OPTIMIZATION OF DRYING TEMPERATURE OF DRAGON FRUIT (*Hylocereus undatus*) PEEL TEA INFUSION

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Approval Letter

This ***dissertation*** entitled ***Optimization of Drying Temperature of Dragon Fruit (Hylocerus undatus) Peel Tea Infusion*** presented by **Bhawana Basyal** has been accepted as the partial fulfillment of the requirement for the **B. Tech. degree in Food Technology.**

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Abstract

Dragon fruit peel tea infusion is a functional drink containing phenolic compounds with antioxidant activity. The aim of this study was to optimize the drying temperature on the bioactive compounds of dried dragon fruit peels. A part of dragon fruit peel was maintained in the fresh form in refrigerator until chemical analysis and the remaining part were chopped in 2.5 cm lengthwise and dried at 50°C, 60°C and 70°C till the moisture content reached 5%. The dried peels were grinded into powder form and sieved through 40 mesh size to a fine consistency. Proximate analysis and bioactive components were determined for fresh samples. Total phenolic content, total flavonoid content, betacyanin content and antioxidant activity were determined for the dried samples. The tea was prepared by infusing 1.5g of dried dragon fruit peels in 50ml of hot water (90°C) and leaving it to stand for 5 min. After that, sensory analysis of tea infusion was carried out using 9-point hedonic scale rating.

The findings indicated that drying dragon peel at higher temperatures resulted in significant losses in bioactive components. The optimum drying temperature of dragon fruit peel was found to be 50°C having TPC, TFC, betacyanin content and antioxidant activity of 64.92 mg GAE/100g, 56.34 mg QE/100g, 52.34 mg/100g and 77.37% respectively. Increase in temperature decreased the bioactive components, i.e. at 70°C the total phenolic content, antioxidant activity and betacyanin content were found to be reduced significantly ($p<0.05$). All the analyzed samples showed that low temperature drying method is the best method for better retention of higher bioactive components. According to sensory analysis, tea infusion at 50°C was found to be the best among other samples.

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List of Abbreviations

Abbreviation	Full form
AA	Antioxidant activity
DPPH	2,2- Diphenyl-1-1picrylhydrazyl
AOAC	Association of Analytical Communities
GAE	Gallic Acid Equivalent
QE	Quercetin Equivalent
FAO	Food and Agriculture Organization
LSD	Least significant difference
RSA	Radical Scavenging Activity
TFC	Total flavonoid content
TPC	Total phenolic content
TTC	Total tannin content
BC	Betacyanin content

Part I

Introduction

1.1 General introduction

Dragon fruit or pitaya is the fruit of several different tropical climbing plants of the genus *Hylocereus*, family Cactaceae (Luu *et al.*, 2021). Although it is native to the tropical areas of North, Central and South America, now it is becoming popular worldwide due to the commercial interests (Nobel and De La Barrera, 2004).

Dragon fruit is a perennial and epiphytic, climbing cactus with triangular, fleshy, jointed green stems (Zee *et al.*, 2004). Five major types of *Hylocereus* species are available which are mainly differentiated based on their fruit characteristics. *Hylocereus undatus* is characterized with white pulped fruits and pink skin, *Hylocereus polyrhizus* have red pulped fruits and pink skin, *Hylocereus costaricencis*, which have violet-red pulp and pink skin, *Hylocereus guatemalensis*, which have red pulp with reddish-orange skin and *Hylocereus megalanthus* have white pulp and yellow skin (Arivalagan *et al.*, 2021). The fruit is oval in shape between 10-15 cm and weighs about 300 to 500 grams. It has sweet to slight sour taste with tiny black seeds (Zainudin and Hafiz, 2015). It is a good source of minerals, glucose, fructose, dietary fiber and betacyanin (Rao and Sasanka, 2015). It is well known for its rich in vitamin C and water-soluble fiber, antioxidants such as flavonoids, hydroxycinnamates and betalains (Moshfeghi *et al.*, 2013). It has health promoting health benefits due to the presence of bioactive compounds related to numerous benefits such as anti-diabetic, anti-inflammatory, antioxidant, anti-cancer and antimicrobial. Phytochemical substances found in dragon fruit peel and pulp have antibacterial properties and can be utilized as a natural antioxidant.

Dragon fruit peel, a byproduct of consumption occupies about 22-35% of the overall fruit weight but has most of the polyphenols. Polyphenols have antioxidant, antimicrobial and anti-inflammatory properties that have helped to promote optimal wellness. Dragon fruit peel is rich in fiber, vitamins, calcium, antioxidants, phenolic compounds and betacyanin. Betacyanin pigment, which indicates that they can be used to make tea, which has the highest antioxidant content. Consequently, dragon fruit peels produced as the tea is expected to

decrease fruit waste (A. R. Sari and Hardiyanti, 2013). Fruit teas, which are popular because of their fragrance and lower amounts of caffeine, could be a good source of compounds with antioxidant properties (Trimedona *et al.*, 2020).

1.2 Statement of the problem

Dragon fruits are usually consumed by people directly or being processed into juice. The fruit consists of 22-35% of peel which is normally discarded during production which creates environmental problems during processing especially beverages industries. These fruit wastes when left in environment for an extended period of time release greenhouse gases as they degrade down and cause growth media for pests, bacteria and mice that can cause the spreading of plague. As a by-product, fruit peels have greater phenolic content and antioxidant level than pulp especially for white dragon fruit. In addition, peel is an excellent source of vitamins, minerals, pectin, betacyanin color and dietary fiber; thus, it can be transformed into products that can be handled easily and have a longer shelf life (Jalgaonkar *et al.*, 2022). Therefore, considering these benefits, dragon fruit peel can be used in tea formulations. It is also considered as a potential source for use as a dietary fiber enhancer, natural colorant and antioxidant in various food products. Thus, the research was necessary for recovery of health –beneficial compounds from dragon fruit peel.

Fresh peel has a shorter shelf life and drying it can improve its stability as it is common method of food preservation. Lots of studies have shown that consuming herbal tea made from leftover fruits, vegetables and herbs improves a product's nutritional value and functional qualities (Nizori and Sihombing, 2020).

1.3 Objectives of the study

1.3.1 General objectives

The general objective was to optimize the drying temperature of strips for the preparation of dragon fruit peel tea infusion.

1.3.2 Specific objectives

The specific objectives of this study were as follows:

1) To prepare dried dragon fruit peels at different drying temperatures.

2) To perform proximate analysis of fresh dragon fruit peels.
3) To perform analysis of bioactive components of fresh and dried dragon fruit peel dried at different temperatures. .
4) To optimize the drying temperature on the basis of bioactive components and sensory analysis of dragon fruit peel tea infusion.

1.4 Significance of the work

There are several factors to consider while adjusting the drying temperature of dragon fruit peel for making dragon peel tea. This discovery opens up the use of dragon fruit peel, which was previously thrown out as waste, creating environmental damage and introduces a new product with great nutritional and medicinal potential. This study contributes to the determination of the optimal temperature for producing high-quality dragon fruit peel tea, by examining the effect of various drying temperatures on bioactive components of dragon fruit peel, which is lacking in scenario of Nepal. This research will also help in innovative applications to use dragon fruit peel as tea infusion. Additionally, this work encourages the farmers to invest in the industrialization of dragon fruit cultivation in Nepal. Overall, it will contribute to the improvement of farmers' economies who are engaged in the production of dragon fruits.

1.5 Limitations of the work

There were some limitations on this work which are listed as follows

1) Microbiological analysis was not performed due to time constraints.
2) Analysis based on the variation of thickness of strips was not carried out.

Part II

Literature review

2.1 Origin and distribution

The scientific name of the dragon fruit (*Hylocereus undatus*) is derived from the Greek words hyle (woody), cereus (waxen), and *undatus*, which alludes to the wavy edges of its stems (Mohd Rozalli *et al.*, 2016).

Pitaya, also known as dragon fruit, is a member of the Cactaceae family and is found primarily in the genera *Hylocereus* and *Selenicereus*. The *Hylocereus* genus, which includes about 16 different species, produces the most widely grown commercially farmed variants (Barthlott and Hunt, 1993). The genus *Selenicereus* comprises 20 species distributed through tropical America and the Caribbean region.

The majority of *Hylocereus* species are native to Latin America, mostly Mexico and Colombia, with some others possibly hailing from the West Indies (Britton and Rose, 1963). The white skinned dragon fruit (*Hylocereus undatus*), which originated in Vietnam, was introduced to Nepal in the year 2000 AD by an American engineer who was stationed there. Only around 2014 AD its commercial plantations began in the Kabhre district (Atreya *et al.*, 2020).

The semi-epiphytic plant known as dragon fruit prefers a dry tropical and subtropical climate conditions that range in temperature from 21 to 29 °C on average, but can sustain temperatures as high as 40 °C and as low as 0 °C for brief periods. It needs plenty of sunshine and 600-1300 mm of rain every year, with alternate dry and rainy seasons. It can reach heights of 1.5 to 2.5 meters, branching like a delicate vine. It is a three-winged, succulent terrestrial or epiphytic cactus (Patel and Ishnava, 2019). The stem has several branching segments and is mushy and vine-like. Each segment bears three wavy wings, one to three spines, or occasionally none at all (Merten, 2003). The plant's aerial roots take up water, grow on the stem’s undersides and hold the stems firmly in place on vertical surfaces. Typically white in color, dragon fruit is 25 to 30 cm in length and 15 to 17 cm in width.

A single pole of a dragon fruit tree with five to six branches can yield 150 to 200 kg of fruit throughout its productive season, which runs from September to May. The dragon fruit has remarkable features, including bright red, purple, or yellow skin variations and noticeable scales. The fruit is characterized by oval, elliptical or pear shape. The flesh has a mildly sweet or occasionally slightly sour flavor. The flesh is either white or red and is covered with edible tiny black seeds all over (Blancke, 2016).

2.1.1 Varieties

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

One type of climbing cactus that has been eaten as food is *Hylocereus undatus*, which is assumed to have originated in the tropical jungles of Central and northern South America. The fruit is about 15-22 cm in length, weighing about 300-800g, is oblong and covered with large and long scales red and green at the tips; it has white flesh with many black seeds, flesh texture and a good taste. It already appreciates the international recognition for the plant's big, fragrant, night-blooming blossoms and as an ornamental. Its fruit is now gaining popularity all over the world, particularly in Israel, Vietnam and Australia (Britton and Rose, 1963).

Hylocereus polyrhizus and *Hylocereus megalanthus* are two other varieties of climbing cacti that are cultivated for their tasty fruit. While *S. megalanthus*, often known as the pitaya Amarillo or yellow pitaya, has yellow skin and clear to white flesh with edible black seeds, *H. polyrhizus* has red skin and red flesh that is speckled with edible black seeds and fruit is 10-15 cm in length and weighs about 130-350g and is oblong and covered with scales that vary in size (Britton and Rose, 1963).

2.1.2 Scientific classification

The nomenclature of dragon fruit is as follows:
Kingdome- Plantae
Phylum- Magnoliophtya
Class- Magnoliopsida
Order- Caryophyllales
Family- Cactaceae
Genus- *Hylocereus*
Species- *Hylocereus undatus*

Source: Elmarzugi *et al.* (2016)

2.2 Dragon fruit production in the world

Pitaya was virtually unknown fifteen years ago, but it is now widely consumed throughout the world, notably in Vietnam, Colombia, Mexico, Costa Rica, the USA (Florida and California), Nicaragua and the European market.

