# PREPARATION AND QUALITY EVALUATION OF MIXED FRUIT (MANGO AND JACKFRUIT) JAM


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**2025**

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***A dissertation submitted to the Central Department of Food Technology, Institute of Science and Technology, Tribhuvan University, in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology***


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**July, 2025**

## Acknowledgements

I would like to express my most sincere gratitude and thankfulness to my respected supervisor, Asst. Prof. Babita Adhikari Dahal of the Central Campus of Technology, for her supervision, encouragement and continuous guidance during this dissertation work.

I am grateful to Assoc. Prof. Basanta Kumar Rai, Campus Chief, Central Campus of Technology, Asst. Prof. Kabindra Bhattarai, HOD, Department of Food Technology for providing kind support, valuable suggestions and necessary facilities during the work.

I would like to extent my heartiest gratitude and deep sense of thankfulness to all the laboratory staffs of Central Campus of Technology whose assistance and guidance hugely simplified the complexities of this work. I am also grateful to each and every individual who has helped me in the slightest possible way during this work. I am especially grateful to my dear friends Rupesh Karki, Sabina Acharya, Kanchan Poudel, Mayasi Bhattarai, Manish Kafle, Vesraj Lamichhane, Nilam Yasmali and Sagar Ghimire for their valuable support and affection during this research work.

Above all, I am indebted to my parents without whose constant encouragements, inspirations and affection, I would never have reached this far, and this work would have never seen the light of the day.

Last but not the least, I express sincere thanks to all those names which have not been mentioned individually but helped me directly and indirectly in this work.

Date of submission: July 24, 2025

(Dip Neupane)

# Abstract

The main aim of the study was to develop mango and jackfruit jam of acceptable quality in terms of appearance, color, aroma and consistency without using any kinds of commercial preservatives. The specification of the best prepared Mango and Jackfruit jam was; TSS 68ºBx, acidity of 0.8% and pectin was 1% and pulp content was 50:50 parts. Yellowish green Jackfuit of Aicho-Paicho variety and Mango fruits of Bombay green variety were collected from Central Campus of Technology which were sorted, graded and washed with water. Pulp was cooked with addition of sugar, pectin and acid according to the formulation until the end point was obtained. Different samples of jackfruit and mango jam were prepared having 100:0, 75:25, 60:40, 50:50, 40:60 and 25:75 parts variation in pulp were prepared. Specification of acidity of the end product was maintained at 0.8% as citric acid pectin content as 1%. Using GenStat 12$^{th}$ Edition, ANOVA and Tukey's test were run to determine the best sample on the basis of sensory analysis at ($p<0.05$).

The jam prepared from 50:50 parts pulp content with 1% pectin was best judged by the sensory evaluation. The best scored mixed fruit jam was subjected to the physiochemical analysis along with commercial (mango and jackfruit) jam of BBSM, Dharan. Moisture content, TSS, titratable acidity, reducing sugar, total sugar, vitamin C content and pH of best sample were 28%, 68ºBx, 1.34%, 30%, 73%, 17.28% and 3.3 respectively. The paired t-test between the best sample and commercial sample suggested there were no significant differences in TSS, %titratable acidity, %reducing sugar, %total sugar and vitamin c content (mg/100gm) among the samples at ($p<0.05$). Thus, these results suggest that the present study can be applied to prepare jam at local levels that is already available in the market.

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# List of abbreviations

| Abbreviations | Full form |
|---|---|
| AD | Aqueous decoction |
| ANOVA | Analysis of variance |
| BBSM | Bhatbhateni supermarket |
| Bx | Brix |
| CCT | Central Campus of Technology |
| DB | Dry basis |
| DM | Degree of methylation |
| DSS | Dextran sulfate sodium |
| GDP | Gross domestic product |
| HCl | Hydrochloric acid |
| HMP | High methoxy pectin |
| LMP | Low methoxy pectin |
| LSD | Least significant difference |
| MT | Metric ton |
| NARC | Nepal Agricultural Research Council |
| SD | Standard deviation |
| WB | Wet basis |

# Part I

# Introduction

## 1.1 General introduction

An early attempt to preserve fruits for use in the off-season may have been the origin of jams and jellies. As the cost of making sugar dropped, so did the popularity and availability of these fruit products. Jam, in all its varieties, is the most basic by-product of citrus fruit production. The production of jelly was first recorded in print in the second part of the 18th century. (Vibhakara and Bawa, 2006b)

Fruit pulp is boiled with sugar, acid, pectin, and additional coloring and flavoring ingredients along with preservatives to create jam, an intermediate food that has a thick consistency and stiffness to keep the fruit tissues. (Yadav *et al.*, 2019)

Jam is a food that is semi-solid and is created using at least 45 parts by weight of fruit juice and pulp to every 55 parts by weight of sugar. This substrate has a minimum TSS concentration of 68.5%. It is possible to add flavoring and color. Pectin and acid may be added to overcome the deficiencies in fruit itself. The acidity should be at least 0.5% but not greater than 1% (usually in the range of 0.6-0.8% but best at 0.75%). Fruit juice, fruit pulp, sugar, pectin, acid, flavor, and color are all needed to prepare it. First, the fruits are cleaned, chopped, and mixed to obtain the pulp. After that, the pulp is concentrated to 68.5% TSS by adding the appropriate amounts of sugar, acid, and pectin. The sugar provides the jam its sweetness and body. Pectin has the ability to jellify, whilst acid contributes to the flavor and consistency of jam. The addition of flavor and color is done at the person's discretion. After achieving the necessary concentration, it is put into the bottle and chilled.(Walter and Oakenfull, 2012)

Jackfruit (*Artocarpus heterophyllus Lam.*) is the largest tree borne fruit in the world, reaching up to 50 kg in weight and 60-90 cm in length. It belongs to the family Moraceae. The Jackfruit (*Artocarpus heterophyllus L.)* is well-known as “poor man’s food” fruit in Bangladesh. It is widely consumed by most of the rural people and it is the national fruit of Bangladesh. Jackfruit is a nutritious fruit rich in carbohydrates, proteins, potassium, calcium, iron, and vitamin A, B, and C. Due to high levels of carbohydrates, jackfruit supplements other staple foods in times of scarcity in some regions. The flesh of the jackfruit is starchy and fibrous, and is a source of dietary fiber. The presence of isoflavones, antioxidants, and phytonutrients in the fruits indicate that jackfruit has cancer-fighting properties. It is also known to help cure ulcers and indigestion. (Sidhu, 2012)

The jackfruit (rukh-katahar) is a large, oblong tree borne fruit with bumpy, dark green skin. It is eaten as a vegetable when green and a dessert when it is ripe. In this recipe, the young green fruit is cut into bunks and simmered with yogurt and spices. Fresh jackfruit is available at Asian food stores, but it is available canned at Indian, Asian, and specialty food markets. This recipe can be prepared from the canned variety, but these need to be rinsed in several changes of water before using. In Nepal, green jackfruit is considered a festive vegetable. In the Hindu marriage ceremonies of some Brahmin families, the bride's family does not serve meat. Instead, unripened jackfruit is substituted during the wedding feast. It is believed that the texture and flavour of cooked jackfruit is similar to meat (Sidhu, 2012).

In addition to its ripe fruit, which has a unique flavor, the jackfruit seed is widely consumed as a dessert or an ingredient in Asian culinary preparations. The jackfruit seeds are used in cooked dishes and its flour is used for baking. Jackfruit seeds are fairly rich in starch (Singh *et al.*, 1991). Ripe fruits can be eaten raw, or cooked in creamy coconut milk as dessert, made into candied jackfruit or edible jackfruit leather. In India, the seeds are boiled in sugar and eaten as dessert (Ranasinghe and Marapana, 2019).

One of the most widely consumed fruits grown in tropical regions of the world is the mango (*Mangifera indica L.*) (Ahmed *et al.*, 2005). Mangoes are exported worldwide and farmed in many tropical and subtropical regions. *Mangifera* is a member of the "Anacardiaceae" family. Mangoes are among the most popular fruits because of their distinctive flavor, aroma, taste, color, and texture, as well as their high nutritional profile. In addition to being a good source of minerals (such as potassium and phosphorus), phenolic compounds, dietary antioxidants, and carbohydrates, mangoes are an excellent source of vitamins A and C (CSA, 2017). Mango consumption has been proposed as a means of overcoming vitamin A deficiency, and dietary carotenoids are thought to be beneficial in preventing eye disorders and some types of cancer (Islam *et al.*, 2013)

Nepal is primarily an agricultural country, with 65.6% of its population engaged in farming. The agricultural and forestry sectors contribute 28.89% to the nation’s GDP (Shrestha *et al.*, 2021). Key mango varieties grown in Nepal include Amarpali, Mallika, Neelam, Maldah, Calcuttia, Dasheri, Bombay Green, Krishnabhog, Chausa, Cipia, Fazil, Alfanso, Pakistani, Gualb Khash, Zardalu, and Sukul (Shrestha *et al.*, 2020). Although mango production is high, the full potential of the industry has yet to be realized. The development of post-harvest techniques to reduce losses during harvesting and storage is crucial for improving the marketability of this perishable fruit (Kaur *et al.*, 2014). Mangoes are mainly grown in the frost-free regions of the Terai, particularly in areas above 600 meters in elevation, where rainfall is minimal. The ideal temperature for mango cultivation ranges from 24°C to 27°C. Mangoes can grow in various soil types, from deep, loamy soils to well-draining sandy loam. Mango cultivation thrives in soils with a pH level between 5.5 and 7.5. These environmental conditions make the Terai region well-suited for mango farming.

Mangoes can be processed into a variety of products. Unripe mangoes are often turned into powders, pickles, preserves, chutneys, or desserts, while ripe mangoes are used to make dried mango chips, mango wine, juice, concentrate, jam, jelly, syrup, and canned mango (Safdar *et al.*, 2012). Among these methods, jam making is one of the most effective ways to preserve mangoes. It is a traditional technique widely used across different cultures. Mango jam is made by boiling fruit pulp (either from mangoes alone or mixed with other fruits) with sugar (sucrose), pectin, acid, and sometimes additional ingredients like preservatives, coloring, fruit peels, and flavorings. The result is a thick, gel-like consistency that holds the fruit tissues together. Mango jams are rich in sugar, fiber, energy, and essential vitamins, minerals, and amino acids, but contain no fat or cholesterol. As a result, consuming jam can help reduce the risk of cardiovascular disease (Levaj *et al.*, 2010).

### 1.2 Statement of the problem

Jackfruit has been reported to contain high levels of protein, starch, calcium, and thiamine (Wickens and Burkill, 1986).The bulbs (excluding the seeds) are rich in sugar, fairly well in carotene and also contain vitamin C (Bhatia *et al*., 1955) . Presence of carotenoids can be important for the prevention of several chronic degenerative diseases, such as cancer, inflammation, cardiovascular disease, cataract and age-related macular degeneration (Krinsky *et al*., 2003). Despite all those merits, jackfruit has remained the most underutilized fruits in Nepal and many other parts of Asia.

People's perception of food is changing, with increasing attention on the link between diet and health. "Functional foods" refers to products that may provide extra health benefits beyond basic nutrition. However, in developing countries like Nepal, these products are not yet available, and the term is unfamiliar to local food industry professionals, business owners, and consumers (Subedi *et al.*, 2015).

This study aims at developing jackfruit jam and evaluate its acceptability by consumers. This will add knowledge on how to process and preserve jackfruit thus reducing postharvest losses. By adding value to the product, it will promote widespread utilization of jackfruit nutrients. Also, post-harvest processing will increase demand for jackfruit and consequently stimulate increased jackfruit production in the areas where it is grown and possibly introduced in the areas where there is potential. Thus, the increased intake of processed jackfruit products will contribute to the nutrition and health benefits of the Tanzanian people throughout the year. Those engaged in jackfruit business will also earn more income through employment and product selling. This will in turn contribute to improve household food security and livelihood.

Commercial production of mango jam in Nepal faces several challenges, such as irregular mango supply due to seasonal fluctuations, ensuring consistent mango quality, developing a dependable distribution network, acquiring necessary food processing and safety certifications, managing production costs, and competing with established brands. Additionally, issues related to packaging, shelf life, and market demand present significant obstacles. Nutritionally, mango jam is a valuable source of vitamins, particularly vitamin C, and minerals, which support immunity and overall health. Mangoes are also rich in antioxidants, making the jam a healthier option compared to other fruit jams. Many farmers in Nepal's Terai region grow mangoes, but cultivation has not yet been commercialized to a large scale. Mangoes have the potential to become a key cash crop for Nepali farmers. However, due to a lack of proper market infrastructure, much of the mango production is wasted, with only a small portion being sold as fresh fruit. By processing mangoes locally to create value-added products like jam, jelly, and juice, significant opportunities can be created for local farmers.

## 1.3 Objectives

### 1.3.1 General objective

The general objective of the study was to prepare and evaluate the quality of jackfruit and mango fruit jam.

### 1.3.2 Specific objectives

For the fulfillment of the general objectives, the specific objectives undertaken were as follows:

1. To determine the physiochemical characteristics of jackfruit and mango pulp.
2. To determine the physiochemical properties of the optimized best product.
3. To evaluate sensory properties and consumer acceptability of the developed and commercial jam.
4. To evaluate the cost of optimized best product.
5. To identify the nutritional benefits of jackfruit and mango jam
6. To compare the physiochemical properties of optimized best product with commercial jackfruit and mango jam.

## 1.4 Significance of the study

Fruits and vegetables are living organisms that continue to respire even after being harvested. During the period between harvest and consumption, they lose water, leading to wilting, and their texture changes due to shriveling. As the produce moves from the farm to the consumer, these losses add up. When considered overall, these losses result in lower profits for growers, which ultimately impacts all consumers.

Mangoes and Jackfruit cannot be stored for a long period of time because they are a seasonal and perishable fruit. However, because it has been treated, jam has the greatest shelf life of any product. The fact that mango goods are available throughout the year is beneficial for people who like mangoes. Before the product can be released into the market in a competitive range, a lot of work needs to be done and very few research has been done in this field. Jackfruit and Mango jam may be one of the potential research topics because there hasn't been much study done on it in Nepal thus far.

A few of the processed meals derived from various fruits is jam. These foods can be stored for a long period of time because of their high sugar content and low water activity (aw) (Baker *et al.*, 1996) . The mango is another fruit that could be sold in the Nepalese market. Jackfruits and Mangoes can be processed so that the market can offer their products all year round, but they are marketed as fresh fruit when they are in season. Thus, one possible product for the Nepalese market is jackfruit and mango jam.

### 1.5 Limitations of the study

- The storage stability analysis was not carried out due to time constraints.

# Part II

## Literature review

### 2.1 Jackfruit

#### 2.1.1 Origin and distribution

There is ongoing debate in the literature regarding the exact origin of jackfruit. Some researchers suggest that Malaysia might be the center of origin (Ruehle, 1967), while (Martin *et al.*, 1987) proposed that jackfruit is native to tropical Asia. However, the majority of scholars believe it originated in the rainforests of India's Western Ghats (Popenoe, 1921). Today, jackfruit is cultivated extensively across several Asian countries, including Bangladesh, Myanmar, Nepal, Sri Lanka, Thailand, Malaysia, Indonesia, India, and the Philippines. It is also grown in southern China and the Indo-Chinese region, including Laos, Cambodia, and Vietnam (Morton, 1987a). Additionally, jackfruit can be found in East Africa (e.g., Uganda, Tanzania), Mauritius, and across Brazil and Caribbean nations like Jamaica.

Jackfruit (Artocarpus heterophyllus) is believed to have originated in the tropical regions of southwest India and spread to various parts of Asia, including Nepal. In Nepal, jackfruit is commonly found in the Terai region, the lowland plains, as well as in parts of the mid-hills, where the climate is warm and humid (Gyawali *et al.*, 2022). The tree thrives in subtropical and tropical environments, which makes Nepal's climate, especially in the Terai and lower hilly areas, suitable for its cultivation.

Jackfruit is widely grown in home gardens and orchards in these regions, although it is not as commercially widespread as some other fruits. It is an important fruit in Nepalese diets, particularly in rural areas, where both the fruit and young green jackfruits are used for food, and its wood is valued for construction and furniture making. The tree is also valued for its resilience to drought and its ability to grow in various soil types, making it a hardy and useful plant in Nepalese agriculture (Poudel *et al.*, 2018)

**Taxonomic Classification**

The taxonomic classification of jackfruit is shown in the Table 2.1.

**Table 2.1** Taxonomic classification of Jackfruit

| | |
|---|---|
| Kingdom | Plantae (plant) |
| Sub kingdom | Tracheobionta |
| Super-division | Spermatophyta |
| Division | Manoliophyta |
| Sub-division | Ageospermae |
| Class | Magnoliopsida |
| Sub-class | Hamamelidiae |
| Order | Urticales |
| Family | Moraceae |
| Genus | Artocarpus |
| Species | *Artocarpus heterophyllus Lam*. |

Source: Zielenski (1955)

### 2.1.2 Climatic Requirements

The jackfruit is well-suited to humid tropical and subtropical climates, thriving at altitudes ranging from sea level up to 1,600 meters. Unlike other Artocarpus species, such as breadfruit, jackfruit can also grow in drier and cooler conditions (Popenoe, 1921). It can be cultivated in a variety of climates, from intermediate to wet and moist types, particularly in regions like Bangladesh, India, and Sri Lanka. The tree produces good yields especially within latitudes 25º N and S of the equator, extending up to 30º N and S (Verheij and Coronel, 1992). However, jackfruit trees above 1,330 meters tend to grow poorly, and any fruits produced are of lower quality. The best fruit quality is observed at elevations between 152 and 213 meters (Crane *et al.*, 2002). For optimal growth, jackfruit requires warm, humid climates with consistent rainfall of at least 1,500 mm (Baltazar, 1984). Growth is hindered when rainfall falls below 1,000 mm. Additionally, jackfruit trees are sensitive to constantly wet or flooded soil, as prolonged exposure (2-3 days) to these conditions can cause the trees to decline or die. For healthy production, annual rainfall should range from 1,000 to 2,400 mm or more.

