Study on Formulation, Quality Evaluation and Storage Stability of Agar Based Dragon Fruit Jelly Incorporated with Stinging Nettle

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

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Approval Letter

This *dissertation* entitled *" Study on formulation, Quality Evaluation, and Storage Stability of Agar Based Dragon Fruit Jelly Incorporated with Stinging Nettle "* presented by **Krishala Oli** has been accepted as the partial fulfilment of the requirements for the ***B.Tech. degree in Food Technology.***

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Abstract

The main aim of this study was to optimize the preparation of jelly made from dragon fruit juice and stinging nettle extract and to evaluate its storage stability at room temperature and refrigeration temperature. Dragon fruit and stinging nettle were purchased from the local market in Dharan, and juice was obtained through the following process. Fully ripened dragon fruits were washed, peeled, and sliced. The flesh was then cooked with water until it softened and then strained through muslin cloth to extract the juice, whereas Fresh nettle leaves were washed, blanched at 90 °C, dried at 50 °C to constant weight, ground into powder, extracted with hot distilled water for 30 min, and filtered through Whatman No. 1 to obtain the nettle extract. Seven different samples of different proportion of dragon fruit juice and stinging nettle extract were taken and coded as A (67: 33), B (63:37), C (75: 25), D (100:0) which is control, E (83:17), F (50: 50) and G (88: 12). The sugar, citric acid and Agar agar was added in the amount of 130g, 0.5% and 2% respectively. Sensory attributes of the jelly were evaluated using a nine-point Hedonic scale rating test to identify the best product. Sample C was the best and was used for further analysis at two different temperatures: room temperature (27±3°C) and refrigeration (7±1°C). The effect of storage time on physicochemical and microbial properties was evaluated.

The jelly was filled in pre-sterilized glass bottles, capped, and covered with aluminium foil and stored at two temperatures as room and refrigeration, for a period of 40 days, and analysed at intervals of 10 days for chemical and microbiological changes. Physicochemical analysis of the optimized product revealed TSS of 67°Bx, pH of 3.1, acidity of 0.56% and notable antioxidant activity 73.48%. During 40 days of storage, TSS, acidity, reducing sugar, and microbial counts gradually increased, whereas vitamin C, pH, moisture, and non-reducing sugars decreased. Even with these changes, the jelly remained microbiologically safe and acceptable without using chemical preservatives. The incorporation of stinging nettle enhanced the phytochemical profile of the jelly, offering a novel, shelf-stable confectionery product with improved nutritional and functional properties. This research also shows how underutilized crops can be turned into valuable food products, while supporting the growing consumer interest in natural and health-promoting foods.

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List of abbreviations

Abbreviations	Full Form
ANOVA	Analysis of variance
AOAC	Association of official analytical chemists
CDFT	Central Department of Food Technology
CCT	Central Campus of Technology
DFTQC	Department of Food Technology and Quality Control
PMAMP	Prime Minister Agriculture Modernization Project.
FAO	Food and Agriculture Organization
HSD	Honestly significance difference
LSD	Least significance difference
PCA	Plate Count Agar
PDA	Potato Dextrose Agar
SD	Standard Deviation
TDS	Total Dissolved Solids

List of plates

Part I

Introduction

1.1 General introduction

Dragon fruit (*Hylocereus sp.*), also known as pitaya, is an exotic fruit belonging to the family Cactaceae (Saenjum *et al.*, 2021). Dragon fruit is so named because of its vibrant red skin adorned with overlapping green scales. It is also commonly referred to as pitaya, dragon pearl fruit, night-blooming cereus, strawberry pear, and Cinderella plant. Depending on the species, the fruit exhibits considerable variation in traits such as shape, thorniness, skin texture, and pulp colour, which highlights its wide genetic diversity. The fruit is typically oval in shape, with pulp characterized by a sweet–tart flavour and numerous small, black seeds (Nishikito *et al.*, 2023). At maturity, dragon fruit is most commonly consumed in its fresh form (Merten, 2003). It is eaten by cutting it, and because of its crunchy, black seeds, some people compare its texture to that of kiwis (Gupta *et al.*, 2024).

Dragon fruit is a tropical fruit with a well-balanced nutritional composition, characterized by high moisture content and including carbohydrates, proteins, fats, and dietary fibre (Katikala *et al.*, 2025). Dragon fruit has obtained significant attention for its rich contents of bioactive phytochemicals such as flavonoids, phenols, anthocyanins, and betacyanins, which contribute to its health benefits. These bioactive compounds are known for their antimicrobial, anti-inflammatory, antioxidant, and anti-cancer properties, further elevating dragon fruit's value as a functional food (Si-Yuan *et al.*, 2024). Red dragon fruit's natural pigment, betalain, can also be used as a natural food colorant, providing an attractive appearance without the need for synthetic dyes for confectionary product (Lim *et al.*, 2011a).

Stinging nettle **(***Urtica dioica L.***)**, locally referred to in Nepal as "sisnu", is a perennial herb belonging to the Urticaceae family and is commonly found throughout the mid-hills and mountainous areas of Nepal, thriving at altitudes ranging from 1,000 to 3,000 meters above sea level (Devkota *et al.*, 2022). The plant is easily recognized by its tiny stinging hairs (trichomes) present on the leaves and stems. These hairs contains formic acid, histamine, and acetylcholine, responsible for the typical irritation when touched (Ayers *et al.*, 2008).

The wild leafy herb stinging nettle has a long history of use as a herbal remedy and dietary supplement (Jan *et al.*, 2017). It is an abundant source of biologically active compounds such as polyphenols, flavonoids, chlorophyll, carotenoids, vitamins (A, C, K, and several B-complex), and essential minerals (iron, calcium, potassium, magnesium, and phosphorus) (Kukrić *et al.*, 2012). These nutrients not only meet human nutritional needs but also have antimicrobial, anti-inflammatory, and antioxidant qualities, making nettle a functional food ingredient with potential health benefits. The plant's high content of proteins and micronutrients makes it particularly valuable as a leafy vegetable, traditionally consumed as "sisnu ko saag," soups, or teas, providing essential nutrition to rural communities (Devkota *et al.*, 2022).

Jelly is a soft, semi-solid dessert popular among all people of all ages for its sweet taste and unique texture. In recent years, natural extracts and fruit juices have been incorporated into jelly formulations to boost functional bioactive properties, improve nutritional content, and replace artificial colorants (Park *et al.*, 2021). An ideal fruit jelly is a brightly coloured, clear, and flavourful product made by processing fruit juice to form a soft, set gel that holds its shape when removed from the mould. It should possess a delicate yet firm texture, allowing it to be easily cut with a spoon while maintaining clean, defined edges. A high-quality jelly is transparent, non-sticky, non-gummy, and non-brittle, breaks with a smooth, glossy surface that reflects light attractively.

The basic components of jellies are fruit, gelling agent, sugar/sweetener, and acid. (Barton, 1989). Fruit serves as a source of flavour, natural sugars, acids, pectin, and colour (Banerjee and Bhattacharya, 2012). A gelling agent, such as pectin, gelatin, or agar, forms a three-dimensional network that traps water and sugar, giving jelly its characteristic firm yet tender texture (Aguilera and Rademacher, 2004).Agar, a plant derived hydrocolloid from red seaweed, is flavoured for creating robust, vegan-friendly jellies. Its main component, agarose, forms a thermally stable and elastic gel structure even at low concentrations, making it a highly effective gelling agent(Armisen and Galatas, 1987). Higher sugar concentrations (typically 60–70°Bx) help agar gels maintain structure and prevent syneresis (weeping). Sugar also slows microbial spoilage, while agar provides the elastic network that traps the sugar solution, giving jelly its characteristic texture (NAGASAKA and TANEYA, 2000) Similarly, acid adjusts the pH to the optimum range for gelation, stabilizes colour and flavour, and inhibits microbial growth, thereby ensuring the jelly develops a consistent, firm, and palatable structure (Schafer and Driessen, 2021).

Recently, there has been growing interest in functional jelly, which incorporate natural plant extracts, vitamins, minerals, or antioxidants to enhance nutritional value and provide health benefits beyond basic energy supply (Tarahi *et al.*, 2024). Natural colorants and functional ingredients are increasingly used in jelly formulations as an innovative approach to create vegan, healthier, and nutrient-enriched confectionery products, enhancing both appearance and nutritional value (Biltekin *et al.*, 2025). However, the development of red dragon fruit jelly enriched with stinging nettle extract has not yet been studied.

1.2 Statement of the Problem

Many farmers worldwide are engaging in commercial cultivation of dragon fruit due to its ability to grow at wide range of conditions and the profitable opportunity it presents to sell their produce at reasonable prices (Hossain *et al.*, 2021). Dragon fruit has gained significant popularity and market value worldwide because of its distinctive flavour and visually appealing, exotic appearance. Like many other climacteric fruits, dragon fruit is highly perishable, necessitating prompt post-harvest processing to minimize deterioration and transform it into value-added products (Nikmat *et al.*, 2025). Moreover, with growing awareness and knowledge about health and nutrition, modern consumers are increasingly prioritizing the health benefits of products over their cost (Moshfeghi *et al.*, 2013b). Processing dragon fruit into value-added products is one way to extend its shelf life.

Stinging nettle (*Urtica dioica L.*) have been known since ancient times as a wild edible plant and an herbal medicine. Despite its many benefits, nettle remains underused in the food industry due to factors like seasonal availability and consumer perceptions. Many people associate it with scarcity or “poor man’s food,” and its stinging nature also reduces its desirability (Shonte and De Kock, 2017).

Dragon fruit is well-known for its rich content of bioactive compounds like betalains, phenolics, and flavonoids, which provide strong antioxidant and health benefits. However, most commercially available dragon fruit jellies do not incorporate other health-promoting ingredients that could boost their nutritional value. Stinging nettle, a plant with vitamins, minerals, and antioxidants, has rarely been considered as an ingredient in such products.

Besides, while the primary gel-forming agent of fruit jellies is typically pectin, its manufacture requires conditions. Agar produces a dense, heat-resistant gel in a wider range of pH values and does not require high sugar or high acidity concentrations in the gelation process. This gives agar significant potential for innovation in functional jelly formulations. Therefore, the purpose of this research is the development of a new dragon fruit-based healthy functional jelly enriched in stinging nettle extract and using agar as a gel-forming agent, indicating the missing link between offering a healthful and nutritious sweet treat and responding to the demand of the market of health function confectionery product.

1.3 Objectives

1.3.1 General Objective

The general objective of the study was to study on formulation, quality evaluation and storage stability of Agar based dragon fruit jelly incorporated stinging nettle.

1.3.2 Specific Objectives

1. To prepare functional jelly formulations using dragon fruit and stinging nettle extract.
2. To identify the optimal formulation of dragon fruit jelly enriched with stinging nettle extract.
3. To study the physico-chemical properties of optimised best product.
4. To study the change in physico-chemical properties during the storage of the jelly.
5. To study the microbiological changes occurring during the storage of jelly.

1.4 Significance of the study

If ingredients with higher levels of beneficial compounds are used, the antioxidant activity of the jelly and its content of vitamins and minerals can be enhanced. Fortification with natural components offers opportunities to develop products with distinctive and desirable flavour characteristics. Numerous studies have emphasized the health-promoting properties of phenolic compounds, including gallic acid, quercetin, and resveratrol, which are associated with the prevention of lifestyle-related diseases and the promotion of overall health (Sotolář *et al.*, 2025)

The production of a jelly using dragon fruit juice and stinging nettle extract holds multiple advantages both to the consumer as well as the industry. Dragon fruit contributes attractive natural colour, flavour, and antioxidant compounds such as betalains and vitamin C, which can serve as natural alternatives to synthetic colorants and preservatives. Stinging nettle extract, on the other hand, provides additional nutrients such as iron, calcium, and polyphenols, which are known to improve antioxidant capacity and health benefits. The combination of these two ingredients may yield a novel confectionery product with improved health-promoting potential while maintaining consumer appeal. These fruits are still underutilized in Nepal despite of having high health benefits and the favourable climate.

Additionally, the research addresses the perishability of dragon fruit by developing a shelf-stable product, which can reduce post-harvest waste while offering economic benefits to growers and local producers. Overall, this research will contribute to the diversification of functional food products by utilizing underexplored natural resources such as dragon fruit and stinging nettle. It aligns with global trends in sustainable food production and functional product development, promoting the utilization of natural, health-promoting, and locally available ingredients in confectionery formulations.

1.5 Limitations of the study

1. Texture profile analysis was not carried out.
2. Study on only one packaging material was carried out.
3. Storage stability was only studied for 40 days.

Part II

Literature Review

2.1 Dragon fruit

2.1.1 Origin and distribution

Dragon fruit is native to Mexico, Central and South America and has been grown in Vietnam for at least 100 years, following its introduction by the French (Wichienchot *et al.*, 2010). The fruit may reach a maximum weight of approximately 900 g, although the average typically ranges between 350–450 g. Fruit weight is influenced by both pollination efficiency and varietal differences (Merten, 2003). Because of its stunning beauty, the dragon fruit flower has earned the nicknames "Noble Woman" and "Queen of the Night.” The large, creamy-white blossoms, which can reach up to 25 cm in diameter, open during the night, enhancing the ornamental value of the plant (Kakade *et al.*, 2022).

Dragon fruit is a semi-epiphytic plant that thrives in dry tropical and subtropical climates, with optimal temperatures ranging from 21 to 29 °C. The plant can withstand extremes, tolerating temperatures up to 38–40 °C and brief periods below freezing. It requires an annual rainfall of 600–1300 mm and benefits from alternating wet and dry seasons (Bakal and Hatwar, 2025). It offers a significant long–term benefit: its lifespan extends over 20 years after initial planting. Though it begins to bear fruit after just the second year, the crop doesn’t reach full production until five years, at which point predicted yields range from 20 to 30 tonnes per hectare (Atreya *et al.*, 2020). In Nepal, the yield data are not yet established; the initial second/third year yields were about 8-10 tons/ha/year from Durga Devi Farm in Temal, Kabhre (Atreya *et al.*, 2020). In recent years, dragon fruit cultivation has grown due to its health benefits and economic importance, resulting in its use as a source of functional materials to supply the body with phytochemicals that have high antioxidant capacity(Mehta *et al.*, 2024).

Dragon fruit, a climbing cactus of the family Cactaceae, is appreciated for its ornamental value. Its increasing worldwide popularity is due to its high nutritional value and possible health benefits. As a promising economic crop, the bioactive compounds in the fruit can be affected by factors that range from the cultivar variety, growing season, and climatic conditions to farming methods, water availability, transportation, handling, and storage practices (Hossain *et al.*, 2021).

2.1.2 Classification

Five major species of Hylocereus are commonly recognized, distinguished primarily by their fruit characteristics. *H. undatus* produces fruits with white pulp and pink skin, while *H. polyrhizus* bears red-pulped fruits with pink skin. *H. costaricensis* is noted for its violet-red pulp and pink skin, whereas *H.* guatemalensis has red pulp with a reddish-orange skin. In contrast, *H.* megalanthus is characterized by white pulp and yellow skin. Regardless of the species, the fruit pulp contains numerous edible black seeds, possesses a sweet flavour, and serves as a rich source of nutrients such as soluble sugars, proteins, and essential minerals including potassium, magnesium, and calcium, in addition to various bioactive compounds (Arivalagan *et al.*, 2021). In Nepal, many varieties have become popular among the farmers because they grow well in the local climate and soil conditions. The primary varieties of dragon fruit grown in Nepal include Red pitaya, American beauty, Costarican sunset, and White pitaya (Chapai, 2024).