Many tropical and subtropical regions, including Thailand, cultivate the fruit which is currently one of the world's top producers and exporters of dragon fruit (*Hylocereus* spp). Thailand's dragon fruit farms can produce between 44 and 65 tons per ha per year. This is comparable with the yield of a well-managed plantation in Malaysia (70 tons per ha per year). However, with the adoption of good cultural practices, Vietnam's dragon fruit productivity may exceed 50 to 80 tons per ha per year. Although dragon fruit plantations is situated in Taiwan, yet output there is rather moderate (16–27 tons per acre per year) (Aziz, 2018). Dragon fruit, which was first produced in Nepal in 2057 B.S. (Gurkha Millennium Multi-Purpose Cooperative Ltd, 2015), is currently gaining popularity and growers' attention across the nation. The yield data for Nepal have not yet been established; the first second/third year yields were around from the Durga Devi Farm in Temal, Kabhre, 8–10 tons per acre each year (Ahmad-Qasem *et al.*, 2017).

2.3 Composition of dragon fruit

The red and white fleshed pitaya fruits are a rich source of phenolic compounds, vitamins (B1, B2, B3, C, niacin, pyridoxine and cobalamin), minerals (calcium, potassium, phosphorus, sodium, iron and zinc), proteins, fats, carbohydrates, sugars, fiber and volatiles.

Table 2.1 Nutritional composition of dragon fruit

Nutrients	Amount per 100 g
Moisture	87 g
Protein	1.1 g
Fat	0.4 g
Carbohydrates	11.0 g
Fiber	3 g
Vitamin B1 (Thiamine)	0.04 mg
Vitamin B2 (Riboflavin)	0.05 mg
Vitamin B3 (Niacin)	0.16 mg
Vitamin C (Ascorbic acid)	20.5 mg
Ash	0.8 mg

Source: Charrondière *et al.* (2013)

2.4 Health benefits of dragon fruit

Dragon fruit is rich source of nutrients such as vitamins, minerals, complex carbohydrates, dietary fibers and antioxidants. According to studies, dragon fruit stimulates the growth of beneficial intestinal flora and a red or purple pigment called betacyanin has anti-oxidant effects (Liaotrakoon, 2013).

The functions of main components contained in dragon fruit as mentioned by (Faisal *et al.*, 2014) are :

1. Flavonoids: Flavonoids lower the risk of heart disease by means of operating on blood arteries and brain cells. It keeps blood pressure stable and reduces heart disease.
2. Betalains: Betalains offer anti-oxidative stress properties, in addition to their potential to inhibit cancer cells. It can strengthen the immune system, lower blood levels of LDL cholesterol, enhance digestion and help with weight loss.
3. Linoleic acid and linolenic acid: The polyunsaturated fats (omega-3 and omega-6 fatty acids) found in dragon fruit seeds lower triglycerides and lower the risk of cardiovascular diseases.
4. Vitamin C: Regular consumption of dragon fruit, which has a high vitamin C content, can help prevent cough and asthma; it also improves wound healing and speeds up the healing of cuts; additionally, it strengthens the immune system and encourages the body's other antioxidants to function.
5. Calcium and phosphorus: High quantities of calcium and phosphorus found in dragon fruit are essential for tissue growth, bone strength, and the development of healthy teeth.
6. Antioxidants: Phenolic compounds, vitamin C, vitamin E, carotenes, betanin present in dragon fruit have excellent antioxidant properties. Thus, it lowers cardio-vascular heart problems and regulates blood pressure since it has limited calories, no cholesterol and plenty of antioxidants.

2.5 Dragon fruit peel

Fruit peels have several health advantages, but they are typically thrown away. Fruit leaves and peels also demonstrate antioxidant and antibacterial activity comparable to fruit due to their substantial biological activities (Pandey *et al.*, 2019).

A dragon fruit constitute three main parts: pulp (47–73%), skin (22-35%), and seed (2-14%). It has unique appearance with bright yellowish or bright pink outer skin that is covered in green scales. The red dragon fruit peel has a deeper shade of red than white dragon fruit

peel (Taharuddin *et al.*, 2023). Dragon fruit peel has the ability to serve as an antioxidant , natural colorant, and antibacterial agent (Lourith and Kanlayavattanakul, 2013).

Peel is an excellent source of pectin, phenols, antioxidants, betacyanin color and total dietary fiber; thus, it must be transformed into products that can be handled easily and have a longer shelf life. Pectin (10.79%), betacyanin pigments (150.46 mg/100g db), and up to 69.30% of the fruit's dietary fiber make up the majority of the dragon fruit peel (Jamilah *et al.*, 2011). Alternatively said, in addition to moisture, fiber makes up the majority of the peels. Additionally, it can be used to remove pigments from peel and used to improve the functional properties of the other goods, extracted pigments are added. Dragon fruit peel powder can be marketed as a high total dietary fiber food with a minimum of 6g fiber/100g solids, in accordance with the Fifth A Schedule (Regulation 18 c) Table II of the Food Act 1983 and Regulations Malaysia (MR, 2010). Each part of dragon fruit (pulp, peel, seeds, flower buds, dried flowers) has tremendous nutritional value in terms of antioxidants, fiber, vitamin C, minerals, especially calcium, and phosphorus. Compared to the pulp, the peel of dragon fruit has a higher phenolic content and a higher capacity to scavenge free radicals, making it a potential source of antioxidants (MR, 2010).

Currently, the fruit juice processing company exclusively uses the agricultural waste from dragon fruit peel as fertilizer. Nevertheless, numerous studies have revealed that dragon fruit peels may contain naturally occurring, useful diet. It is used as dietary fiber enhancer, natural colorant and antioxidant in various food products, it can serve as a practical ingredient used in many cuisines and drinks (Chia and Chong, 2015).

2.5.1 Composition of dragon fruit peel

The table below shows the proximate analysis for every 100g of dragon fruit peel determined by AOAC International.

Table2.2 Nutritional composition of dragon fruit peel

Nutritional content	Amount
Moisture (%)	87.24
Protein (%)	6.39
Fat (%)	2.46
Ash (%)	14.29
Vitamin C (mg/100g)	93.87

Source : (A. R. Sari and Hardiyanti, 2013)

2.5.2 Bioactive compounds of dragon fruit peel

Researchers are particularly interested in the peel of dragon fruit because customers are becoming more interested in natural health-promoting bioactive compounds. The phytochemical compounds found in dragon fruit mainly belong to phenols, flavonoids, sterols, fatty acids, and tocopherol (Joshi and Prabhakar, 2020). Season, weather, cultural customs, water availability, handling and storage can have an impact on the bioactive components of dragon fruit peel (Franke *et al.*, 2004). The pitaya peel has significant quantities of betacyanin, an antioxidant with antibacterial properties, as well as pigments that could be used as food coloring or preservatives providing advantages for the consumer's health (Seth *et al.*, 2021). It was reported that peel contains higher phenolic content and antioxidant than pulp. Some of the important bioactive compounds on dragon fruit peel are:

2.5.1.1 Phenolic compounds

Phenolic chemicals are frequently associated with organoleptic qualities including fruit color, astringency and bitterness in along with antioxidant qualities, they are considered as one of the most significant quality parameters (Mohd Rozalli *et al.*, 2016). Dragon fruit peel is rich source of phenolic compounds. The peel of pitahaya fruits contain about twenty-three polyphenol components, including p-coumaric acid, isorhamnetin triglycoside, quercetin-3-O-rutinoside, gallic acid, protocatechuic acid, vanillic acid, caffeic acid, syringic acid and flavonol glycosidez (Le, 2022).

Dragon fruit peels have significant levels of phenolic compounds, which provide them with the ability to scavenge and reduce radicals. Several studies have shown an excellent relationship between total phenolic content and the ability to scavenge free radicals and reduce ferrous iron. Dragon fruit peels are a rich source of phenolic compounds. However, the peel of *H. undatus* has a larger total phenolic content in contrast to *H. polyrhizus*. Additionally, it has been observed that *H. undatus* peels have a higher total phenolic content than *H. megalanthus* peels (Ferreres et al., 2017).

Phenolic compounds are important for development and reproduction, provide protection from pathogens and predators, and modify the color and sensory aspects of fruits and vegetables. Phenolic content can be used as an indicator of antioxidant potential and as a first screen for any product when thinking about employing it as a natural source of antioxidants in functional foods. Phenolic antioxidants prevent the oxidation of lipid and other compounds by quickly donating hydrogen atoms to radicals. Free, soluble, and bound phenolic compounds are the three different forms of phenolic compounds (Renger *et al.*, 2000). Despite having the ability to change the flavor and color of food products, phenolic chemicals have a considerable antioxidant potential that is beneficial to human health (Santos *et al.*, 2014).

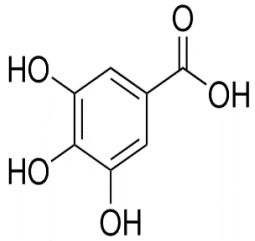

Fig 2.1 Chemical Structure of Gallic acid

Source: Elmarzugi *et al.* (2016)

The fundamental mechanism behind the oxidation and reduction processes of antioxidant substances determines the phenolic content total using the Folin-Ciocalteu reagent (Verzelloni *et al.*, 2007). The decrease in phenolic compounds during drying has two reasons. First of all, some phenolic compounds can degrade while various drying temperatures are used. Second, in the absence of water, the portions of the cells tend to cling

together as the material dries, increasing the difficulty of solvent extraction and reducing the total recovery of phenolic compounds (Ghanem *et al.*, 2012).

2.5.1.2 Flavonoids

The peels, seeds and stems contain the flavonoid chemicals. The study revealed that the total flavonoid content (TFC) of the inedible peels of both species was higher than that of the edible pulps of the *Hylocereus* species (MR, 2010).

Flavonoids are a broad category of secondary plant phenolic with low molecular weight that are typically present in plant leaves, seeds, peels, barks, and flowers. The flavan nucleus helps to differentiate flavonoids. They are a subclass of secondary plant phenols having strong antioxidant and chelating properties. In the human diet, they are most frequently found in fruits, vegetables, wines, teas, and chocolate. Over 4000 flavonoids are among the approximately 8000 polyphenols that are currently recognized. The flavonoids' fifteen carbon atoms are arranged in a C6-C3-C6 structure. The essential elements of the structure are two aromatic rings, A and B, joined by a three-carbon bridge, often a heterocyclic ring, C. The main flavonoid classes, which include flavonols, flavones, flavanones, flavanols (or catechins), isoflavones, flavanols and anthocyanidins, are produced by changes in the substitution patterns of ring C. These compounds have a wide range of structural variations, with flavones and flavonols being the most common. Ring A and B substitutions cause the creation of unique molecules within each class of flavonoids (Pietta, 2000). These substitutions can includes ulphonation, oxygenation, alkylation, glycosnd acylation (Balasundram *et al.*, 2006).

Flavonoids have a high redox potential, allowing them to act as reducing agents. They are particularly important antioxidants because they act as singlet oxygen quenchers, hydrogen donors, and agents. They can chelate metals as well. The flavonoids are the most common phytochemicals, and they typically serve as a plant's defense against UV radiation, fungus, herbivores, diseases, and oxidative cell damage (Heim *et al.*, 2002). When consumed regularly by people, flavonoids have been shown to reduce the occurrence of diseases including cancer and heart conditions. Recent studies have demonstrated a great lot of interest in flavonoids since they could benefit public health through foods like fruits and vegetables. Reactive oxygen species (ROS) cause tissue damage, and flavonoids are now

well recognized as physiological antioxidants with the ability to prevent many degenerative diseases. A large class of phytonutrients (plant components), flavonoids are present in almost all fruits and vegetables. Together with carotenoids, they are responsible for the colorful colours in fruits and vegetables (Balasundram *et al.,* 2006).