### 2.1.3 Harvesting of Jackfruit

In Nepal, jackfruit (*Artocarpus heterophyllus*) is harvested mainly during the monsoon season, which typically spans from June to September, with peak harvesting occurring in July and August. Jackfruit trees are common in the lowland regions, especially in the Terai belt, where the warm and humid climate is conducive to its growth. The fruit is harvested when it reaches full maturity, which can be determined by the size, color, and firmness of the fruit. While some farmers prefer to harvest jackfruits when they are fully ripe and ready to be eaten, others pick them slightly under-ripe to avoid spoilage and to allow them to ripen off the tree, extending their shelf life. After harvest, the fruits are often processed into various local dishes, such as curries or dried into chips, and are also sold in local market (Chapagain *et al.*, 2022).

According to the Ministry of Agriculture and Livestock Development (MoALD) of Nepal, jackfruit is considered an underutilized crop that holds economic potential, especially in rural areas where it can be a reliable source of food and income. The production of jackfruit in Nepal is largely small-scale, and the fruit is primarily consumed domestically, though it has gained attention for export potential, especially in processed forms. Research has also shown that promoting jackfruit cultivation could help improve food security and provide livelihood opportunities in regions vulnerable to climate change (Jha *et al.*, 2021).

### 2.1.4 Uses of Jackfruit

The fruit provides approximately 2 MJ of energy per kg of ripe perianth (Ahmed *et al.*, 1986). Unripe fruits are commonly used in vegetable curries and pickles (Prakash *et al.*, 2009). When ripe, the fruit is utilized to make a variety of products including ice cream, squash, beverages, halwa, jam, and jelly. The pulp is dried and consumed as dried fruit during the off-season. Additionally, the fruit can be used to produce alcoholic beverages (Elevitch and Manner, 2006). Jackfruit has been found to be rich in protein, starch, calcium, and thiamine (Wickens and Burkill, 1986). The seeds can be boiled or roasted and eaten, or they may be preserved in syrup, similar to chestnuts. Roasted and dried seeds are ground into flour and mixed with wheat flour for baking *(Morton, 1987b)*. Beyond the distinct flavor of the ripe fruit, jackfruit seeds are commonly consumed as a dessert or as an ingredient in various Asian dishes. The seeds are also used in cooked meals, and their flour is incorporated into baked goods. Jackfruit seeds are notably high in starch (Singh *et al.*, 2017). Mature jackfruits are often cooked as vegetables and used in curries or salads (Nagy, 1990). Ripe fruits can be eaten raw, cooked in creamy coconut milk as a dessert, or made into candied jackfruit or edible jackfruit leather. Pureed jackfruit is also used to make baby food, juice, jam, jelly, and as a base for cordials.

### 2.1.5 Health benefits of Jackfruit

Jackfruit contains a variety of phytonutrients, including lignans, isoflavones, and saponins, which offer a wide range of health benefits. These phytonutrients have been shown to possess anticancer, antihypertensive, antiulcer, and anti-aging properties. As a result, they can help prevent the formation of cancer cells, reduce blood pressure, combat stomach ulcers, and slow down the degeneration of skin cells, promoting youthful-looking skin. Additionally, jackfruit is a good source of niacin (vitamin B3), which is essential for energy metabolism, nerve function, and the production of certain hormones (Soobrattee *et al.*, 2005).

The presence of high fiber content (3.6 g/100 g) in the jackfruit prevents constipation and produces smooth bowel movements. It also offers protection to the colon mucous membrane by removing carcinogenic chemicals from the large intestine (colon) (Siddappa, 1957). Eating jackfruit offers several health benefits, as it is a rich source of vitamin C. Since the human body cannot produce vitamin C naturally, it must be obtained from foods containing this essential nutrient to enjoy its health benefits. Jackfruit is both gluten-free and caseinfree, providing anti-inflammatory benefits for the skin. It is also packed with antioxidants, as well as vitamin C, flavonoids, potassium, magnesium, and fiber. Vitamin C plays a crucial role in collagen production, a protein that gives skin its structure, firmness, and strength (Babitha *et al.*, 2003).

### 2.1.6 Varieties of Jackfruit

In Nepal, jackfruit is an important tropical fruit, especially in the subtropical and tropical regions of the country. There are several varieties of jackfruit cultivated in Nepal, each varying in size, shape, taste, and texture. However, comprehensive academic or official references specifically listing jackfruit varieties in Nepal are limited. Nonetheless, some notable varieties commonly found in the country can be broadly categorized as (Paudel and Joshi, 2018):

1. **Nepali Local Varieties**: These are the traditional varieties, often referred to by the local names based on shape, size, or taste. The local jackfruit varieties are typically large, with yellow or golden flesh, and are grown in the mid-hill and terai regions. These fruits are known for their sweetness and aroma.

2. **Kathmandu Local Variety**: A variety grown around the Kathmandu Valley, known for its large fruits with a strong aroma and sweet taste. This variety is primarily used for both fresh consumption and cooking.

3. **Terai Variety**: Grown in the Terai region, these jackfruits tend to be larger and have a more fibrous texture. They are used mainly for their pulp, which is boiled and eaten in various dishes or used to make pickles.

4. **Bajhang Jackfruit**: Grown in the Bajhang region of Nepal, these jackfruits are noted for their sweetness and larger size. The trees in this area produce fruits that are often preferred for fresh consumption.

5. **Kailali Variety**: Found in the Kailali District in western Nepal, this variety produces medium-sized fruits with a sweet flavor. It is widely grown in the Terai region and is important for both commercial sale and home consumption.

These varieties are mostly classified based on their geographical origin, as there is no detailed, standardized classification system for jackfruit varieties in Nepal. Farmers in Nepal often select and grow varieties suited to local climates and preferences.

## 2.2 Mango

### 2.2.1 Origin and distribution

The Mangifera genus is part of the Sapindales order in the Anacardiaceae family, comprising over 40 species globally, with 15 of them producing edible fruits. The common mango (*Mangifera indica L.)* is believed to have originated as an alloploid in eastern India, Assam, and Burma (Popenoe, 1920). There are more than 1,600 mango cultivars worldwide, exhibiting considerable intraspecific variation. Around 350 of these cultivars are commercially produced, while the others are typically found in mixed orchards or home gardens (Subedi *et al.*, 2008).

Mango is one of the most important tropical fruits grown in Nepal, covering 9% of the country's total fruit cultivation area (Subedi *et al.*, 2008). Approximately 14,000 acres are dedicated to mango farming, yielding over 100,000 tons annually (Subedi *et al.*, 2004), primarily in the Terai, low-hills, mid-hills, and mountain regions. Known as the 'king of all fruits,' mango is highly valued for its appealing appearance and delightful taste, making it the most important summer fruit. Mangoes are climacteric fruits, which means they can undergo changes in color, scent, and flavor before or after harvest, signaling their ripeness (Griesbach, 2003).

Nepal is a key region for tropical fruit cultivation, with strong potential for high production and a thriving market, thanks to its favorable geographic advantages (Yadav *et al.*, 2022). In Nepal, 32,228 hectares are used for fruit production, with 40,110 hectares dedicated specifically to mango cultivation. The productivity stands at 10.21 MT/ha, leading to a total annual production of 328,883 MT (Devkota, 2016). Mango production and marketing involve a large number of workers, with key activities in the market channel including production, harvesting, wholesale, and retail. However, agricultural marketing is mainly hindered by perishability and seasonality (Pokharel, 2021). According to the Project for Agricultural Commercialization and Trade (2014), major production challenges include disease infestations, poor-quality inputs, limited technical knowledge, and marketing issues such as price fixation, low farmer bargaining power, middlemen, inadequate infrastructure, and lack of market information. These challenges lead mango growers to sell their produce at lower prices. Additionally, fluctuations in mango arrival times significantly affect market prices and contribute to considerable losses for farmers. Other challenges include insufficient post-harvest management and a lack of extension services (Honja *et al.*, 2016).

**Taxonomic Classification**

**Table 2.2** Taxonomic classification of mango

| | |
|---|---|
| Kingdom | Plantae (plant) |
| Sub kingdom | Tracheobionta |
| Super-division | Spermatophyta |
| Division | Manoliophyta |
| Class | Magnoliopsida |
| Sub-class | Rosidae |
| Order | Sapinadales |
| Family | anacerdiaceae |
| Genus | Magnifera |
| Species | Magnifera indica L. |
| Scientific name | *Magnifera indica L.* |

Source: Yadav and Singh (2017)

### 2.2.2 History of Mango Cultivation in Nepal

Mangoes were likely brought to Nepal through trade and cultural exchanges with neighboring countries like India, where mango cultivation has a long history. Initially, traditional mango varieties were grown in various regions of Nepal, adapting to local climates and becoming a key part of the Nepali diet. In the mid-20th century, the Nepal Agricultural Research Council (NARC) began researching and promoting modern mango farming methods. They introduced improved varieties and encouraged farmers to adopt more effective cultivation techniques.

Prominent local mango cultivars in Nepal include Sinduriya, Kali, Supare, and Lohare from the lower hills, as well as Chinia, Sipiya, Chausa, and Safeda from the Terai and hilly areas (Subedi *et al.*, 2008). Well-known mango varieties grown in Nepal are Alphonso, Bombay Yellow, Maldaha, Dussehri, and Calcuttia. In Sunsari district, the major mango cultivars include Maldah, Bambai, Amarpali, Kalkatia, Sipia, Dashari, Krishnabhog, and Sindure.

### 2.2.3 Climatic Requirements

Mango trees are well-suited to both tropical and subtropical climates. They grow successfully across most parts of the country, from coastal areas up to elevations of 600 meters. The optimal temperature for mango cultivation during the growing season ranges from 24°C to 30°C, accompanied by high humidity. Dry conditions before flowering promote abundant blooms, whereas rainfall during this period can harm the crop by disrupting pollination. Like many fruit trees, mangoes perform best in deep, loose loamy soil that drains well and is rich in organic matter. Therefore, those planning to grow mangoes commercially should aim to acquire land with these soil qualities (Vélez Colón *et al.*, 2006)

Mango cultivation is mainly concentrated in frost-free areas, especially in Nepal's Terai region. Madesh Pradesh (Province No. 2) offers a hot and humid climate that is particularly favorable for mango farming. These trees grow best in deep, well-drained soils ranging from loamy to sandy loam, with a pH between 5.5 and 7.4. The Terai region meets all these ideal conditions for mango cultivation. Rising temperatures during the colder months have led to increased yields; however, climate change has negatively influenced the flowering and fruiting cycles (Makhmale *et al.*, 2016). Moreover, proper irrigation and fertilizer application are crucial for maintaining productivity, as their absence results in lower yields (Panwar *et al.*, 2007).

### 2.2.4 Harvesting of Mango

To extend the shelf life and maintain the quality of fruits, careful handling is essential during harvesting, transport, storage, and packaging (Kitinoja and Kader, 2015). Mishandling during these stages can lead to bruises and physical damage. Ensuring the preservation of quality is particularly important for perishable produce like mangoes, especially during harvest and when transporting over long distances (Jedermann *et al.*, 2014).

Although initially more expensive, plastic crates are durable, reusable, easy to clean, well-ventilated, and suitable for stacking. They serve multiple purposes such as harvesting, storing, cooling, transporting, and even displaying fruits in retail markets. Cloth bags designed with openings at both ends and adjustable shoulder harnesses can be worn comfortably and help minimize fruit damage during harvesting (Kader, 2013). Using a long pole with a collection bag allows harvesters to pick fruits from tall trees without the need to climb. Additionally, to prevent fruits from damaging each other during transport, peduncles, woody stems, or spurs should be trimmed as closely as possible (Kader, 2013).

Fruits destined for fresh markets are typically hand-picked, while those meant for processing are often harvested using machines, as minor damage has little effect on processed products due to rapid handling (Kader, 2013). However, fruits are vulnerable to mechanical damage such as bruising, punctures, and scratches, which can significantly impact quality by increasing water loss, ethylene production, respiration, and susceptibility to decay (Kader, 2013).It is best to harvest during the coolest part of the day, usually early morning, and to pre-cool the fruits immediately after picking to remove field heat. Delays in cooling can reduce both shelf life and quality (Jacobi *et al.*, 2001). When harvesting mangoes, fruits should be handled gently, using clean, trimmed nails, and should not be wet from rain or dew. Mangoes can be removed by snapping, cutting, or carefully detaching them from the tree. After harvest, picking containers should be emptied promptly, and the fruits should be kept cool (Kader, 2002).

### 2.2.5 Uses of Mango

Mango (Mangifera indica) is a tropical fruit widely enjoyed for its rich flavor. It is also a valuable source of phytochemicals with strong antioxidant properties, including carotenoids, phenolics, and flavonoids (Makroo *et al.*, 2019). Often referred to as the "king of fruits," mangoes are among the most consumed fruits globally, second only to bananas (Torres-León et al., 2016). India leads the world in mango production, contributing around 18 million tons, which represents roughly 50% of global output (Lebaka *et al.*, 2021).

Mangoes are used throughout their development stages—from unripe to fully ripe—either in their natural form or as processed products. Since mangoes are seasonal, preservation is essential to ensure year-round availability. Common commercial mango products include pulp, puree, nectar, leather, pickles, and canned slices (Siddiq *et al.*, 2017). Typically, unripe mangoes are green and have a sour taste, except for a few varieties. In contrast, ripe mangoes are sweeter and serve as the main ingredient in many of the processed items mentioned above. Mature but unripe mangoes are rich in vitamins A and C(Medlicott and Thompson, 1985). They also offer numerous health benefits, such as preventing dehydration, aiding digestion, boosting immunity, and treating various illnesses (Deeksha and Sunita, 2020).

Processing fruits plays a vital role in preserving seasonal excesses, ensuring food availability during off-seasons, and providing a consistent supply of diverse food items throughout the year (Sinha *et al.*, 2012). To minimize postharvest losses and support the growth of the fruit processing industry, it is essential to focus on developing various value-added products and adopting suitable technologies (Vibhakar *et al.*, 1972).

### 2.2.6 Health Benefits of Mango

Abdalla *et al.* (2007) found that using both mango kernel extract and oil together provides strong antioxidant properties and helps extend the shelf life of edible oils such as sunflower oil. Additionally, this combination enhances the stability of both fresh and stored potato chips. The antioxidant activity of the combined extract and oil is significantly greater than when each is used individually, likely due to the synergistic effect of polyphenolics and phospholipids (Abdalla *et al.*, 2007). (Prabhu *et al.*, 2006) demonstrated that mangiferin, a mango-derived polyphenol, enhances mitochondrial energy metabolism by mitigating oxidative damage and exerts cardioprotective effects against isoproterenol-induced myocardial infarction in a murine model.

Some studies suggest that mango possesses anti-inflammatory and anti-allergic properties. For instance, mango stem bark extract showed anti-inflammatory effects in a rat model of Dextran sulfate sodium (DSS)-induced colitis (Márquez *et al.*, 2010). Furthermore, research by (Arbizu-Berrocal *et al.*, 2019) indicates that mango phenolic compounds may serve as promising anti-inflammatory agents for breast cancer prevention and as selective cytotoxic treatments that target cancer cells without harming healthy ones. Mango stem bark extract (Vimang) has traditionally been used in various countries to treat conditions such as menorrhagia, diarrhea, syphilis, diabetes, scabies, skin infections, and anemia (Scartezzini and Speroni, 2000). Rich in mangiferin, its primary active compound, the stem extract is also utilized as a nutritional supplement and has demonstrated multiple pharmacological properties, including antioxidant, analgesic, anti-diabetic, anti-inflammatory, antitumor, and anti-HIV activities (Guha *et al.*, 1996). Mango and its bioactive polyphenols exhibit notable anti-ulcer activity in addition to their antioxidant effects (Priya *et al.*, 2011). In a mouse model, pretreatment with an aqueous decoction (AD) of mango flowers significantly reduced gastric lesions and the gastric index caused by ethanol and HCl/ethanol in a dose-dependent manner. Moreover, it notably accelerated the healing of subacute gastric ulcers induced by acetic acid. These gastroprotective and ulcer-healing properties of AD provide strong scientific support for its traditional use in treating gastrointestinal disorders in the Caribbean (Lima *et al.*, 2006).

### 2.2.7 Varieties of mango

Over 500 varieties of the mango in various shapes and sizes exists today, with over 750 hybrid selections having been perfected over the years. In Nepal, the Terai regions of Siraha, Sarlahi, Mahottari, Sunsari, Jhapa, Kapilvastu and Morang are fertile breeding grounds.

Some hilly districts like Kavre and Dhading also produce this fruit, totaling Nepal's production to more than 140,000 megaton last year alone.

There are many types of mangoes available in the market. From the exotic Rajapuri to the home-grown Supariya, mangoes come in all shapes, sizes, and color. Some of the famous varieties found in Nepal are followings (Adak *et al.*, 2016);

- **Alphonso:** Produced during the mid-season, these mangoes are of the highest quality, and are equally expensive. They are used especially for canning, or pulping, and are mainly exported.

- **Maldaha:** These have a rich and a fleshy texture, and are found during the early monsoon months of April-June. Because of its wide availability and sweetness, this type is the most common.

- **Bombay:** This is another high-quality mango which can be found abundantly in the Nepali markets. They are bright yellow-orange in color and are produced between the early seasons of February-April.