<u>Scientific Classification</u>

Kingdom: Plantae

Sub-kingdom: Tracheophytes

Division: Magnoliophyta

Class: Magnoliopsida

Order: Caryophyllales

Family: Cactaceae

Genus: *Hylocereus* (currently treated under *Selenicereus*)

Species: *Hylocereus polyrhizus* (syn. *Selenicereus polyrhizus*)

Source:(Korotkova *et al.*, 2017)

2.1.3 History of Dragon fruit development in Nepal

The white-fleshed dragon fruit (*Hylocereus undatus*) was first introduced to Nepal from Vietnam by an American engineer in 2000 AD. However, its commercial cultivation began only after 2014 BS in Kabhre district. Encouraged by the positive outcomes of these initial plantations, several farmers across the country have initiated trials of both white- and red-fleshed cultivars, either on a small scale or commercially, covering approximately 8–10 hectares. Notably, former Minister Mr. Lokendra Bist pioneered large-scale cultivation in Dang district. Consequently, dragon fruit is gradually emerging as a promising new fruit crop for the warmer regions of Nepal (Atreya *et al.*, 2020).

Dragon fruit is increasingly attracting the attention of growers across Nepal. With rising awareness of its nutritional and economic value, consumer demand has also been growing steadily in the domestic market, where it was priced between NRs. 500–900 per kilogram in early 2020. As a perennial climbing cactus, it begins fruiting within 15 months of planting and continues production for 15–20 years, a characteristic highly appreciated by cultivators. Given its potential, dragon fruit cultivation can play a significant role in strengthening the agricultural economy of the country. The Terai region offers favourable conditions for its production, making it a promising alternative crop for farmers seeking diversification in their farming practices (Dhakal *et al.*, 2021). In the current situation, the government of Nepal is also promoting dragon fruit farming by setting up many pocket and block zones in Terai districts. But the number of people applying for the PMAMP programs is higher than the seats available. This shows that farmers are still not confident about growing this crop. Because they do not have enough information, they are unable to use resources in the most efficient and economical way (Mehta *et al.*, 2024).

2.1.4 Nutrient composition of Dragon fruit

Dragon fruit is classified as a functional food because of its rich nutritional and nutraceutical value. It contains essential vitamins such as C, A, and niacin, along with carbohydrates, proteins, fats, and minerals (Tarte *et al.*, 2023). The nutritional composition of dragon fruit, particularly its antioxidant activity, total soluble phenolic content, ascorbic acid levels, dietary fibre, and pectin, has been found to vary significantly depending on the cultivar.

The composition of dragon fruit is given in a **Table 2.1** below:

Table 2.1: Composition of dragon fruit

Nutrient	Amount per 100 g
Water	87 g
Protein	1.1 g
Fat	0.4g
Carbohydrate	11.0g
Fibre	3.0g
Ash	0.8g
Calcium	8.5mg
Vitamin C	20.5mg

Source:(Sonawane and Shrikant, 2017)

2.1.5 Health benefits of Dragon fruit

Dragon fruit is considered beneficial for health-conscious individuals due to its low-fat content, abundance of minerals and vitamins, and rich supply of dietary fibre (Tarte *et al.*, 2023).

Studies indicate that red-fleshed dragon fruit can inhibit both Gram-positive and Gram-negative bacteria. Dragon fruit is a rich source of natural antioxidants and anti-inflammatory compounds, including polyphenols, flavonoids, carotenoids, betalains. Free radicals are neutralized by these bioactive compounds, decreasing the rate of oxidative stress and thereby causing minimal cell damage; this reduces the risk of cancer and other cardiovascular diseases. Antioxidative, anti-inflammatory, and anti-diabetic potential of peel, flesh, and seeds contributes to such effects, which can be modulated by encapsulation and optimized processing and storage to improve stability and bioactivity (Si-Yuan *et al.*, 2024).

Regular consumption has been shown to enhance glycaemic control by increasing insulin sensitivity and slowing down glucose absorption which adds up to the role in the management of Type 2 diabetes (Flores-Verastegui *et al.*, 2025). *Hylocereus polyrhizus* is rich in lycopene, a potent antioxidant that prevents cancer-causing free radicals. It also promotes wound healing and exhibits hypolipidemic and hepatoprotective effects by lowering cholesterol and protecting the liver from oxidative damage (Bhadauria *et al.*, 2024). It also contributes to lipid profile improvement by decreasing total cholesterol, LDL-C, and triglycerides while increasing HDL-C levels (Putriningtyas *et al.*, 2024). Encapsulation methods, like the addition of carriers such as maltodextrin and gum Arabic, which can increase the heat-resistant capabilities, antioxidant activity, as well as anti-inflammatory properties of betalains found in peels of red dragon fruits (Li *et al.*, 2022).

2.1.6 Uses of Dragon fruit

Dragon fruit has gained increasing popularity worldwide and is consumed fresh or incorporated into products such as beverages, jellies, and candies. Its natural pigments are also utilized as colouring agents in the food and pharmaceutical industries (Nishikito *et al.*, 2023). The fruit is commonly consumed fresh, often chilled after removing the peel, or in dried form. It also serves as a flavouring ingredient in beverages, including juices, alcoholic drinks, sorbets, smoothies, and various pastries. The unopened flower buds are utilized as a vegetable after cooking, the peel serves as a rich source of natural pigments and pectin, and dried flowers are traditionally employed for medicinal purposes (Sonawane and Shrikant, 2017).

2.2 Stinging Nettle

Stinging nettle (*Urtica dioica L.*), a perennial herb belonging to the family Urticaceae, is widely distributed in temperate regions of Asia, Europe, and North America, including the hilly regions of Nepal where it is locally known as *Sisnu (*Bhusal *et al.,* 2022). It grows abundantly in moist, nitrogen-rich soils and is characterized by serrated leaves and fine stinging hairs (Rawat *et al.*, 2020). The plant is monoecious and undergoes flowering and fruiting during the summer season (Bisht *et al.*, 2012) and both the aerial and underground parts are utilized for food and medicinal purposes (Taheri *et al.*, 2022).

According to (Dreyer and Müssig, 2000), *Urtica dioica* is a perennial crop capable of producing satisfactory yields for a duration of 10 to 15 years. Traditionally, stinging nettle has been used as a nutrient-rich vegetable and herbal medicine. In Nepal and other South

Asian countries, young shoots and leaves are boiled and consumed as a green vegetable, while decoctions and pastes are used to treat joint pain, wounds, and skin irritation (Devkota *et al.*, 2022). The leaves are reported to possess anti-inflammatory, diuretic, and blood-purifying properties (Bhusal *et al.*, 2022). Its long history of ethnomedicinal use has made it an important source of phytochemicals for both traditional and modern herbal formulations (Taheri *et al.*, 2022).

Phytochemical studies have identified that the primary bioactive components of *Urtica dioica* include flavonoids such as quercetin and kaempferol, phenolic acids like caffeic and chlorogenic acid, along with tannins, carotenoids, and lignans (Taheri *et al.*, 2022). These compounds are mainly responsible for its antioxidant, anti-inflammatory, antimicrobial, and anti-diabetic activities. The potent antioxidant activity of nettle extract has been confirmed using DPPH, ABTS, and FRAP assays, indicating that phenolic compounds significantly contribute to its free radical–scavenging ability (Jaiswal and Lee, 2022). This characteristic is especially valuable in formulating functional foods like fruit jellies, as the presence of antioxidants helps improve product stability while offering added health advantages (Đurović *et al.*, 2024).

2.2.1 Scientific classification of Stinging nettle

In the context of Nepal, the wild nettle flora includes several important species. *Girardinia diversifolia*, locally called bhangre sisnu, is abundant in hill and mountain forests and valued for both its edible leaves and fibre. *Urtica dioica*, the common stinging nettle (Sisnu), grows in moist habitats across the hills and is widely used as a leafy vegetable. *Urtica parviflora*, another species known locally as gharaiya sisnu, is also present in Nepal (Pyakurel and Baniya, 2011).

Scientific Classification

Kingdom: Plantae

Subkingdom: Tracheobionta (Vascular plants)

Super division: Spermatophyta (Seed plants)

Division: Magnoliophyta (Flowering plants)

Class: Magnoliopsida (Dicotyledons)

Subclass: Hamamelididae

Order: Urticales

Family: Urticaceae

Genus: *Urtica* L.

Species: *Urtica dioica* L.

2.2.2 Nutrient composition of Stinging nettle

Table 2.2: Nutritional composition of stinging nettle

parameters	values
Moisture content (%)	7.95
Protein (g/100g)	23.17
Ash(g/100g)	6.2
Calcium (mg/100g)	408.16
Vitamin C (mg/100g)	28.6
Total phenol (mg GAE/g)	2.98

Source:(Bhattarai *et al.*, 2017)

Nutritionally, nettle leaves contain abundant proteins, vitamins, and minerals particularly calcium, iron, potassium, and magnesium which enhance their value as a functional food ingredient (Adhikari *et al.*, 2016).

2.2.3 Health benefits of stinging nettle

Urtica dioica L., commonly known as stinging nettle, is valued for its remarkable nutritional profile and diverse health-promoting effects as demonstrated by both traditional use and scientific research. Its therapeutic properties arise from an abundance of phytochemicals such as flavonoids, phenolic acids, carotenoids, tannins, and lignans (Taheri *et al.*, 2022).

For centuries, *Urtica dioica* has been used to treat a variety of disorders ranging from allergic rhinitis to hypertension. It can be consumed as a vegetable, tea, or juice, primarily to help with rhinitis and to act as a blood-nourishing tonic. Important property of nettle is that the entire plant can be used for various purposes such as food, fodder, medicine, cosmetic, biodynamic agriculture, and textile production (Jan *et al.*, 2017). Aqueous extracts of nettle leaves have been shown to exhibit significant anti-diabetic effects, as several studies indicate that nettle extract may stimulate insulin secretion, thereby helping to regulate blood glucose levels and improve glycemic control (Ziaei *et al.*, 2020). In addition, regular consumption of nettle tea has been associated with improved cardiovascular health, as it may help lower systolic blood pressure, reduce stress on the cardiovascular system, and support overall heart function and circulatory efficiency (Bhusal *et al.*, 2022). A proprietary nettle leaf extract exhibited anti-inflammatory properties, as it was shown to inhibit key enzymes responsible to produce pro-inflammatory prostaglandins, including COX-1, COX-2, and Prostaglandin D2 Synthase (Ayers *et al.*, 2008).

As a natural diuretic, stinging nettle promotes the efficient elimination of neutralized toxins from the body, supporting overall detoxification. It is considered as an alternative herb, as it aids in improving nutrient absorption within the digestive tract and maintain efficient digestive function, which helps minimize the accumulation of harmful metabolic by-products (Yarnell, 1998). Stinging nettle (*Urtica dioica*) provides a range of nutritional and therapeutic benefits, making it a valuable herb for supporting both skin and bone health. Its antihistamine, anti-inflammatory, and antibacterial properties contribute to manage acne and other skin conditions by reducing redness, inflammation, and microbial activity (Bhusal *et al.*, 2022).

2.2.4 Uses of stinging Nettle

Stinging nettle (*Urtica dioica L.)* is a versatile plant widely used for culinary, medicinal, and functional food applications. Traditionally, young shoots and leaves are consumed as a leafy vegetable in various parts of Asia and Europe. To remove their stinging properties, the leaves are typically boiled or steamed before being used in soups, teas, and stews., providing a rich source of proteins, minerals, and vitamins (Bhusal *et al.*, 2022). Urtica dioica is often eaten as a vegetable, and when dried, it serves as animal feed during times of food scarcity. Traditionally, people also use a practice called urtication, where fresh stems and leaves are applied to the skin to help relieve joint pain(Devkota *et al.*, 2022).

The rich levels of calcium and iron allow nettle leaves to be used as a natural fortificant in developing nutrient-dense foods, such as enriched jellies and beverages (Bhusal *et al.*, 2022). Additionally, the leaves are a good source of vitamins A, C, and K, as well as essential amino acids, contributing to their potential as a beneficial dietary supplement.(Sahal *et al.*, 2025) Concentrated extracts of nettle are utilized as natural green colorants (chlorophyll, E140) in food products. Additionally, these extracts are incorporated into edible films and coatings for their antimicrobial activity, which helps prolong the shelf life of perishable foods (Mohammadian *et al.*, 2024).

Stinging nettle is widely utilized in both cosmetic and pharmaceutical industries for its rich bioactive composition. Its extracts are commonly added to hair care formulations, and skincare products, as they help stimulate hair growth, combat oxidative stress, and enhance overall health (Rawat *et al.*, 2020). Moreover, research indicates that nettle may contribute to weight management, cardiovascular health, and immune system function, making it highly versatile functional ingredient (Sahal *et al.*, 2025).

2.3 Jelly

Jelly is a sweet, gelled treat made by combining sugar with the juice or water-based extracts of one or more fruits. From a legal standpoint, jelly is a confection with a gel-like consistency formed by the addition of gelling agents, mainly pectin, agar, starch, or gelatin. Jelly products must meet certain specifications and standards for example, achieving an optimal consistency suitable for confectionery use and able to withstand handling during transport (Sotolář *et al.*, 2025)

Jelly is a semi-transparent, sweet spread made by boiling fruit juice with sugar and gelling agents like pectin, Agar-agar and gelatin until it congeals into a firm, elastic consistency. It is typically prepared by extracting the juice from fruits, sweetening it, and then boiling it to achieve the desired gel-like texture (Wikipedia, 2025). The practice of making jams and jellies originated as a domestic method, primarily employed by housewives, to preserve fruits at the peak of their harvest (Vibhakara and Bawa, 2006).

2.3.1 History of jelly.

Since ancient times, fruits have constituted a fundamental component of the human diet. Among various preservation methods, the production of jams and jellies represents a traditional technique that enables the utilization of surplus or cosmetically imperfect fruits that may not be suitable for direct consumption or baking. Unlike modern preservation methods such as canning and freezing, jelly-making is rooted in older, more conventional food preservation practices (McLellan and Singh, 2021). Historically, the preparation of jams and jellies likely emerged as an early method for preserving fruits for consumption during off seasons. The widespread popularity and availability of these preserved fruit products increased significantly with the advent of more cost-effective sugar production. The simplest by-product of citrus fruit production is undoubtedly jams in all their varieties. In the latter half of the 18^{th} century, the first recorded instance of jelly production was printed (Vibhakara and Bawa, 2006).

2.3.2 Ingredients Used in Jelly Preparation

Fruit jelly is prepared using a combination of ingredients that contribute to its texture, flavour, colour, and stability. The mixture is concentrated by heating until the soluble solids content of the finished jelly reaches a minimum of 65%. Optional ingredients such as spices, benzoic acid, flavour, and permitted artificial green colouring may be incorporated to enhance flavour, stability, and appearance (Vibhakara and Bawa, 2006).

2.3.2.1 Fruit

Fruit is what gives jelly its distinct flavour and texture. It naturally provides some of the pectin and acid needed for the jelly to set, along with the liquid that helps dissolve the other ingredients. To make a jelly with the best taste and quality, it’s important to use fresh and flavourful fruits (Wells-Moses, 2016). Fruits have less pectin and acid when fully ripe, so it is recommended that some underripe fruit be used when extracting juice for jelly. Fruits are usually gently heated to make it easier to extract the juice and to help release more of the natural pectin (Barton, 1989).

2.3.2.2 Acid

Acid plays a vital role in jelly making as it helps in the gel formation and enhances the flavour of the final product. In combination with pectin and sugar, acid assists in forming the correct gel structure. The acidity (pH between 2.8–3.5) ensures that the pectin molecules can properly link together, trapping water and forming a semi-solid gel (Wells-Moses, 2016).

If the acidity is too low (high pH), the jelly may not set properly, while excessive acidity can cause the jelly to become too stiff or result in pectin precipitation. In addition, acid improves the colour, taste, and preservation of the jelly by inhibiting the growth of spoilage microorganisms. Common acids used include citric acid, tartaric acid, and malic acid, either naturally present in fruits or added externally to adjust the pH.(Srivastava and Kumar, 2016) Since gelling agents such as agar are sensitive to both heat and low pH, it's best to reduce the pH only after the mixture has cooled slightly to prevent them from losing their gelling ability (Phillips and Williams, 2009).

