vitamin C of refrigeration stored jelly decreased from 2.9 to 2.5 over 45 days of storage. The room sample and refrigeration samples' vitamin C was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed an decrease in vitamin C as the storage duration was extended. Since ascorbic acid is extremely sensitive to light, oxygen, and temperature, oxidation was the source of the notable drop in ascorbic acid. One possible explanation for the jelly's decreased ascorbic acid level is that the oxygen contained in the bottles caused oxidation, which created unstable and highly volatile dehydroascorbic acid (Kumar and Deen, 2017).

4.4.7 pH

The relationship between the pH of sample and control with the storage period is shown in figure 4.12

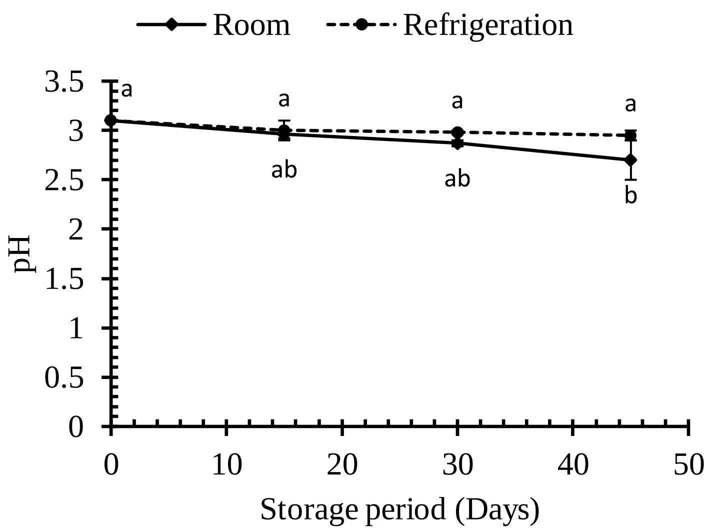

Fig 4.12 Effect of storage period on pH of sample and control

The pH of jelly stored at room temperature and refrigeration temperature were found to be 3.1, 2.96, 2.87 and 2.7 and 3.1, 3.0, 2.98 and 2.95 for 0, 15, 30 and 45 days respectively. The moisture content of the jelly at room temperature decreases from 3.1 to 2.7 whereas moisture content of refrigeration stored jelly decreased from 3.1 to 2.95 over 45 days of storage. The room sample and refrigeration samples' pH was not statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in pH as the storage duration was extended.

4.4.8 Moisture content

The relationship between the vitamin C of sample and control with the storage period is shown in figure 4.13.

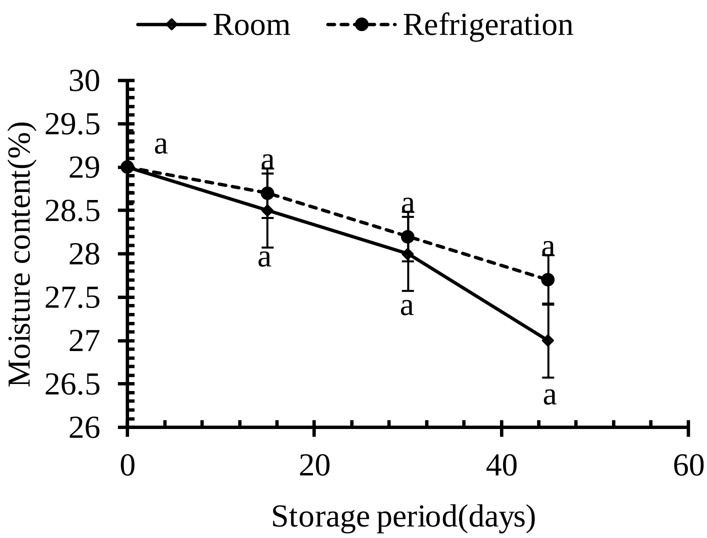

Fig 4.13 Effect of storage period on moisture content of sample and control

The moisture content of jelly stored at room temperature and refrigeration temperature were found to be 29, 28.5, 28 and 27 and 29, 28.7, 28.2, and 27.7 for 0, 15, 30 and 45 days respectively. The moisture content of the jelly at room temperature decreases from 29 to 27 whereas moisture content of refrigeration stored jelly decreased from 29 to 27.7 over 45 days of storage. The room sample and refrigeration samples' moisture was not statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in moisture content as the storage duration was extended. Reopening the same pack during storage for analysis may be the cause of this drop in moisture (Moshfeghi *et al.*, 2013a; Muhammad *et al.*, 2008).