- **Dussehri:** This variety is grown in the northern part of India and is one of the best varieties imported to Nepal. Their flesh is fibreless and this variety is available in the months of June-August.

### 2.2.8 History and general overview of jam

Jam is a semi-solid meal prepared by combining at least 45 parts by weight of fruit juice or pulp with 55 parts by weight of sugar. This substrate is concentrated to not less than 68.5% TSS. They can be made from single fruits or a combination of fruits. Flavoring and coloring may be added. Pectin and acid may be added to overcome the deficiencies in fruit itself. The acidity should be at least 0.5% but not greater than 1% (usually in the range of 0.6-0.8% but best at 0.75%). The materials required for its preparation are the fruit juice and pulp, sugar, pectin, acid, flavor and color (Hood, 2021). Good jam has a soft even consistency without distinct pieces of fruit, a bright color, a good fruit flavor, easy to spread semi-jellied texture without free liquid (Gupta *et al.*, 2016).

Historically, jams and jellies may have originated as an early effort to preserve fruits for consumption in the off-season. As sugar manufacture became more affordable, the popularity and availability of these fruit products increased. Jams in their various forms are probably the easiest by-products made of citrus fruits. The earliest published record of jelly making appeared in the later part of the 18th century (Vibhakara and Bawa, 2006c). The homemaker turned the process of making jams and jellies into an art form and used it to preserve fruit at the appropriate time of harvest. The public appears to frequently an associate sophistication with science when it comes to jam production. For example, factory made jam needs to meet certain requirements and criteria that are not necessary for homemade jam. It also need to have a firm consistency to survive handling during transportation and satisfy the needs of confectioneries (Vibhakara and Bawa, 2006c).

The consistency depends upon the presence of pectin. Hence, scientific jam manufacture is largely based on the correct application of knowledge about pectin and the laws governing the formation of the pectin-sugar-acid gel. Jam and jelly products were prepared with a high concentration of dissolved solids so that fermentation could not occur. However, only pectin and sugar are not sufficient for the formation of the products. Equally important is the acidity of the fruit, resulting in a definite equilibrium in the "pectin-acid-sugar" system (Mizrahi, 1979).

Based on the high solids-high acid principle, jam, jellies, fruit bars, and preserves are produced as significant fruit byproducts in businesses. Such fruit concentrates are a valuable way to use fruits in addition to being a means of fruit preservation. Not only do these preserved fruits have a delicious flavor, but they are also highly nutritious. Jams are of two kinds one prepared from a single fruit and another is prepared from a combination of two or more fruits. Realizing the importance of fruit, as a cheap, highly nutritious foodstuff and because of its perishable nature and seasonally availability, it was deemed necessary to make a preserved product for human consumption throughout the year (Vibhakara and Bawa, 2006c).

Standards for jams and preserves are similar to those for jelly except that fruits are used rather than fruit juice ingredients, and mint flavor and green coloring are not optional ingredients. The fruit mixture is concentrated by heat to such an extent that the total soluble solids content is not less than 65% for certain specified fruits and 68% for others (Thakur *et al.*, 1997).

## 2.3 Jam market size and trends

Nepal's domestic jam production largely takes place in small-scale and artisanal formats, often using locally sourced seasonal fruits. However, high production costs—stemming from imported equipment, smaller yields, and high overhead—translate to higher retail prices, even for locally made jams.

Jam products are sold across supermarkets like Bhat-Bhateni as well as local haat bazaars and online platforms. However, production and import costs, taxes, and smaller market scale drive prices up, which can limit consumption uptake.

Nepal's jam market, while not large in absolute terms, is growing within the broader spreads category that's forecast at about US $210 million in revenue for 2018, with steady growth expected ahead. Most brands are domestic and artisanal, catering to health-conscious and quality-driven consumers. Opportunities lie in natural, low-sugar formulations, local fruit sourcing, and affordable premium positioning. Key challenges include high local production costs, limited export scale, and price sensitivity among consumers (Friedman, 2019).

## 2.4 Product type and recipes

According to U.S. federal guidelines, jam must contain at least 45 parts of prepared fruit and 55 parts of sugar, concentrated to a solid content of 65% or more, resulting in a semi-solid consistency. Jellies are similar but made with 45 parts of clarified fruit juice instead of whole fruit, also requiring 55 parts of sugar and a minimum of 65% solids. Both jams and jellies may include up to 25% corn syrup as a sweetener and can contain added pectin and acid to help achieve the desired gel texture (Baker *et al.*, 2005).

Given the standards and the inclusion of soluble substances like pectin and acid, it becomes clear that the sugar level in jam or jelly must be sufficient to create a firm pectin-sugar-acid gel. Typically, about 3–5% of the total product weight comes from naturally occurring sugars, while approximately 65% of the content is added sugar. This ratio can vary depending on the type of jam or jelly the manufacturer is aiming to create. If the fruit used lacks sufficient pectin, acid, or both, or if there's less fruit overall in the recipe, additional pectin or acid may be necessary to ensure the final product gels properly (Raphaelides *et al.*, 1996).

Some typical recipes found useful in large-scale manufacture of jams mentioned by (Pokharel, 2024)are given below:

- To prepare jam, the requirement of pulp (fresh or canned) is 75 kg, with sugar 75 kg, citric acid 35 g, pectin 150 grade 565 g, and pineapple essence 75 ml.

- To prepare orange jam, 50 kg of lye peeled segments require 50 kg of sugar, citric acid 250 g, pectin 150 grade 375 g, and sweet orange essence 50 ml.

- To prepare mango jam, 40 kg of mango pulp requires sugar 40 kg, pectin 150 grade 500 g, citric acid 400 g, and mango essence 70 ml.

- To prepare apple jam, 40 kg of apple pulp requires sugar 44 kg, pectin 150 grade 400 g, citric acid 500 g, and apple essence 60 ml.

To make mixed fruit jam, a combination of fruits such as mango, pineapple, orange, apricot, papaya, and guava is used. An equal amount of sugar, based on the weight of the blended fruit pulp, is added along with citric acid at around 0.75–1.0% and pectin at about 0.5–1.0%, both calculated based on the pulp weight. These quantities may vary depending on the specific fruits used. Food-grade red coloring and a suitable essence can also be added for visual appeal and flavor enhancement (Barwal, 1999). Adjustments in the fruit-to-sugar ratio and acid levels may be necessary. Additionally, to enhance the taste, extra fruit flavors can be added in some cases (Garcıia-Viguera *et al.*, 1997).

A newer method for making jam and jelly involves using uncooked recipes, often referred to as freezer jams. This approach retains the fresh fruit taste without being affected by cooking or wine-like flavors. In this method, raw fruit is mixed with sugar, lemon juice, and pectin. The powdered pectin is typically dissolved in water first before being combined with the fruit mixture. It's important to stir thoroughly to ensure the sugar dissolves completely and to avoid a gritty texture. The mixture is then transferred into sealed plastic freezer containers or jars and left at room temperature to set, which can take up to 24 hours. Each brand of pectin usually includes specific instructions, with slight variations in preparation methods (Peckham, 1964b).

## 2.5 Gelling agent

Gelling agents have widespread application in the food industry across a variety of classic and innovative products, and their use is growing at a rapid pace in tandem with the rise in convenience foods. A perfect gelling agent should not alter the taste, smell, or flavor of the substance it is introduced to (Fishman and Jen, 1986). Improvements to existing and development of new ones require basic understanding of the processes of gelatin and the properties of gels at the molecular level (Multon, 1984).

Gels are a form of matter intermediate between a solid and a liquid. They consist of polymeric molecules cross-linked to form a tangled, interconnected molecular network immersed in a liquid medium (Vibhakara and Bawa, 2006c). The polymer network holds the water, preventing it from flowing away. The water, as a solvent, influences the nature and magnitude of the intermolecular forces that maintain the integrity of the polymer network; the polymer network holds the water, preventing it from flowing away in acid medium; pectin with sugar affects the pectin-water equilibrium and forms a network of fibers throughout the jelly (Mitchell and Blanshard, 1979). This structure is capable of supporting liquids. In gels, the molecules are held together by a combination of weak intermolecular forces such as hydrogen bonds, electrostatic forces, Vander Waals forces, and hydrophobic interactions. The cross-linkages are not point interactions but involve extensive segments from two or more polymer molecules, usually in well-defined structures called junction zones (Rees, 1969). The gelation process is essentially the formation of these junction zones (Fig.2.1).

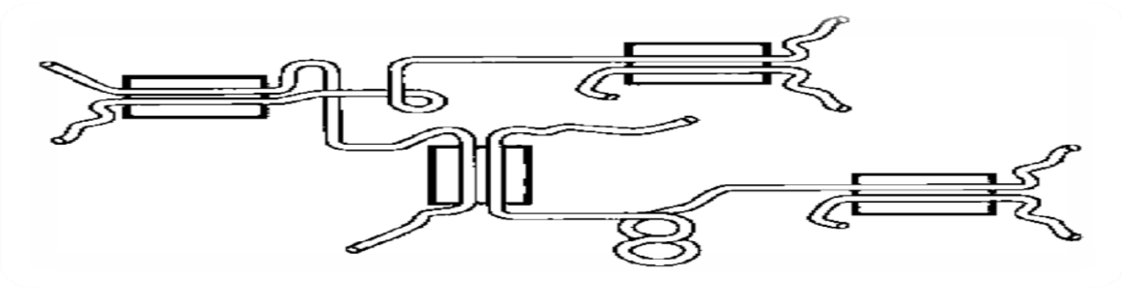

**Fig. 2.1** Gel Network

Source: Mitchell and Blanshard, (1979)

The physical characterizations of gel are the consequence of the formation of a continuous three-dimensional network of cross-linked polymer molecules on a molecular level; an aqueous gel consists of three elements (Jarvis, 1984).

1. Junction zones where polymer molecules are joined together.

2. . Inter-junction segments of polymers those are relatively mobile.

3. Water entrapped in the polymer network.

Gels are always formed in an aqueous environment. Thus, the interactions of protein and polysaccharides with water are by themselves important factors in the gelation process(Rees, 1969). Both types of polymers are strongly hydrated in aqueous solution, so that some water molecules are so tightly bound that they fail to freeze even at temperatures as low as -60ºC (Eagland, 1975). Although the formation of a stable intermolecular junction is a critical requirement for gelation, some limitation on the inter-chain association is also necessary to give a hydrated network rather than an insoluble precipitate (Axelos and Thibault, 1991).

It is important to know the condition for the onset of gelation in technological processes involving gelling food products. Several methods are used to characterize this change in consistency. Physically, the critical stage of gelation may be monitored from the loss of fluidity or from the rise of the elastic property of the growing network (Shomer, 1991). Table 2.3 gives different types of gelling agents used in the manufacture of jellies.

## 2.6 Pectin

Pectin is the most frequently used hydrocolloids in processed fruits. Jams and jellies are the major food type using larger amounts of pectin. Pectin is a class of complex hetero polysaccharides found in the cell walls of higher plants, where they function as a hydrating agent and cementing material for the cellulosic network (Mualikrishna and Tharanathan, 1994).

Pectin is primarily a polymer of D-galacturonic acid (homopolymer of [1→4] α-D-galactopyranosyluronic acid units with varying degrees of carboxyl groups methylated esterified) and rhamnogalacturonan (hetero polymer of repeating [1→2] α-l-rhamnosyl [1-l] α-D-galactosyluronic acid disaccharide units), making it an α-D-galacturonan. The molecule is formed by l-1, 4- glycosidic linkages between the pyranose rings of D-galacturonic acid units. As both hydroxyl groups of D-galacturonic acid at carbon atoms 1 and 4 are on the axial position, the polymer formed is 1, 4- polysaccharide (Oakenfull, 1991).

The most unique and outstanding property of pectin is their ability to form gel in the presence of $Ca^{2+}$ ions in sugar and acid solution (Halliday and Bailey, 1924). Esterification, attached chain of neutral sugars, acetylation, and cross-linking of pectin molecules also affect the texture of pectin gels (Guichard *et al.*, 1991). Pectin chains carry negative charge and the change in density is higher at higher pH and lower degree of methoxylation (DM) (Guichard *et al.*, 1991).

Depending on the DM, pectin are classified into:

1. Low methoxy (25–50%)
2. High methoxy (HM) (50–80%) pectin

In HM pectin, the effect of sugars depends specially upon molecular geometry of the sugar and the interactions with neighboring water molecules. Non-covalent forces (i.e. Hydrogen bonding and hydrophobic interactions) are believed to be responsible for gel formation in HM pectin. In LM pectin, gel is formed in the presence of $Ca^{2+}$, which acts as a bridge between pairs of carboxyl groups of pectin molecules. The two kinds of pectin are relatively stable at the low pH levels existing in jams and jellies (Pilgrim, 1991). HM pectin is used to form gels in acid media of high sugar content and LM pectin are used in products of lower sugar content(Axelos and Thibault, 1991). Pectin can be further divided into rapid-set, medium-set, and low-set pectin, depending upon the time the gel takes to set. The functionality of pectin molecules is determined by a number of factors, including DM and molecular size (Multon, 1984).

Guichard *et al.* (1991) investigated the composition of headspace, consistency, taste and flavor characteristics in jams made with different pectin. At usual concentration higher methoxylated pectin induced an undesirable modification of typical flavor and intensity of flavor and taste, whereas low methoxylated pectin induced few alternations. A fixed concentration and molecular weight, a disease in degree of esterification, produced a significant disease in consistency and noticeable modifications of the flavor perception but not taste alteration. Mechanical reduction of pectin molecular weight significantly modified only the consistency.

Pectin of 100–500 grades is available in the market. Their application as a food hydrocolloid is mainly based on their gelling properties (Voragen *et al.*, 1986). Selection of pectin for a particular food depends on many factors, including the texture required, Ph, processing temperature, presence of ions, proteins, and the expected shelf life of the product (Thakur *et al.*, 1997). Combinations of gelling agents are often used because a combination gives a desirable texture. For this reason, mixed systems are of great technological importance. The Physical chemistry of mixed system is obviously very complex. However, there has recently been significant progress in developing a suitable theoretical framework, at least for two component systems (Morris, 1986).

## 2.7 Sweetening agent

Sweeteners are used in fruit processing for many functional reasons as well as to impart sweetness. They add flavor, body, bulk, and control viscosity that contribute to texture and prevent spoilage. It binds moisture in fruits that is required by detrimental microorganism. Too little sugar prevents gelling and may allow yeast and mold growth. Sugar serves as a preserving agent and aids in gelling. Sucrose, commonly known as table sugar (or refined sugar), is the standard against which all sweeteners are measured in terms of quality, taste, and taste profile. However, glucose syrups have been widely used as a part of sugar source in recent years. An invert sugar component is necessary to prevent sucrose crystallization in high solids jellies and jams during storage. Such crystallization is rare in products containing less than 68% solids. If the concentration of sugar is high, the jelly retains less water resulting in a stiff jelly, probably because of dehydration (Yaseen *et al.*, 2018).

The optimum percentage of invert sugar is between 35% and 40% of the total sugar in the jam. During the process of inversion, molecular water is taken into the sugars; that is the reason why 95 parts of sucrose yield 100 parts of invert sugar (Hyvönen and Torma, 1983).

Desrosier and Desrosier (1977a) studied the rate of inversion is influenced by three factors:

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

During the process of boiling, sucrose undergoes chemical change. Cane and beet sugars are non-reducing sugars. However, when boiled with acid or treated with some enzymes, sucrose is converted into two reducing sugars, namely dextrose and levulose in equal parts. Sucrose has a molecular weight of 342, invert sugar 360, the difference of 18 being the molecular weight of water molecule added during inversion (Rees, 1969).

The characteristics of jelly with respect to different ºBrix values are as follows.

- 70ºBx- crystallization may occur
- 68ºBx- good texture of jelly
- 65ºBx- legal minimum
- 62ºBx- weak gel
- 60ºBx- no gel, viscous liquid

The same kinds of fruits may vary, not only in the amount but also in the kind of acid they contain. The H+ ion concentration is affected very considerably by buffering substances such as organic bases and inorganic and organic salts and is of the utmost importance in connection with fruit preservation and a determining factor in the formation of the pectin-sugar-acid gel (Sarower *et al.*, 2015b).

It has been found that gel formation occurs only within a certain range of hydrogen ion concentration, the optimum acidity Figure for ions and jellies being around pH 3.0. The gel strength fouls slowly on decreasing and rapidly on increasing the pH value. Beyond pH 4.0, no gel formation occurs in the usual soluble solid range. The pH value is also critical in determining the temperature at which jam/jellies set. Insufficient acidity is one of the common causes of jelly failure. The pH value of jam/jelly should be taken when the jam/jelly is concentrated sufficiently to pour. Different juices will require different amounts of additional acid depending upon the original acidity of the juice and buffering capacity of the juice. The pH may be adjusted to attain optimum flavor to control or modify the rate of setting and to modify the degree of sugar inversion (Smit and Bryant, 1968a).

Control of pH is critical to successful gel formation with pectin, particularly in the case of HM pectin. Low pH increases the percentage of unionized carboxyl groups, thus reducing electrostatic repulsion between adjacent pectin chains. Rapid-set pectin with high degree esterification will gel at higher pH than the one with lower degree esterification, slowest pectin; however, this difference is slight, with the optimum pH for slow-set pectin being about 3.1 and for rapid-set pectin being 3.4 (Crandall and Wicker, 1986). Substitution of other sugars for sucrose, by modifying hydrophobic interactions between chains, allows gels to be formed at somewhat higher pH. Since they rely on calcium bonding to effect gelation, low methoxy pectin can form gels at higher pH than high methoxy pectin. Gels can be made at pH values near neutrality (Chang and Miyamoto, 1992) which is advantageous in producing dairy-based products (Baker *et al.*, 2005).