2.3.2.3 Sweetener

Sweeteners play multiple roles in jelly formulation. They act as the primary source of sweetness, enhancing flavour and consumer acceptability. In addition, sugars such as sucrose, glucose syrup, and invert sugar help control crystallization, influence gel strength, and determine the moisture retention and chewiness of the final product. They also contribute to the preservation of jelly by reducing water activity, thus inhibiting microbial growth. The ratio and type of sweeteners used can significantly affect the clarity, elasticity, and mouthfeel of the jelly (Hartel *et al.*, 2018).

2.3.2.3.1 Sugar

Sugar is a main ingredient in confectionery products, not only for providing sweetness but also for improving texture. Sucrose is a disaccharide composed of two different monosaccharaides, glucose, and fructose with alpha 1-2 glycosidic linkage (Efe and Dawson, 2022). Sugar aids in the formation of the gel, enhances the flavour of the jelly, and acts as a preservative when present at around 55% by weight (Schafer and Driessen, 2021). It is a hygroscopic compound known as a humectant, which means that it can entrap water from the environment in two ways, absorption, or adsorption. Since sucrose acts as a water activity (aw) depressor, it helps reduce microbial spoilage by lowering the aw(Efe and Dawson, 2022). Sugars strengthen the gel structure by forming hydrogen bonds with water an effect that doesn't occur with sugars or gels by themselves (Gekko *et al.*, 1992).

2.3.2.4 Gelling agent

Gels are semisolid systems that exhibit properties of both solids (elasticity) and liquids (flow). This state is formed through a sol (liquid) to gel (solid) transition (Banerjee and Bhattacharya, 2012). Gelling agents are functional food ingredients responsible for altering the texture of products by forming a gel-like structure. They are defined by their ability to create continuous three-dimensional networks through interactions among specific proteins and polysaccharides. Common hydrocolloids such as gelatin, starch, pectin, carrageenan, and alginate are widely utilized as gelling agents. Beyond their primary role in enhancing the rheological and textural characteristics of foods, certain hydrocolloids can replace fats to reduce calorie intake (Kane *et al.*, 2024). Many commercial food products such as jams, jellies, confectioneries, fruit- and vegetable-based desserts, and quick-set gels utilize one or more permitted hydrocolloid gelling agents.

Table 2.3: Different types of gelling agent

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

Source:(Vibhakara and Bawa, 2006)

2.3.2.4.1 Agar

Agar is extracted from red algae (Rhodophyta) which can be divided into two components: agarose and agaropectin. Agarose is a neutral polysaccharide with a stronger gelling ability compared to agaropectin which contains charged polysaccharide components. Agarose is therefore the preferable component of agar and is used in the food, medicine, and pharmacy industry as well as for bacteria cultures. Agar has a gelling temperature at 40°C and melting temperature close to 90°C (Grétarsdóttir, 2019)

Agar-agar, commonly referred to as agar, is recognized as the earliest phycocolloid utilized as a food additive, with its use in the Far East dating back more than 300 years. Phycocolloids are those gelling substances derived from marine algae, utilized solely based on their colloidal properties (Phillips and Williams, 2009). The gelling capacity and solubility of agar polysaccharides depend on the relative hydrophobic nature of their repeating structural units, which consist of alternating 1,3-linked β-D-galactopyranose and 1,4-linked 3,6-anhydro-α-L-galactopyranose, collectively known as agarobiose (Lahaye and Rochas, 1991).

Agar gelation occurs primarily due to its agarose content, which forms gels through hydrogen bonding without requiring cations or other additives (Phillips and Williams, 2009). Gel formation can be viewed as a type of macromolecular aggregation, where linear agarose chains associate into double helices that further aggregate to form a three-dimensional network, entrapping water to create a gel. At temperatures above the gelling point, agarose exists as random coils, upon cooling, double helices form and aggregate into gel domains. Factors such as 6-sulfated residues in the polymer chain can reduce gel strength by disrupting helix formation, whereas alkaline treatment enhances gelation by forming 3,6-anhydro bridges. Overall, agar gelation is driven by helix formation, aggregation of domains, and hydrogen bonding, resulting in strong, stable gels even at low concentrations (Stanley, 2006).

Agar forms a reversible gel with a distinct property known as gel hysteresis, where the difference between its setting and melting temperatures is relatively large. As a result, agar solutions stay liquid at around 40 °C before solidifying and remain firm and stable up to nearly 80 °C (Imeson, 2009). It is tasteless and does not affect delicate flavours. Other gelling agents, like alginates or carrageenans, need cations to gel and are better for foods with strong flavours (Phillips and Williams, 2009) The FAO/WHO Codex Alimentarius permits its use in foods, and it is approved by regulatory authorities in many countries. In the United States, the FDA classifies agar as GRAS (Generally Recognized as Safe). In food applications, agar is primarily used as a gelling agent. It is employed in small amounts typically up to 1% for gelling making its contribution to nutrition and calories negligible. Agar is only partially digested, with studies showing that less than 10% is assimilated, which allows its use in special diet foods. In fruit jelly preparations, agar has an advantage over pectin as it can form gels without requiring high sugar concentrations (Armisen and Galatas, 1987).

2.3.3 Factors Affecting Gel Formation

Gel formation occurs spontaneously from a simple polymer dispersion or particulate suspension under externally controlled factors such as temperature or the composition of the solution (Banerjee and Bhattacharya, 2012). The formation of gels can be classified broadly as physically induced (heat, pressure) and chemically induced (acid, ionic, enzymatic) gelation reactions (Totosaus *et al.*, 2002).

2.3.3.1 Temperature

Heat-induced gelation is considered one of the most significant and widely used methods for gel formation. Gelation is a two-step process: First, an unfolding or dissociation of molecules takes place by heating to the required temperature. Then the temperature is brought down so that unfolded molecules associate and aggregate to form higher molecular weight complexes, thus forming gels. The first stage of the process is often reversible, while the second stage tends to be permanent. During gel formation, disulfide (–S–S–) bonds and hydrophobic interactions are mainly responsible for stabilizing the structure (Banerjee and Bhattacharya, 2012).

2.3.3.2 Pressure

High pressure is a valuable for modifying a molecule's functional properties because it can be used alone or in conjunction with other conditions, such as increased temperatures. In general, applying high pressure favors reactions that result in a decrease in the system's total volume (Heremans, 2009). For aqueous systems, pressure can cause water to dissociate, leading to a more acidic pH the resulting gels produced using high pressure have distinct differences in their appearance and rheological properties (flow and deformation characteristics) when compared to those made with conventional heat treatment (Ma *et al.*, 2015).

2.3.3.3 Ionic strength

Monovalent and divalent ions, such as sodium and calcium, can raise the ionic strength of the gel. This neglects the electrostatic repulsion between molecules, which enables gelation to occur. Such ion-triggered gelation, Ex Monovalent and divalent ions, for example, sodium and calcium, respectively, can raise the ionic strength of the gel. The addition of these ions minimizes the electrostatic repulsion between molecules. Such ion-triggered gelation, experienced in pre-denatured whey proteins, occurs in the absence of heat and is, hence, termed cold gelation. Ionic-induced gelation is of greater importance in polysaccharide gels, for instance, alginate, pectin, or carrageenan (Banerjee and Bhattacharya, 2012).

2.3.3.4 pH

Changes in pH, either through acid addition or microbial fermentation, alter the net charge of the molecules, which in turn affects the balance of attractive and repulsive forces between them, as well as their interactions with the solvent, influencing hydration properties (Banerjee and Bhattacharya, 2012). At the isoelectric point, proteins possess no net electrical charge, allowing closer molecular association. However, as the pH shifts away from this point, protein molecules become increasingly charged, resulting in greater electrostatic repulsion. This repulsion inhibits molecular interactions necessary for network formation, thereby weakening or preventing stable gel structure development (Totosaus *et al.*, 2002).

2.3.3.5 Concentration of Gelling Agent

Gel formation occurs above a critical minimum concentration, $C*$, which is specific for each hydrocolloid. For example, agarose can form gels at concentrations as low as 0.2%, whereas acid-thinned starch requires a concentration around 15% to gel (Aguilera and Rademacher, 2004).

2.3.4 Packaging material used in jelly production

Demand for processed products with sensory characteristics like fresh foods is increasing. To meet this demand requires appropriate packaging. To prevent losses in physical, chemical, nutritional and sensory characteristics, packages that block the incidence of light are used (Cunha *et al.*, 2020). The quality of jelly is influenced by proper processing, packaging, and storage. The packaging process and storage conditions are important factors that must be considered during the storage period of a jelly. Research indicates that the chosen packaging must effectively protect the product from contamination; otherwise, it could become a source of contamination for jelly. Common types of packaging used in the market include polypropylene (PP) plastic, aluminium foil, and glass jars (Nita *et al.*, 2024).

Packaging materials and storage conditions plays an important role in extending the shelf life of processed products by acting as barriers against airborne contamination and the loss or gain of moisture, thus ensuring the retention of all the desirable quality of the product during storage (Kuchi *et al.*, 2015). Glass jars with hermetically sealed lids are the most suitable containers for jams and jellies. A paraffin seal is insufficient to keep the product from spoiling. If jelly is to be poured into glass jars, the sides should be smooth to allow the jelly to be removed without losing its shape or structure. Before pouring the jelly, containers should be warmed before filling to avoid breakage. After filling, jars should be cooled quickly to around 21°C. Jelly that is hot filled above 83°C does not require pasteurization, since the heat of the jelly sterilizes the container. Jars should be filled to at least 90% capacity, leaving no more than 1.25 cm of headspace. Scalded lids should be placed loosely on the jars immediately after filling and then tightened firmly within 2–3 minutes, allowing air in the headspace to escape. As the jelly cools, the steam condenses, forming a vacuum seal (Meena and Meena, 2016).

2.3.5 Defects in jellies

Different types of defects that might be found during jelly making processes which are described in following paragraphs.

2.3.5.1 Failure of jellies to set

2.3.5.1.1 Lack of acid or gelling agent

Insufficient levels of gelling agent, acid, or both in the fruit from which jam or jelly is made, can result in the failure of jam or jelly to set properly. The fruit jelly also fails to set due to insufficient fruit cooking, resulting in inadequate gelling agent and acid extraction (Biswas, 2021).

2.3.5.1.2 Addition of too much sugar

Excess sugar can cause jelly to become syrupy or result in a very soft jelly. This texture can be corrected or stabilized by incorporating fresh clarified fruit juice that is high in pectin (Biswas, 2021).

2.3.5.1.3 Cooking below the end point

If cooking is stopped before reaching the 65 percent sugar concentration, the texture of the jelly will fail to set and remain syrupy and soft (Swer *et al.*, 2019).

2.3.5.1.4 Cooking beyond the end point

Continue heating beyond the gelation point can make jelly tough because of over-concentration. This typically occurs when the juice contains high levels of both acid and pectin, but insufficient sugar has 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).

2.3.5.2 Cloudy or foggy jelly

2.3.5.2.1 Cloudy jelly

When the juice or extract remains unclarified, this type of jelly is produced (Swer *et al.*, 2019).

2.3.5.2.2 Use of immature fruits

Green, immature fruits contain starch that does not dissolve in juice, which causes jelly made from them to appear cloudy (Swer *et al.*, 2019).

2.3.5.2.3 Over-cooking

Overcooked jellies become gummy and sticky, and their high viscosity prevents them from achieving a transparent appearance when placed in a container (Swer *et al.*, 2019).

2.3.5.2.4 Over cooling

Allowing the mixture to stand for an extended period after cooking before filling can result in a cloudy appearance (Darkwa and Boakye, 2016).

2.3.5.2.5 Faulty pouring into containers

Pouring jelly from a great height into jars can trap air bubbles, which are difficult to clear. The spout of the pouring vessel should not be more than about 2.5 cm from the top of the container (Darkwa and Boakye, 2016)

2.3.5.2.6 Non removal of scum

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

2.3.5.3 Formation of crystals

Crystallization in jelly occurs when there is an excess of sugar and the final product exceeds 70° Brix, with crystals forming even at room temperature. Monitoring the solids content of the boiling fruit solution using a refractometer helps prevent over-crystallization and excessive sugar concentration (Biswas, 2021).

2.3.5.4 Syneresis or weeping of jelly

The weeping / syneresis jelly is a phenomenon of spontaneous exudation of fluid from a gel (Biswas, 2021). Syneresis in jelly is influenced by several formulation and processing factors. Excess acidity can promote the hydrolysis and degradation of pectin, leading to weakening and collapse of the gel structure, particularly in softer jellies, thereby increasing water release (Moyls *et al.*, 1962) Similarly, a low concentration of sugar or soluble solids reduces the ability of the pectin network to effectively bind water, resulting in greater liquid separation. Premature gelation during processing may disrupt the formation of a uniform pectin network while filling containers, producing a weak and fractured gel structure that enhances syneresis (Swer *et al.*, 2019)

2.3.5.5 Fermented jellies

Naturally fruits are prone to fermentation, and this can also be a problem when the amount of sugar is too small or the jar that it is placed in is not sealed properly. To prevent fermentation and to ensure proper sealing, the boiling water process needs to be used. The top of the container can at times make the jam or jelly dark. The boiling water method is a process whereby the jars are placed in a pot filled with water and boiled. By applying this process fermentation in foods with a high acid content is lowered thereby extending its shelf (Darkwa and Boakye, 2016).

2.3.6 Microbial spoilage of jelly

Jelly affected by syneresis undergo fermentation during storage. When jelly is sealed using paraffin wax and stored under moist conditions, the growth of mold is often encouraged. Mold development in jelly can occur due to improper covering of the product, pouring the paraffin wax at an insufficient temperature to destroy surface microorganisms, and the failure or cracking of the wax seal during storage (Board, 2012) The growing demand for low-calorie foods has encouraged the production of low-sugar jams/ jelly however, these products are more susceptible to spoilage by xerophilic molds and osmophilic yeasts due to the increase in water activity from 0.80 to 0.94 (Peckham, 1964). According to established microbiological standards, the acceptable limit for both standard plate count (SPC) and yeast and mold count (YMC) is $\leq 6 \log_{10}$ CFU/g (Anuar *et al.*, 2022). During storage, microbial counts in jelly generally increase due to the growth of surviving microorganisms, but they often remain within permissible limits. (Prisacaru *et al.*, 2025) reported that total plate counts (TPC) in commercial jams /jelly rose from approximately 3 $\log_{10}$ CFU/g to 6–7 $\log_{10}$ CFU/g over storage, while yeast and mould counts increased up to 6.79 $\log_{10}$ CFU/g without visible spoilage, reflecting typical microbial behaviour in such high-sugar, low-pH products.

2.3.7 Physiochemical properties of jelly

2.3.7.1 TSS

Sugar, a naturally occurring preservative in foods, is among the most important constituents of fruits. It is advised to use a Brix of 68±0.71 to slow down microbial development (Ahmed *et al.*, 2016). The ideal total soluble solids content for proper gel formation is slightly above 65% however, gelation can still be achieved at 60% solids if the pectin and acid concentrations are increased (Desrosier and Desrosier, 1977).

2.3.7.2 Titratable acidity

Titratable acidity (TA) is an important chemical parameter that represents the total concentration of organic acids present in a food product (Sadler and Murphy, 2010). In jelly products, titratable acidity plays a critical role in determining flavour, gel stability, microbial safety, and overall shelf life. Unlike pH, which measures only the intensity of acidity, titratable acidity reflects the total acid content responsible for sour taste and buffering capacity of the product.