Despite the fact that flavonoids are often considered to be non-nutritive chemicals, many researchers are curious to find out more about how they might help avoid serious chronic diseases. Because flavonoids are heat-sensitive phenolic compounds, heat treatment during blanching reduces the overall flavonoid concentration. Flavonoids are used to treat diseases like hypertension, vascular fragility, allergies and hypercholesterolemia as well as antibiotics, anti-diarrheal, anti-ulcer, and anti-inflammatory drugs . Flavonoids are also recognized to have antioxidant qualities. In addition, these flavonoids are known to have gastroprotective, anti-inflammatory, anti-allergic, and anti-cancer activities (Sreerama *et al.*, 2012). Dietary antioxidants may inhibit the therapeutic effects of several neurodegenerative diseases, including Alzheimer's and Parkinson's, as well as in vitro neuronal death. Dietary polyphenols are thought to have far higher antioxidant activity than essential vitamins (Mrkìc *et al.*, 2006).

2.5.1.3 Antioxidants

H. undatus peels had the maximum percentage of scavenging activity (87.02 ±2.24%). Peels from *H. polyrhizus* had slightly lower radical scavenging activity (83.48 ±1.02%) at the same concentration compared to those from *H.undatus* (MR, 2010).

The oxidation of cellular oxidisable substrates carried on by reactive oxygen species can be delayed or prevented by any antioxidant molecule(Ajila *et al.,* 2007). The availability of electrons to neutralize any free radicals is the basic concept behind antioxidant action. Because of their high degree of reactivity, free radicals which are created during the oxidation process have the ability to harm temporary chemical species. The most prevalent antioxidants in tropical fruit are betalains, phenolics and carotenoids. On the basis of experiments using phenolic acids, it was found that there was a correlation between the relative reduction in antioxidant activity with increasing temperature and the oxidisability of the antioxidants. This relationship states that, in contrast to their activity at low temperatures, the more easily oxidizable antioxidants exhibit a slower rate of antioxidant activity loss with

increasing temperature and maintain their antioxidant activity at higher temperatures (Réblová, 2012).

Foods contain antioxidants, which are chemicals that reduce the impact of free radicals, unstable molecules produced during oxidation. A compound's level of antioxidant activity depends on a number of factors, such as its antioxidant structure, the composition of its lipid fraction, the presence of additional oxidation inhibitor (Clement and Mabry, 1996) or promoters, the presence of non-lipidic components, moisture content, microstructure, temperature, and so forth (Mrkìc *et al.*, 2006).

A rapid, simple, and affordable method of determining the antioxidant capacity of food is to utilize the free radical 2, 2-Diphenyl-1-picrylhydrazyl (DPPH), which is commonly used to assess a compound's ability to act as a free radical scavenger or hydrogen donor and to evaluate antioxidant activity. The DPPH test involves reducing a stable free radical known as DPPH. The odd-electron free DPPH radical causes absorption (purple color) at 517 nm. When the antioxidants in the plant extract react with DPPH, it is reduced to DPPH-H and, depending on how many electrons are captured, decolorizes to a yellow color. The ability of the sample extract to scavenge free radicals is inversely correlated with color absorbance.

The radical scavengers' DPPH scavenging is best described as:

$$DPPH\bullet + FE \longrightarrow DPPH - H + A\bullet$$

$$DPPH + A\bullet \longrightarrow DPPH - A$$

$$A\bullet + A\bullet \longrightarrow A - A$$

Here FE is an extract scavenger and A• is a radical. The freshly created radical (A•) can primarily be produced through radical-radical contact, collision of radicals, and the abstraction of an atom by one radical from another equations.

Temperature often has a negative effect on antioxidants because drying causes irreversible oxidative processes. Phytochemical substances may oxidize during hot-air drying because the food ingredient is exposed to more oxygen. When exposed to hot air directly, fruits lose their color, vitamins, and flavor (Mrkìc *et al.*, 2006).

2.5.1.4 Betacyanin

Betacyanin is a red violet colored compound which is produced from water soluble pigment called betalins and consists of nitrogen molecules (Esatbeyoglu et al., 2015). The members of betacyanin found in dragon fruit include betanin, isobetalin, phyllocactin, hylocerenin and isohylocerein (Stintzing et al., 2007). The betalain content was reported to be higher in peel than in pulp (Wu et al., 2006). Jamilah et al. (2011) has found that for every 100g of dry weight, *Hylocereus undatus* has 150.46 ± 2.19 mg of polyphenolic components, including betalains, gallic acid, and betacyanins. It has been shown that the betalains derived from dragon fruit peels have health-promoting properties, including such as an antioxidant, anti-inflammatory, antiangiogenic, and stimulant of glutathione S-transferas (Rodriguez et al., 2016).

As synthetic dyes continue to be replaced, food manufacturers and consumers are becoming more interested in natural colorants derived from plants. Natural colors are mostly derived from biological matter through mechanical retention, the production of covalent chemical bonds, complexes with salts or metals, physical absorption, or by solution. There are four different types of betacyanin: betanin, amaranthin, gomphrenin, and bouginvillein .They possess anti-inflammatory, antioxidant, and anti-cancerous properties and also can be researched more thoroughly as a natural food source colorant. The nitrogenous vacuolar pigments known as betalains are found in 13 families of plant species and several Basidiomycetes (Clement and Mabry, 1996). They are divided into two subgroups: the yellow-orange betaxanthins and the red-violet betacyanins (Ghosh *et al.*, 2022). Temperature, oxygen, light and water activity are the main factors that affect the majority of natural plant pigments, such as betacyanins and anthocyanins (Cai *et al.*, 2005). Due to its therapeutic and medicinal benefits as well as the high toxicity of synthetic hues, natural colorants have gained popularity around the world.

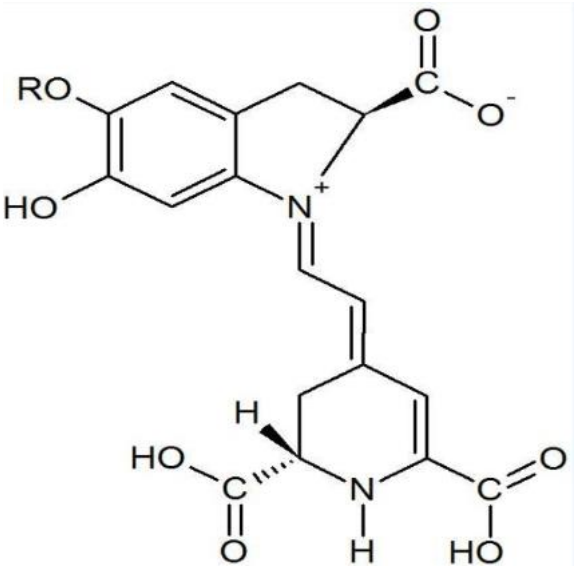

Fig 2.2 Chemical Structure of Betacyanin

Source : Elmarzugi *et al.* (2016)

The betalains extracted from pitaya, unlike the red beet, can be used in foods without flavor and it covers a wide spectrum of color from yellow-orange (*Opuntia*) to red-violet (*Hylocereus) (*Mobhammer et al., 2005).

2.6 Benefits of Dragon fruit peel

The health benefits of dragon fruit peel are:

1) Dietary fiber: Dragon fruit peels are high in dietary fiber, which can help suppress food cravings and maintain blood sugar levels. The dragon fruit peel powder has potential to reduce total cholesterol, triglyceride, and LDL-c and to increase HDL-c levels (Chumroenvidhayakul *et al.*, 2022).
2) Antioxidants: The peels contain antioxidants such as polyphenols, carotenoids, flavonoids and betacyanins, which protect cells from damage by free radicals and may help prevent inflammation and disease. Thus, it is significant in the fields in healthcare, food processing, nutraceutical and cosmeceutical industries (Chumroenvidhayakul *et al.*, 2023).
3) Vitamins and minerals: Dragon fruit peels are rich in vitamins and minerals, including vitamin C, vitamin E, iron and magnesium, which can strengthen the

immune system and boost iron levels in the body. Therefore, peel powders can be consumed as a supplement in foods that are expected to maintain a healthy body and prevent hyperlipidemia (Setiawan et al., 2018).

4) Potential antidiabetic and antihyperlipidemic properties: Scientific studies have suggested that dragon fruit peels may have antidiabetic, antihyperlipidemic and anticancer activities (Cheok *et al.*, 2018).
5) Betains: It has been shown that the betalains derived from dragon fruit peels have health-promoting properties, including such as an antioxidant, anti-inflammatory, antiangiogenic, and stimulant of glutathione S-transferas (Rodriguez et al., 2016).

2.7 Tea

Tea is one of the most important beverages in the world. Due to its wonderful flavor and aroma, as well as its health advantages, the usage of tea is currently steadily increasing. The prevention and treatment of cancer, cardiovascular disease, osteoporosis and dental cavities are among many the health advantages of tea (Bushman and cancer, 1998). Many studies have demonstrated the effectiveness of tea's polyphenols and flavonoids as antioxidants and their ability to reduce the deterioration of an organism's cells and tissues caused by free radicals (Almajano *et al.*, 2008).

On the basis of degree of fermentation, tea is divided into three types- unfermented green tea, partially fermented oolong tea and completely fermented black tea (S. D. Lin *et al.*, 2010).

2.7.1 Green tea

Green tea is consumed as a well known refreshment around the world, especially in Asian nations like China, Korea and Japan. There is barely any other nourishment or drink detailed to have as numerous health benefits as green tea. The chemical composition of green tea shifts with climate, season, agricultural practices and position of the leaf on the gathered shoot. The major components of intrigued are the polyphenols. The major polyphenols in green tea are flavonoids. The four major flavonoids in green tea are the catechins, epicatechin (EC), epigallocatechin (EGC), epicatechingallate (ECG) and epigallocatechin gallate (EGCG) (Sinija and Mishra, 2008). Additionally, green tea, its

extract and its isolated constituents were too found to be compelling in avoiding oxidative stretch and neurological issues (Unno *et al.*, 2007). Drinking green tea has moreover been related to lessening the chance of creating cancers of the kidney, pancreas, esophagus, mouth, stomach, little digestive system, lung and mammary organs, among other cancers (Koo and Cho, 2004). Green tea boosts resistant system function by securing it from oxidants and radicals. GTPs have been appeared to ensure against Parkinson's, Alzheimer's and other neurodegenerative disorders in recent studies (Pan *et al.*, 2003).

2.7.2 Herbal tea

A beverage infusion known as herbal tea or tisane is made without the use of tea leaves (*Camellia sinensis*). It usually consists of a blend of aromatic dried leaves, herbs, tree bark, dried fruits, flowers, or plant components that provide aroma and flavor along with health benefits. Tea enthusiasts are attracted to herbal tea because, in addition to its delightful flavor and scent, it promotes relaxation and wellness. Herbal tea can be consumed on a regular basis to promote heart health, heal digestive problems, increase vitality and energy, strengthen the immune system, give the body essential antioxidants, lower stress levels, enhance sleep quality and stimulate the operation of different organs (Ravikumar, 2014).

Herbal teas are free of caffeine, compared to most other kinds of tea. They taste great and simple to drink. A blend of herbal ingredients or a single major herbal ingredient is typically used in herbal teas with the aim of promoting a particular effect, such as relaxation, rejuvenation, or relief from a certain illness, among additional advantages (Aoshima *et al.*, 2007).