### 2.8 Coloring agent

The color of jam is a factor of considerable importance(Abers and Wrolstad, 1979). A good jam should appeal to the eye as well as to the palate. No coloring is required for jams produced from fresh fruit, provided the boiling time is short and the heat not excessive. The natural color of the fruit is, however, always affected by presentation with $SO_2$ and in some cases by the process of boiling, necessitating the addition of artificial color. The aim should be to restore the original natural appearance. Only permitted edible food colors should be used. Coal tar colors are most frequently used to a lesser extent. It is essential that the colors should be intensive, readily soluble, and stand up to high concentration in solution. As a rule, acid colors are of higher stability than basic ones. Color should be acid proof; many are affected by acids and particularly by Sulphur dioxide present in glucose and fruit pulp. They must also excessive heat and should therefore be added at the last stage of the boiling process (Rees, 1969).

Traditionally, coal tar dyes have been used two-color jams and marmalades, particularly those prepared from sulfated fruit. Color testification of jams with natural colors, notably with anthocyanins from grape skins, is increasing as artificial additives become less acceptable to consumers (García-Viguera *et al.*, 1999). Colors available in powder form should be prepared just before the time of addition, since many colors have a tendency to precipitation standing. When dissolving, the color is mixed to paste with a little cold water then adding the required amount of boiling water and stirring well (Abers and Wrolstad, 1979).

### 2.9 Preservatives used in jam production

Preservatives play a vital role in maintaining the safety, quality, and shelf life of jam. During jam preparation, common preservatives include sugar, citric acid, and chemical preservatives like potassium metabisulphite (KMS) and sodium benzoate. Sugar acts as a natural preservative by binding water molecules, thus lowering water activity and inhibiting microbial growth. Citric acid is used to adjust the pH, creating an acidic environment that prevents spoilage and helps in gel formation with pectin. In commercial production, potassium metabisulphite is commonly added after cooling to prevent the growth of yeasts and molds, especially in light-colored jams, as it does not discolor the product. Sodium benzoate is another preservative used in acidic foods and is effective against fungi and some bacteria. The careful use of these preservatives ensures that jam remains safe to consume for an extended period while retaining its taste, texture, and nutritional value (Saad *et al.*, 2005).

### 2.10 Effect of time, temperature on during cooking of jam

Boiling is one of the most important steps in the Jam/jelly making process, as it dissolves the sugar and causes union of the sugar, acid, and pectin to form jam/jelly. It usually causes a coagulation of certain organic compounds that can be skimmed from the surface during boiling, and their removal renders the jelly clearer. The principal purpose of boiling is to increase the concentration of the sugar to the point where gelling occurs (Mudasir and Anju, 2018).

The boiling operation, while normally being a necessary step in jam/jelly making, should be as short as possible. Prolonged boiling results in loss of flavor, change in color, and hydrolysis of the pectin; consequently, it is a frequent cause of jelly failure (Vibhakara and Bawa, 2006c). In jam making, the fruits resistant to boiling are desirable to concentrate the product by evaporation of excess moisture. Boiling in commercial practice is usually conducted in open steam jacketed stainless steel kettles (Rees, 1969).

Boiling of the sugar solution in the presence of acid, results in inversion of some amount of cane sugar. Hence, a jam/jelly that is boiled for a long period is less liable to develop crystals of sucrose than a jelly boiled for a short time. Prolonged boiling may result in loss of flavor through evaporation, hydrolysis, or other forms of decomposition (Moyls *et al.*, 1962).

Sometimes jam is boiled in a vacuum pan at a lower temperature in the range of 65–76°C. The vacuum boiling or cooking minimizes the undesirable changes in color and prevents loss of vitamin C. However, the jam mixture has to be boiled for a long time to soften the fruit pieces resulting in some loss of flavor which can, however, be restored by recovering the volatile esters and putting them back into the jam (Basu and Shivhare, 2010). Proper control of boiling is necessary to avoid over concentration of soluble solids, over inversion of sugar, and hydrolysis of pectin (Lund, 1975).

## 2.11 Packaging materials used in jam production

Jams are stored in a wide range of shapes and sizes of containers. Glass is the usual material, although enamel-lined tin cans and special containers are also used (Mesallam, 1987). Glass jars with hermetically sealed lids are best for jam. A paraffin seal is insufficient to keep the product from spoiling. Container filled scalding hot (in excess of 83°C) need not be pasteurized, as the hot-filled jelly itself will sterilize the container. The jar should be filled to at least 90% full leaving not more than 1.25 cm head space. The scalded lids should be loosely placed on the containers immediately following filling, and then tightened firmly within 2-3 min. This allows time for exhausting of air from the head space. The steam in the head space condenses when the jelly cools, creating a vacuum seal. Capping with superheated steam injection is often used to attain a hermetic seal. Where the product is not filled sufficiently hot to ensure head space sterilization, or where superheated steam injection is not used, a post-capping sterilization treatment is employed. Some jellies form during boiling and filling a layer of bubbles on the surface of the jar of hot jelly. The jelly should be quickly skimmed while in the kettle just prior to pouring. If the jelly can be drawn from the bottom of the kettle, clear jelly can be filled into the jars (Meena and Meena, 2016).

If jelly is to be poured into glass jars, the sides of the jar should be smooth so that the jelly can be turned out without breaking its shape or structure. Before pouring the jelly, containers should be warmed to prevent breakage. After filling, the jars should be cooled rapidly to about 21°C. Pectin jellies set more quickly at this temperature than at lower temperatures. If the jelly fails to set or is weak, it is placed in a drier to evaporate the excess of water in it and promote setting (Meena and Meena, 2016).

Deterioration in storage is now largely prevented by hermetically sealing the jars, while still hot, in sterile manner using metal caps fitted with rubber gaskets. Many patented caps of this kind have been devised which can be placed in position, sterilized by steam jets in a steam box and, finally, held firmly by creating a partial vacuum in the head space of the jars, either in a specially constructed vacuumed chamber or merely by screwing them up tightly while still hot. Jars sterilized and sealed in this way form an ideally hygienic package and are to a very large extent independent of storage conditions (Morris, 1986). Two types of vacuum-sealed jars are in common use. In one of these, the seal between the glass and jar cover is made with a rubber composition ring attached to the cap. This composition melts during pasteurization, and after cooling of the jar and contents, it solidifies to form an airtight seal. The lid must be held in place with a clamp during pasteurization. The second type of jar is sealed with a rubber gasket similar to a fruit jar rubber, but this rubber is pressed against the side of the jar rather than the top. It is held in place by friction and the cap is rolled in much the same manner as an ordinary sanitary can top. The cap needs no clamp to hold it in place during pasteurization. A similar lid is pressed into position but is not rolled (Karim *et al.*, 2008).

## 2.12 Defects in jam

Different types of defects in jam are observed during jam making processes which are described in following paragraphs.

### 2.12.1 Failure of jam to set

#### 2.12.1.1 Lack of acid or pectin

A jam/jelly may fail to set due to lack of acid or pectin or of both in the fruit from which it is made. It may also fail to set due to insufficient cooking of the fruit resulting in inadequate extraction of pectin and acid (Basu and Shivhare, 2010).

#### 2.12.1.2 Addition of too much sugar

If sugar is added in excess amount, a syrupy or highly soft jelly may form. This can be corrected by adding a sufficient quantity of fresh juice rich in pectin (Raphaelides *et al.*, 1996).

#### 2.12.1.3 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 (Swer *et al.*, 2019).

#### 2.12.1.4 Cooking beyond the end point

If heating is continued beyond the end point, the jam/jelly becomes tough due to over concentration. This usually happens when the juice is rich in both acid and pectin, and enough sugar has not been added. If the acid is in excess, the pectin breaks down and consequently ropy syrup or a jelly with waxy consistency results (Swer *et al.*, 2019).

#### 2.12.1.5 Slow cooking for a long time

Since the coagulating proportion of pectin is destroyed when heated for a long time in the presence of acid, prolonged heating should be avoided (Thakur *et al.*, 1997) .

### 2.12.2 Cloudy or foggy jam

#### 2.12.2.1 Cloudy jam

This type of jam/jelly is formed if the juice or extract is not clarified (Swer *et al.*, 2019).

#### 2.12.2.2 Use of immature fruits

Green, immature fruit contain starch which is insoluble in juice and the jam/jelly made from them has, therefore, a cloudy appearance (Swer *et al.*, 2019).

#### 2.12.2.3 Over-cooking

Over-cooked jam/jellies are gummy and sticky and on account of their excessive viscosity, they do not become clear after they are poured into container (Swer *et al.*, 2019).

#### 2.12.2.4 Over cooling

When the jam/jelly is cooled too much, it becomes viscous and sometimes lumpy. Such a jam/jelly is almost cloudy (Swer *et al.*, 2019).

#### 2.12.2.5 Faulty pouring into containers

The jam/jelly should not be poured into containers from a great height because air gets incorporated into the mass, and the bubbles formed do not clear easily, especially when the jelly is well made and sets within a short period. The spout of the pouring vessel should not be more than about 2.5 cm from the top of the container (Swer *et al.*, 2019).

#### 2.12.2.6 Non removal of scum

The jam/jelly becomes cloudy also when the scum is not removed before pouring (Swer *et al.*, 2019).

#### 2.12.2.7 Premature gelation

If there is excess of pectin in the juice, it may cause premature gelation with the result that air may get trapped and thus make the jam/jelly opaque. There are four ways of avoiding premature gelation in the jelly. According to (Voragen *et al.*, 1986), they are:

a. Heating the solution to the boiling point only and then quickly pouring it into containers so as to shorten the time of contact between pectin, acid and sugar in the jelly-boiling kettle.

b. Eliminating the acid from the cooking batch and placing it in the container in the form of a concentrated solution prior to pouring in the jelly batch.

c. Working at low sugar concentration; and

d. Using relatively slow setting pectin

### 2.12.3 Formation of crystals

The formation of sugar crystals in a jam/jelly is caused by adding excess of sugar. It is also indication of over-concentration of the jam/jelly. In making a jam/jelly from fruits deficient in acid, the mixture should be boiled for a few minutes after adding the sugar so that the sugar is hydrolyzed adequately and it does not crystallize later. Crystals are cream of tartar sometimes separate out in grape jam/jelly. Although they are harmless, they spoil the appearance of the jam/jelly. The cream of tartar should be eliminated from the grape juice by cooling and settling the juice, and the treated juice only used for making the jam/jelly (Peckham, 1964b).

### 2.12.4 Syneresis or weeping of jam

The Phenomenon of spontaneous exudation of fluid from a gel is called syneresis or weeping of jam/jelly. It is caused by several factors.

#### 2.12.4.1 Excess of acid

Addition of excess of acid results in the breakdown of jelly structure owing to the hydrolysis of decomposition of pectin. Syneresis is more noticeable in tender jellies. It can be prevented by mixing either some quantity of juice low in acid or more of pectin so that a larger quantity of sugar can be added thereby increasing the volume of the jam/jelly and decreasing its acidity (Moyls *et al.*, 1962).

#### 2.12.4.2 Too low concentration of sugar or soluble solids

This cause the network of pectin to hold more liquid than it possibly can do under normal conditions (Swer *et al.*, 2019)

#### 2.12.4.3 Insufficient pectin

This results in the formation of a pectin network which is not sufficiently dense and rigid enough to hold the sugar syrup (Swer *et al.*, 2019)

#### 2.12.4.4 Premature gelation

This causes the network of pectin to break during the pouring of the jelly into the containers so that the jelly becomes weak and remain broken (Swer *et al.*, 2019). Syneresis in jam/jellies can be checked by adding a small proportion of buffer salts like sodium citrate, disodium hydrogen citrate, or even a small quantity of common salt (Swer *et al.*, 2019).

### 2.12.5 Fermented jam

While most jams and jellies have a high sugar content (65%) that inhibits all common kinds of development, fermented jams and jellies are frequently encountered. Fermentation usually takes place in these jam/jellies in which syneresis has taken place (Vibhakara and Bawa, 2006a). Storage in a damp place favors with the growth of molds even in jellies covered with a seal of paraffin wax. Molding may be due to several factors such as:

a. Not covering the jam/jelly properly

b. Not pouring paraffin wax sufficiently hot so as to kill mold and bacteria present at the surface of the jam/jelly, and

c. Breakdown of the wax seal.

Hermetically sealable glass jars and cans are best suited for packing jam/jellies and preventing mold growth inside the container (Ventura *et al.*, 2013).

### 2.13 Microbial spoilage of jam

Jams that have undergone syneresis undergo fermentation. Jams sealed with paraffin wax encourage the growth of mold when stored in a moist environment. Mold developed in jam due to several factors (Board, 2002).

1. Not covering the jam properly
2. Not pouring paraffin wax sufficiently hot so as to kill mould and bacteria present at the surface of the jelly, and
3. Breakdown of the wax seal.

Recent spoilage problems in jams include fermentation by *Torulopsis colliculosa* and *Torulopsis cantarellii.* Current interest in low-calorie foods has led to the production of lowsugar jams .These are prone to spoilage by XeroPhilic moulds and osmoPhilic yeast as their water activity is raised from 0.08 to 0.94 (Peckham, 1964a).

### 2.14 Physiochemical properties of jam

#### 2.14.1 TSS

One of the most important constituent of fruits is sugar which acts as a natural food preservative (Ahmed *et al.*, 2016).To retard microbial growth, Brix of 68±0.71 is recommended (Ahmed *et al.*, 2016). (Desrosier and Desrosier, 1977b) stated that the optimum solid range is slightly above 65% and it is also possible to have gel formation at 60% solids, by increasing the pectin and acid levels.

#### 2.14.2 Titratable acidity

Acidity gives imperative effect on the gelation property of pectin (Mizrahi, 1979). Several workers have reported a range of acidity with proper gelation properties. (Desrosier and Desrosier, 1977b) Argued that added acid should be adjusted to maintain proper pH range necessary for gel formation. (Yadav *et al.*, 2018) suggested a minimum of 0.65% acidity in table jelly crystals.

### 2.14.3 Reducing sugar

During the cooking process for the jam manufacturing, the sucrose underwent an inversion process, due to the acid medium, being prevent crystallization during the process (Damiani *et al.*, 2017). Egan et al. (1981) claimed that manufactures prefer the reducing sugar content to fall within the range of 20-40 (calculated as a percentage of preserve) in order to prevent separation of crystal during storage.

### 2.14.4 Ascorbic acid

Vitamin C i.e. ascorbic acid acts as antioxidant, it is important to know the amount present in a preparation to determine its quality (Siddiqui *et al.*, 2015). The naturally occurring antioxidants was significantly decreased during heating (Borrelli *et al.*, 2002). (Jawaheer *et al.*, 2003)concluded that there was 62.5% loss in ascorbic acid during processing of guava jam.

### 2.14.5 pH

The pH value is most important factor that should be monitored and controlled in jam processing. It has been found that gel formation occurs only within a certain range of hydrogen ion concentration, the optimum acidity Figure for ions and jellies being around pH 3.0. The gel strength fouls slowly on decreasing and rapidly on increasing the pH value. Beyond pH 4.0, no gel formation occurs in the usual soluble solid range (SMIT and BRYANT, 1968b). Low pH is required for food products like Jams in order to protect bacterial contamination and growth (Siddiqui *et al.*, 2015).

### 2.14.6 Moisture content

Moisture content decides the shelf life of the fruit and high moisture content of fruit is not desirable for jam production (Fellows, 2000). Fruit with a high moisture content needs a high temperature and a lengthy time to concentrate and reach the right brix value. Excessive temperatures during preparation or storage resulted in decreased quality and necessitated longer processing times and more energy at the industrial level. In the end, this high temperature technique led to Millard darkening and off flavor development (Bates *et al.*, 2001).

# Part III

## Materials and methods

### 3.1 Materials

### 3.1.1 Raw materials and sources

#### 3.1.1.1 Jackfruit (Artocarpus heterophyllus)

Yellowish green Jackfruit (Artocarpus heterophyllus) was brought from Central Campus of Technology having average weight 2.3 kg.

#### 3.1.1.1 Mango fruit (Mangifera indica)

Bombay green (*Mangifera indica*) variety, fresh and sound mango fruits having 92±5 g average weight was brought from Central Campus of Technology.

#### 3.1.1.2 Sugar

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

#### 3.1.1.3 Citric acid

The citric acid (reagents grade) was obtained from Central Campus of Technology laboratory.

#### 3.1.1.4 Pectin

The pectin was taken from Central Campus of Technology laboratory which was manufactured by Himedia Company, India. Pectin grade was found to be 150.

### 3.1.2 Chemicals, glass-wares and equipment

The names of chemicals, glass-wares and equipment were used for the lab work was provided by Central Campus of Technology laboratory and are listed on Appendix D.

### 3.1.3 Preservative

The preservative (Potassium Metabisulphite) of 200 ppm was taken from Central Campus of technology

### 3.1.4 Packaging material

Glass bottle used for packing of jam were brought from Central Campus of Technology laboratory store and local supermarket of Dharan.

## 3.2 Methods

### 3.2.1 Extraction of jackfruit pulp

The fully ripe, healthy and fresh jackfruit was cut into half lengthwise with the help of a knife, then into quarters. It was sorted, graded, and foreign materials and defective pieces were removed. Then seeds were removed and the obtained pulp were grinded finely with the help of electronic grinder from the laboratory of CCT, Dharan. A representative portion of the pulp was kept for physiochemical analysis. Jackfruit pulp was extracted as shown in figure 3.1.