4.4.9 Microbiological analysis

In microbiological analysis TPC and YMPC were performed and the changes in microbial counts during storage are given in the table 4.5. Two different samples were taken and coded as R and C where R is jelly stored in room temperature and C is jelly stored in refrigeration temperature.

Table 4.5 Microbiological analysis of product

Parameters/Days	TPC (10^3 cfu/ml) (R)	TPC (10^3 cfu/ml) (C)	YMPC (10^3 cfu/ml) (R)	YMPC (10^3 cfu/ml) (C)
Day 0	1.00	1.00	0	0
Day 15	4.00	3.00	2.00	1.00
Day 30	5.00	4.00	2.00	2.00
Day 45	7.00	5.00	3.00	2.00

Ranganna (1986) stated that the maximum number of microorganisms in one ml or g of jelly is 10^3. According to the current data, the microbe count stayed within this range till the jelly's organoleptic properties were still acceptable.

4.5 Cost evaluation of a product

The market price of mixed jelly ranges from NRs 200-400 for 500 g. The total cost associated with the best product was calculated and the cost per 500 g of dragon fruit and pineapple jelly was NRs 493.68. The processing and packaging cost are excluded. The calculation is made in Appendix E.

Part V

Conclusions and recommendations

5.1 Conclusions

The study was carried out in a controlled condition using different materials and methods. The conclusions are given on this research based on the obtained results and discussions made. From the above result and discussion, the following conclusions were drawn from this research work.

1. The dragon fruit and pineapple jelly with 87.5% dragon fruit juice and 12.5% pineapple juice was found to be best from sensory analysis.

2. The TSS, acidity, reducing sugar, total sugar, and microbial count increased while non-reducing sugar, vitamin C content, pH and moisture content decreased during storage.

3. The jelly can be stored upto 45 days at both room and refrigeration temperature without adding any chemical preservative with desirable acceptability.

4. The cost of the product was higher than the other commercial production cost due to the high market value of dragon fruit.

5. Preparation of dragon fruit and pineapple jelly could be a promising use of utilizing excess dragon fruit and pineapple thus aiding in the income of producers by value addition as well as providing new taste for consumers.

5.2 Recommendations

From present study following recommendations can be made for future studies.

1. With the use of modern instruments, other micronutrients in this formulation could be evaluated.

2. A shelf life study examining the product in various packaging materials with appropriate preservatives could be conducted.

3. The sensory quality of pectin at different pectin content and acidity can be studied.

Part VI

Summary

Jelly is a food product with an intermediate moisture level that is semi-solid. It is produced by boiling fruit juice with sugar, either with or without the addition of pectin and acid, until the TSS content reaches a minimum of 65%. Dragon fruit and pineapple jelly was prepared with the extraction of their respective juices. Firstly, dragon fruit and pineapple were selected, washed, peeled off, and cut. Pineapple slices were grinded for juice extraction and filtered through muslin cloth whereas dragon fruit slices were cooked with equal amount of water until soft and juice was extracted with muslin cloth.

The main aim of this study was to develop the acceptable quality of jelly from dragon fruit and pineapple with good color, flavour, texture, taste and acceptance. Juice was cooked with addition of sugar, pectin and acid according to formulations. Different samples of jelly were prepared as A (50:50), B (65.5:37.5),C (66.67:33.33), D (75:25), E (83.33:16.67), F (87.5:12.5) and Control (100:0) maintaining 68 ºBx TSS, 0.8% acidity and 1% pectin content.

The jelly prepared from 87.5 parts dragon fruit juice and 12.5 parts pineapple juice was best judged by sensory evaluation. The best scored jelly were filled in pre-sterilized glass bottles, capped and sealed with aluminium foil and subjected to physiochemical analysis during 45 days storage period in two different temperatures: room and refrigeration and TSS, titratable acidity, reducing sugar, non-reducing sugar, total sugar, vitamin C, pH and moisture content were analyzed in an interval of 15 days. From statistical analysis, it was found that the storage period had significant effect ($p < 0.05$) in change in reducing sugar, non-reducing sugar, total sugar and vitamin c and no significant effect in TSS, titratable acidity, pH and moisture content.