A result of the study indicate that two g of red dragon fruit peel herbal tea, brewed at 100°C with water, has a moderately high phenolic content (0.83g/100g) and antioxidants with an IC50 value of 8.50 mg/ml. Red dragon fruit peel antioxidant content can achieve an IC50 value of 2,713 ppm with appropriate drying techniques. Because of its established health advantages, red dragon fruit peel can therefore be used as an ingredient in tisanes (Purnomo and Johan, 2016)

2.8 Drying

2.8.1 Introduction

Drying is the process of removing the water vapor that has separated from the material after applying heat to evaporate the volatile chemicals (moisture). Due to the heat and mass transfer phenomenon, water moves from the interior of the drying product to the surface where it evaporates. The surface of the product receives heat from the surrounding air. After using a portion of this heat to warm the interior of the product, which increases temperature and creates water vapor, the remaining energy is used to evaporate the moisture from the surface (Matin *et al.*, 2017). The effectiveness of drying is influenced by air, including its temperature, relative humidity, air flow velocity and dryer design. When changing the drying process, including the drying air temperature and the temperature to which the product is exposed, it is important to consider the characteristics of the product and its intended use (Zhang *et al.*, 2006).

Human has been drying and/or smoking meat, fish, fruits and vegetables for thousands of years to supply for himself during the year's off-season. The food industry's dehydration section is now global in scope and affects every country on the planet. Drying equipment may involve simple hot air or solar dryers as well as more effective spray drying or freeze drying devices. The convenience food sector greatly depends on the large variety of dehydrated meals. Dehydration or drying is the process of removing the bulk of water that is generally present in food by evaporation or sublimation as a result of the application of heat. The primary advantage of food drying is that it can be transported and has a longer shelf life than fresh food while being preserved without refrigeration. The amount of moisture that is available or the water activity must be sufficient to reduce to a level that delays the occurrence of harmful chemical changes, inhibits the activity of enzymes and stops the growth of spoilage and pathogenic bacteria (Deng *et al.*, 2019).

2.8.2 Drying methods

2.8.2.1 Sun drying

The standard drying process, known as "sun drying" comprises simply setting out mats, roofs or drying floors and letting the product bake in the sun. Because solar and wind energy are

readily available nearby, less capital is required. Vegetables and fruits are still primarily dried by the sun. By convection from the surrounding air passing through the crop's surface and absorption of both direct and diffuse sunlight, heat is transferred during sun drying. Two uses for the converted heat are: slightly raising the temperature of food goods, and to partially distribute moisture from the interior to the surface (López *et al.*, 2009). The remaining energy is expended in the evaporation of water from the surface. Natural convection with the aid of wind forces must be used to remove the evaporated water from the area around the crop. Sun drying has the advantages of being straightforward, having low setup and recurring costs and requiring no technical knowledge. On the other hand, there are many technical difficulties, including inability to manage drying conditions, contamination from external sources and uncertainties such cloudy and rainy. Long drying durations and large areas are required. The finished product could be rather damp due to over or under-drying and polluted by dust, insects, birds, enzymes and microbial activity. Additionally, it can be of poor quality. Only hot, dry climates with high winds are suitable for it (Matin *et al.*, 2017).

2.8.2.2 Cabinet drying

The bulk of industrial drying installations employ convectional hot-air drying since it is the simplest and most economical technology. Thus, a variety of food products, including fruit, vegetables, herbs and cereal crops, have been dried using convectional hot air dryers. These dryers also make it simple to produce and control the optimal drying conditions, especially cabinet dryers. Common atmospheric hot-air dryers include kilns, cabinets (trays), tunnels, belt dryers, and conveyor dryers (Wang *et al.*, 2010).

An atmospheric hot-air dryer's basic structure is an enclosed, heated chamber where foodstuff is placed. It also features ducts and a blower (sometimes referred to as a fan) that allow hot air to be moved across and around the food. Natural convection drives the drying process in the absence of a fan. Drying is achieved in an atmospheric dryer by heating the object and removing water from its surface (Rahman, 2007).

Conventional convective drying systems use continually consistent air temperature to remove moisture from the food product. Thermal energy is transferred from the heater to the food substance through convection. How well this thermal energy permeates a substance

depends on its thermal conductivity. During drying, gas replaces moisture as it exits the pores in the food's outer layers (Mohd Rozalli *et al.*, 2016).

The outer layers' heat conductivity decreases because air has a lower thermal conductivity than water. As a result, the product surface serves as an insulator. The interior of the food sample receives progressively less heat, and water moves to the surface more slowly, where evaporation occurs. Therefore, large heat transfer rates applied at the surface will only result in overheating or over drying of the surface layer, which will negatively impact quality without a significant increase in the drying kinetics (Lewis, 1990).

2.9 Effect of temperature on various bioactive compounds in dried product

To improve the drying process and boost product quality, it is critical to take temperature into account since it affects dried product quality. The amount of total phenolic compounds, total flavonoid compounds and antioxidant activity in tea can all be affected by temperature which are important indicators of tea quality. Although initial increase and decrease in antioxidant activity, total phenolic and total flavonoid concentration decreases as drying temperature rises. According to the study, green tea's quality was best retained when dried at a temperature of 60 °C, investigated how the flavor of apple tea was changed by drying temperature. The study found that when drying temperature increased, antioxidant activity and total phenolic compound concentration decreased, whereas total flavonoid compound content initially varied between both rise and fall (Z. Lin *et al.*, 2020). The study discovered that the optimum quality preservation occurred when drying apple tea at a temperature of 50°C. Overall, it can be said that the appropriate drying temperature for preserving tea quality can vary based on the type of tea and the particular quality indicators being analyzed (Ahmad-Qasem *et al.*, 2017).

Several studies have shown that polyphenolic contents of fruit skins decreases during drying process. The reason behind reduction may be due to transformation or polymerization of the antioxidant molecules caused by the high temperatures as well as by the chemical or enzymatic oxidations of these molecules associated with long drying times. In the study of green tea leaves the highest TPC was obtained at 60°C (Galaz *et al.*, 2017).

Flavonoids' stability and biological activity are both controlled by temperature. Flavonoids breakdown during hot air drying because they are heat sensitive. Flavonoid breakdown increases with heating intensity and duration (Chaaban *et al.*, 2017). Heating has the potential to degrade some phytochemicals that change the integrity of cell walls and cause some flavonoids to migrate. Moreover, flavonoids can be broken down or seep out due to chemical reactions involving oxygen, enzymes and light (Buchner *et al.*, 2006).

According to (Réblová, 2012), antioxidant activity drastically declines during the drying process and continues to do so as the temperature rises from 50 to 70 °C. Peels that are low-temperature dried retain far more antioxidant activity (Réblová, 2012). High temperature intense heat processing has the potential to deactivate enzymes, destroy phytochemicals and significantly reduce antioxidant content in plants (Davey *et al.*, 2000).

Betalains are highly sensitive to temperature, light and oxygen. (Santos *et al.*, 2017) studied the retention of betalain in dragon fruit peel dried at 50°, 60° and 70 ° observed that lower temperature resulted in the greater retention of betalains.

2.10 Sensory attributes of tea infusion

Sensory analysis evaluates a product's or food's attributes such as texture, flavor, taste, look and odor, using the panelists' senses of sight, smell, taste, touch and hearing. Since ancient times, this type of research has been used to approve or oppose food products. It was once considered a methodology that improves technological and microbiological security when assessing the quality of food. Nevertheless due to its great growth and significance in recent decades, it has become one of the most important innovation and application strategies to ensure consumer acceptance of the finished product (Ruiz-Capillas and Herrero, 2021).

A tea infusion's attributes, including its color, flavor, aftertaste and general acceptability are important factors in establishing the tea's quality and level of consumer acceptance. An apple tea infusion's sensory characteristics were investigated. According to the study, the apple tea infusion had a light brown color, a fruity scent, a sweet flavor and a pleasant aftertaste. The apple tea infusion was favorably received by the trial participants overall (Castiglioni *et al.*, 2015). Zhu *et al.* (2016) study the sensory characteristics of a black tea brew. The study found that the infusion of black tea had a rich dark color, a floral aroma, a

moderate flavor, and a lingering aftertaste. The black tea infusion received generally favorable reviews from the trial participants. In general, it may be argued that a tea infusion's sensory attributes can vary depending on the type of tea used (Zhu *et al.*, 2016).

Sensory evaluation is a measurement-based science that places a high importance on precision, accuracy and sensitivity. Using the senses of sight, smell, taste and touch, a product is evaluated for a variety of quality features such as appearance, flavor, scent, texture, etc. through sensory analysis. The practice of customer evaluation is common in the field of research. Ahead-of-the-curve technology is examined for analyzing consumer behavior and creating innovative products (Tan *et al.*, 2023).

2.11 Hedonic rating of sensory

Hedonic response quickly developed in the 20th century alongside the growth of the food processing industry. It contains a selection of techniques required for getting precise readings on how individuals react to food, which in turn affects how customers view things. According to the Institute of Food Technologists, sensory evaluation is a scientific method for generating, measuring, analyzing and interpreting reactions to products as experienced through the senses of sight, hearing, touch, smell and taste. Using the senses of taste, smell and touch, sensory analysis examines a product for its appearance, flavor, aroma, and other quality attributes (Sharif *et al.*, 2017).

Customers decide whether to accept or reject food depending on the sensory analysis needed for verification of the new product's responsiveness. It is the study of weighing and judging food attributes utilizing human senses (Falade and Omojola, 2010). The hedonic scale is employed to determine how agreeable one or more things are. This scale is a categorical scale, with an odd number (five to nine) of categories ranging from "dislike extremely" to "like extremely". There is a neutral choice included that is neither liked nor disliked. Customers rate the item on a scale based on their comments (Stone and Sidel, 2004).

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Part III

Materials and methods

3.1 Materials

3.1.1 Collection of dragon fruit

Matured dragon fruit were purchased from local market of Dharan, Sunsari at the rate of Rs 350 kg.

3.1.2 Chemicals and apparatus

All the lab grade quality chemicals, laboratory glassware and equipment used for study were obtained from Central Campus of Technology. The major apparatus and chemicals required are list in Appendix A.

3.2 Methods

3.2.1 Preparation of dragon fruit peel powder

The dragon fruit free from any defects or damage were taken and subsequently washed in tap water. After manual separation of peel and pulp, peels were cut into 2.5 cm lengthwise. Those peels were spread on trays and dried at various temperatures of 50°C, 60°C and 70°C respectively in a cabinet dryer. A built-in heaters on the cabinet dryer's side walls generated heat, and a fan circulated the hot air around the samples. The temperature of the cabinet dryer was changed through a temperature control dial. Once the cabinet dryer reached the proper temperature, slices were placed on trays and placed into the drying chamber. The drying samples were sampled, allowing for the hourly measurement of mass and moisture loss. The samples were dried until they reached a constant weight, where the point was found using a weighing balance technique. The studies were run three times to guarantee both reliability and accuracy.

The samples after reaching moisture content of 5% were taken out, cooled and sealed in bags made of high- density polyethylene (HDPE). To guarantee the samples would be safe until their next time use, the bags were heat sealed. Dried dragon fruit peel powder were

crushed in an electric blender after drying at various temperatures. The processed powder were tightly sealed in plastic bags to avoid moisture absorption. For further analysis, these bags were kept at a temperature of 5±1°C.