2.3.7.3 Reducing sugar

During jam or jelly production, sucrose undergoes inversion in the acidic environment, which helps prevent crystallization during cooking. Manufacturers aim for the reducing sugar content to be between 20–40% of the preserve to avoid sugar crystal formation during storage (Girdhari, 2018).

2.3.7.4 Ascorbic acid

Vitamin C (ascorbic acid) functions as an antioxidant, and its content is crucial for assessing the quality of a product. However, naturally occurring antioxidants are significantly reduced during heating (Mumtaz *et al.*, 2019)

2.3.7.5 PH

Agar gelation is generally less affected by pH compared to pectin, as agar can form a gel across a relatively wide pH range of approximately 4–8. Unlike pectin, it does not require highly acidic conditions (pH below 4.5) for gel formation., extremely low pH values (below 3) may slightly weaken the gel, while a neutral to mildly acidic pH (around 4–6) is considered optimal for achieving stable gelation. Although agar itself is tolerant to higher pH levels, the overall pH of the product still influences flavour and microbial safety (Phillips and Williams, 2009).

2.3.7.6 Moisture content

Moisture content determines the shelf life of fruit, and fruits with high moisture are not ideal for jam or jelly production. Such fruits require higher temperatures and longer cooking times to reach the desired Brix level. Excessive heat during preparation or storage can reduce product quality, increase processing time and energy consumption, and ultimately cause Maillard browning and the development of off-Flavors (Bates *et al.*, 2001)

2.3.8 Sensory properties of jelly

Sensory analysis uses human senses (sight, smell, taste, touch, and hearing) to evaluate a product's overall characteristics, including its texture, flavour, appearance, and aroma. While historically used to judge basic food quality and safety, its significant advancements have made it a critical strategy for innovation and application in recent decades, primarily ensuring products meet consumer acceptance (Ruiz-Capillas and Herrero, 2021).

The overall acceptance of a food product, such as fruit jelly, is fundamentally driven by its intrinsic sensory attributes including the expected transparency, gelatinous consistency, and characteristic fruit flavour, colour, and aroma. These sensory properties are vital because consumers actively use them as quality cues (Sharif *et al.*, 2017). The successful meeting or exceeding of these expectations across key attributes such as flavour, texture, and colour is essential, and determining which single sensory feature most heavily influences the ultimate quality assessment and repurchase decision is a crucial objective for food manufacturers (Pereira *et al.*, 2020).

2.4 Effect of Plant Extracts on Quality Attributes of Jelly

The incorporation of plant extracts into jelly and gelled products has received considerable attention due to their ability to enhance the nutritional quality, antioxidant potential, and functional value of traditional confectionery foods. Herbal and leafy plant extracts, including stinging nettle (*Urtica dioica* L.), are rich sources of phenolic compounds, flavonoids, vitamins, and minerals, making them suitable ingredients for the development of value-added gelled products. Several studies have investigated how plant extracts influence the quality characteristics of jelly and gelled foods, demonstrating notable effects on colour, texture, sensory attributes, and antioxidant activity.

Research on medicinal plant extracts added to jelly systems has shown that incorporation of plant bioactives can significantly affect antioxidant activity, physicochemical and sensory properties. For example, (Kim *et al.*, 2013) developed gelatin jelly fortified with medicinal plant extracts and found that the extracts increased antioxidant activity, while altering colour and texture compared to control samples. The interaction between plant extract compounds and hydrocolloid matrices also plays an important role in jelly quality. A study on red beet jelly candy with added ginger extract showed that the presence of ginger influenced antioxidant activity and physicochemical properties, with variations depending on the type of hydrocolloid used (agar vs carrageenan). This illustrates that plant extracts can modulate gel network behaviour and functional attributes in combination with hydrocolloids (Fitriah *et al.*, 2025).

Several studies have reported that moderate levels of herbal extract incorporation can result in acceptable or even improved overall sensory scores, particularly when combined with fruit Flavors that mask potential herbal notes. Consumer acceptance of such products is further enhanced by the increasing awareness of the health benefits associated with plant-based ingredients (Lawless and Heymann, 2010). Plant extracts can significantly affect the colour of jelly products because they contain natural pigments like chlorophylls, flavonoids, and betalains. These pigments may change the traditional look of jellies, but they often create a more appealing sense of freshness and health for consumers. In fact, research suggests that using plant-based colorants in gelled products supports the growing trend toward clean-label, naturally coloured foods (Sigurdson *et al.*, 2017)

Part III

Materials and methods

3.1 Materials

3.1.1 Dragon fruit

Mature and fully ripened dragon fruits (*Hylocereus polyrhizus*) were brought from the local market in Dharan.

3.1.2 Stinging nettle

Stinging nettle (*Urtica dioica* L.) buds were brought from the local market of Dharan.

3.1.3 Sugar

Crystalline cane sugar was used which was purchased from local market of Dharan as needed.

3.1.4 Citric acid

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

3.1.5 Agar

Agar agar Type I, manufactured by HiMedia Laboratories Pvt. Ltd., India, was used as the gelling agent and sourced from the laboratory of the Central Campus of Technology.

3.1.6 Packaging materials

Glass bottles were used as the primary packaging materials, and caps sealed with aluminium foil were employed as closures. Both were purchased from Bhatbhateni Supermarket, Dharan.

3.1.7 Chemicals and equipment

All the equipment and chemicals required during the dissertation were provided by Central Campus of Technology.

3.1.8 Other materials

Other materials such as muslin cloth, glass bottles, plastic cups, and aluminium foil were sourced from the local market in Dharan for use in this study.

3.2 Methods

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

3.2.1 Preparation of dragon fruit juice

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

Dragon fruit

↓

Washing

↓

Peeling and cutting into slices

↓

Addition of water (1:1 slices: water)

↓

Boiling for about 20 - 30 minutes

↓

Straining the extract with muslin cloth

↓

Dragon fruit juice

Figure 3.1: Flowchart for preparation of dragon fruit juice

Source:(Panchal *et al.*, 2018)

Fully ripened dragon fruits were thoroughly washed, peeled, and sliced. The flesh was then cooked with an equal amount of water for a few minutes with occasional stirring until it softened. The softened mixture was subsequently strained through muslin cloth to extract the juice.

3.2.2 Extract recovery

The whole extract was gathered and measured in a glass jar, and the percentage recovery was calculated based on the total quantity of materials used.

3.2.3 Preparation of stinging nettle extract

Fresh nettle leaves are first cleaned thoroughly with water to remove dust and impurities, then blanched at 90 °C for about one minute to inactivate enzymes and reduce stinging compounds. The blanched leaves are dried at 50 °C until constant weight is achieved, ground into fine powder, and mixed with hot distilled water for 30 minutes to extract bioactive compounds. Finally, the mixture is filtered through Whatman No. 1 filter paper to obtain the nettle extract.

Fresh nettle leaves

↓

Cleaning

(Wash thoroughly with clean water to remove dust and impurities)

↓

Blanching at 90degree for about 1 min

(In hot water to inactivate enzymes and reduce stinging compounds)

↓

Drying (at 50°C)

(Until constant weight to remove moisture)

↓

Grinding

(Grind dried leaves into fine powder)

↓

Extraction (1:10 nettle powder: water)

(Mix nettle powder with distilled hot water and soak for 30 minutes)

↓

Filtration

(Filter through Whatman No. 1 filter paper)

↓

Nettle Extract

Figure 3.2: Flowchart for preparation of stinging nettle extract

Source:(Nallan Chakravartula *et al.*, 2021; Muceniece *et al.*, 2025)

3.2.4 Design of experiment

The formulation was developed using Design Expert software version 13.05, employing a D-optimal design approach. The experiment focused on varying the concentration of dragon fruit and stinging nettle extract as independent variables, while keeping the concentration of sugar(130g), citric acid (0.5%) and agar-agar (2%) constant.

Table 3.1: Design of experiment

S.N.	Sample	Dragon fruit (%)	Stinging nettle (%)
1.	A	67	33
2.	B	63	37
3.	C	75	25
4.	D	100	0
5.	E	83	17
6.	F	50	50
7.	G	88	12

3.2.5 Preparation of dragon fruit and stinging nettle jelly

Jelly was prepared with the variation in dragon fruit juice and nettle extract content. **Figure 3.3** shows the process flowchart for the preparation of dragon fruit and stinging nettle extract jelly.

Dragon fruit juice | Stinging nettle extract | Boil 20ml of water to dissolve sugar and gelling agent completely

↓

Mixing the ingredients

↓

Boiling the juice with continuous stirring until the TSS reaches~67° Bx

↓

Addition of citric acid

↓

Blend well and pour the mixture into the mold of the desired shape

↓

Keep the mold undisturbed at room temperature for about 1-2 hrs until it sets

↓

Store in the refrigerator for about 24 hrs.

↓

Demold and Pack in sterilized glass jar

Figure 3.3: General flow chart for jelly preparation

3.2.6 Process optimization in the preparation of dragon fruit and stinging nettle jelly

Seven different samples of different proportion of dragon fruit and stinging nettle were taken and coded as A (67% dragon fruit juice and 33% stinging nettle extract), B (63% dragon fruit juice and 37% stinging nettle extract), C (75% dragon fruit juice and 25% stinging nettle extract), D (100% dragon fruit juice)which is control, E (83% dragon fruit juice and 17% stinging nettle extract), F (50% dragon fruit juice and 50% stinging nettle) and G(88% dragon fruit juice and 12% stinging nettle extract). The citric acid and Agar agar was added in the amount of 0.5% and 2% respectively. The best quality jelly was selected based on sensory evaluation (colour, flavour, texture, taste, overall acceptability).

3.2.7 Filling, Sealing and cooling

The hot jelly mixture was filled into pre-sterilized moulds to achieve the desired shape. After setting and cooling to attain the appropriate texture, the candies were transferred into sterilized glass bottles, which were then capped and sealed with aluminium foil to ensure product safety and maintain quality. The best sample after sensory evaluation through 9-point hedonic scale rating was stored in two different storage conditions: refrigeration temperature and room temperature.

3.2.8 Physiochemical analysis

3.2.8.1 Determination of Total Soluble Solid (TSS)

The TSS of the pulp and the samples were determined using a hand refractometer, and the results were expressed as °Bx.

3.2.8.2 Determination of Moisture content

The moisture content of the samples was determined by weight loss during heating in a thermostatically controlled oven at 90°C by the hot air oven method as given by (Ranganna, 1986)

3.2.8.3 Determination of acidity

Acidity was measured using the titrimetric method outlined by (Ranganna, 1986). The acidity was calculated using the formula:

$$\%\text{acidity (as citric acid)} = \frac{\text{Titre} \times \text{Normality of NaOH} \times \text{Vol. makeup} \times 64}{\text{Aliquot} \times \text{Weight of sample} \times 1000} \times 1000$$

3.2.8.4 Determination of Vitamin C

Ascorbic acid (Vitamin C) was determined by the 2,6-dichlorophenol indophenol titration method as described by (Kc and Rai, 2007). About 15 g sample was taken, extracted with 100 ml 3% HPO_3 and filtered to get a clear filtrate. Filtrate was titrated with a dye solution to the pink endpoint, persisting for at least 15 s. The standard ascorbic acid solution was used to standardize the dye, and the dye factor was determined using the formula:

$$\text{Dye factor} = \frac{\text{mg of ascorbic acid}}{\text{ml of dye}}$$

Ascorbic acid was calculated as:

$$\text{mg \% ascorbic acid} = \frac{\text{Titer} \times \text{Dye factor} \times \text{Vol. madeup} \times 100}{\text{Aliquot} \times \text{Weight of sample taken}}$$

3.2.8.5 Determination of pH

It was directly measured by using pH meter. pH meter was standardized by using buffer solution of pH 4, 7 and 10 at the room temperature.

3.2.8.6 Reducing Sugar and total sugar

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

3.2.8.7 Non- reducing sugar

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

3.2.8.8 Determination of protein content

Protein content in the sample was determined by micro- kjeldahl method (by estimating nitrogen content) according to (Ranganna, 1986).

3.2.8.9 Calcium content

The calcium content of the sample was determined by flame photometer as method given by (Kc and Rai, 2007).

3.2.9 Antioxidant

The antioxidant activity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay.

A 0.1 mM DPPH solution was prepared in methanol and stored protected from light. For the assay, 1.0 mL of each sample extract was mixed with 3.0 mL of the DPPH solution in a test tube. The mixture was vortexed and incubated for 30 min in the dark at room temperature to allow the reaction between antioxidants in the sample and DPPH radicals. After incubation, the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. A control was prepared by mixing 1.0 mL of solvent (water or methanol, matching each sample) with 3.0 mL DPPH solution, and methanol was used as blank. The antioxidant activity (%) was calculated using:

$$\text{DPPH Scavenging Activity (\%)} = \frac{A_0 - A_s}{A_0} \times 100$$

where A_0 is the absorbance of the control (DPPH + solvent) and A_s is the absorbance of the sample–DPPH mixture. Higher percentage values indicate stronger free-radical scavenging capacity. This simple spectrophotometric method is widely used for evaluating the antioxidant activity of plant extracts and food products (Brand-Williams *et al.*, 1995)

3.2.10 Determination of total phenolic content (TPC)

For the TPC assay, an aliquot of 0.5–1.0 mL of each filtered sample was mixed with 2.5 mL of 10% (v/v) Folin–Ciocalteu reagent. After standing for 3–5 min, 2.0 mL of 7.5% (w/v) sodium carbonate (Na_2CO_3) solution was added. The mixture was thoroughly mixed and incubated for 30 min at room temperature in the dark to allow color development. The absorbance was then measured at 765 nm using a UV–Vis spectrophotometer against an appropriate reagent blank prepared in the same way.

A standard calibration curve was prepared using gallic acid solutions of known concentrations, and TPC was expressed as mg gallic acid equivalents per 100 g of sample (mg GAE/100 g). The Folin–Ciocalteu method is a widely used and reliable procedure for determining phenolic content (Singleton and Rossi, 1965).

3.2.11 Determination of total flavonoid content (TFC)

Total flavonoid content (TFC) was determined using the aluminium chloride ($AlCl_3$) colorimetric method. The filtered samples prepared were used. For each assay, 1.0 mL of sample extract was pipetted into a test tube and mixed with 3.0 mL methanol, 0.2 mL of 10% (w/v) $AlCl_3$, 0.2 mL of 1 M potassium acetate and 5.6 mL distilled water. The mixture was vortexed and incubated for 30 min at room temperature. After incubation, the absorbance was measured at 415 nm using a UV–Vis spectrophotometer, with an appropriate blank prepared by replacing the sample with the corresponding solvent.

A calibration curve was constructed using quercetin standard solutions, and TFC was expressed as mg quercetin equivalents per 100 g of sample (mg QE/100 g). The $AlCl_3$ colorimetric method is simple, inexpensive, and widely used for estimating flavonoids in plant-based foods and beverages (Chang *et al.*, 2002)

3.2.12 Preparation of betacyanin extract

The juice was mixed with distilled water in the ratio of 1:2 for 5 min. Juice mixture was shaken using volumetric shaker at 200 rpm for 120 min and then filtered through Whatman no. 41 filter paper. After centrifugation at 5000g for 15 min, the supernatant collected was used for determination of betacyanin.

3.2.13 Determination of betacyanin content

For total betacyanin determination, the absorbance of aqueous extract was measured at 538 nm using a spectrophotometer (Lim *et al.*, 2011b), and the concentration was calculated using the formula:

$$\text{Betacyanin content (mg/100g)} = \frac{A(MW) \times V \times (DF) \times 1000}{ELW} \times 100$$

Where A= absorbance at 538nm, L (path length) =1.0cm, DF= dilution factor, V= volume extract (ml), W= fresh weight of extracting material (g). For betanin, E (mean molar absorptivity) = 6.5×10^4 L/mol cm in H2O and MW (molecular weight) = 550g/mol.