Fresh Jackfruit

↓

Sorting and grading

↓

Cut into half and yellow bulbs are taken out

↓

Seed removal (manually)

↓

Blending (by electrical grinder)

↓

Fine Jackfruit pulp

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

**Fig 3.1** Preparation of jackfruit pulp

### 3.2.2 Extraction of mango pulp

The fully ripe, healthy and fresh mangoes were washed thoroughly with potable water, and mango was peeled off. Mangoes were sorted, graded, washed thoroughly with water to remove foreign materials and defective pieces. Then seeds of mangoes were removed and the obtained mango pulp were grinded finely with the help of electronic grinder from the laboratory of CCT, Dharan. A representative portion of the pulp was kept for physiochemical analysis. Mango pulp was extracted as shown in figure 3.2.

Fresh mango fruits
↓
Surface washing to remove surface microbes and adherent particles
↓
Sorting and grading
↓
Hand peeling
↓
Seed removal (manually)
↓
Blending (by electrical grinder)
↓
Fine mango pulp

**Fig 3.2** Preparation of mango pulp

Source: (Pokharel, 2024)

### 3.2.4 Process optimization in the preparation of mango and jackfruit jam

According to six different combinations of jackfruit and mango fruit pulp were tried at pectin content (1%) keeping the acidity level constant at 0.8% as shown in table. Based on sensory evaluation (color, flavor, texture, and overall acceptability), the best-judged jam was chosen. The recipe formulation for the preparation of jackfruit and mango jam is presented in Table 3.1.

**Table 3.1** Recipe formulation for the preparation of jackfruit and mango jam

| Sample | Jackfruit Pulp content(part) | Mango Pulp content(part) | Pectin content (%) | Acidity (% as citric acid) |
|---|---|---|---|---|
| A | 100 | 0 | 1 | 0.8 |
| B | 75 | 25 | 1 | 0.8 |
| C | 60 | 40 | 1 | 0.8 |
| D | 50 | 50 | 1 | 0.8 |
| E | 40 | 60 | 1 | 0.8 |
| F | 25 | 75 | 1 | 0.8 |

### 3.2.3 Preparation of jackfruit and mango jam

Jam was made using the pulp that was removed and that included no big particles. Jam was made with variations Jackfruit and Mango pulp. Fig 3.3 describes the flowchart of the preparation process.

Heating the extracted pulp

↓

Addition of 2/3 amount of calculated quantity of sugar

↓

Heating the content to higher temperature until it reaches 50° BX

↓

Addition of the remaining sugar and pectin mixture

↓

Boiling at high temperature (around 103-105°C)

↓

Addition of calculated amount of Citric acid

↓

Judging the end point (drop test, by refractometer)

↓

Hot filling into clean sterilized bottles (not less than 90°C)

↓

Storage at dry and cool temperature

↓

Sensory and lab analysis

Source; (Pokharel, 2024)

**Fig 3.3** General flowchart of Jackfruit and mango jam preparation

### 3.2.5 Analytical procedure

Although numerous writers have detailed various methods and parameters for analyzing jam, this study only determined those factors and related procedures that were viable in the laboratory. The test was carried out in triplicates.

#### 3.2.5.1 Determination of total soluble solids (TSS)

Total soluble solids were determined with the help of hand refractometer (0-30), (30-60) and (60-90) and the observed values were expressed as °Brix according to ((Ranganna, 1986).

#### 3.2.5.2 Determination of moisture content

Moisture content of the samples was determined according to (Feldsine *et al.*, 2002) by hot air oven method by using the gravimetric method.

#### 3.2.5.3 Determination of pH

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

#### 3.2.5.4 Determination of vitamin C

Vitamin C or ascorbic acid was determined by 2-6-dichloro-indophenol visual titration as per (Ranganna, 1986).

#### 3.2.5.5 Determination of titrable acidity

The titrable acidity was determined as per (Ranganna, 1986).

#### 3.2.5.6 Determination of reducing sugar

Reducing sugar was determined by Lane and Eynon method as described in (Ranganna, 1986). 2 gram of jam was dissolved in 100 ml distilled water. The burette was filled with this solution. 5 ml of Fehling A and 5 ml of Fehling B solution along with 10 ml of distilled water were taken in a conical flask. The flask was heated till boiling without disturbing the flask. Jam solution was added from the burette drop by drop while boiling till the color became brick red in the flask. A drop of methylene blue was added as an indicator in the boiling solution without shaking the flask. If color changed from red to blue for a moment, reduction was not complete and more jam solution was added till red color persisted.

#### 3.2.5.7 Determination of total sugar

The reducing sugar and total sugar of prepared mango jam was determined as per Lane and Eynon method as described in (Ranganna, 1986).

#### 3.2.5.8 Determination of non-reducing sugar

It was determined as per Lane and Eynon method as described in (Ranganna, 1986).

### 3.2.6 Sensory evaluation

Among the different treatments, the best one in terms of sensory quality was determined. For sensory evaluation 9 points hedonic rating (1= dislike extremely, 9= like extremely) method (Ranganna, 1986) was used. The semi-trained panelist members consisted of research students and faculties of Central Campus of Technology, Dharan who had some previous experience in the sensory evaluation. Using the ANOVA (no blocking) and LSD at 5% level of significance with the help of software GenStat 12th edition, version 12.1.0, 2009, the best product was determined. The sensory score card is presented in the Appendix A.

### 3.2.7 Statistical analysis

All the data obtained in this experiment were analyzed by using a statistical package . Sample means were compared by two-way ANOVA (No blocking) followed by LSD method at 5% level of significance. All the referencing of citations were done using Endnote X9.

# Part IV

## Results and discussion

A ripe jackfruit (*Artocarpus heterophyllus)* which outer skin turns from green to yellowish-brown was obtained from CCT. It was then sorted, graded and cut into lengthwise. Fully ripened fresh mangoes (*Mangifera indica*) were obtained from CCT, which were sorted, graded and washed in water. The pulp was extracted by hand pulping method and the so obtained pulp was blended in an electronic grinder to obtain the pulp. Thus, obtained pulp was used in the preparation of jam with variation in pulp content of the jam. Pectin content remains constant in each pulp content whereas acid was added at the constant amount of 0.8%. The six prepared samples were subjected for sensory analysis to study the effect of the pulp content and pectin variation on the sensory qualities. The selected best sample was studied further with analytical test with commercially available mango jam from the BBSM, Dharan.

### 4.1 Physiochemical analysis of raw materials

The result of the physiochemical analysis of the fresh mango pulp is shown in Table 4.1.

**Table 4.1** Physiochemical analysis of mango fruit pulp

| Parameters | Value ± SD |
|---|---|
| Moisture (%) | 80.36 ± 0.69 |
| TSS (ºBx) | 18 ± 0.02 |
| pH | 3.54 ± 0.03 |
| Titratable acidity (%) | 0.37 ± 0.016 |
| Reducing sugar (%) | 3.19 ± 0.18 |
| Non- reducing sugar (%) | 7.75 ± 0.82 |
| Vitamin C (mg/100gm) | 34.57 0.77 |

*Values in the table are the means of three determination ± standard deviation.

**Table 4.2** Physiochemical analysis of jackfruit pulp

| Parameters | Value ± SD |
|---|---|
| Moisture (%) | 75 ± 1.67 |
| Carbohydrate (% db) | 79 ± 1.24 |
| Protein (% db) | 3.1 ± 1.77 |
| Fat (% db) | 0.7 ± 0.04 |
| Crude fiber (% db) | 4.98 ± 0.2 |
| Ash (% db) | 3.7 ± 0.4 |
| TSS (ºBx) | 20 ± 1.64 |
| pH | 4.7 |
| Titrable acidity (% db) | 0.8 ± 0.002 |
| Reducing sugar (% db) | 4 ± 0.2 |
| Total sugar (% db) | 11 ± 0.64 |

*Values in the table are the means of three determination ± standard deviation.

The proximate composition of jackfruit pulp reflects its nutritional richness and suitability for product development. The pulp exhibited a moisture content of 75%, indicating high water activity typical of ripe tropical fruits Hussain *et al.* (2020). Similarly, carbohydrate was found to be 79% and protein was found to be 3.1%. Similar type of findings was reported by Ocloo *et al.* (2010). The fat content, crude fiber and ash content was found to be 0.7%, 4.98% and 3.7% . Eke-Ejiofor *et al.* (2014) reported that the fat content, crude fiber and ash content of jackfruit pulp to be 1.1%, 5.3% and 3.9 %. The total soluble solid was found to be 20 ºBx and pH was 4.7 as mentioned by Srinivasan (2010). The titrable acidity was found to be 0.8% which was slightly lower than the finding by Al-Amiri *et al.* (2009). Similarly total sugar and reducing sugar was found to be 11% and 4% which was according to the finding by Panesar *et al.* (2017).

## 4.2 Sensory Evaluation

Six different samples of mixed fruit (mango and jackfruit) jam were subjected for sensory evaluation. The samples were judged for color, flavor, texture and overall acceptability through hedonic rating method. The data obtained from sensory analysis were statistically analyzed using Two-way ANOVA (No blocking) and mean values are compared by using LSD at 5% level of significance.

### 4.2.1 Optimization of pectin content and pulp content

The ratio of pulp and sugar content in three different formulation and the use of pectin in two different formulations in the present work was set up keeping the acidity constant. The different formulations set up is shown in Table 3.1.

### 4.2.2 Sensory evaluation of samples of mango and jackfruit jams with different pulp variation (optimization of pulp content )

Statistical analysis using ANOVA (No blocking) followed by LSD (5%) was done to find out the difference between the formulations with respect to color, flavor, texture and overall acceptability for all samples which is shown in appendix C. The ANOVA table for sensory evaluation of different pulp content and pectin variation interaction is provided in Appendix B.

From Table in appendix C, in terms of superiority (at 5% level of significance) of the formulations with respect to color, flavor, texture and overall acceptability, following conclusions can be drawn:

#### 4.2.2.1 Color

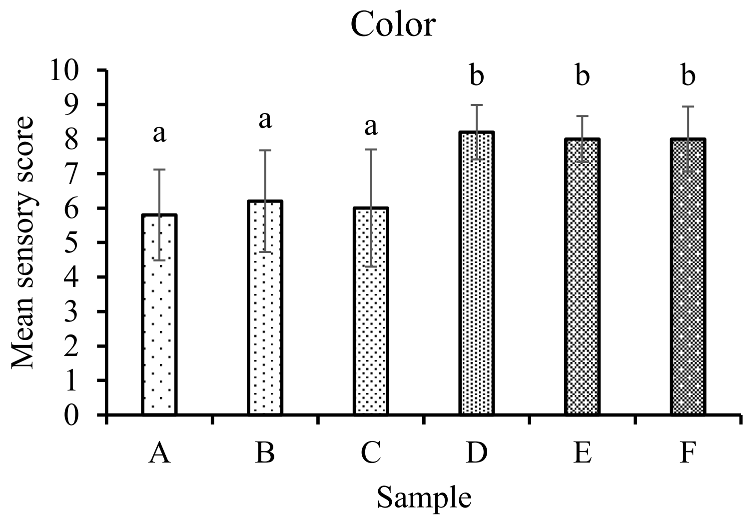


**Fig 4.1** Characteristics of product with respect to color

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 5 version 12.1. The mean sensory scores for color were 5.8, 6.2, 6, 8.2, 8 and 8 respectively for sample A, B, C, D, E, and F. The obtained means are represented as bar diagram in figure **4.1**. Letters on 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.

Sample D had the highest mean sensory score for colour out of the six samples (A to F), suggesting that the panelists found it to be the most visually pleasing. It differed considerably ($p < 0.05$) from samples A, B, and C, which scored lower, indicating less pleasant colour. Although moderately acceptable, Samples E and F were not as favoured as sample D.

The superior performance of sample D in terms of color could be attributed to the optimal combination of mango and jackfruit pulp, which provided a rich concentration of natural pigments such as carotenoids and flavonoids. Mango pulp contains high levels of carotenoids, which are responsible for the bright yellow to orange coloration (Manthey and Perkins-Veazie, 2009), while jackfruit pulp adds a golden hue, contributing to an attractive appearance. Since no artificial colorants were used in any sample, the differences in color were entirely due to variations in pulp concentration and composition.

#### 4.2.2.2 Flavor

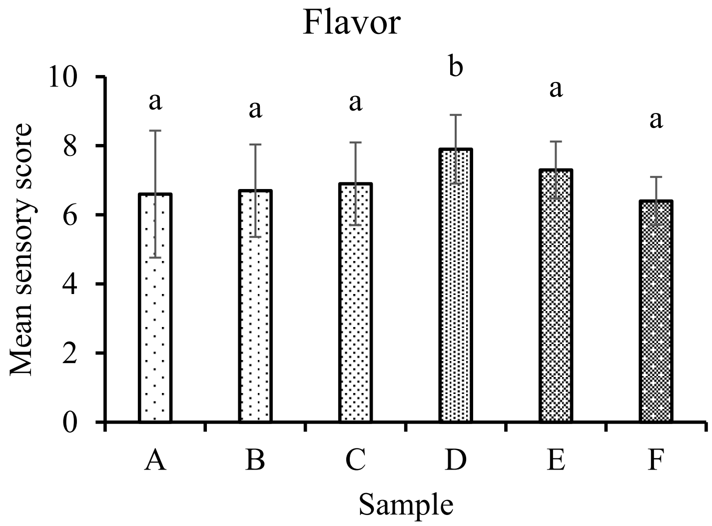


**Fig 4.2** Characteristics of product with respect to flavor

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 5 version 12.1. The mean sensory scores for flavor were 6.6, 6.7, 6.9, 7.9, 7.3 and 6.4 respectively for sample A, B, C, D, E, and F. The obtained means are represented as bar diagram in figure **4.2**. Letters on 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.

The sample D received the highest flavor score (~8.0), significantly different ($p < 0.05$) from other samples, as indicated by the different letter (b). This suggests that the formulation used in sample D, possibly with an optimal mango:jackfruit ratio, enhanced the overall flavor profile, making it more acceptable to the panelists. Samples A, B, C, E, and F were not significantly different from each other (denoted by 'a'), indicating that their flavor characteristics were perceived similarly.

The higher flavor score for Sample D may be attributed to an optimal mango-to-jackfruit ratio, which likely enhanced the sweetness, fruity aroma, and overall palatability of the jam.

Mango pulp is rich in volatile compounds, sugars, and acids that contribute significantly to flavor ARISE and Olaide (2020).

#### 4.2.2.3 Taste

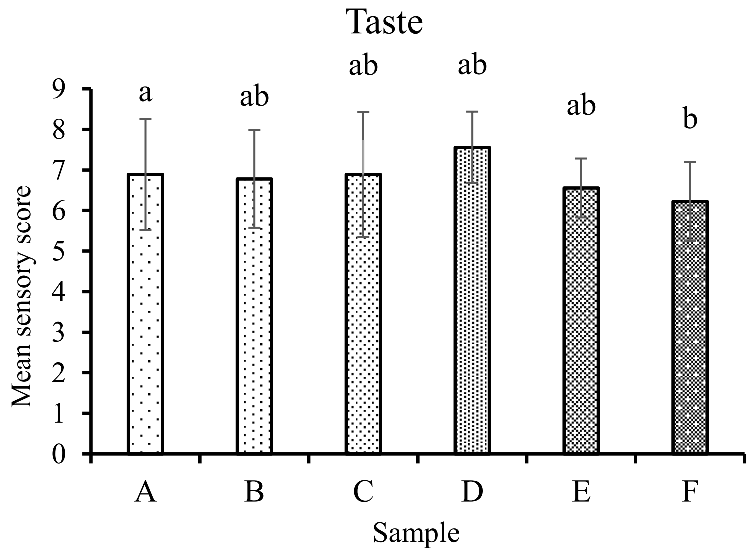


**Fig 4.3** Characteristics of product with respect to taste

The sensory score values of taste for all the samples were subjected to two-way ANOVA (No blocking) at 5% level of significance using Genstat 5 version 12.1. The mean sensory scores for taste were 6.6, 6.7, 6.9, 7.9, 7.3 and 6.4 respectively for sample A, B, C, D, E, and F. The obtained means are represented as bar diagram in figure **4.3**. Letters on 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 highest score was observed for sample D, followed closely by samples A, B, C, and E, all of which showed no significant difference in taste (denoted by 'a' and 'ab'). However, Sample F received a significantly lower taste score (grouped under ‘b’), indicating less acceptability in terms of taste compared to other formulations.

The differences in taste scores may be attributed to variations in mango and jackfruit pulp ratios, as the sweetness, acidity, and aromatic compounds differ between the two fruits. Mango pulp contains high levels of sugars, citric acid, and aromatic esters, which are known to enhance taste acceptability Borges *et al.* (2010). Sample F likely had either excessive jackfruit or reduced mango content, which may have led to a dominant musky or bland flavor, affecting overall taste perception (González-Molina *et al.*, 2009).