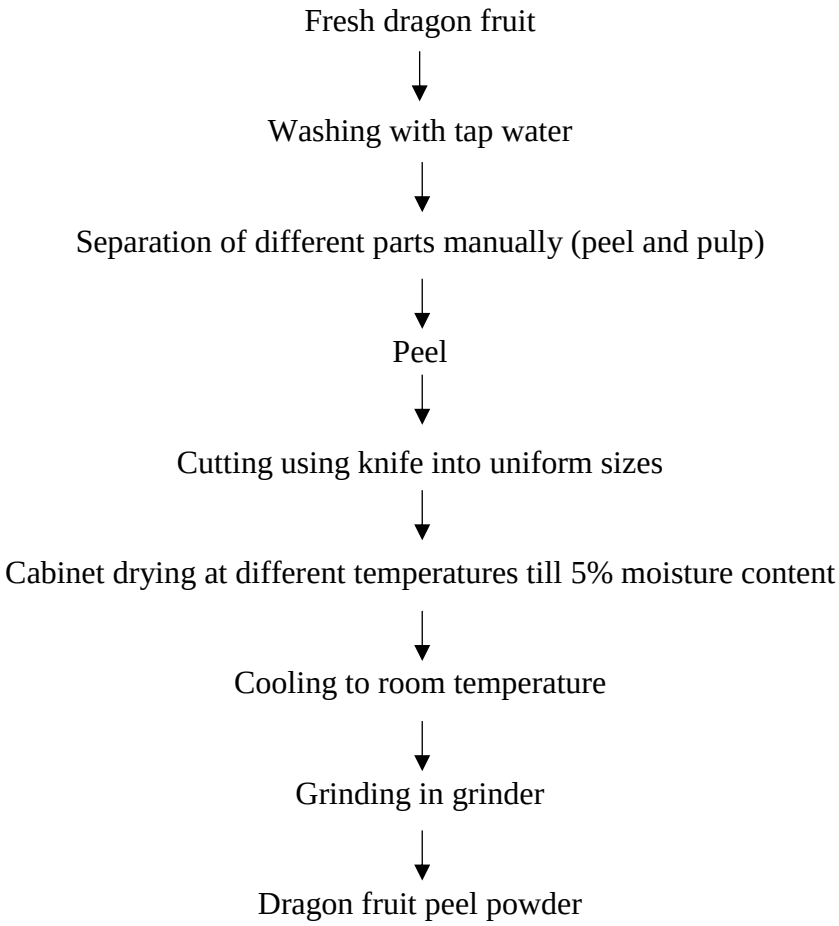

Fig. 3.1 General steps of dragon fruit peel powder preparation

Source : Pokhrel (2023)

3.2.2 Analytical methods

3.2.2.1 Chemical analysis

Moisture content, crude fiber, total ash, total phenolic content, total flavonoid content, total tannin content, betacyanin content and DPPH radical scavenging activity were determined in the laboratory of Central Campus of Technology by the following methods. The infusion

was prepared by dipping 1.5 g of dried peel in 50 ml hot water and left for 5 min. The sensory analysis was done by 10 panelists.

3.2.2.2 Determination of moisture content

The moisture content of the fresh and dried dragon fruit peel was determined by weight loss in thermostatically controlled oven at 105°C by hot air oven method as described in (Ranganna, 1986).

3.2.2.3 Determination of crude fiber

The crude fiber of the peels was determined as described in (Ranganna, 1986).

3.2.2.4 Determination of total ash

Total ash of dragon fruit peel was determined by drying ashing as described in (Ranganna, 1986).

3.2.2.5 Determination of crude protein

The crude protein of dragon fruit peel was determined by using micro-Kjeldahl method with conversion factor 6.25 as described in (Ranganna, 1986).

3.2.2.6 Determination of Vitamin C

The vitamin C was determined by iodine titration method as per (Suntornsuk *et al.*, 2002) with slight modifications. Starch indicator solution was prepared by mixing 1g of starch with 200ml of boiling water. The solution must immediately remove from heat and left for cool. Each 25ml of fresh juice sample was transferred into a 250ml Erlenmeyer flask. 25mL of 2N sulfuric acid was added, mixed, diluted with water (50ml) and starch indicator (3ml) was added. The solution was directly titrated with 0.01 N standardized iodine solution until the blue color has emerged within 15 seconds. A blank titration was performed prior to titration of each sample. Iodine titration volume is converted to ascorbic acid, where 1 ml of 0.01 standard iodine is equivalent with 0.88 mg of vitamin C.

3.2.2.7 Preparation of extract

Methanolic extraction method was used to extract the bioactive compounds. 10 g of the peel powder was taken and mixed with 100 ml of 80% methanol and left overnight in the dark by covering with aluminum foil. The extract was filtrated through Whattman no. 41 filter paper and the obtained filtrate were used for the analysis of TPC, TFC, TTC and DPPH radical scavenging activity.

3.2.2.8 Determination of total phenolic content

The phenolic content of fresh and dried dragon fruit peel powder was determined as per (Šeruga *et al.*, 2011) with slight modifications. 0.25ml of extracted samples were measured into test tubes, then 1.3ml of 10-fold Folin-Ciocalteu's reagent and 3.75ml of 7.5%w/v sodium were added. The mixtures was diluted with distilled water and inverted 20 times and left to stand for 30 min. A blank for the reagent was used to measure absorbance at 760 nm. Gallic acid equivalents, or GAE, were used to express the total phenolic content in mg per 100 g extract.

3.2.2.9 Determination of the antioxidant activity

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

3.2.2.10 Determination of total flavonoid content

A slightly modified aluminum chloride test procedure was utilized to calculate the total flavonoid content of the fresh and dried powder peel as described by (Barek *et al.*, 2015). 2

ml of the extract solution from each extract was added into a volumetric flask with a 10 ml capacity. 0.2ml of 5% NaNO3 solution was added to the flask, then let it rest for five min. The mixture was then given 0.2 ml of a 10% AlCl3 solution and let to stand for an additional 5 min. After including 2 ml of 1N NaOH, distilled water (DW) was added to increase the capacity in the flask to 5ml. The solution's absorbance at 510 nm was measured after 15 min using a reagent blank.

Quercetin standard curves with concentrations of 100, 200, 300, 400, and 500 mg/L were used to compare the test result. The amount of total flavonoids content was determined and expressed as mg of quercetin equivalents (QE).

3.2.2.11 Determination of total tannin content

The Folin-Ciocalteu method was applied to assess the tannin concentration in accordance with the methods published by (Mythili *et al.*, 2014). 0.1ml of the sample extract, 7.5 ml of distilled water, and 0.5ml of Folin-Ciocalteu reagent were mixed in a 10ml volumetric flask. Then, 10 ml of distilled water were added to the mixture to dilute it, and 1 ml of a 35% Na2CO3 solution was then added. The mixture was vigorously shaken and allowed to stand at room temperature for 30 min. The same procedure was used to create a series of reference standard solutions of tannic acid with concentrations of 100, 200, 300, 400, and 500 mg/L. The absorbance of the test solution and the reference solution were measured with a UV-visible spectrophotometer.

3.2.2.12 Preparation of betacyanin extract

10g (macerated fresh peels and dried powder peels) was weighed and 100ml of methanol was kept in a beaker. The extraction was carried out by maceration process for 24h in a refrigerator. The extract was then filtrated by using a Whattman no. 41 filter paper. The filtrate was stored in a refrigerator for further analysis.

3.2.2.13 Determination of total betacyanin content in fresh and dried samples

All extracted samples absorbance were measured at 538 nm using a spectrophotometer. The absorbance readings was used to calculate the total betacyanin concentration sample. The

quantification was described by (Lim *et al.*, 2011). The betacyanin content (mg/100g) was calculated using the equation:

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

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) = 550 g/mol.

3.2.3 Sensory analysis

The sensory assessment for overall quality was conducted with the help of 10 panelists. Color, flavor, smell, taste, aftertaste and general acceptability were the criteria for sensory evaluation. 9-point hedonic rating scales were used to complete sensory evaluations. The sensory sample graph is shown in Appendix A.

3.2.4 Overall work flow chart

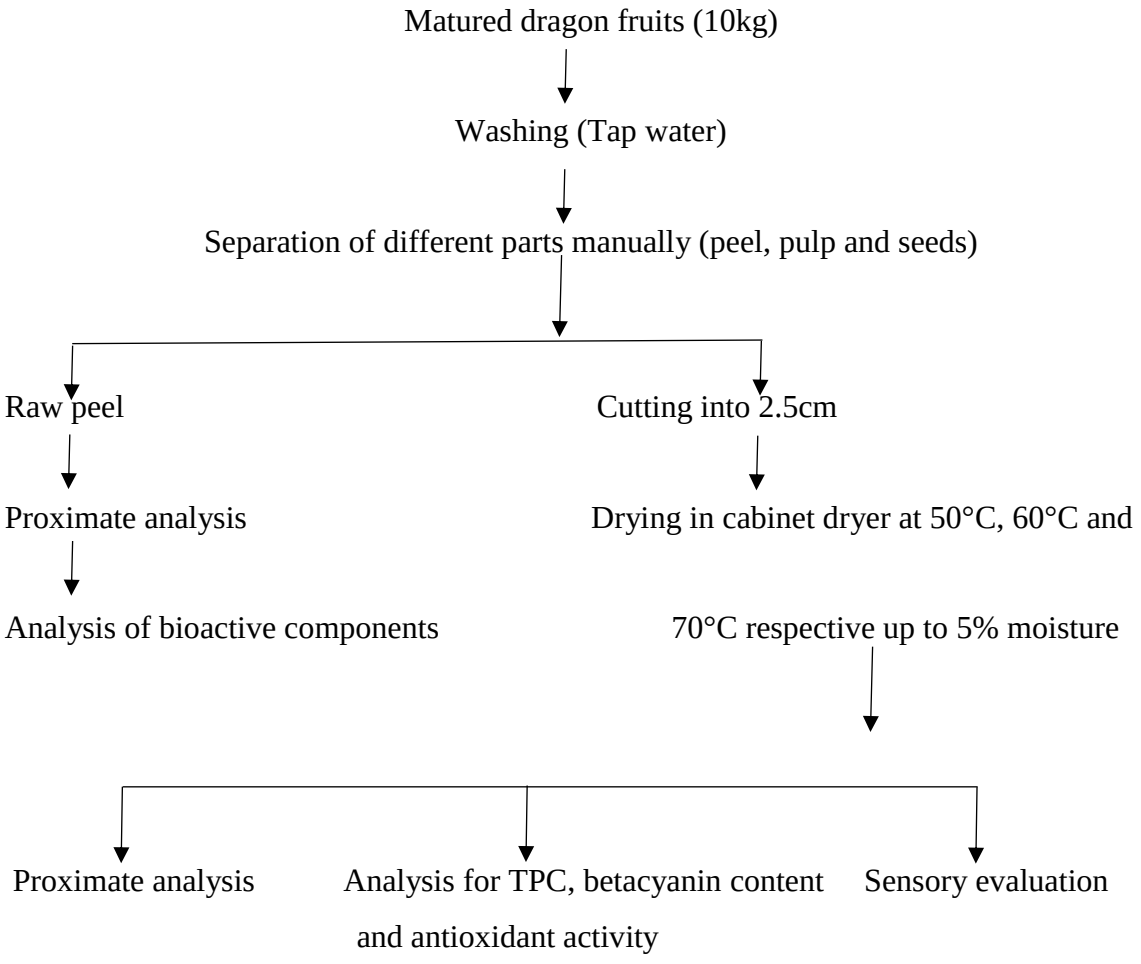

Fig 3.2 Overall work flow chart

Source : Pokhrel (2023)

3.2.5 Data analysis

The triplicate data from each experiment analysis were subjected to one-way analysis of variance (ANOVA) using GenStat Release 12.1 software (Copyright 2009, VSN International LTD.). Mean values were compared using Tukey's HSD poc hoc test ($p<0.05$) for determining significant differences and to determine the superior one among samples. MS-Excel 2016 was also employed for the general calculations, graph and diagram construction. The mean sensory score were subjected to two –way analysis of variance using GenStat.