3.2.14 Statistical analysis

All the data obtained in this work was analyzed by the statistical program known as Statistical Package for the Social Sciences (SPSS) Version 27. For Product formulation Design expert 13 was used. MS- Excel 2025 was also employed for general calculations, graph and diagram construction.

3.2.15 Microbiological analysis

Plate Count Agar (PCA) medium was used to determine Total Plate Count (TPC) using the pour plate technique (incubated at 37°C/24 h). Using the spread plate technique on Potato Dextrose Agar (PDA) medium (incubated at 30°C/48 hours), the number of yeast and moulds was counted.

3.2.16 Storage stability of the jelly

Glass bottles that had been previously sterilised were aseptically filled with the jelly, which was then kept at room temperature (27±3°C) and refrigeration temperature (7ºC).Following 40 days of storage, the storage stability was then assessed at 10-day intervals based on changes in TSS, acidity, pH, reducing sugar, total sugar, vitamin C retention, moisture content and microbial alterations.

3.2.17 Sensory evaluation

The prepared samples were evaluated for consumer acceptability through sensory analysis. Attributes such as appearance, texture, taste, flavour, and overall quality were assessed using a 9-point hedonic rating scale, as outlined by Ranganna (1986). The evaluation was conducted with the help of 10 semi-trained panellists, comprising teachers and students of B. Tech (Food) at CCT. The format of the specimen card used is shown in Appendix A.

Result and discussion

The work was carried out to prepare agar-based dragon fruit jelly incorporated with stinging nettle and investigate how well they stored. The key ingredients were dragon fruit juice and stinging nettle extract, plus varying amounts of sugar, citric acid, and agar agar. A sensory analysis was performed on seven distinct jelly samples that had varying ratios of stinging nettle extract and dragon fruit juice. The best sample was chosen, and it was examined for storage stability during a 40-day period at room temperature and refrigeration.

4.1 Physiochemical properties of Fruit

4.1.1 Dragon fruit and stinging nettle

The result of the physiochemical analysis of the fresh dragon fruit is shown in **Table 4.1**.

Table 4.1: Chemical analysis of fresh dragon fruit.

Parameters	Dragon Fruit
TSS(°Bx)	11.1±0.56
pH	4.57±0.20
Reducing sugar (mg/100)	4.86±0.13
Non reducing sugar (mg/100)	4.18±0.81
Total sugar (mg/100)	9.04±0.89
Vitamin C (mg/100)	8.43±0.47
Acidity (%)	0.19±0.01
Moisture content (%)	87±1

Calcium content(mg/100)	7.6±0

* All data are expressed as the mean standard deviation (SD) of three independent replicates

Table 4.2: Phytochemical analysis of fresh dragon fruit.

Parameters	Dragon fruit
Total phenolic content (mg GAE/100g)	16.40±0.68
Total flavonoid content (mg QE/100g)	3.07±0.16
Radical scavenging activity (%)	74.59±0.20
Betacyanin content (mg/100 g)	29.45±0.40

* All data are expressed as the mean standard deviation (SD) of three independent replicates

The TSS, pH, reducing sugar, non-reducing sugar, total sugar, vitamin C, acidity, moisture content of Dragon fruit was found to be 11.1°Bx, 4.57, 4.86mg/100g, 4.18mg/100g, 9.04mg/100g, 8.43mg/100g, 0.19% and 87% respectively. Similarly, the total phenolic content, total flavonoid content, betacyanin content and radical scavenging activity of dragon fruit juice were found to be 16.40 mg GAE/100g, 3.07 mg QE/100g, 29.45 mg/100g and 74.59% respectively. The moisture content of the pulp was found to be consistent with the findings of(Sonawane and Shrikant, 2017).

The pH, TSS, vitamin C, calcium content, total phenolic content and betacyanin content of the dragon fruit were found in accordance with (Rathi *et al.*, 2024) but radical scavenging activity were slightly higher than the findings. According to(Abd Manan *et al.*, 2019) dical scavenging activity and total flavonoid content were 73.38 ± 2.24% and 2.26 ± 0.14 mg of QE/100g. The acidity, reducing sugar, non-reducing sugar and total sugar of the dragon fruit were found accordance with (Budhathoki *et al.*, 2023). Findings obtained during this study were in range. Some were slightly higher or lower than the findings which may be due to the variation of species and also the tropical regions where it is grown (Atreya *et al.*, 2020).

Table 4.3: Chemical and phytochemical analysis of stinging nettle powder.

Parameters	Stinging nettle
pH	6.83±0.05
Vitamin C (mg/100g)	25.5±0.15
Protein (%)	20.87±0.04
Moisture content (%)	8.14±0.22
Calcium content(mg/100g)	164.32±0.88
Total phenolic content (mg GAE/100g)	19.98±0.41
Radical scavenging activity (%)	56.83±0.39

* All data are expressed as the mean (±) standard deviation (SD) of three independent replicates

The pH, vitamin C, protein, moisture content, calcium, total phenolic content, radical scavenging activity of nettle powder was found to be 6.83, 25.5 mg/100g, 20.87%, 8.14%, 164.32 mg/100g, 19.98 mg GAE/100g and 56.83% respectively.

The moisture content, vitamin C, protein and calcium content of stinging nettle powder were similar with the findings of (Bhattarai *et al.*, 2017). The total phenols content and radical scavenging activity was 20.72 mg GAE/100g and 53.60% in accordance with (Tarasevičienė *et al.*, 2023) which is slightly higher or lower with current data that may be due to the variation of species and also the tropical regions where it is grown. Findings obtained during this study were in range.

4.2 Sensory Analysis

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

4.2.1 Appearance

Sensory evaluation for Appearance yielded mean scores ranging from 5.13 to 8.13 across samples A through G, as presented in **Figure 4.1**. The mean scores were 5.13, 8.13, 7.38, 7.88, 7.38, 7.13, and 7.25 respectively for sample A, B, C, D, E, Fand G.

These mean scores are graphically depicted in **Figure 4.1** Statistical analysis using ANOVA, detailed in (Appendix B) revealed significant differences in appearance scores among the samples. Post-hoc analysis using Tukey's Honestly Significant Difference (HSD) test at a 95% confidence level (α=0.05) identified specific groupings, as indicated by the letters above each bar in **Figure 4.1**

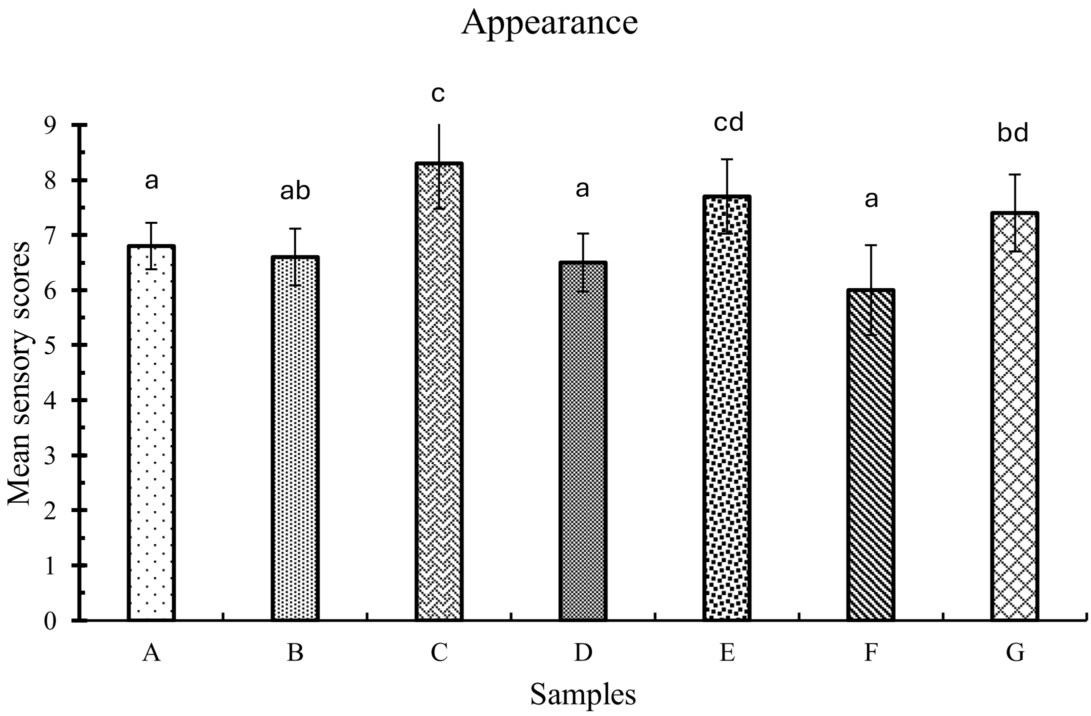

Figure 4.1: Sensory evaluation on attribute "Appearance"

Similar alphabet above the bar graph indicates no significant difference where different letters indicate significant difference and error bars shows standard deviation of scores given by 10 panellists whereas different letters represent the differences. Based on mean score with respect to appearance given in Appendix C., the superiority/inferiority ($p \leq 0.05$) of the jelly was found to rank as follows:

[C] > [E] > [G] > [A] > [B] > [D]

From the mean score it can be concluded that Sample C got the highest score in appearance as compared to other samples in series. Since no additional artificial color has been added to the products, the fluctuation in the appearance seen in the product is fully dependent on the composition of dragon fruit juice and stinging nettle extract, the different variation made in composition may be the reason that shows difference in color of different products.

4.2.2 Texture

Sensory evaluation for texture yielded mean scores ranging from 6 to 8.3 across samples A through G, as presented in **Figure 4.2**. The mean scores were 6.3, 6.3, 7.7, 8.3, 7.3, 6, and 6.8 respectively for sample A, B, C, D, E, F and G. The error bars show the standard deviation between the sensory panellist scores. These mean scores are graphically depicted in **Figure 4.2**.

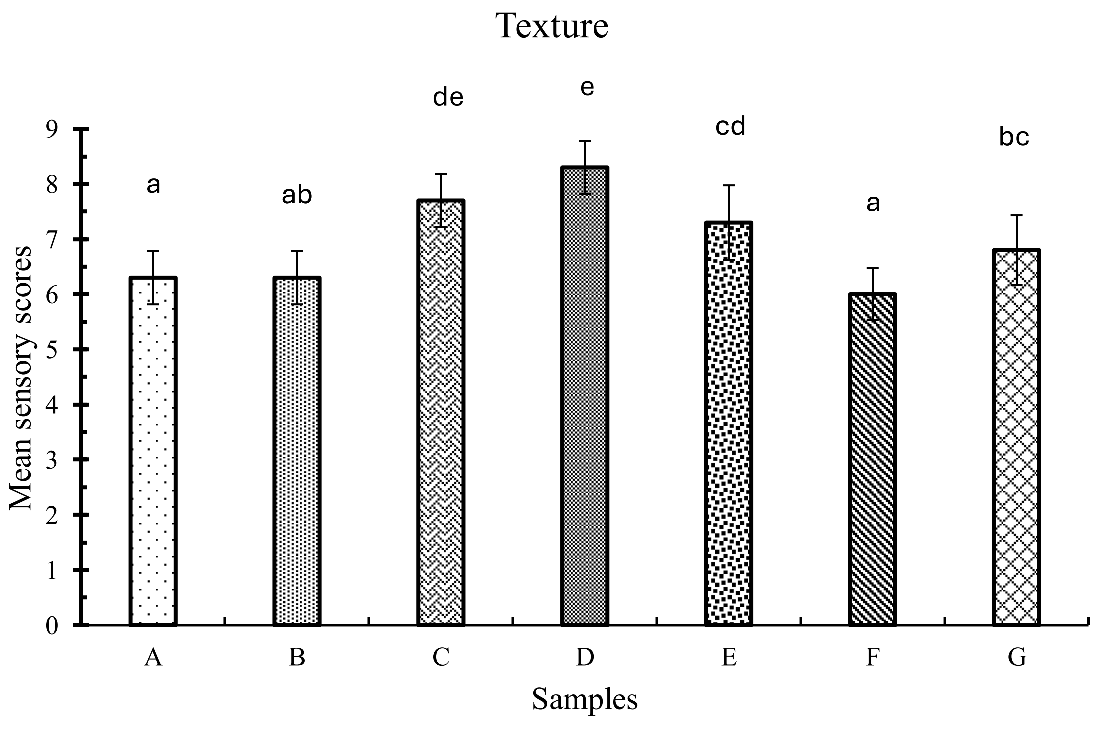

Figure 4.2: Sensory evaluation on attribute "Texture"

Similar alphabet above the bar graph indicates no significant difference where different letters indicate significant difference and error bars shows standard deviation of scores given by 10 panellists whereas different letters represent the differences. The sensory evaluation demonstrated significant variations in texture across the different samples. Sample D exhibited the highest mean score, significantly exceeding those of samples A, B, C, E, F, and G. Based on mean score with respect to texture given in Appendix, the superiority/inferiority ($p \leq 0.05$) of jelly was found to rank as follows:

[D] > [C] > [E] > [G] > [A, B] > [F]

From the mean score it can be concluded that Sample D got the highest score in texture as compared to other samples in series. Since sample D consists entirely of dragon fruit juice and serves as the control, it indicates that the addition of stinging nettle extract influences the jelly's texture.

4.2.3 Taste

Sensory evaluation for Taste yielded mean scores ranging from 8.1 to 6 across samples A through G, as presented in **Figure 4.3**. The mean scores were 6.9, 6.4, 8.1, 6.6, 7.8, 6, and 7.4 respectively for sample A, B, C, D, E, F and G. The error bars show the standard deviation between the sensory panellist scores. These mean scores are graphically depicted in **Figure 4.3**.

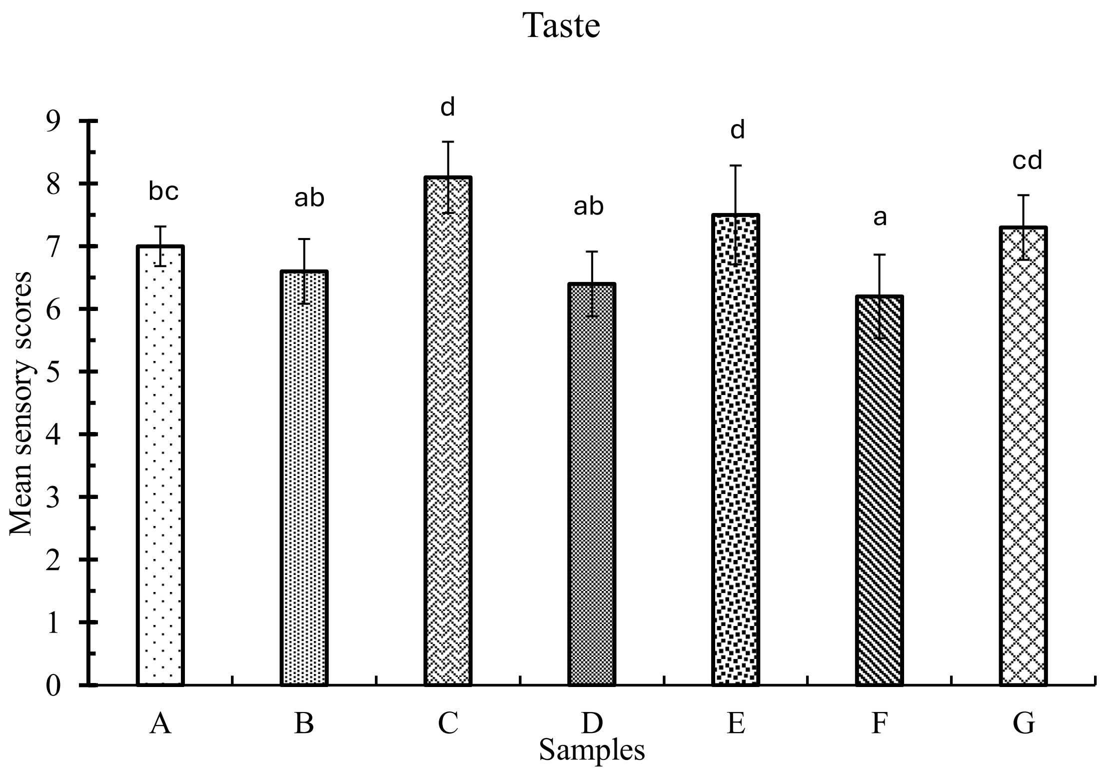

Figure 4.3: Sensory evaluation on attribute "Taste"

Similar alphabet above the bar graph indicates no significant difference where different letters indicate significant difference and error bars shows standard deviation of scores given by 10 panellists whereas different letters represent the differences. The sensory evaluation demonstrated significant variations in taste across the different samples. Sample C exhibited the highest mean score, significantly exceeding those of samples A, B, D, E, F and G. Based on mean score with respect to taste given in Appendix C the superiority/inferiority ($p \leq 0.05$) of jelly was found to rank as follows:

[C] > [E] > [G] > [A] > [D] > [B]>[F]

Significant differences in taste were observed across the samples during sensory evaluation may be due to variation in composition of dragon fruit juice and stinging nettle extract.