#### 4.2.2.4 Texture

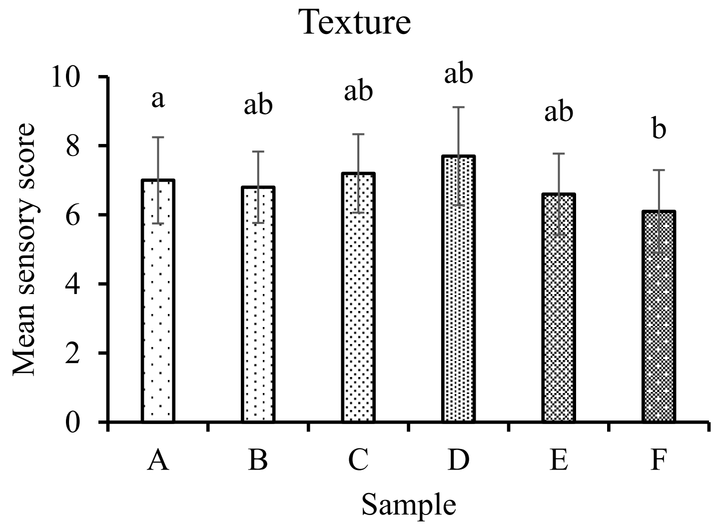


**Fig 4.4** Characteristics of product with respect to texture

The sensory score values of texture for all the samples were subjected to two-way ANOVA (No blocking) at 5% level of significance using GenStat 5 version 12.1. The mean sensory scores for texture were 7, 6.8, 7.2, 7.7, 6.6 and 6.1 respectively for sample A, B, C, D, E, and F. The obtained means are represented as bar diagram in figure **4.4**. Letters on 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.

The highest score was observed for Sample D, exhibiting the perfect mouthfeel and gel firmness. Samples A, B, and C likely suffer from textural defects like excessive softness or syneresis. Intermediate samples E and F denoted by ("bc", "cd") show partial letter overlap, indicating they share some textural similarities but fail to match the balanced quality of sample D.

The texture variations likely result from differences in pectin interactions between mango and jackfruit, fiber content, and processing conditions. Mango's high pectin content may enhance gel formation when properly balanced with jackfruit's fibrous texture (Al-Sharify *et al.*, 2025). The lower performance of Sample F could stem from improper fruit ratios, inadequate pectin activation, or processing issues affecting the gel network (Maryani *et al.*, 2023). These findings emphasize how formulation adjustments and process optimization can improve texture in composite fruit jams, particularly when combining fruits with distinct structural properties like mango and jackfruit (Nansereko and Muyonga, 2021).

#### 4.2.2.5 Overall acceptance

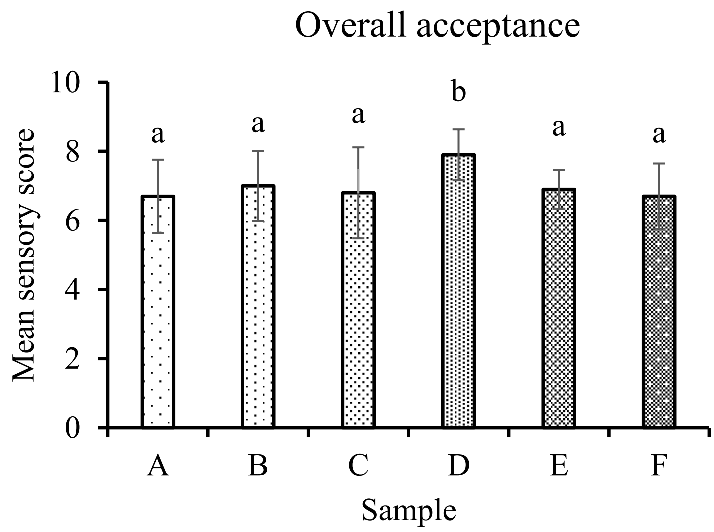


**Fig 4.5** Characteristics of product with respect to overall acceptance

The sensory score values of overall acceptance for all the samples were subjected to two-way ANOVA (No blocking) at 5% level of significance using Genstat 5 version 12.1. The mean sensory scores for overall acceptance were 6.7, 7, 6.8, 7.9, 6.9 and 6.7 respectively for sample A, B, C, D, E, and F. The obtained means are represented as bar diagram in figure **4.5**. Letters on top of the bar diagram in Fig **4.5** 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.

The sensory analysis revealed Sample D was highest in overall acceptance, achieving the highest preference scores (denoted by 'b'). This formulation demonstrated ideal sensory characteristics, successfully balancing the sweet-tart flavor profile of mango with the distinctive tropical notes of jackfruit while maintaining perfect texture (Mondal and Rahim, 2015). Samples A, B, C, and E showed statistically comparable acceptance levels (denoted by 'a' ), indicating they were nearly as well-liked as sample D, though with minor but non-significant differences in flavor balance or mouthfeel. Sample F exhibited significantly lower sensory acceptance, as indicated by 'a'. The reduced preference for this sample may be attributed to several potential factors, such as an unbalanced ratio of mango and jackfruit pulp leading to an undesirable flavor profile, textural shortcomings like grittiness or an improper gel structure, or processing-related flaws affecting visual appeal or aroma (Meilgaard *et al.*, 2007).

## 4.3 Physiochemical analysis of best sample

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

**Table 4.3** Physiochemical analysis of best jam sample and commercial mixed fruit jam from BBSM, Dharan.

| Parameters | Best sample (%) | Commercial mixed fruit jam (%) |
|---|---|---|
| TSS (ºBx, wb) | 68 | 68 |
| Acidity (% citric acid) | 1.34 ± 0.1 | 0.67 ± 0.04 |
| Moisture content (%) | 28 ± 0.03 | 30 ± 0.04 |
| Reducing sugar (dextrose anhydrous) | 30 ± 0.4 | 37 ± 0.02 |
| pH | 3.3 | 3.4 |
| Vitamin C (mg/100 gm) | 17.28 ± 0.5 | 16.45 ± 0.4 |
| Non reducing sugar | 43 ± 0.8 | 52.4 ± 0.06 |
| Total sugar | 73 ± 0.57 | 89.4 ± 0.77 |

*Values in the table are the means of three determination ± standard deviation

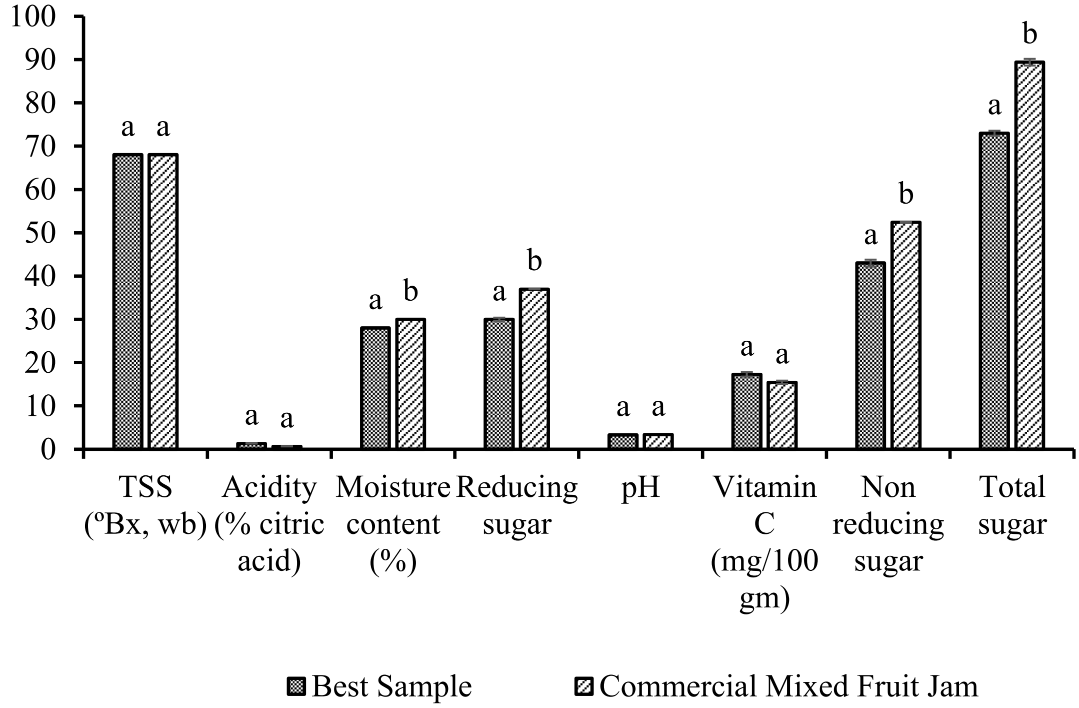


**Fig. 4.6** Physiochemical analysis representation of best sample and commercial sample in bar diagram

The physiochemical analysis of best judged product and commercial mixed fruit jam was carried out. The result is interpreted on bar diagram in figure no. 4.6. The same letter on the bar represents no significant differences between the samples and different letters represents significant differences among the samples. The result was further subjected to paired t-test. The result of the paired test is presented on appendix E. During observations, there were no significant differences in TSS, titratable acidity, % and vitamin c content (mg/100 gm) among the best judged sample and the commercial mixed fruit jam. However, significant differences in moisture content, reducing sugar, non-reducing sugar and total sugar among the samples were observed. The paired t-test (5% threshold of significance) revealed significant variation in physiochemical parameters between the samples. The findings show that the current work can be applied on a commercial scale to produce jam of comparable quality to what is already available on the market.

### 4.3.1 Total soluble solids

TSS of the jam was found to be 68 ºBrix. Researchers and various authorities discussed and classed jams based on their soluble solids levels. (Karel *et al.*, 1975) stated that the optimum solid range is slightly above 65%. Gel formation can also be achieved at 60% solids by increasing the pectin and acid levels.

### 4.3.2 Acidity

Titratable acidity of mixed fruit (mango and jackfruit) jam after preparation was found to be 1.34% (as citric acid). The acidity in jams was reported in the range of 0.8– 1.4 mg/100 g by previous study (Yahia, 2011). Because the acidity of the source material (mango and jackfruit fruit pulp) was low, citric acid was added to ensure adequate gelation. Several workers have reported a range of acidity with proper gelation properties. (Karel *et al.*, 1975) argued that added acid should be adjusted to maintain proper pH range necessary for gel formation. (Prakash and Priya, 2016) suggested a minimum of 0.65% acidity in the table jelly crystals.

### 4.3.3 pH

pH value of the mixed fruit (mango and jackfruit) jam was found to be 3.3. Gel production has been discovered to occur within a specific range of hydrogen ion concentration, with the ideal acidity level for ions and jellies being approximately pH 3.0. The gel strength falls slowly on decreasing and rapidly on increasing the pH value. Beyond pH 4, no gel formation occurs in the usual soluble solid range (Doesburg and Grevers, 1960).

### 4.3.4 Reducing sugar

Reducing sugar was found to be 30%. This result was in agreement with previous study (26.13%–35.70%) of the jams from mixed varieties of jackfruit and mango (Kansci *et al.*, 2003). (Sarower *et al.*, 2015a) claimed that manufacturers prefer the reducing sugar content to fall within the range of 20-40 (calculated as a percentage of preserve) in order to prevent separation of crystals during storage. The present usage of glucose syrups in jams and jellies greatly minimizes the likelihood for crystallization.

### 4.3.5 Total sugar

Total sugar of the mixed fruit (mango and jackfruit) jam was found to be 73%. Total sugar content was reported in a range of 38.86%–80.53% by previous report (Ahmmed *et al.*, 2015). The values of total sugars in all jam sample were higher than in fresh fruits, mainly due to addition of sugar and thermal processing. Sugar is a key component of fruit products, serving as a natural food preservative (Davidova *et al.*, 2024). Choosing jams with lower sugar content or opting homemade versions allows for better control over our sugar intake while still enjoying the delightful taste of fruity spreads.

### 4.3.6 Vitamin C

Vitamin C content of the mixed fruit (mango and jackfruit) was found to be 17.28 mg/100 gm of jam. The vitamin C in mango mixed with jackfruit jams was reported in the range of 15.8–33.57 mg/100 g by previous researchers (Hada and Singh, 2018) and the result obtained in this study was within the range of reported study. The heat processing of the jam resulted in a lower vitamin C content than that of the fresh fruits. The high temperature causes ascorbic acid to oxidize more quickly to dehydroascorbic acid, which is next hydrolyzed to 2,3diketogulonic acid and finally polymerized to other nutritionally inactive substances (Chuah *et al.*, 2008).

### 4.3.7 Moisture content

Moisture content of the mixed fruit (mango and jackfruit) jam was found to be 28%. High sugar content makes the moisture not available as free water; this bounded water may not readily available for microbial growth and prolong the shelf life of the jam. So, low moisture content is preferred for stable storage of jam (Kaur *et al.*, 2024).

# Part V

## Conclusions and Recommendations

### 5.1 Conclusions

The objectives and results of my study led me to develop the following conclusions:

1. The TSS, titratable acidity, moisture content, reducing sugar and total sugar of jackfruit pulp was found to be 20ºBx, 0.8%, 75%, 4%, 11% and 34.57mg/100gm respectively.
2. The TSS, titratable acidity, moisture content, reducing sugar, total sugar and vitamin C content of mango pulp was found to be 18ºBx, 0.37%, 80.36%, 3.19%, 10.94% and 34.57mg/100gm respectively.
3. According to sensory analysis, jam with 50-50% mango and jackfruit pulp content and 1% pectin was judged best and significant differences were observed among the samples by statistical analysis.
4. The TSS, titratable acidity, moisture content, reducing sugar, total sugar and vitamin c content of best judged sample were found to be 68ºBx, 1.34%, 28%, 30%, 73% and 17.28 mg/100gm respectively.
5. During observations, there were no significant differences in % titratable acidity, vitamin C content (mg/100 gm), and TSS among the best judged sample and the commercial mixed fruit jam. However, significant differences in % moisture content and total sugar between the samples were observed.

### 5.2 Recommendations

On the basis of present study, following recommendations can be made for the future study on mango jam:

1. Effect of storage on overall physiochemical properties of mango incorporated jackfruit jam could be studied.
2. A shelf-life study on mango jam examining the finest items in various packaging materials with appropriate preservatives could be examined

# PART VI

## Summary

Jackfruit and mango production in Nepal has increased significantly, supporting both domestic use and export potential. These fruits, commonly grown in various regions, are rich in flavor and nutrients. To utilize seasonal abundance and reduce postharvest loss, jackfruit incorporated mango jam was developed using fresh jackfruit and mangoes from the Central Campus of Technology. The jackfruit pulp had 20°Bx TSS, 0.8% acidity, 75% moisture, 4% reducing sugar, and 11% total sugar. Mango pulp showed 18°Bx TSS, 0.37% acidity, 80.36% moisture, 3.19% reducing sugar, 10.94% total sugar, and 34.57mg/100g vitamin C.

Jams were prepared with different jackfruit-to-mango pulp ratios (100:0 to 25:75), with 1.0% pectin and 0.8% acid added to all samples. Among them, the 50:50 pulp ratio was best rated in sensory evaluation. The physicochemical properties of this sample were: 68°Bx TSS, 1.34% acidity, 28% moisture, 30% reducing sugar, 73% total sugar, 17.28mg/100g vitamin C, and pH 3.3. These results indicated a balanced product with favorable taste and nutritional content.

A commercial mixed fruit jam from BBSM, Dharan was analyzed for comparison, showing 68°Bx TSS, 0.67% acidity, 30% moisture, 37% reducing sugar, 89.4% total sugar, 16.45mg/100g vitamin C, and pH 3.4. A paired t-test revealed no significant difference in total sugar, vitamin C, acidity, and reducing sugar between the samples. Thus, jackfruit incorporated mango jam can serve as a nutritious, value-added product that supports local fruit utilization and offers income opportunities for Nepalese farmers.

## Reference

Abdalla, A. E. M., Darwish, S. M., Ayad, E. H. E. and El-Hamahmy, R. M. (2007). Egyptian mango by-product 2: Antioxidant and antimicrobial activities of extract and oil from mango seed kernel. *J. Food. chemistry*. **103** (4), 1141-1152.

Abers, J. E. and Wrolstad, R. E. (1979). Causative factors of color deterioration in strawberry preserves during processing and storage. *Journal. of. Food. Sci*. **44** (1), 75-81.

Adak, T., Kumar, K. and Singh, V. K. (2016). An appraisal of seasonal variations in thermal indices, heat and water use efficiency in mango. *J Kumar-Rao, R., Sharma, PK, Jirli, B. y Raghuraman, M., Climate change its implications on crop productionfood security*. 183-188.

Ahmed, A., Ali, S. W., Rehman, K. u., Manzoor, S., Ayub, S. R. and Ilyas, M. (2016). Influence of sugar concentration on physicochemical properties and sensory attributes of sapodilla jam. *J. PeerJ PrePrints*. **4**, e1777v1771.

Ahmed, J., Ramaswamy, H. S. and Hiremath, N. (2005). The effect of high pressure treatment on rheological characteristics and colour of mango pulp. *J. International. Food. Sci. Technol.* **40** (8), 885-895.

Ahmed, K., Malek, M., Jahan, K. and Salamatullah, K. (1986). Nutritive value of Food Stuff 3rd edn Institute of Nutrition and Food Science. *J. University. Dhaka. Bangladesh*. 16-17.

Ahmmed, L., Islam, M. N. and Islam, M. S. (2015). A quantitative estimation of the amount of sugar in fruits jam available in Bangladesh. **3** (5), 52-55.

Al-Amiri, H. A., Al-Otaibi, J. A., Al-Foudari, M. Y. and Heji, A. H. B. (2009). The nutritive value of selected commonly consumed Kuwaiti dishes. **60** (8), 668-676.

Al-Sharify, Z. T., Al-Najjar, S. Z., Anumudu, C. K., Hart, A., Miri, T. and Onyeaka, H. (2025). Non-Thermal Technologies in Food Processing: Implications for Food Quality and Rheology. **15** (6).

Arbizu-Berrocal, S. H., Kim, H., Fang, C., Krenek, K. A., Talcott, S. T. and Mertens-T., S. U. (2019). Polyphenols from mango (Mangifera indica L.) modulate PI3K/AKT/mTOR-associated micro-RNAs and reduce inflammation in non-cancer and induce cell death in breast cancer cells. *Journal of Functional Foods*. **55**, 9-16.

ARISE, A. K. and Olaide, A. (2020). 13 Understanding sensory evaluation of food. 345.