Part IV

Results and discussion

The present study was conducted to optimize the drying temperature of strips for dragon fruit peel tea infusion. Matured dragon fruit were purchased from local market of Dharan. Some fresh dragon fruit peel were separated and stored in refrigerator for chemical analysis. The remaining fruit peels were chopped with knife in constant length and dried at different temperatures i.e. 50°, 60° and 70 °C till moisture content reached 5% . The dried dragon fruit peels were powdered using grinder and sieved with 40 mesh size sieve. The fresh dragon fruit peel and dried peel powder were analyzed for the proximate analysis and bioactive compounds determination.

4.1 Proximate analysis of fresh peel

Table 4.1 Proximate composition of fresh dragon fruit peel

Parameters	Fresh dragon fruit peel	Dried dragon fruit peel
Moisture (%wb)	90.12 ± 0.22	9.34 ± 0.18
Ash (%db)	13.32 ± 0.13	10.12 ± 0.32
Crude protein (%db)	6.68 ± 0.45	5.45 ± 0.27
Crude fiber (%db)	30.23 ±0.04	2.67 ± 0.62
Vitamin C (mg)	90.34 ± 0.09	16.23 ± 0.40

Values are expressed as mean of the three determinations ± standard deviation.

Fresh white flesh dragon fruit peel contained moisture content 90.12% which is similar to the study by (Alam *et al.*, 2023) where the moisture content is found to be 91.88%. The ash content, crude protein, crude fiber and ascorbic acid were found to be 13.32 %, 6.68%, 30.23% and 90.34mg respectively which were similar to the study by (A. R. Sari and Hardiyanti, 2013). The slight variation in the proximate analysis may be due to the location, season, harvesting time and maturity. The dried peel had a moisture content similar to commerical dry products such as mango (8.1%), bran flakes, oat cookies, whaet germ and

Valencia orange (10.5%) (Borchani *et al.*, 2012). The ash content represents the total mineral content in food. As most minerals are unaffected by heat, they cannot be destroyed like other nutrients. Thus, the decrease in ash content was only 3.2% on dry basis. The protein content of fresh and dried peel was almost the same. The peel is good source of fiber. In this study, only crude fiber was examined. Compared to total dietary fiber of all-bran cereal (28.1%), lettuce (26%), carrots (23.9%), strawberries (24.2%), the crude fiber content of dragon fruit peel powder was similar (DeMan *et al.*, 1999).

4.1.2 Chemical composition of fresh dragon fruit peel

Table 4.2 Chemical composition of dragon fruit peel

Parameters	Values
Total phenolic content (mg GAE/100g,db)	134.33 ± 0.16
Total flavanoid content (mg QE/100g,db)	90.36 ±1.73
Total tannin content (mg TAE/100g,db)	360.12 ± 0.45
Antioxidant activity by DPPH method (%)	85.07 ± 0.20
Betacyanin content (mg/100g DM**)**	143.02 ± 1.43

Values were the mean of three determinations ± standard deviation.

The values for all parameters were found similar with several studies. According to Tarte *et al.* (2023), the total phenolic content, total flavonoid content and total tannin content were reported to be 125.74 mg GAE/100g, 96.72 mg QE/100g and 364.77 mg TAE/100g respectively on dry basis. The radical scavenging activity of dragon fruit peel was reported to be 87.02% by (MR, 2010). Similarly, the betacyanin content by Taharuddin *et al.* (2023) was 150.45 mg/100g in dry basis.

Table 4.3 Chemical composition of dried dragon fruit peel at various temperatures

Parameters	50°C	60°C	70°C
Total phenolic content(mg GAE/100g)	64.92 ± 0.83	43.66 ± 1.50	35.22 ± 1.88
Total flavonoid content (mg QE/100g)	56.34 ± 1.30	44.74 ± 0.90	31.74 ± 0.45
Antioxidant activity (%)	77.37 ± 0.84	69.33 ± 0.77	54.58 ± 1.25
Betacyanin content(mg/100g)	52.34± 1.32	26.50 ± 0.89	20.19 ± 1.56

The reduction in TPC content in the dried dragon fruit peel could be due to the degradation (oxidation) of phenolic compounds during thermal treatment (Kondareddy *et al.*, 2021). The TFC decreased with increasing temperature because heat sensitive flavonoids degrade during hot air drying (Chaaban *et al.*, 2017). The values of antioxidant activity were decreasing along with the increasing drying temperature. In most cases, changes in TPC come after changes in the antioxidant capacities of the samples. An increase in drying temperature may affect the molecular makeup of phenols, which could lead to a decrease in TPC. Also, betacyanin content was reduced with rise in temperature due to the heat that results in the isomerization, decarboxylation, or cleavage of betalins which gradually reduces red color and leads the appearance of a shade of light brown (Herbach *et al.*, 2006).

4.1.3 Effect of drying temperature on bioactive components of dragon fruit powder

In this study, bioactive components including total phenolic content (TPC), antioxidant activity and betacyanin content were all examined. All the parameters mentioned here were measured in dry basis (db).

4.1.3.1 Total Phenolic Content

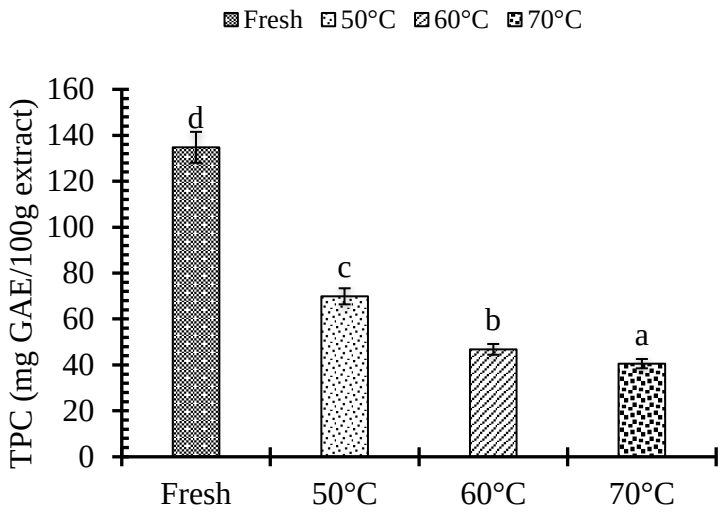

Fig 4.1 Total phenolic content of fresh and dried samples of dragon fruit peel

Fresh dragon fruit peel was found to contain higher TPC i.e.134.33 ± 0.16 mg GAE/100g extract. Fig 4.1 shows that as the temperature increases above 50°C, the number of polyphenols decreases up to 70°C. The total phenolic content at various drying temperature of 50 °C, 60°C and 70°C were found to be 64.92 ± 0.83 mg GAE/100g extract, 43.66 ± 1.50 mg GAE/100g extract and 35.22 ± 1.88 mg GAE/100g extract. This shows that there was huge difference in TPC in fresh and dried dragon fruit peel powder while there was slight differences in TPC values between dried samples. Similar study was found by (Alam *et al.*, 2023) where TPC value of fresh dragon fruit peel was found to be 125 mg GAE/100g extract. Samples dried at 50°C, 60°C and 70°C had values of 65.7 mg GAE/100g extract, 48.15 mg GAE/100g extract and 38.12 mg GAE/100g extract respectively (MR, 2010). Thus, there was significant differences among samples.

As the drying temperature rises, the total amount of polyphenols falls because of processes known as oxidative degradation and condensation. A potential reason for the degradation of phenolic during drying operations would be as follows: (i) Some of the phenols may be destroyed during the drying process due to the change in temperature; and (ii) even in the

absence of water, all the components of the cells adhere to one another in the dried product, thereby delaying the solvent extraction process. Therefore, it was discovered that the overall recovery was less (Ghanem *et al.*, 2012).

4.1.3.2 Total Flavonoid Content

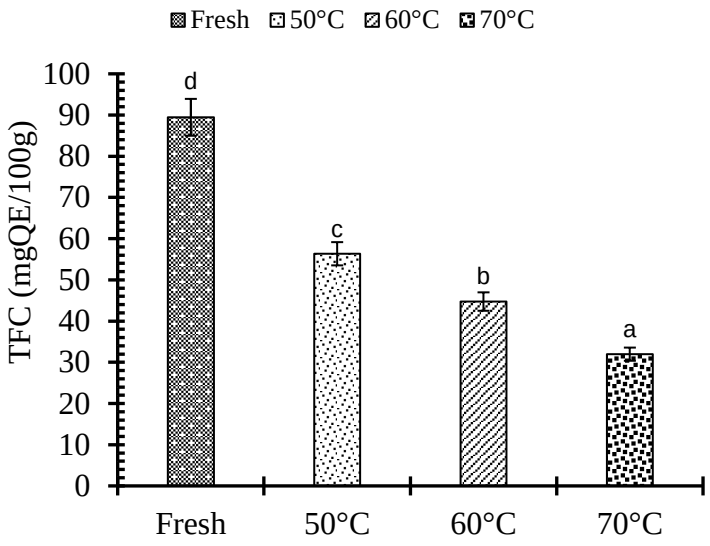

Fig 4.2 Total flavonoid content of fresh and dried dragon fruit peel powder

The total flavonoid content of fresh dragon fruit was found to be 89.45 ± 1.12 mg QE/100g. Fig 4.2 showed that the TFC content of dried samples were lower than fresh samples i.e. 56.34 ± 1.30 mg QE/100g, 44.74 ± 0.90 mg QE/100g and 31.97 ± 0.45 mg QE/100g extract at 50°C, 60°C and 70°C. There was a slight differences between samples as per (Alam *et al.*, 2023). The values from dried dragon fruit peel showed that TFC content reduces significantly with increasing temperature because heat sensitive flavonoids degrade during hot air drying (Chaaban *et al.*, 2017). The total flavonoid content found in this study was lower than those found in avocado peel by (Pokhrel, 2023).

4.1.3.3 Antioxidant activity

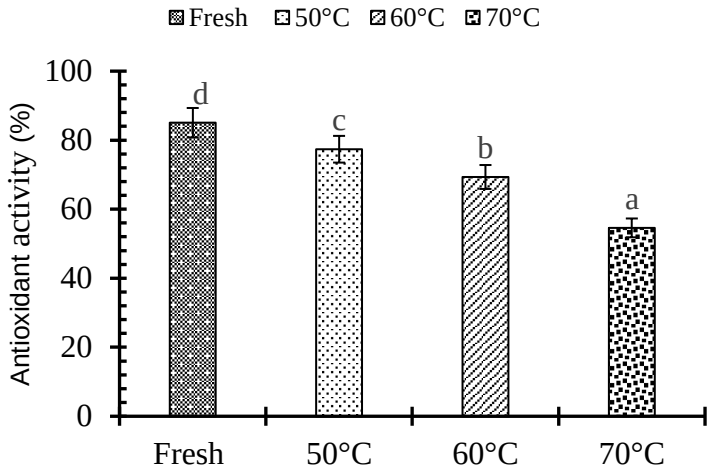

Fig 4.3 Antioxidant activity by DPPH radical scavenging activity of fresh and dried dragon fruit peels

The antioxidant activity of fresh dragon fruit peel was found to be 85.07 ± 0.20%. According to (MR, 2010), the antioxidant activity found to be 87.02% which was slightly higher than obtained value. The antioxidant activity of dried dragon fruit peel were 77.37 ± 0.84%, 69.33 ± 0.77% and 54.58 ± 1.25% at 50°C, 60°C and 70°C respectively as shown in Fig 4.3. According to Sengkhamparn *et al.* (2013) the radical scavenging activity ranged from 50 to 80%. In a study conducted by Jeong *et al*. (2004), it was observed that the antioxidant activity of dragon fruit peel extracts is significantly influenced by the temperature and duration of heating treatment applied to the dragon fruit peel. The effect of temperature on the levels of polyphenols and ascorbic acid in dried dragon fruit peel was observed to result in a decrease. Consequently, drying the peels at high temperatures was found to significantly increase the loss of antioxidant activity. There was significant differences among the fresh and dried samples.