4.2.4 Flavour

Sensory evaluation for flavour yielded mean scores ranging from 6 to 8 across samples A through G, as presented in **Figure 4.4**. The mean scores were 6.4, 6.1, 8.1, 7.6, 6.8, 6 and 7.2 respectively for sample A, B, C, D, E, F and G.

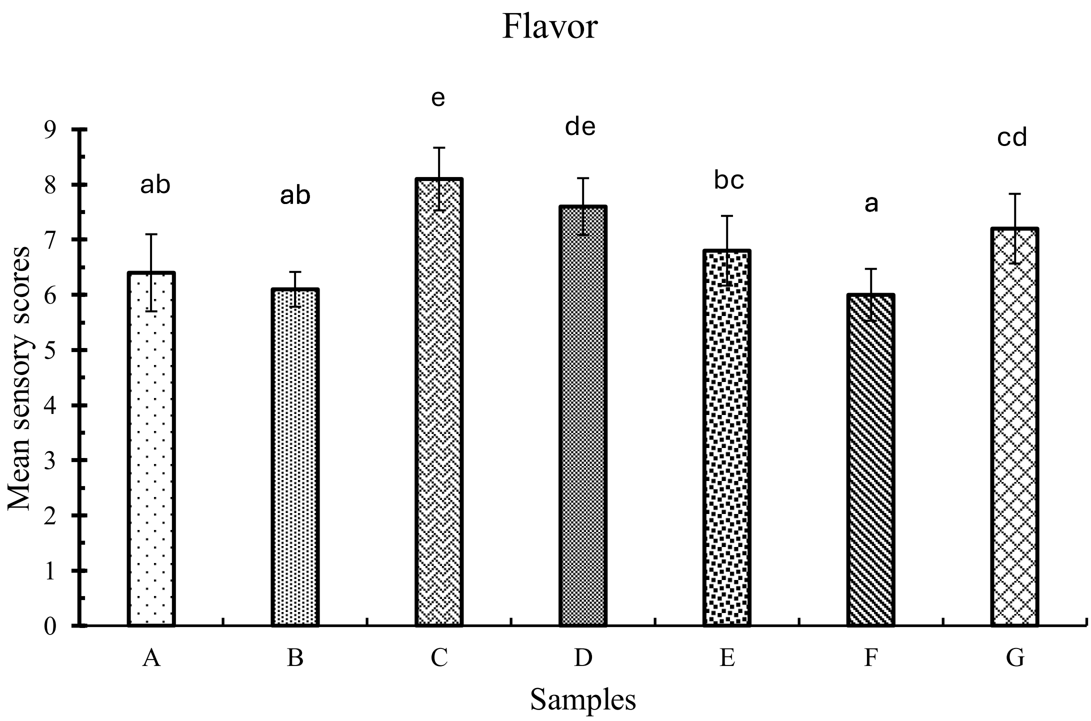

Figure 4.4: Sensory evaluation on attribute "Flavour"

Similar alphabet above the bar graph indicates no significant difference where different letters indicate significant difference and error bars shows standard deviation of scores given by 10 panellists whereas different letters represent the differences. The sensory evaluation demonstrated significant variations in flavour across the different samples. Samples C and D exhibited the highest mean scores, significantly exceeding samples A, B, E, F and G. Based on mean score with respect to flavour given in Appendix C, the superiority/inferiority ($p \leq 0.05$) of the jelly was found to rank as follows:

[C] > [D] > [G] > [E] > [A] > [B] > [F]

Among all the other attributes sample C score exceeded the score of all other samples that might be due to good combination of composition and cooking time. Since colour or flavour are not added during the jelly making process, the quality and type of ingredients used determines the sensory attributes like appearance and flavour.

4.2.5 Overall acceptability

Sensory evaluation for overall acceptance yielded mean scores ranging from 6.2 to 8.3 across samples A through G, as presented in **Figure 4.5**. The mean scores were 6.9, 6.5, 8.3, 6.5, 7.8, 6.2 and 7.4 respectively for sample A, B, C, D, E, F and G.

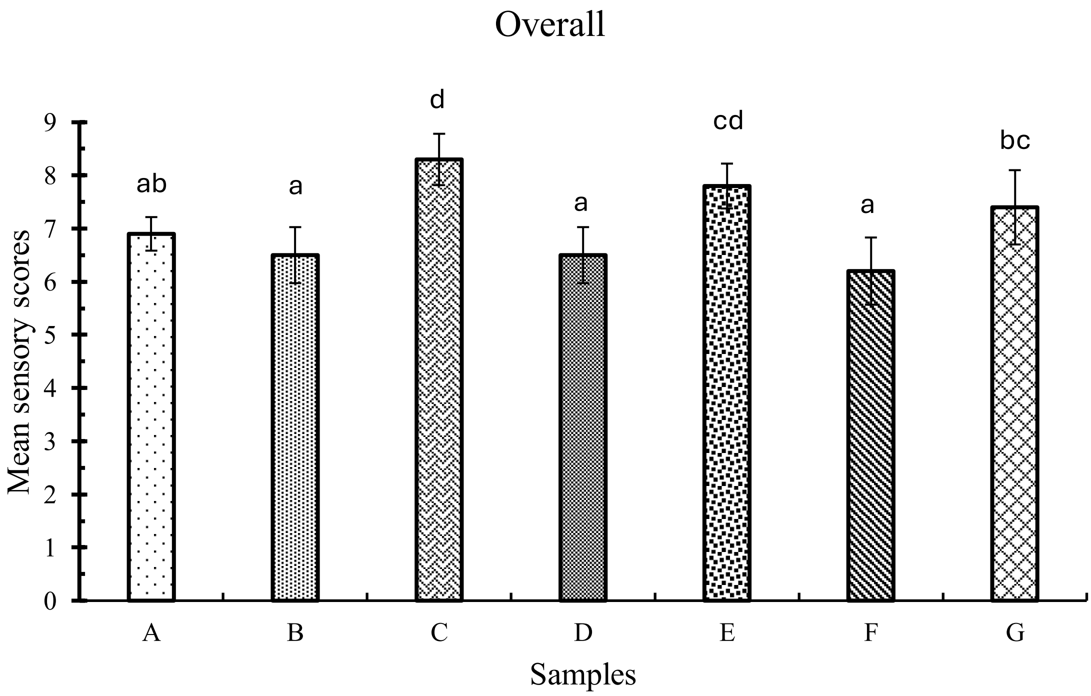

Figure 4.5: Sensory evaluation on attribute "Overall"

Similar alphabet above the bar graph indicates no significant difference where different letters indicate significant difference and error bars shows standard deviation of scores given by 10 panellists whereas different letters represent the differences. The sensory evaluation demonstrated significant variations in overall across the different samples. Based on mean score with respect to overall acceptance given in Appendix C, the superiority/inferiority ($p \leq 0.05$) of the jelly was found to rank as follows:

[C] > [E] > [G] > [A] > [B, D] > [E]

Samples C exhibited the highest mean overall scores, significantly exceeding samples A, B, D, E, F and G likely due to its improved colour and unique flavour.

4.3 Physiochemical analysis of the best product

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

Table 4.4 Physiochemical analysis of best sample

Parameters	Best sample
TSS	67±0.15
pH	3.1±0.03
Reducing sugar (mg/100)	27.05±0.05
Non reducing sugar (mg/100)	37.53±0.05
Total sugar (mg/100)	64.6±0
Vitamin C (mg/100)	7.66±0.05
Acidity (%)	0.56±0.01
Moisture content (%)	28±0.25
Calcium content(mg/100)	20.24±0.1
Radical scavenging activity (%)	73.48±0.77
Betacyanin content (mg/100 g)	14.74±0.01

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

4.4 Chemical analysis

The jelly after the preparation were stored in sterilized glass bottles, in both room temperature and refrigeration temperature for a period of 40 days. The sample were analysed for 0, 10, 20, 30 and 40 days for its TSS, acidity, reducing sugar, non-reducing sugar, total sugar, moisture, pH and vitamin C content. The effect of storage intervals on the physicochemical characteristics of jelly is presented in Appendix

4.4.1 TSS

The effect on the TSS of best sample with the storage period is shown in **Figure 4.6**.

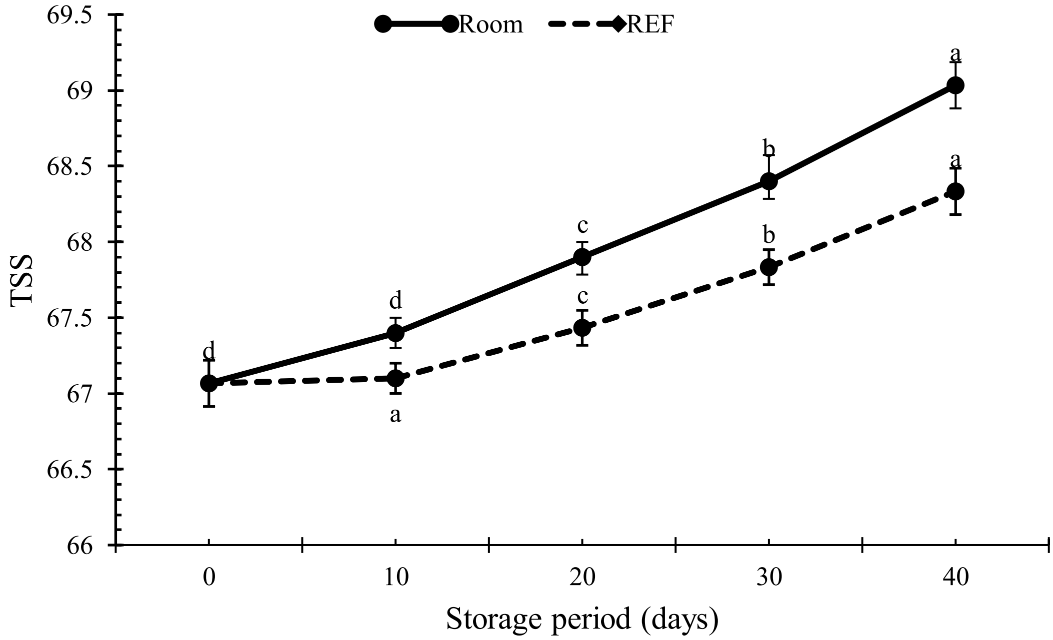

Figure 4.6: Effect of storage period on TSS

The TSS of jelly stored at room temperature and refrigeration temperature were found to be 67.06, 67.4, 67.9, 68.4 and 69.03 and 67.06, 67.1, 67.43, 67.83 and 68.33 for 0, 10, 20, 30 and 40 days respectively. The TSS of the jelly at room temperature increases from 67 ºBx to 69 ºBx whereas TSS of refrigeration stored jelly increased from 67 ºBx to 68 ºBx over 40 days of storage. The TSS of room sample and refrigeration was statistically significantly impacted by the storage duration ($p<0.05$). Both the room and the refrigeration sample showed an increase in TSS as the storage duration was extended.

The increase in total soluble solids (TSS) in jelly during storage can be attributed mainly to the hydrolysis of sucrose into glucose and fructose under acidic conditions, a process known as sugar inversion, which increases the concentration of dissolved solids (Ranganna, 1986). Slight moisture loss during storage leads to a higher concentration of sugars and soluble components increasing TSS (Fellows, 2022). The solubilization of agar and plant polysaccharides originating from the nettle extract into soluble fractions can also contribute to the increase in TSS over the storage period (Thimmaiah, 1999)

4.4.2 Titratable acidity

The effect on the acidity of best sample with the storage period is shown in **Figure 4.7**.

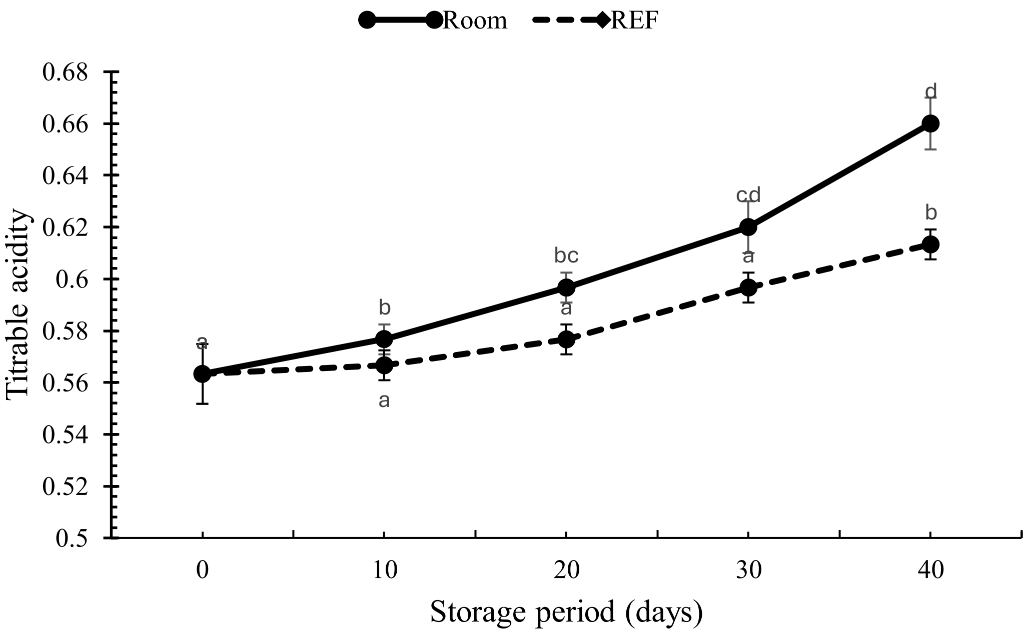

Figure 4.7: Effect of storage period on acidity

The acidity of jelly stored at room temperature and refrigeration temperature were found to be 0.56, 0.57, 0.59, 0.62, and 0.66 and 0.56 and .56, 0.57, 0.59 and 0.6 for 0, 10, 20, 30 and 40 days respectively. The acidity of the jelly at room temperature increases from 0.56 to 0.66 whereas acidity of refrigeration stored jelly increased from 0.56 to 0.6 over 40 days of storage. The room sample and refrigeration samples titrable acidity was statistically significantly impacted by the storage duration ($p<0.05$). Both the room and the refrigerated sample showed an increase in acidity as the storage duration was extended. The titrable acidity level increased significantly during storage. During storage, slow hydrolysis of sugars and ascorbic acid degradation can lead to the formation of organic acids, contributing to a rise in titratable acidity (Voragen *et al.*, 1986).