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Appendices

Appendix A

Specimen card for sensory evaluation

Name of panellist: Date:

Product:

Dear panellist, you are provided with six samples of dragon fruit and pineapple jelly with varying pulp proportion. Please taste the samples of jelly and check how much you prefer for each of the samples. Give the point for your degree of preference for each sample as shown below.

Judge the characteristics on the 1-9 scale as below:

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

Sensory parameter	Samples						
	A	B	C	D	E	F	Control
Color							
Flavor							
Taste							
Texture							
Overall acceptance							

Comments: ……………...

……………………………………………………………………………………………..

Signature: ……………

Appendix B

B.1 Equipment

All the equipment required for the experiment was obtained from the laboratory of CCT. List of equipment used for this work is shown in Table B.1.

Table B.1 List of equipment used

Equipment	Equipment
Grinder machine	Juice extractor
Volumetric flask	Beaker
Test tube and pipette	Weighing machine
Refractometer	Conical flask
Electronic balance	Measuring cylinder
Spectrophotometer	pH meter
Knives	Thermometer
Chopping board	Round bottom flask
Burette	Kjeldahl apparatus

B.2 Chemicals

All the chemicals required for the experiment were obtained from the laboratory of CCT. List of chemicals used for this work is shown in Table B.2.

Table B.2 List of chemicals used

Chemicals	Chemicals
Boric acid	Fehling's solution
Ascorbic acid	Dye solution
Oxalic acid	Dextrose solution
Lead acetate	Petroleum ether
Sodium hydroxide pellets	Hydrochloric acid
Sodium carbonate	Methanolic KOH
Methylene blue	Phenolphthalein
Meta phosphoric acid	Buffer solution
Methyl orange	Sodium alginate
Citric acid	Acetic acid
Carrez solution I and II	2,6-dichlorophenol Indophenols dye
60% ethanol	Malt extract
Sodium bicarbonate	Bromocresol green
Sulphuric acid	Methyl red
	95% alcohol

Appendix C

Table C.1 ANOVA: Two way analysis of mean sensory score of color, flavor, texture, taste and overall acceptance of dragon fruit and pineapple jelly.

	Source of variation	d.f.	s.s	m.s	v.r	F. pr
	Samples	6	13.5238	2.2540	5.00	<.001
Color	Panelists	8	10.6032	1.3254	2.95	0.009
	Residual	48	21.6190	0.4504		
	Total	62	45.7460			
	Samples	5	15.9683	2.6614	6.12	<.001
Flavor	Panelists	8	2.2222	0.2278	0.64	0.742
	Residual	48	20.8889	0.4352		
	Total	62	39.0794			
	Samples	6	17.3333	2.8889	5.14	<.001
Taste	Panelists	8	3.2698	0.4087	0.73	0.666
	Residual	48	26.9524	0.5615		
	Total	62	47.5558			
	Samples	6	24.6032	4.1005	8.41	<.001
Texture	Panelists	8	5.2698	0.6587	1.35	0.242
	Residual	48	23.3968	0.4874		
	Total	62	53.2698			
	Samples	6	17.0794	2.8466	7.58	<.001
Overall	Panelists	8	4.6032	0.5754	1.53	0.172
	Residual	48	18.0635	0.3763		
	Total	62	39.7460			

Appendix D

Table D.1 ANOVA: One way analysis of vitamin C of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	0.44250	0.14750	14.75	0.001
Residual	8	0.08000	0.01000		
Total	11	0.52250			

Table D.2 ANOVA: One way analysis of vitamin C of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	0.275625	0.091875	11.31	0.03
Residual	8	0.065000	0.008125		
Total	11	0.340625			

Table D.3 ANOVA: One way analysis of acidity (%) of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	0.021825	0.007275	2.19	0.167
Residual	8	0.026600	0.003325		
Total	11	0.048425			

Table D.4 ANOVA: One way analysis of acidity (%) of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	0.013700	0.004567	1.66	0.253
Residual	8	0.022067	0.002758		
Total	11	0.035767			

Table D.5 ANOVA: One way analysis of TSS of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	8.2500	2.7500	5.50	0.024
Residual	8	4.0000	0.5000		
Total	11	12.2500			