Dried peel powder exhibited notably less radical scavenging action in comparison to fresh peel. This may be a result of the breakdown of phytochemical components after heat treatment. The phytochemicals that impact the integrity of cell structure can be broken down

by heat processing, which can lead to component movement and other chemical processes. This could be the cause of the product's decreased ability to scavenge radicals (Davey *et al.*, 2000). Antioxidant activity and polyphenol concentration are affected by drying temperature. The total phenolic content and antioxidant activity decline with an increase in drying temperature (Mrkìc *et al.*, 2006). According to Réblová (2012), antioxidant activity reduced dramatically after drying of the peels and declined as temperature increased from 50 to 70°C. As a result, drying peels greatly reduces the loss of antioxidant activity.

4.1.3.4 Betacyanin Content (BC)

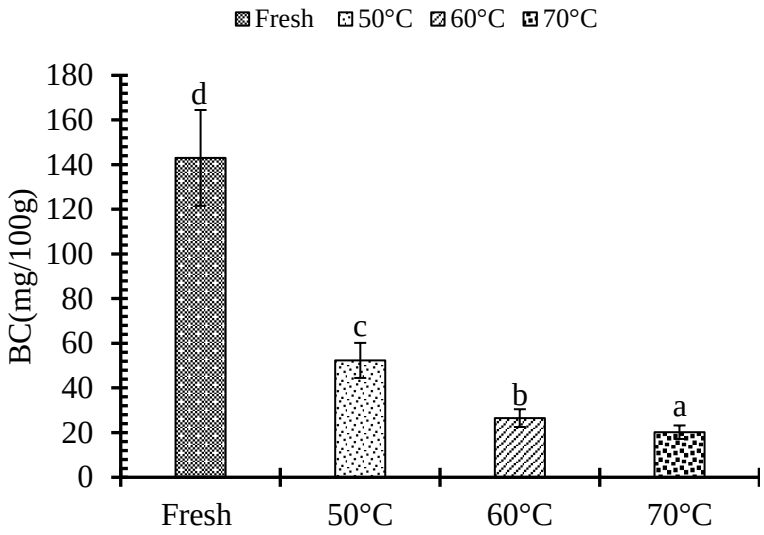

Fig 4.4 Betacyanin content of fresh and dried dragon fruit peel

The BC content of fresh dragon fruit was found to be 143.02 ± 0.67 mg/100g which was close to with the outcome of a study conducted by (Taharuddin *et al.*, 2023) where BC was accounted to be 150.45 mg/100g. Similarly, BC of dried sample at 50°C, 60°C and 70°C were found to be 52.34 ± 1.32 mg/100g, 26.50 ± 0.89 mg/100g and 20.19 ± 1.56 mg/100g which was similar to result conducted by (Santos *et al.*, 2017) where BC were reported to be 51.81 mg/100g, 24.39 mg/100g and 17.25 mg/100g respectively. Fig 4.4 showed that BC content decreases with increasing temperature. This might be due to the heat that results in the isomerization, decarboxylation, or cleavage of betalains, which gradually reduces red color and leads the appearance of a shade of light brown (Herbach *et al.*, 2006). There were significant differences among fresh and dried samples.

4.2 Sensory evaluation of dragon fruit peel tea infusion

The infusion was subjected to a 9-point hedonic rating test for sensory evaluation. The sensory analysis was carried out for all three samples. Samples A, B and C were those dried at 50°C, 60°C and 70°C respectively.

4.2.1 Color

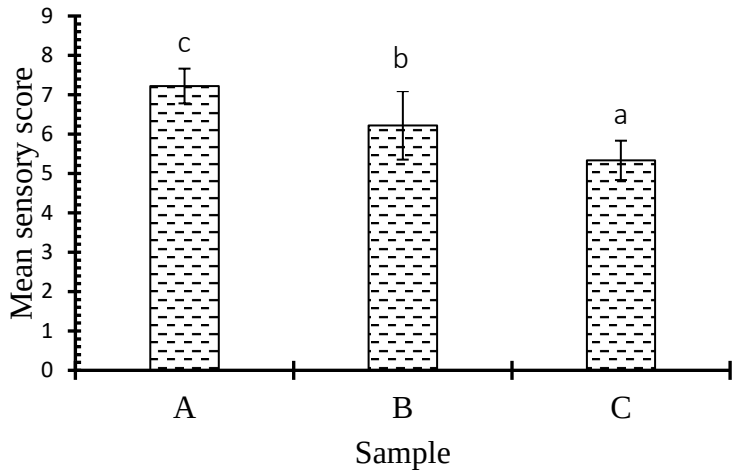

Fig 4.5 Sensory evaluation on color of tea infusion

The mean scores of color for dragon fruit tea infusion samples A, B and C were found to be 7.222, 6.333 and 5.333 respectively as shown in Fig 4.5. Sample A (7.222) had the highest mean score among all the samples. Therefore based on color, sample A was found to be the best among the three samples. Statistical analysis showed that there was significant effect ($p<0.05$) of variation at 5% level significance. As the drying temperature increases, the betacyanin content decreases which might be the cause for the decreament in mean senosry score of samples according to colour.

4.2.2 Aroma

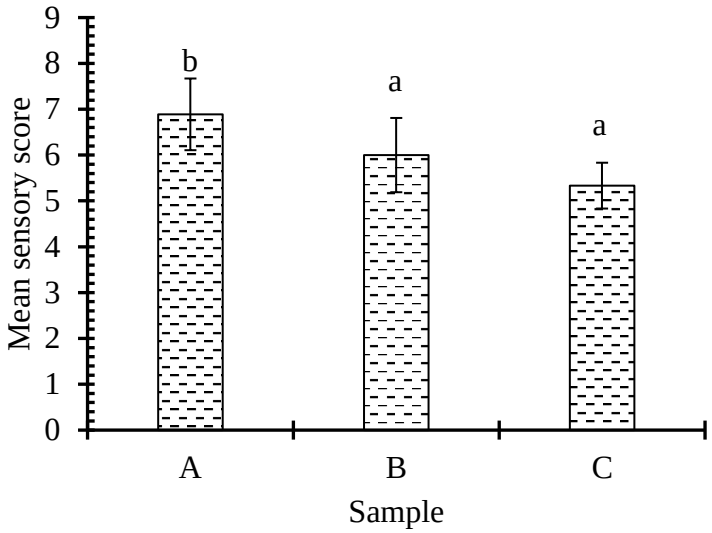

Fig 4.6 Sensory evaluation on aroma of tea infusion

The dragon fruit tea infusion samples A, B and C were found to have mean aroma ratings of 6.889, 6 and 5.333 respectively. Out of all the three samples, Sample A (6.889) had the highest mean score. At the 5% level of significance, statistical analysis revealed a significant effect of variance ($p<0.05$). Thus, sample A was determined to be the best of the three samples based on aroma.

4.2.3 Taste

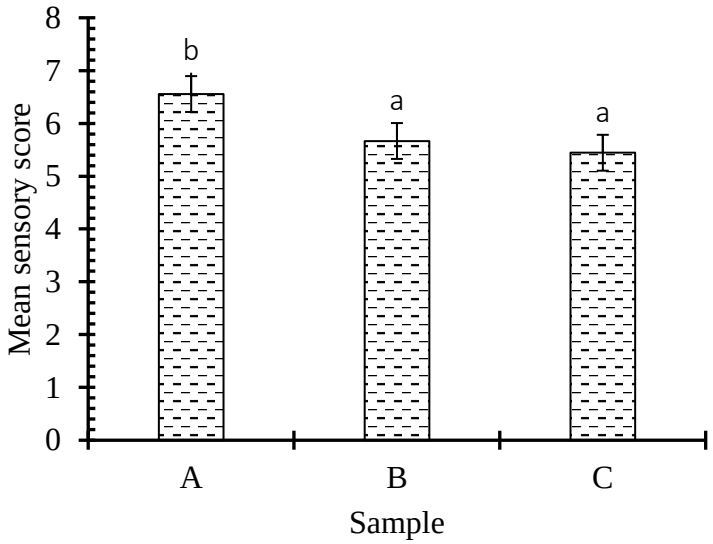

Fig 4.7 Sensory evaluation on taste of tea infusion

The mean taste score of dragon fruit tea infusion samples A, B and C were found to be 6.556, 5.667 and 5.444 respectively. Sample A (6.556) had the highest mean score among three samples. Therefore, sample A was found to be the best sample among three samples based on taste Statistical analysis showed that there was significant difference ($p<0.05$) at the 5% level of significance where sample A was significantly different with sample B and sample C. Since phenolic content is associated with organoleptic properties and increase in drying temperature leads to decrease in total phenolic content which might be cause for decrease in mean sensory score based on taste.

4.2.4 Mouthfeel

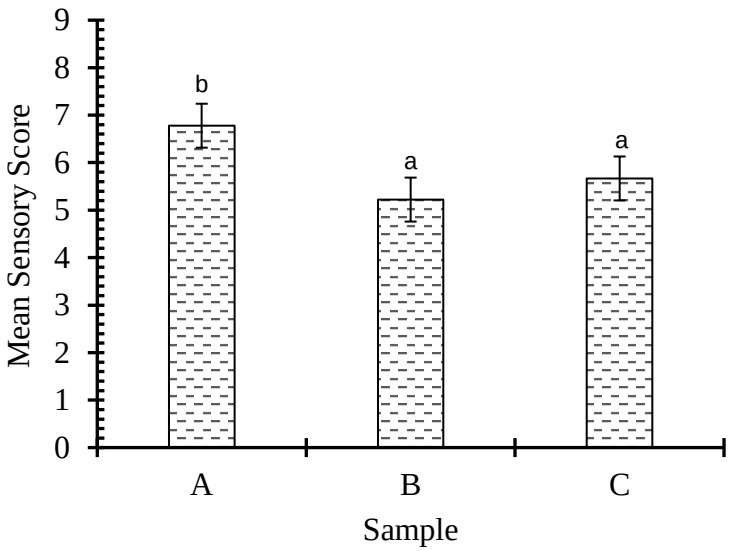

Fig 4.8 Sensory evaluation on mouthfeel of tea infusion

The mean mouthfeel values of the dragon fruit tea infusion samples A, B, and C were determined to be 6.778, 5.222 and 5.667, respectively. Sample A (6.778) obtained the highest mean score among the three samples. Statistical analysis showed a significant effect of variation ($p<0.05$) at the 5% level of significance. Based on mouthfeel, Sample A was found to be the best among three samples.