4.4.3 Vitamin C

The effect on the Vitamin C of best sample with the storage period is shown in **Figure 4.8**.

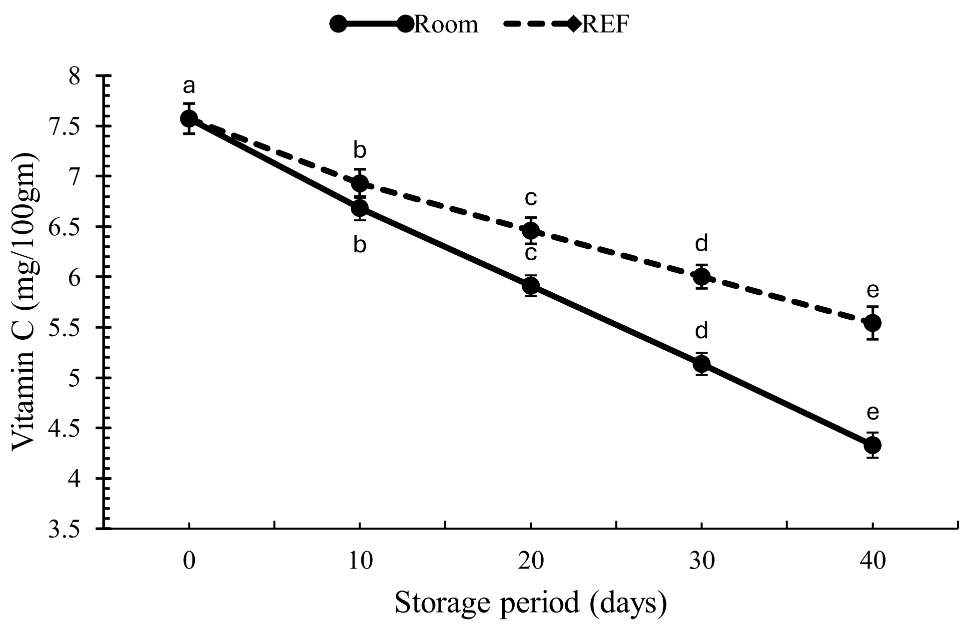

Figure 4.8: Effect of storage period on Vitamin C

The vitamin C of jelly stored at room temperature and refrigeration temperature were found to be 7.57, 6.68, 5.91, 5.13 and 4.33 and 7.57, 6.93, 6.46, 6.00 and 5.54 for 0, 10, 20, 30 and 40 days respectively. The vitamin C of the jelly at room temperature decreases from 7.57 to 4.33 whereas vitamin C of refrigeration stored jelly decreased from 7.57 to 5.54 over 40 days of storage. The room sample and refrigeration samples vitamin C was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in vitamin C as the storage duration was extended

The decrease in vitamin C content in jelly during storage is mainly due to the high instability of ascorbic acid, which is highly sensitive to oxygen, light, heat, and acidic conditions. During storage, ascorbic acid readily undergoes oxidative degradation to dehydroascorbic acid, leading to a continuous loss of vitamin C even under refrigerated or ambient conditions. The presence of dissolved oxygen trapped in the jelly matrix, along with residual enzymatic activity from plant extracts can accelerate this oxidation process (Damodaran *et al.*, 2007).

4.4.4 pH

The effect on the pH of best sample with the storage period is shown in figure 4.9

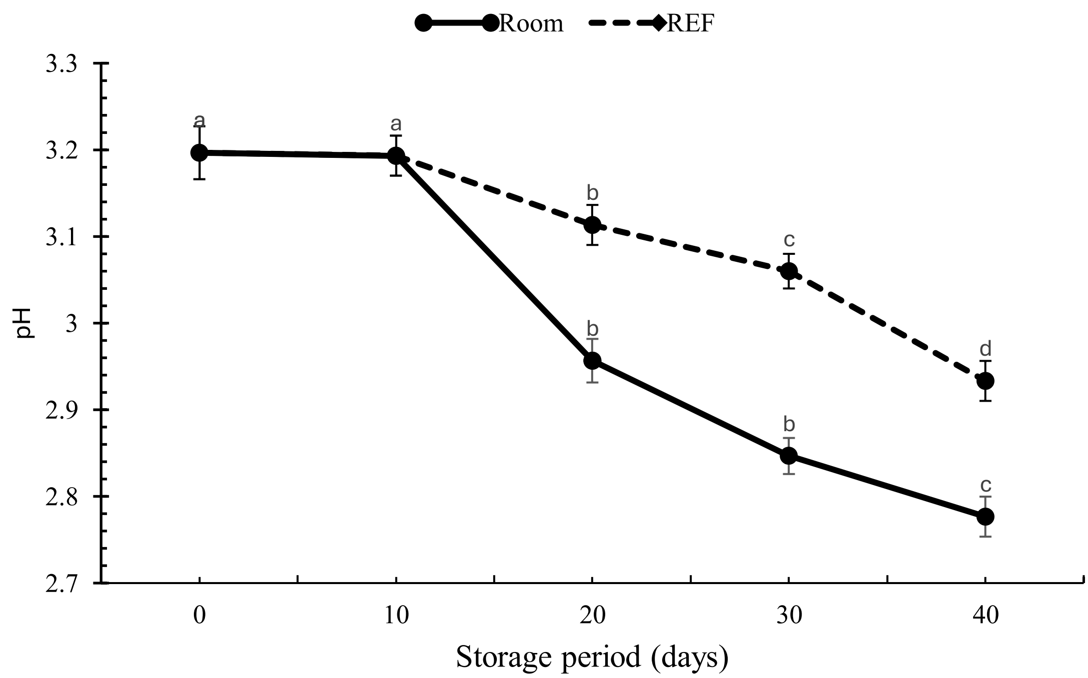

Figure 4.9: Effect of storage period on pH

The pH of jelly stored at room temperature and refrigeration temperature were found to be 3.19, 3.19, 2.95, 2.84 and 2.77 and 3.19, 3.19, 3.11, 3.06 and 2.93 for 0, 10, 20, 30 and 40 days respectively. The pH of the jelly at room temperature decreases from 3.19 to 2.77 whereas pH of refrigeration stored jelly decreased from 3.19 to 2.93 over 40 days of storage. The room sample and refrigeration samples pH was significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in pH as the storage duration was extended.

Decrease in pH is may be due to the gradual formation and accumulation of organic acids because of chemical, enzymatic, and minor microbial reactions within the product (Damodaran *et al.*, 2007).

4.4.5 Moisture content

The effect on the moisture content of best sample with the storage period is shown in **Figure 4.10**.

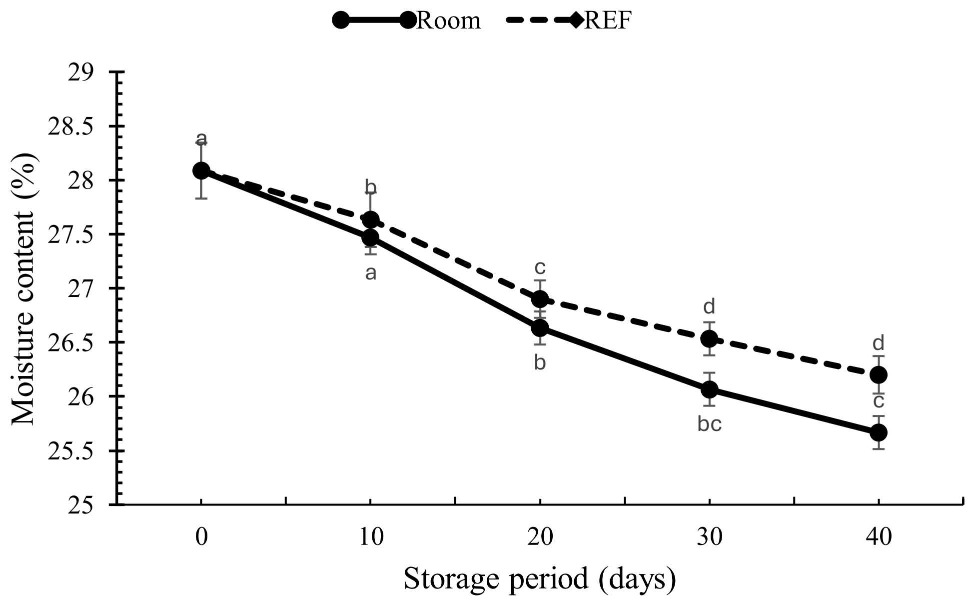

Figure 4.10: Effect of storage period on moisture content

The moisture content of jelly stored at room temperature and refrigeration temperature were found to be 28.08, 27.46, 26.63, 26.06 and 25.66 and 28.08, 27.63, 26.9, 26.53 and 26.2 for 0, 10, 20, 30 and 40 days respectively. The moisture content of the jelly at room temperature decreases from 28.08 to 25.66 whereas moisture content of refrigeration stored jelly decreased from 28.08 to 26.2 over 40 days of storage. The room sample and refrigeration samples moisture was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in moisture content as the storage duration was extended.

Even when stored in sealed containers, slight moisture migration can occur from the jelly to the surrounding headspace or packaging material, reopening the same pack during storage for analysis may be the cause of this drop in moisture (Moshfeghi *et al.*, 2013a)

4.4.6 Reducing sugar

The effect on the reducing sugar of best sample with the storage period is shown in **Figure 4.11**.

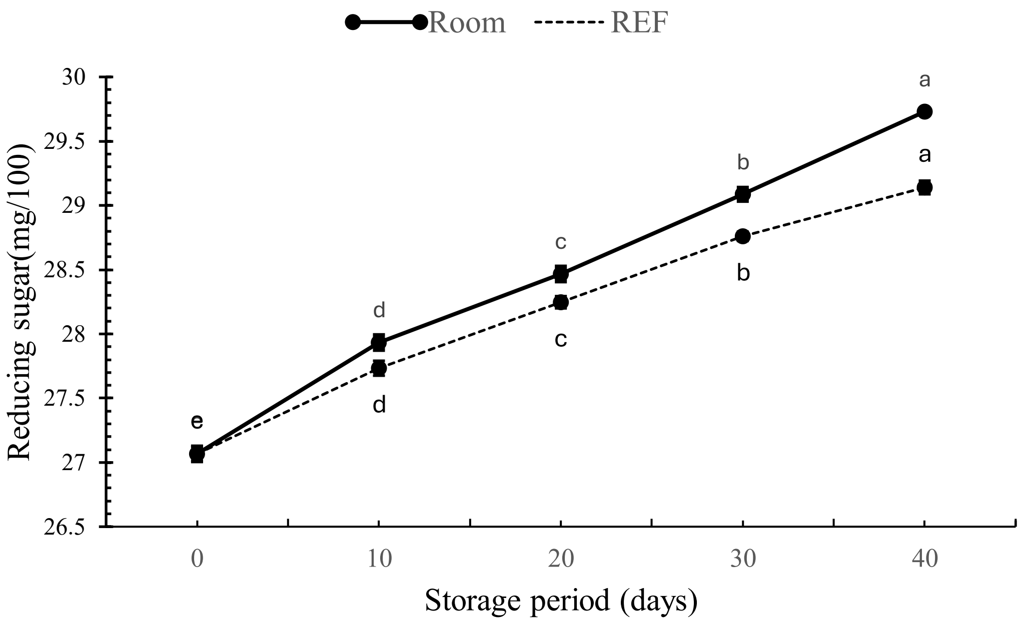

Figure 4.11: Effect of storage period on reducing sugar

The reducing sugar of jelly stored at room temperature and refrigeration temperature were found to be 27.06, 27.93, 28.46, 29.08 and 29.73 and 27.06, 27.73, 28.24, 28.76 and 29.14 for 0, 10, 20, 30 and 40 days respectively. The reducing sugar of the jelly at room temperature increases from 27.06 to 29.73 whereas reducing sugar of refrigeration stored jelly increased from 27.06 to 29.14 over 40 days of storage. The room sample and refrigeration samples reducing sugar was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed an increase in reducing sugar as the storage duration was extended. The observed decrease in non-reducing sugars alongside an increase in reducing sugars indicates that non-reducing carbohydrates may have undergone inversion into reducing sugars. The rise in overall sugar concentration could be attributed to the breakdown of polysaccharides such as pectin and starch through hydrolysis (Kumar and Deen, 2017).

4.4.7 Non-reducing sugar

The effect on the non-reducing sugar of best sample with the storage period is shown in **Figure 4.12**.

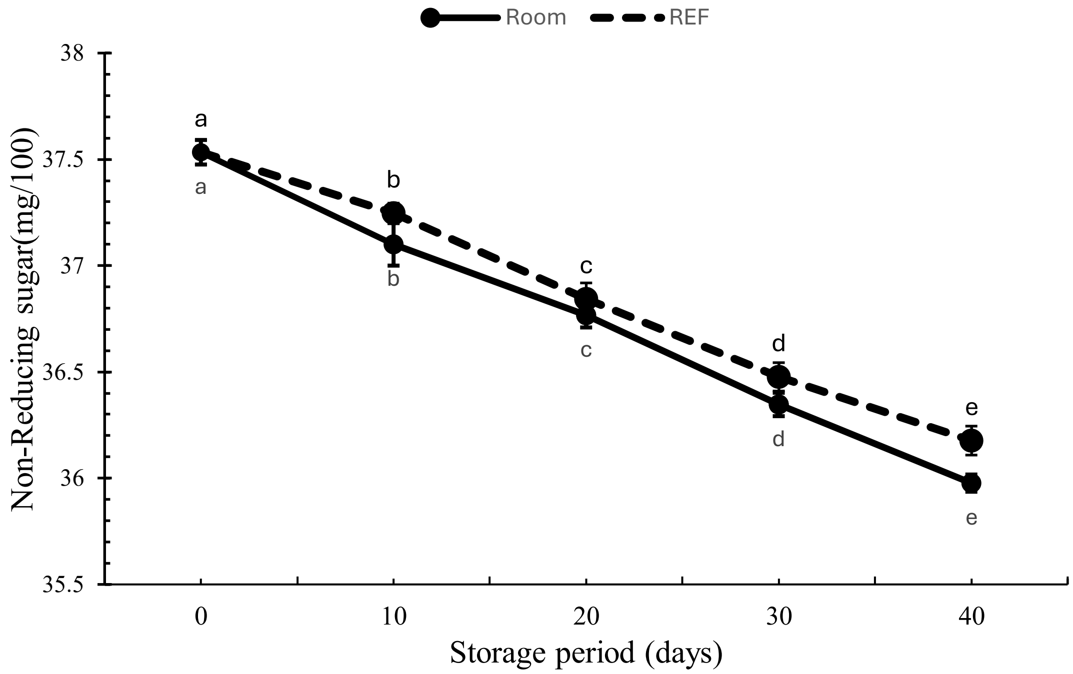

Figure 4.12: Effect of storage period on non-reducing sugar

The non-reducing sugar of jelly stored at room temperature and refrigeration temperature were found to be 37.53, 37.1, 36.76, 36.34 and 35.97 and 37.53, 37.24, 36.84, 36.47 and 35.17 for 0, 10, 20, 30 and 40 days respectively. The non-reducing sugar of the jelly at room temperature decreases from 37.53 to 35.97 whereas non-reducing sugar of refrigeration stored jelly decreased from 37.53 to 35.17 over 40 days of storage. The room sample and refrigeration samples non-reducing sugar was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed a decrease in non- reducing sugar as the storage duration was extended. A decline in non-reducing sugars was found to correlate with an increase in reducing sugars, suggesting that non-reducing carbohydrates may have been converted into reducing sugars, thereby explaining the reduction in non-reducing sugar content in the jelly (Kumar and Deen, 2017).

4.4.8 Total sugar

The effect on the total sugar of best sample with the storage period is shown in **Figure 4.13**.