Table D.6 ANOVA: One way analysis of TSS of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	2.2500	0.7500	1.00	0.441
Residual	8	6.0000	0.7500		
Total	11	8.25000			

Table D.7 ANOVA: One way analysis of reducing sugar of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	12.5025	4.1675	5.48	0.024
Residual	8	6.0800	0.7600		
Total	11	18.5825			

Table D.8 ANOVA: One way analysis of reducing sugar of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	6.6600	2.2200	3.93	0.054
Residual	8	4.5200	0.5650		
Total	11	11.1800			

Table D.9 ANOVA: One way analysis of non-reducing sugar of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	1.432200	0.477400	55.35	<.001
Residual	8	0.069000	0.008625		
Total	11	1.501200			

Table D.10 ANOVA: One way analysis of non-reducing sugar of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	0.940200	0.313400	97.18	<.001
Residual	8	0.025800	0.003225		
Total	11	0.966000			

Table D.11 ANOVA: One way analysis of total sugar of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	5.30250	1.76750	18.61	<.001
Residual	8	0.76000	0.09500		
Total	11	6.06250			

Table D.12 ANOVA: One way analysis of total sugar of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	2.54250	0.84750	9.42	0.005
Residual	8	0.72000	0.09000		
Total	11	3.26250			

Table D.13 ANOVA: One way analysis of moisture content of dragon fruit and pineapple jelly (room)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	6.5625	2.1875	2.69	0.117
Residual	8	6.5000	0.8125		
Total	11	13.0625			

Table D.14 ANOVA: One way analysis of moisture content of dragon fruit and pineapple jelly (refrigeration)

Source of variation	d.f.	s.s	m.s	v.r	F pr.
Time (days)	3	2.9400	0.9800	3.50	0.069
Residual	8	2.2400	0.2800		
Total	11	5.1800			

Appendix E

Table E.1 Cost analysis of the product

Particular	Quantity	Rates (Rs/kg)	Amount (Rs)
Dragon fruit	4 kg	400	1600
Pineapple	1 pieces	200	200
Sugar	2 kg	100	200
Citric acid	50 g	142	7
pectin	50 g	1000	50
Total			2057

Total price of the product including 20% overhead cost= Rs 2469

Price of 500 g of product = Rs. 493.68

Photo Gallery

Plate 1 Raw materials

Plate 2 Preparation of dragon fruit pulp

Plate 3 Chemical analysis of raw material

Plate 4 Chemical analysis of product

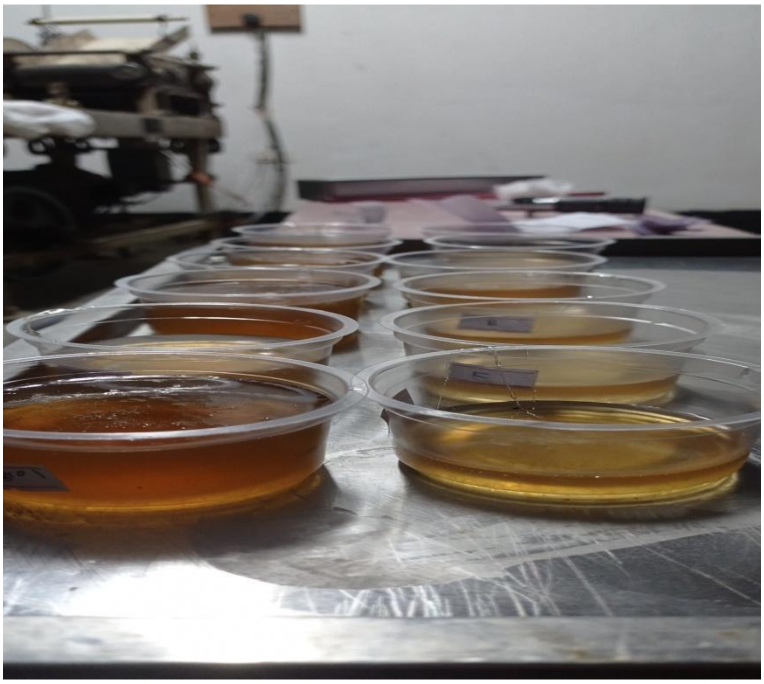

Plate 5 Sample for sensory evaluation