Axelos, M. A. V. and Thibault, J.-F. (1991). The chemistry of low-methoxyl pectin gelation. *J. The. chemistry. technol. of. pectin*. **6**, 109-118.

Babitha, S., Sandhya, C. and Pandey, A. (2003). Natural food colourants. *Appl. Bot. Abstracts*. **23** (4), 258–266.

Baker, R. A., Berry, N., Hui, Y. H. and Barrett, D. M. (1996). Fruit preserves and jams. *J. Biol. Principles. Applications*. **1**.

Baker, R. A., Berry, N., Hui, Y. H. and Barrett, D. M. (2005). Fruit preserves and jams. *J. Processing Fruits: Sci.Technol.*

Baltazar, E. J. S. F., La Union, Philippines. (1984). A handbook of philippine crops. *J. San. Fernando. La. Union. Philippines*. 76-80.

Barwal, V. S. (1999). Development and significance of low calorie fruit products. *The Indian J. of Nutr. Dietetics*. 378-383.

Basu, S. and Shivhare, U. S. (2010). Rheological, textural, micro-structural and sensory properties of mango jam. *J. Food. Engineering*. **100** (2), 357-365.

Bates, R. P., Morris, J. R. and Crandall, P. G. (2001). "Principles and practices of small- and medium-scale fruit juice processing". Food & Agriculture Org. [9251046611].

Bhatia, B. S., Siddappa, G. S. and Lal, G. (1955). Composition and nutritive value of jack fruit. *Indian J. Agric. Sci.* **24** (4), 30-36.

Board, N. (2002). Jam, jelly and marmalade. *J. Hand Book on "fruits, vegetables food processing with canning preservation". Asia Pacific Business Press Inc. Delhi. Pp* 238-252.

Borges, G., Mullen, W. and Crozier, A. (2010). Comparison of the polyphenolic composition and antioxidant activity of European commercial fruit juices. **1** (1), 73-83.

Borrelli, R. C., Visconti, A., Mennella, C., Anese, M. and Fogliano, V. (2002). Chemical characterization and antioxidant properties of coffee melanoidins. *Journal. of. agric. food. chem.* **50** (22), 6527-6533.

Chang, K. C. and Miyamoto, A. (1992). Gelling characteristics of pectin from sunflower head residues. *Journal. of. food. sci*. **57** (6), 1435-1438.

Chapagain, T. R., Karki, T. B., Shah, P., Acharya, G. D., Gyeltshen, K., Islam, M. R. and Hossain, M. B. (2022). Climate-Smart Agriculture Technologies and Practices in Nepal.

Chuah, A. M., Lee, Y.-C., Yamaguchi, T., Takamura, H., Yin, L.-J. and Matoba, T. (2008). Effect of cooking on the antioxidant properties of coloured peppers. **111** (1), 20-28.

Crandall, P. G. and Wicker, L. (1986). Pectin internal gel strength: theory, measurement, and methodology. *In*.). ACS Publications. [1947-5918].

Crane, J. H., Balerdi, C. F. and Campbell, R. J. (2002). The Jackfruit (Artocarpus heterophyllus Lam.) in Florida. *J. University. Florida. IFAS. Extension. Fact. Sheet. HS-882*.

Damiani, C., Silva, E. P., Becker, F. S., Endrigo, D. E., Asquieri, E. R., da Silva, F. A. and Boas, E. V. d. B. V. (2017). Antioxidant potential of marolo jam (Annona crassiflora Mart) during storage. *J. Open. Access. Library. Journal*. **4** (5), 1-12.

Davidova, S., Galabov, A. S. and Satchanska, G. (2024). Antibacterial, antifungal, antiviral activity, and mechanisms of action of plant polyphenols. **12** (12), 2502.

Deeksha, K. and Sunita, M. (2020). Utilization of mango and its by-products by different processing methods. *J. Sci. Technol* **9**, 8896-8910.

Desrosier, N. W. and Desrosier, J. (1977a). "The technology of food preservation".[0870552325].

Desrosier, N. W. and Desrosier, J. N. (1977b). "The technology of food preservation".[0870552325].

Devkota, S. (2016). Government policies and periodic plan along with statistical data and pocket area of different commercial fruits grown in Nepal. *%J. Institute. of. Agric. Animal. S.,Rampur,Chitwan*.

Doesburg, J. and Grevers, G. (1960). Setting time and setting temperature of pectin jellies. **25** (5), 634-645.

Eagland, D. (1975). Nucleic acids, peptides, and proteins. *In:* "Water A Comprehensive Treatise: Aqueous Solutions of Amphiphiles and Macromolecules".). pp. 305-518. Springer.

Eke-Ejiofor, J., Beleya, E. and Onyenorah, N. (2014). The effect of processing methods on the functional and compositional properties of jackfruit seed flour. **3** (3), 166-173.

Elevitch, C. R. and Manner, H. I. (2006). Artocarpus heterophyllus (jackfruit). *J. Species. Pacific. Island. Agroforestry*. **10**, 1-25.

Feldsine, P., Abeyta, C. and Andrews, W. H. (2002). AOAC International methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. *.J. Journal. of. AOAC. international*. **85** (5), 1187-1200.

Fellows, P. (2000). Food processing technology: principles and practice.

Fishman, M. L. and Jen, J. J. (1986). "Chemistry and function of pectins". ACS Publications. [084120974X].

Friedman, K. (2019). Market Trends. **81**.

García-Viguera, C., Zafrilla, P., Romero, F., Abellán, P., Artés, F. and Tomás-Barberán, F. A. (1999). Color stability of strawberry jam as affected by cultivar and storage temperature. *J. Journal. of. Food. Sci*. **64** (2), 243-247.

Garcıia-Viguera, C., Zafrilla, P. and Tomás-Barberán, F. A. (1997). Determination of authenticity of fruit jams by HPLC analysis of anthocyanins. *Journal of the Sci. of Food. Agric.* **73** (2), 207-213.

González-Molina, E., Moreno, D. A. and García-Viguera, C. (2009). A new drink rich in healthy bioactives combining lemon and pomegranate juices. **115** (4), 1364-1372.

Griesbach, J. (2003). "Mango growing in Kenya". World Agroforestry Centre. [9290591498].

Guha, S., Ghosal, S. and Chattopadhyay, U. (1996). Antitumor, immunomodulatory and anti-HIV effect of mangiferin, a naturally occurring glucosylxanthone. *J. Chemotherapy*. **42** (6), 443-451.

Guichard, E., Issanchou, S., Descourvieres, A. and Etiévant, P. (1991). Pectin concentration, molecular weight and degree of esterification: influence on volatile composition and sensory characteristics of strawberry jam. *J. of. Food. Science*. **56** (6), 1621-1627.

Gupta, E., Purwar, S., Jaiswal, P., Chaturvedi, R. and Rai, G. K. (2016). Sensory evaluation and nutritional composition of developed papaya-gooseberry jam. *J. Food. Nutrition. Sci.* **7** (7), 600-608.

Gyawali, P., Bhandari, S. and Shrestha, J. (2022). Journal of Agriculture and Food Research. *J.Agric.Food.Research*. **7**, 100278.

Hada, T. S. and Singh, A. K. (2018). Evaluation of mango (Mangifera indica L.) cultivars for physical characteristics and quality parameters of fruit under Indo-Gangetic Plains. **6** (2), 2560-2563.

Halliday, E. G. and Bailey, G. R. (1924). Effect of Calcium Chloride on Acid-Sugar-Pectin Gels. *J. Industrial. Engineering. Chem.* **16** (6), 595-597.

Honja, T., Geta, E. and Mitiku, A. (2016). Mango Value Chain Analysis: The Case of Boloso Bombe Woreda, Wolaita Zone, Southern Ethiopia. *J. Developing. Country. Studies*. **6** (1), 103-123.

Hood, S. B. (2021). "Jam, Jelly and Marmalade: A Global History". Reaktion Books. [178914390X].

Hossain, M. A., Evan, M. S. S., Moazzem, M. S., Roy, M. and Zzaman, W. (2020). Response surface optimization for antioxidant extraction from jackfruit (Artocarpus heterophyllus Lam.) seed and pulp. *J.Scientific. Research*. **12** (3), 397-409.

Hussain, S., Jõudu, I. and Bhat, R. (2020). Dietary fiber from underutilized plant resources—A positive approach for valorization of fruit and vegetable wastes. **12** (13), 5401.

Hyvönen, L. and Torma, R. (1983). Examination of sugars, sugar alcohols, and artificial sweeteners as substitutes for sucrose in strawberry jam. Product development. **48** (1), 183-185.

Islam, M. K., Khan, M. Z. H., Sarkar, M. A. R., Absar, N. and Sarkar, S. K. (2013). Changes in acidity, TSS, and sugar content at different storage periods of the postharvest mango (Mangifera indica L.) influenced by Bavistin DF. *International. J. Food. Sci.* **2013** (1), 939385.

Jacobi, K. K., MacRae, E. A. and Hetherington, S. E. (2001). Postharvest heat disinfestation treatments of mango fruit. *J. Scientia. Horticulturae*. **89** (3), 171-193.

Jarvis, M. C. (1984). Structure and properties of pectin gels in plant cell walls. *J. Plant, Cell. Environment*. **7** (3), 153-164.

Jawaheer, B., Goburdhun, D. and Ruggoo, A. (2003). Effect of processing and storage of guava into jam and juice on the ascorbic acid content. *J. Plant. Foods. for. Human. Nutrition*. **58**, 1-12.

Jedermann, R., Nicometo, M., Uysal, I. and Lang, W. (2014). Reducing food losses by intelligent food logistics. In J. P. T. o. t. R. Society (Ed.), (Vol. 372, pp. 20130302): The Royal Society Publishing.

Jha, S., Singh, B., Poudel, D., Shingh, S., Tiwari, P. and Shrestha, P. (2021). Analyzing the Growth and Performance of Agriculture Sector in Nepal. *Asian J. Advances, Agric. Research*. **16** (3), 22-40.

Kader, A. A. (2002). "Postharvest technology of horticultural crops". Vol. 3311. University of California Agriculture and Natural Resources. [1879906511].

Kader, A. A. (2013). Postharvest technology of horticultural crops-An overview from farm to fork. *J.of.Applied.Sci.Technol.*. (1), 1-8.

Kansci, G., Koubala, B. B. and Lape, I. M. (2003). Effect of ripening on the composition and the suitability for jam processing of different varieties of mango (Mangifera indica). **2** (9), 296-300.

Karel, M., Fennema, O. R. and Lund, D. (1975). "Principles of food science. Part II. Physical principles of food preservation".[082476322X].

Karim, O. R., Awonorin, S. O. and Sanni, L. O. (2008). Effect of pretreatments on quality attributes of air-dehydrated pineapple slices. *Journal. of. Food. Technol*. **6** (4), 158-165.

Kaur, J., Singh, Z., Shah, H. M. S., Mazhar, M. S., Hasan, M. U. and Woodward, A. (2024). Insights into phytonutrient profile and postharvest quality management of jackfruit: A review. **64** (19), 6756-6782.

Kaur, M., Bal, J. S., Sharma, L. K. and Bali, S. K. (2014). An Evaluation of Mango (Mangifera indica L.) Germoplasm for Future Breending Programme. *J Afr. J. Agric. Res*. **9** (20), 1530-1538.

Kitinoja, L. and Kader, A. A. (2015). Measuring postharvest losses of fresh fruits and vegetables in developing countries. *J.PEF.white.paper*. **15**, 26.

Krinsky, N. I., Landrum, J. T. and Bone, R. A. (2003). Biologic mechanisms of the protective role of lutein and zeaxanthin in the eye. *J. Annu. Review. Nutr.* **23** (1), 171-201.

Lebaka, V. R., Wee, Y. J., Ye, W. and Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. *J.International.journal.of.environmental.research.public.health* **18** (2), 741.

Levaj, B., Dragović-Uzelac, V., Delonga, K., Kovačević G. , K., Banović, M. and Bursać K. (2010). Polyphenols and volatiles in fruits of two sour cherry cultivars, some berry fruits and their jams. *J. Food. Technol. Biotechnol.* **48** (4), 538-547.

Lima, Z. P., Severi, J. A., Pellizzon, C. H., Brito, A., Solis, P. N., Cáceres, A., Girón, L. M., Vilegas, W. and Hiruma-Lima, C. A. (2006). Can the aqueous decoction of mango flowers be used as an antiulcer agent? *Journal of Ethnopharmacology*. **106** (1), 29-37.

Lund, D. B. (1975). Effects of blanching, pasteurization and sterilization on nutrients. *J. Nutritional. evaluation. of. food. processing*. 205-240.

Makhmale, S., Bhutada, P., Yadav, L. and Yadav, B. K. (2016). Impact of climate change on phenology of mango-the case study. *Ecol. Environ. Conversation*. **22** (9), S127-S132.

Makroo, H. A., Prabhakar, P. K., Rastogi, N. K. and Srivastava, B. (2019). Characterization of mango puree based on total soluble solids and acid content: Effect on physico-chemical, rheological, thermal and ohmic heating behavior. *J. Lwt* **103**, 316-324.

Manthey, J. A. and Perkins-Veazie, P. (2009). Influences of harvest date and location on the levels of β-carotene, ascorbic acid, total phenols, the in vitro antioxidant capacity, and phenolic profiles of five commercial varieties of mango (Mangifera indica L.). **57** (22), 10825-10830.

Márquez, L., Pérez-Nievas, B. G., Gárate, I., García-Bueno, B., Madrigal, J. L. M., Menchén, L., Garrido, G. and Leza, J. C. (2010). Anti-inflammatory effects of Mangifera indica L. extract in a model of colitis. *J. World journal of gastroenterology: WJG*. **16** (39), 4922.

Martin, F. W., Campbell, C. W. and Ruberté, R. M. (1987). "Perennial edible fruits of the tropics: an inventory". US Department of Agriculture, Agricultural Research Service.

Maryani, N. W. A., Suriati, L. and Candra, I. P. (2023). Addition of Sugar and CMC to the Characteristics of Arumanis Mango Jam (Mangifera indica L.). **7** (1), 39-51.

Medlicott, A. P. and Thompson, A. K. (1985). Analysis of sugars and organic acids in ripening mango fruits (Mangifera indica L. var Keitt) by high performance liquid chromatography. *J.Journal of the Sci. of Food Agriculture* **36** (7), 561-566.

Meena, M. L. and Meena, P. L. (2016). Effect of different packaging materials on physical parameters and self-life of guava (Psidium guajava L.).

Meilgaard, M., Civille, G. and Carr, B. (2007). Sensory evaluation techniques 4th ed CRC Press LLC.

Mesallam, A., S. (1987). Heavy metal content of canned orange juice as determined by direct current plasma atomic emission spectrophotometry (DCPAES). *J. Food.chem*. **26** (1), 47-58.

Mitchell, J. R. and Blanshard, J. M. V. (1979). On the nature of the relationship between the structure and rheology of food gels. *J. Food. Texture. Rheology* 425-435.

Mizrahi, S. (1979). A review of the physicochemical approach to the analysis of the structural viscosity of fluid fruit products. *J. Texture Studies* **10** (1), 67-82.

Mondal, M. and Rahim, M. (2015). Characterization of different germplasm of jackfruit. MS Thesis, Department of Horticulture, BAU: Mymensingh,

Morris, V. J. (1986). Analysis, structure and properties of biopolymer mixtures. *J. Gums. Stabilizers. for. the. Food. Industry*. **3**, 89-93.

Morton, J. F. (1987a). Fruits of warm climates.

Morton, J. F. (1987b). "Fruits of warm climates". Creative Resource Systems, Inc.

Moyls, A. W., Strachan, C. C. and Atkinson, F. E. (1962). Making jam commercially. *J. Canada. Dept. of Agric. Ottawa, Pub*. **114**, 3-25.

Mualikrishna, G. and Tharanathan, R. N. (1994). Characterization of pectic polysaccharides from pulse husks. *J.Food.chem*. **50** (1), 87-89.

Mudasir, B. and Anju, B. (2018). A study on the physico-chemical characteristics and storage of pumpkin-guava blended jam. *J. Pharmacogn. Phytochem*. **7** (3), 1180-1184.

Multon, J.-L. (1984). Additifs et auxiliaires de fabrication dans les industries agro-alimentaires.

Nagy, S. (1990). "Fruits of tropical and subtropical origin". Florida Science Source.

Nansereko, S. and Muyonga, J. H. (2021). Exploring the potential of jackfruit (Artocarpus heterophyllus Lam). **20**, 97-117.

Oakenfull, D. G. (1991). The chemistry of high-methoxyl pectins. *%J The. chem. technol. of. pectin*. 87-108.

Ocloo, F., Bansa, D., Boatin, R., Adom, T. and Agbemavor, W. (2010). Physico-chemical, functional and pasting characteristics of flour produced from Jackfruits (Artocarpus heterophyllus) seeds. **1** (5), 903-908.

Panesar, P., Joshi, V., Bali, V. and Panesar, R. (2017). Technology for production of fortified and sparkling fruit wines. 487-530.

Panwar, S. K. S., SINGN, P. and SINGH, P. (2007). Mango fruit yield and qualitgi improvement through fertigation along with mulch.

Paudel, M. N. and Joshi, B. K. (2018). Agriculture plant genetic resources behind the eyes of researchers and policy makers. *Working Groups Workshop of Agricultural Plant Genetic Resources (APGRs) in Nepal*. 1-41.

Peckham, G. (1964a). Jams, jellies and conserves. *J. Foundation of food preparation. Macmillan comp., New York*. 443-448.

Peckham, G. C. (1964b). Jams, jellies and conserves. *J. Foundation of food preparation. Macmillan comp., New York*. 443-448.