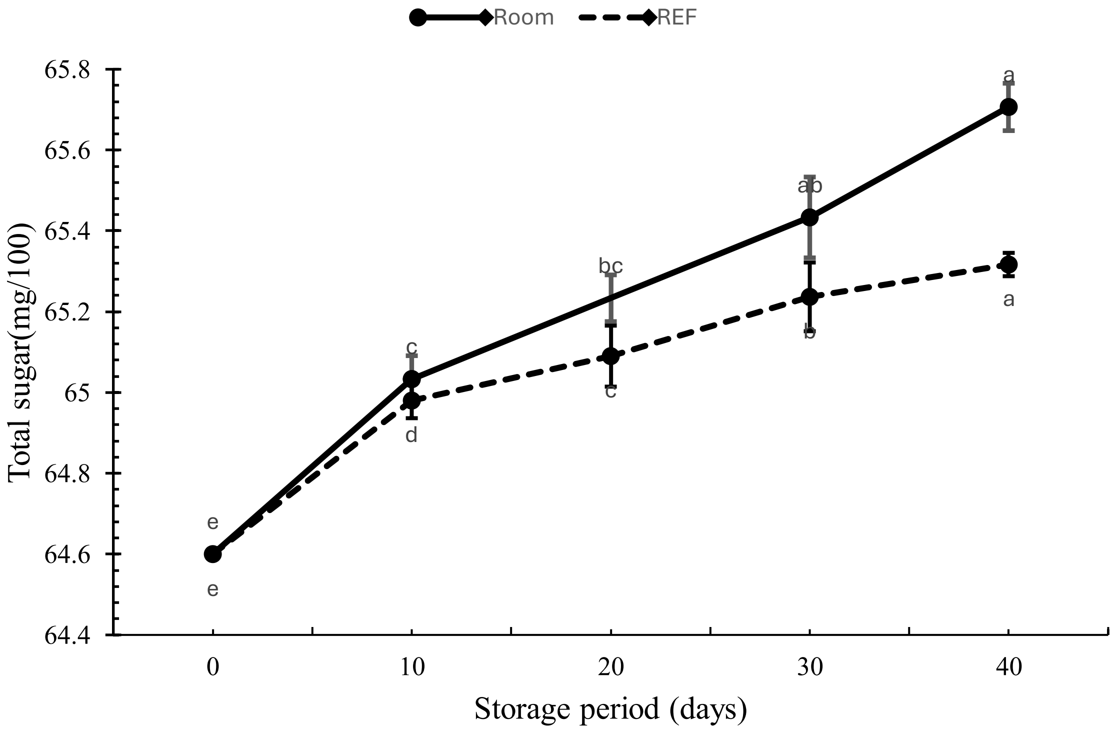

Figure 4.13: Effect of storage period on total sugar

The total sugar of jelly stored at room temperature and refrigeration temperature were found to be 64.6, 65.03, 65.23, 65.43 and 65.70 and 64.6, 64.98, 65.09, 65.23 and 65.31 for 0, 10, 20, 30 and 40 days respectively. The total sugar of the jelly at room temperature increases from 64.6 to 65.7 whereas total sugar of refrigeration stored jelly increased from 64,6 to 65.31 over 40 days of storage. The room sample and refrigeration samples total sugar was statistically significantly impacted by the storage duration ($p<0.05$). Both the room sample and the refrigeration sample showed an increase in total sugar as the storage duration was extended. Increase in total sugar may be due to sucrose hydrolysis and slight moisture loss during storage (Kumar and Deen, 2017).

4.5 Microbiological analysis

In microbiological analysis TPC and YMPC were performed and the changes in microbial counts during storage are given in the **Table 4.4**. Two different samples were taken and coded as RO and RE where RO is jelly stored in room temperature and RE is jelly stored in refrigeration temperature.

Table 4.4: Microbiological analysis of product

Parameters/Days	TPC (log CFU/g) (RO)	TPC (log CFU/g) (RE)	YMPC (log CFU/g) (RO)	YMPC (log CFU/g) (RE)
0	3.00	3.00	ND	ND
10	3.48	3.30	3.00	ND
20	3.60	3.48	3.30	3.00
30	5.78	4.43	3.30	3.00
40	7.56	5.70	3.48	3.30

The total plate count and yeast–mould counts of the jelly samples increased gradually during storage. At day 40, TPC in RO became 7.56 log CFU/g showing spoilage risk, whereas RE maintained 5.70 log CFU/g. while yeast–mould counts remained below levels that cause visible spoilage. According to (Anuar *et al.*, 2022), the microbial counts observed in the study at day 40 is slightly higher than the permissible limit of 6 $\log_{10}$ CFU/g.

4.6 Cost evaluation of a product

The market price of mixed jelly ranges from NRs 200-400 for 500 g. The total cost associated with the best product was calculated and the cost per 500 g of dragon fruit and stinging nettle jelly was NRs. 578. The processing and packaging cost are excluded. The calculation is made in Appendix E.

Part V

Conclusions and recommendations

5.1 Conclusions

The study was carried out in a controlled condition using different materials and methods. From the above result and discussion, the following conclusions were drawn from this research work.

1. The dragon fruit and stinging nettle extract jelly with 75% dragon fruit juice and 25% stinging nettle extract was found to be best from sensory analysis.
2. The TSS, acidity, reducing sugar, total sugar, and microbial count increased while non-reducing sugar, vitamin C content, pH and moisture content decreased during storage.
3. The jelly can be stored up to 40 days at refrigeration temperature without adding any chemical preservative with desirable acceptability.
4. The dragon fruit and stinging nettle jelly can be commercialized as a standalone product or incorporated into fruit-based beverages, like the popular jelly drinks produced by Singapore Beverage in Jhapa.
5. Preparation of dragon fruit and stinging nettle jelly could be a promising use of utilizing excess dragon fruit and stinging nettle thus aiding in the income of producers by value addition as well as providing new taste for consumers.

5.2 Recommendations

Based on the present study, the following recommendations have been made.

1. Advanced analytical techniques can be used to assess additional micronutrients in the formulation.
2. A shelf-life study examining the product in various packaging materials with appropriate preservatives could be conducted.
3. The sensory quality of jelly using different gelling agent and acidity can be studied.

Part VI

Summary

Dragon fruit, also known as pitaya, comes from various tropical climbing plants in the genus Hylocereus and the family Cactaceae. Dragon fruit have antioxidant, antimicrobial, and anti-inflammatory properties that have helped to promote optimal wellness. Stinging nettle (*Urtica dioica*) is a traditional food and medicinal plant rich in vitamins A, C, B vitamins, and minerals like iron, calcium, magnesium, and potassium. It also contains beneficial polyphenols and antioxidants. Jelly is a food product with an intermediate moisture which is produced by boiling fruit juice with sugar, either with or without the addition of pectin and acid, until the TSS content reaches a minimum of 65%.

This study focused on developing a functional jelly using dragon fruit (*Hylocereus polyrhizus*) and stinging nettle (*Urtica dioica L.*), aiming to optimize formulation and evaluate its storage stability under two conditions: room temperature (27 ± 3 °C) and refrigeration (7 ± 1 °C). Dragon fruit was selected for its vibrant natural colour and antioxidant compounds like betalains, while stinging nettle was incorporated for its rich nutritional profile, including vitamins, minerals, and polyphenols.

Seven formulations with varying ratios of dragon fruit juice and nettle extract were prepared using agar as the gelling agent and citric acid for acidity adjustment. Sensory evaluation using a nine-point hedonic scale identified the formulation with 75% dragon fruit juice and 25% nettle extract as the most acceptable in terms of appearance, taste, flavor, and overall acceptability.

The best scored jelly was filled in pre-sterilized glass bottles, capped and sealed with aluminium foil and subjected to physiochemical analysis for 40 days storage period in two different temperatures: room and refrigeration. During 40 days of storage, TSS, acidity, reducing sugar, and microbial counts increased, while vitamin C, pH, moisture, and non-reducing sugar decreased. Despite these changes, the jelly remained microbiologically safe and acceptable without chemical preservatives. The research demonstrates that incorporating stinging nettle into dragon fruit jelly enhances its nutritional and functional properties, offering a novel, shelf-stable confectionery product.

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Appendices

Appendix A

Specimen card of sensory evaluation by 9-point hedonic rating test

Sensory evaluation Card

Name of panelist: .... Date.........................

Name of Product: Dragon fruit Jelly

Details of product: Dragon fruit jelly incorporated with stinging nettle extract.

Sample	Appearance	Texture	Taste	Flavour	Overall
A					
B					
C					
D					

Please conduct sensory analysis using the given scale based on the following parameters. Panellists are requested to provide points on their individual choice Score.

Dislike extremely-1

Dislike very much-2

Dislike moderately-3

Dislike slightly-4

Neither like nor dislike-

Like slightly-6

Like moderately-7

Like very much-8

Like extremely-9

Comments: ....

Signature

Appendix B

ANOVA: Two-way analysis of mean sensory score of appearance, flavor, texture, taste and overall acceptance of dragon fruit jelly incorporated with stinging nettle.

Table 6B.1: ANOVA table for hedonic sensory scores.

		Sum of Squares	df	Mean Square	F	Sig.
Appearance	Between Groups	37.771	6	6.295	14.635	0
	Within Groups	27.1	63	0.43		
	Total	64.871	69			
Texture	Between Groups	42.771	6	7.129	24.812	0
	Within Groups	18.1	63	0.287		
	Total	60.871	69			
Taste	Between Groups	35.343	6	5.89	18.015	0
	Within Groups	20.6	63	0.327		
	Total	55.943	69			
Flavor	Between Groups	37.286	6	6.214	19.773	0
	Within Groups	19.8	63	0.314		
	Total	57.086	69			
Overall	Between Groups	35.886	6	5.981	21.409	0
	Within Groups	17.6	63	0.279		
	Total	53.486	69			

Appendix C

Table C6.1: Tukey table for Appearance

Sample	N	Subset for alpha = 0.05			
		1	2	3	4
6	10	6			
4	10	6.5			
2	10	6.6	6.6		
1	10	6.8	6.8		
7	10		7.4	7	
5	10			8	7.7
3	10				8.3
Sig.		0.108	0.108	1	0.397

Means for groups in homogeneous subsets are displayed.

Uses Harmonic Mean Sample Size = 10.000

Table C6.2: Tukey table for

Sample	N	Subset for alpha = 0.05				
		1	2	3	4	5
6	10	6				
1	10	6.3	6.3			
2	10	6.3	6.3			
7	10		6.8	6.8		
5	10			7.3	7.3	

3	10				7.7	7.7
4	10					8.3
Sig.		0.871	0.374	0.374	0.639	0.176

Means for groups in homogeneous subsets are displayed.

Uses Harmonic Mean Sample Size = 10.000

Table C6.3: Tukey table for Taste

Sample	N	Subset for alpha = 0.05			
		1	2	3	4
6	10	6			
2	10	6.4	6.4		
4	10	6.6	6.6		
1	10		6.9	7	
7	10			7	7.4
5	10				7.8
3	10				8.1
Sig.		0.239	0.453	0	0.106

Means for groups in homogeneous subsets are displayed.

Uses Harmonic Mean Sample Size = 10.000

Table C6.4: Tukey table for Flavour

Sample	N	Subset for alpha = 0.05				
		1	2	3	4	5
6	10	6				

2	10	6.1	6.1			
1	10	6.4	6.4			
5	10		6.8	6.8		
7	10			7.2	7.2	
4	10				7.6	7.6
3	10					8.1
Sig.		0.686	0.093	0.686	0.686	0.428

Means for groups in homogeneous subsets are displayed.

Uses Harmonic Mean Sample Size = 10.000

Table C6.5: Tukey table for Overall

Sample	N	Subset for alpha = 0.05			
		1	2	3	4
6	10	6.2			
2	10	6.5			
4	10	6.5			
1	10	6.9	6.9		
7	10		7.4	7	
5	10			8	7.8
3	10				8.3
Sig.		0.062	0.357	1	0.357

Means for groups in homogeneous subsets are displayed.

Uses Harmonic Mean Sample Size = 10.000

Appendix D

Table D6.6:- ANOVA: One way analysis of pH of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	0.4534	0.1134	184.8	2.51E-09
Residuals	10	0.0061	0.0006		
Total	14	0.4595			

Table D6.7:- ANOVA: One way analysis of pH of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	0.1428	0.0357	60.86	5.55E-07
Residuals	10	0.0059	0.0006		
Total	14	0.1487			

Table D6.8:- ANOVA: One way analysis of moisture content of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.

Days	4	11.85	2.962	92.62	7.36E-08
Residuals	10	0.32	0.032		
Total	14	12.17			

Table D6.9:- ANOVA: One way analysis of moisture content of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	7.274	1.8186	42.65	2.98E-06
Residuals	10	0.426	0.0426		
Total	14	7.7			

Table D6.10:- ANOVA: One way analysis of Acidity of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	0.0175	0.0044	54.79	9.15E-07
Residuals	10	0.0008	0.0001		
Total	14	0.0183			

Table D6.11:- ANOVA: One way analysis of Acidity of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.

Days	4	0.0054	0.0014	25.31	3.26E-05
Residuals	10	0.0005	0.0001		
Total	14	0.0059			

Table D.6.12:- ANOVA: One way analysis of Vitamin C of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	19.37	4.843	321.9	1.62E-10
Residuals	10	0.15	0.015		
Total	14	19.52			

Table D.6.13:- ANOVA: One way analysis of Vitamin C of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	7.501	1.8753	94.81	6.57E-08
Residuals	10	0.198	0.0198		
Total	14	7.699			

Table D.6.14:- ANOVA: One way analysis of Total soluble sugar of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	7.383	1.8457	95.47	6.36E-08
Residuals	10	0.193	0.0193		
Total	14	7.576			

Table D.6.15:- ANOVA: One way analysis of Total soluble sugar of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	3.431	0.8577	51.46	1.23E-06
Residuals	10	0.167	0.0167		
Total	14	3.598			

Table D.6.16:- ANOVA: One way analysis of Total sugar of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	0.9444	0.2361	75.35	1.99E-07
Residuals	10	0.0313	0.0031		

Total	14	0.9757

Table D.6.17:- ANOVA: One way analysis of Total sugar of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	2.1001	0.525	256.5	4.98E-10
Residuals	10	0.0205	0.002		
Total	14	2.1206			

Table D.6.18:- ANOVA: One way analysis of Reducing sugar of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	8.103	2.0258	779.1	2E-12
Residuals	10	0.026	0.0026		
Total	14	8.129			

Table D.6.19:- ANOVA: One way analysis of Reducing sugar of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	3.651	0.9127	225.2	9.49E-10
Residuals	10	0.041	0.0041		
Total	14	3.692			

Table D.6.20:- ANOVA: One way analysis of non-reducing sugar of dragon fruit jelly incorporated with stinging nettle (room)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	3.651	0.9127	225.2	9.49E-10
Residuals	10	0.041	0.0041		
Total	14	3.692			

Table D.6.21:- ANOVA: One way analysis of non-reducing sugar of dragon fruit jelly incorporated with stinging nettle (refrigeration)

Source of variation	d.f.	Sum of squares	mean squares	F value	sig.
Days	4	4.491	1.1227	263.1	4.4E-10
Residuals	10	0.043	0.0043		
Total	14	4.534			

Appendix E

Table E. 6.22: Cost analysis of the product

Particular	Quantity	Rates (Rs/kg)	Amount (Rs)
Dragon fruit	2 kg	400	800
Stinging Nettle	1 kg	200	200
Sugar	800g	100	80
Citric acid	10g	142	1.42
Agar Agar	25g	1400	35
Total			1339.70

Total price of the product including 20% overhead cost= Rs 1339.70

Price of 500 g of product = Rs. 578

Color Plates

Fig: a

Fig: b

Fig: c

Fig: d