Pilgrim, G. W. (1991). Jams, jellies and preserves. *J. The. chem. technol. of. pectin*. 25-35.

Pokharel, A. (2021). Economic analysis of offseason tomato production in Kathmandu, Nepal: A Study of Nepalese tomato growers.

Pokharel, P. (2024). PROCESS OPTIMIZATION AND STUDY ON STORAGE STABILITY OF DRAGON FRUIT [Hylocereus Undatus] AND PINEAPPLE [Ananas Comosus] MIXED JELLY. Department of Food Technology Central Campus of Technology Institute of …,

Popenoe, W. (1920). "Manual of tropical and subtropical fruits: excluding the banana, coconut, pineapple, citrus fruits, olive, and fig". Macmillan. [0598887040].

Popenoe, W. (1921). Manual of tropical and sub-tropical fruits. *J Agric. South. Africa*. **12** (1), 80.

Poudel, P. R., Paudel, R. and Pathak, R. (2018). Grouping of Agricultural Plant Genetic Resources in Education System of Nepal. *J. Working. Groups. of. Agric. Plant. Genetic. Resources. in. Nepal* 251.

Prabhu, S., Jainu, M., Sabitha, K. E. and Devi, C. S. S. (2006). Role of mangiferin on biochemical alterations and antioxidant status in isoproterenol-induced myocardial infarction in rats. *J. Journal of ethnopharmacology*. **107** (1), 126-133.

Prakash, N. and Priya, S. (2016). Development of novel functional confectionery using low reduced sugar. **4** (4), 141-148.

Prakash, O. m., Kumar, R., Mishra, A. and Gupta, R. (2009). Artocarpus heterophyllus (Jackfruit): an overview. *J. Pharmacognosy. Reviews*. **3** (6), 353.

Priya, T. T., Sabu, M. C. and Jolly, C. I. (2011). Role of Mangifera indica bark polyphenols on rat gastric mucosa against ethanol and cold-restraint stress. *J. Natural. Product. Research*. **25** (8), 815-826.

Ranasinghe, R. and Marapana, R. (2019). Effect of maturity stage on physicochemical properties of jackfruit (Artocarpus heterophyllus Lam.) flesh. *World J. Dairy. Food. Sci.* **14** (1), 17-25.

Ranganna, S. (1986). "Handbook of analysis and quality control for fruit and vegetable products". Tata McGraw-Hill Education. [0074518518].

Raphaelides, S. N., Ambatzidou, A. and Petridis, D. (1996). Sugar composition effects on textural parameters of peach jam. *J. food. science*. **61** (5), 942-946.

Rees, D. A. (1969). Structure, conformation, and mechanism in the formation of polysaccharide gels and networks. *J. Advances. in. carbohydrate. chem. biochem.* **24**, 267-332.

Ruehle, G. D. (1967). Miscellaneous tropical and subtropical Florida fruits. Agric., Extension Survey, IFAS, University of Florida. *J. Bull. pp. 156a*.

Saad, B., Bari, M. F., Saleh, M. I., Ahmad, K. and Talib, M. K. M. (2005). Simultaneous determination of preservatives (benzoic acid, sorbic acid, methylparaben and propylparaben) in foodstuffs using high-performance liquid chromatography. **1073** (1-2), 393-397.

Safdar, M. N., Amer M., A. M. and Tabassum H., N. S. S. K., Muhammad A. (2012). Storage studies of jam prepared from different mango varieties.

Sarower, K., Uddin, B. and Jubayer, F. (2015a). An approach to quality assessment and detection of adulterants in selected commercial brands of jelly in Bangladesh. **10** (1-2), 50-58.

Sarower, K., Uddin, B. and Jubayer, F. (2015b). An approach to quality assessment and detection of adulterants in selected commercial brands of jelly in Bangladesh. *J. Hrvatski časopis za prehrambenu. tehnologiju,. biotehnologiju. nutricionizam*. **10** (1-2), 50-58.

Scartezzini, P. and Speroni, E. (2000). Review on some plants of Indian traditional medicine with antioxidant activity. *Journal of ethnopharmacology*. **71** (1-2), 23-43.

Shomer, I. (1991). Protein coagulation cloud in citrus fruit extract. 1. Formation of coagulates and their bound pectin and neutral sugars. *J. of. Agric. Food. Chem.* **39** (12), 2263-2266.

Shrestha, A., Joshi, N. R., Dahal, B. R., Bhandari, S., Acharya, S. R. and Osti, B. (2021). determinants of productivity and major produciton constraints of mango farming in Saptari District of Nepal. *Malaysian. J. Sustainable. Agric.* **5** (2), 77-81.

Shrestha, S. L., Dhakal, M., Gautam, I. P., Paudel, S. and Pandey, S. (2020). Recent technology development and research status of fruit crops. Role of Nepal agriculture research council in Nepal. *Proceedings of 11th national horticulture seminar*.

Siddappa, G. S. (1957). Development of products from jackfruit-canned jackfruit, frozen canned jackfruit and jackfruit jam. *J. Sci. Ind. Res.* **9** (11), 166-199.

Siddiq, M., Sogi, D. S. and Roidoung, S. (2017). Mango processing and processed products. *J.Handbook of mango fruit: production, postharvest sci, processing technol.nutrition* 195-216.

Siddiqui, N. H., Azhar, I., Tarar, O. M., Masood, S. and Mahmood, Z. A. (2015). Influence of pectin concentrations on physico-chemical and sensory qualities of jams. *J. World. Journal. of. Pharmacy. Pharmaceutical. Sciences*. **4** (6), 68-77.

Sidhu, A. S. (2012). A Status Report [Report]. Bangkok 10200, Thailand, Asia. [Accessed June, 2012].

Singh, A., KUMAR, S. and Singh, I. (1991). Functional properties of jack fruit seed flour. **24** (4), 373-374.

Singh, B., Singh, J. P., Kaur, A. and Singh, N. (2017). Phenolic composition and antioxidant potential of grain legume seeds: A review. **101**, 1-16.

Sinha, N. K., Sidhu, J., Barta, J., Wu, J. and Cano, M. P. (2012). "Handbook of fruits and fruit processing". John Wiley & Sons. [1118352637].

Smit, C. J. and Bryant, E. F. (1968a). Ester content and jelly pH influences on the grade of pectins. **33** (3), 262-264.

SMIT, C. J. and BRYANT, E. F. (1968b). Ester content and jelly pH influences on the grade of pectins. *J. Food. Science*. **33** (3), 262-264.

Soobrattee, M. A., Neergheen, V. S., Luximon-R.A., Aruoma, O. I. and Bahorun, T. (2005). Phenolics as potential antioxidant therapeutic agents: mechanism and actions. *J. Mutation. Resesrch/Fundamental. Mol. Mechanisms. Mutagensis*. **579** (1-2), 200-213.

Srinivasan, K. (2010). Traditional Indian functional foods. **10**, 51-76.

Subedi, A., Bajracharya, J., Joshi, B. K., Gupta, S. R., Regmi, H. N. and Sthapit, B. R. (2008). Locating and managing the mango (Mangifera indica L.) genetic resources in Nepal. *J. PGR. Newsletter*. **155**, 52-61.

Subedi, A., Bajracharya, J., Joshi, B. K., KC, H. B., Gupta, S. R., Regmi, H. N., Baral, K. P., Shrestha, P., Thagunna, P. and Tiwari, R. K. (2004). Ecogeographic survey of mango (Mangifera indica L.) genetic resources in Nepal. *J. On-farm. conservation. of. agric. biodiversity. in. Nepal.* **1**, 176.

Subedi, Y. R., Bhandari, K. and Thapa, R. K. (2015). Assessment of Climate Change Impact on Food Security with Respect to Agriculture and Livestock Production in Siraha District of Nepal.

Swer, T. L., Rani, S. and Bashir, K. (2019). Manufacturing of jams, jellies, and marmalades from fruits and vegetables. *In:* "Processing of Fruits and Vegetables".). pp. 59-80. Apple Academic Press.

Thakur, B. R., Singh, R. K., Handa, A. K. and Rao, M. A. (1997). Chemistry and uses of pectin—A review. *J. Critical. Reviews. in. Food. Science. Nutrition*. **37** (1), 47-73.

Vélez Colón, R., Flores Ortega, C., Henríquez, S. A. and Cedeño Maldonado, A. (2006). Significant differences in vegetative growth of Mayagüezano mango cultivars. *Proceedings of the Interamerican Society for Tropical Horticulture*. **50**, 120-124.

Ventura, J., Alarcón-Aguilar, F., Roman-Ramos, R., Campos-Sepulveda, E., Reyes-Vega, M. L., Boone-Villa, V. D., Jasso-Villagómez, E. I. and Aguilar, C. N. (2013). Quality and antioxidant properties of a reduced-sugar pomegranate juice jelly with an aqueous extract of pomegranate peels. *J. Food. chem*. **136** (1), 109-115.

Verheij, E. W. M. and Coronel, R. E. (1992). Plant Resources of South-East Asia. No. 2: Edible Fruits and Nuts. **1** (2).

Vibhakar, S., Nagaraja, K. V., Prabhakar, J. V. and Bhatnagar, H. C. (1972). Determination of fruit pulp content in mango (Mangifera indica) beverages. *J.Indian.Food.Packer*. **26** (2), 21-26.

Vibhakara, H. and Bawa, A. (2006a). Manufacturing jams and jellies. *J. Handbook. of. fruits. fruit. processing*. 187-204.

Vibhakara, H. S. and Bawa, A. (2006b). Manufacturing jams and jellies. *J. Handbook food fruits processing*. **2** (1), 187-204.

Vibhakara, H. S. and Bawa, A. S. (2006c). Manufacturing jams and jellies. *J. Handbook. of. fruits. fruit. processing*. 187-204.

Voragen, A. G. J., Schols, H. A. and Pilnik, W. J. F. H. (1986). Determination of the degree of methylation and acetylation of pectins by HPLC. *J. Food. hydrocolloids*. **1** (1), 65-70.

Walter, R. H. and Oakenfull, D. G. (2012). Jams, Jellies. *J. Chem. Technol. Pectin*. 23.

Wickens, G. E. and Burkill, H. M. (1986). The useful plants of west tropical Africa. *J. Kew. Bulletin*. **41** (2), 471.

Yadav, D. and Singh, S. P. (2017). Mango: History origin and distribution. *Journal. of. Pharmacognosy. Phytochem.* **6** (6), 1257-1262.

Yadav, M., Hossain, S. A., Bharti, B. K., Das, A., Wasnik, P. K. and Thakur, S. N. (2019). Study on microbiological characteristics of different brands of jam, honey and jelly. *J. IJCS*. **7** (3), 280-282.

Yadav, M., Hossain, S. A. and Jaiswal, B. K. B. M. (2018). Comparative study of physico-chemical property in different brands of jam, honey and jelly. *Journal. of. Pharmacognosy. Phytochem.* **7** (5), 2186-2191.

Yadav, P. K., Bhujel, P. and Kafle, N. (2022). Chestnut production and its prospects in Nepal. *J. Sustainability. in. Food. Agric.* **3** (1), 1-10.

Yahia, E. (2011). Mango (Mangifera indica L.). *In:* "Postharvest biology and technology of tropical and subtropical fruits".). pp. 492-567e. Elsevier.

Yaseen, M., Rani, S., Shahni, U., Rahman, Z., Khan, N., Saeed, B., Shah, J. A., Nasir, J. A. and Wahab, H. (2018). 3. Stabilization, physiochemical and sensory evaluation of mango jam with jaggery stored at ambient temperature (25-30ºC). *J. Pure. Applied. Biology*. **7** (2), 427-434.

Zielenski, Q. B. (1955). Modern Systematic Pomology. WMC Bio. Co., Iowa, USA. *J. Degrees. freedom*. 50.

# Appendices

## Appendix A

Name……………………………
Date: …/…/…

Observe the product by tasting. Use appropriate scale to show your attitude by checking at the point that best describes your feeling of the products. Write any of defects present described below. An honest expression of your personnel feeling will help me.

| Sensory attributes | Sample A | Sample B | Sample C | Sample D | Sample E | Sample F |
|---|---|---|---|---|---|---|
| Color | | | | | | |
| Flavor | | | | | | |
| Taste | | | | | | |
| Texture | | | | | | |
| Overall Acceptance | | | | | | |

**Judge the above characteristics on the 1-9 scale described as follows:**

| | | |
|---|---|---|
| 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 |

Any comments………………………………………………………………………………
………………………………………………………………………………

……………………………
Signature

# Appendix B

**Table B.1** Two-way ANOVA (no blocking) for color as variate

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 65.133 | 5 | 13.027 | 8.927 | .000 |
| Within Groups | 78.800 | 54 | 1.459 | | |
| Total | 143.933 | 59 | | | |

**Table B.2** Two-way ANOVA (no blocking) for flavor as variate

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 15.133 | 5 | 3.027 | 2.074 | .083 |
| Within Groups | 78.800 | 54 | 1.459 | | |
| Total | 93.933 | 59 | | | |

**Table B.3** Two-way ANOVA (no blocking) for taste as variate

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 14.133 | 5 | 2.827 | 2.258 | .062 |
| Within Groups | 67.600 | 54 | 1.252 | | |
| Total | 81.733 | 59 | | | |

**Table B.4** Two-way ANOVA (no blocking) for texture as variate

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 14.800 | 5 | 2.960 | 2.034 | .088 |
| Within Groups | 78.600 | 54 | 1.456 | | |
| Total | 93.400 | 59 | | | |

**Table B.5** Two-way ANOVA (no blocking) for overall acceptance as variate

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 11.150 | 5 | 2.230 | 2.329 | .055 |
| Within Groups | 51.700 | 54 | .957 | | |
| Total | 62.850 | 59 | | | |

## Appendix C

Paired t-test for comparison of the best sample jam and the commercial mixed fruit jam from BBSM, Dharan

**Table C.1** Paired t-test for comparison of TSS between best sample and commercial mixed fruit jam

| | Best sample | Commercial jam |
|---|---|---|
| Mean | 67.66667 | 68 |
| Variance | 0.333333 | 0 |
| Observations | 3 | 3 |
| Hypothesized Mean Difference | 0 | |
| df | 2 | |
| T Stat | -1 | |
| P(T<=t) one-tail | 0.211325 | |
| t Critical one-tail | 2.919986 | |
| P(T<=t) two-tail | 0.42265 | |
| t Critical two-tail | 4.302653 | |

**Table C.2** Paired t-test for comparison of titrable acidity between best sample and commercial mixed fruit jam

| | Best sample | Commercial jam |
|---|---|---|
| Mean | 1.34 | 0.67 |
| Variance | 0.01 | 0.0016 |
| Observations | 3 | 3 |
| Hypothesized Mean | | |
| Difference | 0 | |
| df | 3 | |
| t Stat | 10.77473 | |
| P(T<=t) one-tail | 0.000855 | |
| t Critical one-tail | 2.353363 | |
| P(T<=t) two-tail | 0.00171 | |
| t Critical two-tail | 3.182446 | |

**Table C.3** Paired t-test for comparison of vitamin C between best sample and commercial mixed fruit jam

| | Best sample | Commercial jam |
|---|---|---|
| Mean | 17.28 | 16.4833 |
| Variance | 0.25 | 0.20333 |
| Observations | 3 | 3 |
| Hypothesized Mean | | |
| Difference | 0 | |
| df | 4 | |
| t Stat | 2.04941 | |
| P(T<=t) one-tail | 0.05488 | |
| t Critical one-tail | 2.13185 | |
| P(T<=t) two-tail | 0.10976 | |
| t Critical two-tail | 2.77645 | |

**Table C.4** Paired t-test for comparison of reducing sugar between best sample and commercial mixed fruit jam

| | Best sample | Commercial jam |
|---|---|---|
| Mean | 30 | 37 |
| Variance | 0.16 | 0.0004 |
| Observations | 3 | 3 |
| Hypothesized Mean | | |
| Difference | 0 | |
| df | 2 | |
| t Stat | -30.273 | |
| P(T<=t) one-tail | 0.00054 | |
| t Critical one-tail | 2.91999 | |
| P(T<=t) two-tail | 0.00109 | |
| t Critical two-tail | 4.30265 | |

**Table C.5** Paired t-test for comparison of total sugar between best sample and commercial mixed fruit jam

| | Best sample | Commercial jam |
|---|---|---|
| Mean | 73 | 89.4 |
| Variance | 0.3249 | 0.5929 |
| Observations | 3 | 3 |
| Hypothesized Mean | | |
| Difference | 0 | |
| df | 4 | |
| t Stat | -29.6504 | |
| P(T<=t) one-tail | 3.85E-06 | |
| t Critical one-tail | 2.131847 | |
| P(T<=t) two-tail | 7.7E-06 | |
| t Critical two-tail | 2.776445 | |

## Appendix D

### Chemicals Required

| | |
|---|---|
| Ascorbic acid | Carrez solution I and I |
| Oxalic acid | Fehling's solution |
| Sodium hydroxide pellet | Phenolphthalein |
| Methylene blue | Buffer solution |
| Sulphuric acid | 2-6 dichlorophenol indophenol dye |
| Hydrochloric acid | Dextrose solution |

### Equipments Required

| | |
|---|---|
| Grinder machine | Beaker |
| Volumetric flask | Pan |
| Test tube | Pipette |
| Refractometer | Conical flask |
| Knives | Petri plate |
| Chopping board | Measuring cylinder |
| Burette | pH meter |
| Thermometer | Round bottom flask |

## Color plates

Plate 1: Sensory analysis

Plate 2: Sensory analysis

Plate 3: Physiochemical analysis

Plate 4: Sampling and measurement