4.2.5 Overall acceptability

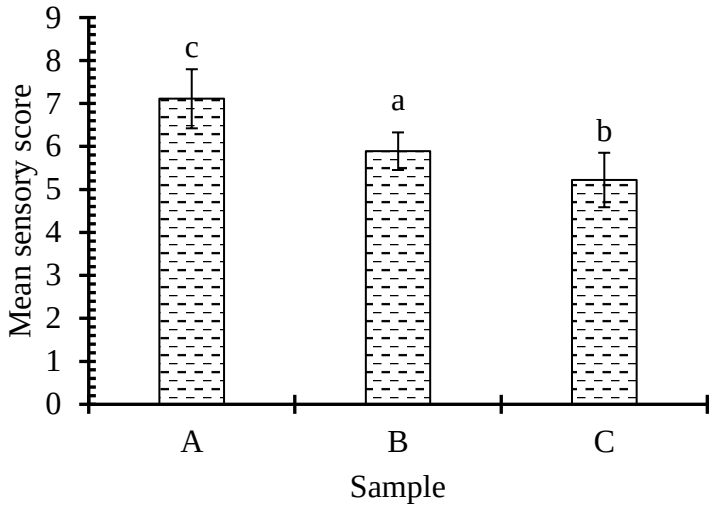

Fig 4.9 Sensory evaluation on overall acceptability of tea infusion

The mean overall acceptability of the dragon fruit tea infusion samples A, B and C were found to be 7.111, 5.889 and 5.222 respectively. Sample A (7.111) had the highest mean score among three samples. Statistical analysis showed a significant effect of variation ($p<0.05$) at the 5% level of significance. Thus, sample A was found to be the best sample among three samples based on overall acceptability.

The score of overall acceptance was similar to (P. Sari *et al.*, 2019) for Jamun tea infusion where tea infusion at 50°C was found to be best among the samples. Also, the score for overall acceptance for avocado tea infusion for peel dried at 57.5°C was found to be best sample (Pokhrel, 2023).

Part V

Conclusions and recommendations

5.1 Conclusions

This study was carried out to develop the optimum drying temperature for dried dragon fruit peel. Based on the results of present study, the following conclusions were drawn:

i. The proximate composition of fresh dragon fruit was found to be 90.12% moisture with the value of crude protein, crude ash, crude fiber and vitamin C to be 6.68%, 13.32%, 30.23% and 90.34 mg.
ii. The optimum drying temperature of dragon fruit peel was found to be 50°C having TPC, TFC, betacyanin content and antioxidant activity of 64.92 mg GAE/100g, 56.34 mg QE/100g, 52.34 mg/100g and 77.37% respectively.
iii. The temperature of 50 °C would be the most adequate for pitaya peel drying, because it retains high concentrations of betacyanins, which highlights its potential to be used by industries to replace artificial dyes, promoting benefits to health, such as antioxidant activity.
iv. Most of the bioactive components had significant effect on drying temperature at range of 50-70°C.
v. Drying temperature had significant effect on sensory parameter.

5.2 Recommendations

This study can be further contained with the following recommendations,

i. Study on blending of dragon peel powder with green tea can be done.
ii. Further studies could be done below 45°C can be done.
iii. Further study can be done to study changes at drying methods.

Part VI

Summary

Dragon fruit or pitaya is the fruit of several different tropical climbing plants of the genus *Hylocereus,* family Cactaceae (Luu *et al.*, 2021). Although it is native to the tropical areas of North, Central and South America, now it is becoming popular worldwide due to the commercial interests. Dragon fruit peel, a byproduct of consumption occupies about 22-35% of the overall fruit weight but has most of the polyphenols (Jamilah *et al.*, 2011). Polyphenols have antioxidant, antimicrobial, and anti-inflammatory properties that have helped to promote optimal wellness. Fruit teas, which are popular because of their fragrance and lower amounts of caffeine, could be a good source of compounds with antioxidant properties (Trimedona *et al.*, 2020).

In this study, dragon fruit was purchased from local market of Dharan. The study was carried out to optimize drying temperature for dragon fruit tea infusion. After manual cleaning and separation into three parts, the peel strips were cut in 2.5 cm lengthwise and dried at 50°C, 60°C and 70°C. The analysis were done for both fresh and dried dragon fruit peels. The drying process was continued till the sample reached moisture content of 5% wb using mass balance method. The phytochemical components including antioxidant activity (%), total phenolic content (mg GAE/100g extract), flavonoid content(mg QE/100g extract) and betacyanin content (mg/100g) were determined for the fresh and dried samples. The sensory analysis of tea was carried out by placing 1.5g of peel in 50 ml hot water and leaving for infusion for 5 min for all three samples.

The moisture, ash, crude protein, crude fiber and vitamin C were found to be 90.12% 13.32%, 6.68%, 30.23% and 90.34mg. Similarly, it was observed that the optimum drying temperature of dragon fruit peel was found to be 50°C having TPC, TFC, betacyanin content and antioxidant activity of 64.92 mg GAE/100g, 56.34 mg QE/100g, 52.34 mg/100g and 77.37% respectively. According to sensory analysis, tea infusion at 50° was found to be the best among three samples.

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Appendices

Appendix A

Sensory Analysis Score Card

Date: 2080/02/23

Name of the panelist:

Name of the product: Dragon fruit peel tea

Dear panelist, you are provided with three samples dragon fruit peel tea on each proportion with variation on temperature. Please, taste the following samples of tea and check how much you prefer for each of the samples. Give the point for your degree of preference for each sample as shown below.

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

Like extremely – 9 Like very much-8 Like moderately-7

Like slightly – 6 Neither like nor dislike Dislike slightly- 4

Dislike moderately -3 Dislike extremely -2 Dislike very much – 1

Sensory parameters	Sample						
Color							
Taste							
Aroma							
Mouthfeel							
Overall acceptability							

Any comments…….

…….

Signature:……

Appendix B

Equipment and utensils

i. Grinder
ii. Weighing machine
iii. Muffle furnace
iv. Standard sieve (40 mesh size)
v. Cabinet dryer
vi. Hot air oven
vii. Refrigerator
viii. UV spectrophotometer
ix. Heating mantle
x. Glassware
xi. Pipette
xii. Crucible
xiii. Conical flask

Chemicals required

i. NaOH (HIMEDIA-GRM1183 Assay 97, 00-103.50%)
ii. Oxalic acid (Qualigens, Assay99.5%)
iii. Indicators (Methyl blue, Phenolphthalein)
iv. Na2CO3 (Qualigens, Assay 99-101%)
v. Folin-Ciocalteu phenol reagent (FC reagent)
vi. AlCl3
vii. 2,2- Diphenyl-1-picrylhydrazyl (DPPH)
viii. Gallic acid (Trupati Enterprises)
ix. Ethanol
x. Sulphuric acid

Appendix C

ANOVA result for analysis of different parameter of dragon fruit peel

Table C.1 One way ANOVA (no blocking) for Total phenolic content

Source of variation	d.f.	s.s.	m.s.	V.r	F.pr
Temperature	3	18199.397	6066.466	2252.16	<0.001
Residual	8	21.549	2.964		
Total	11	18220.94			

Table C.2 One way ANOVA (no blocking) for Antioxidant Activity

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Temperature	3	1529.0143	509.6714	593.77	<0.001
Residual	8	6.8669	0.8584		
Total	11	1535.8812			

Table C.3 One way ANOVA (no blocking) for Betacyanin content

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Temperature	3	28937.785	9645.928	3940.44	<0.01
Residual	8	19.583	2.448		
Total	11	28957.368			

Table C.4 One way ANOVA (no blocking) for Total flavonoid content

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Temperature	3	5732.770	1910.923	686.90	<0.01
Residual	8	22.256	2.782		
Total	11	5755.026			

Table C.5 Two way ANOVA (no blocking) for taste

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Sample	2	6.2222	3.111	20.36	<0.01
Panelists	8	12.000	1.500	9.82	<0.01
Residual	16	2.444	0.1528		
Total	26	20.667			

Table C.6 Two way ANOVA (no blocking) for color

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Sample	2	16.0741	8.0370	16.22	<0.01
Panelists	8	3.6296	0.4537	0.92	0.528
Residual	16	7.9259	0.4954		
Total	26	27.6296			

Table C.7 Two way ANOVA (no blocking) for aroma

Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Sample	2	12.0741	6.0370	13.31	<0.01
Panelists	8	5.6296	0.7037	1.55	0.216
Residual	16	7.2593	0.4537		
Total	26	24.9630			

Table C.8 Two way ANOVA (no blocking) for mouthfeel

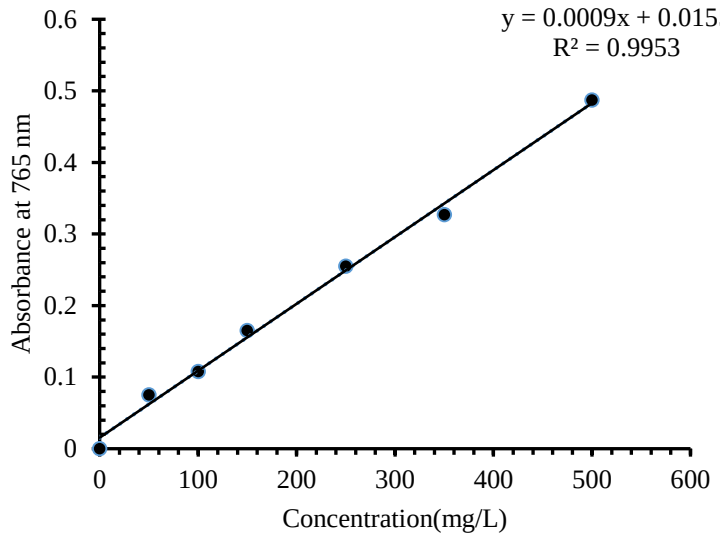
Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Sample	2	11.5556	5.7778	24.47	<0.01
Panelists	8	5.3333	0.6667	2.82	0.037
Residual	16	3.7778	0.2361		
Total	26	20.6667			

Table C.9 Two way ANOVA (no blocking) for overall acceptability

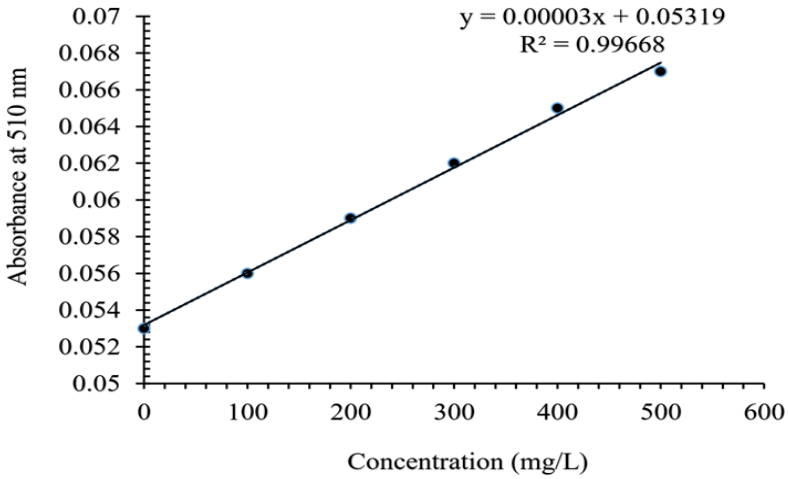
Source of variation	d.f.	s.s.	m.s.	v.r.	F.pr
Sample	2	16.5185	8.2593	31.86	<0.01
Panelists	8	5.1852	0.6481	2.50	0.057
Residual	16	4.1481	0.2593		
Total	26	25.8519			

Appendix C

1. Standard calibration curve for Gallic acid curve



2. Standard curve for total flavonoid content determination



3. Standard curve for total tannin content determination

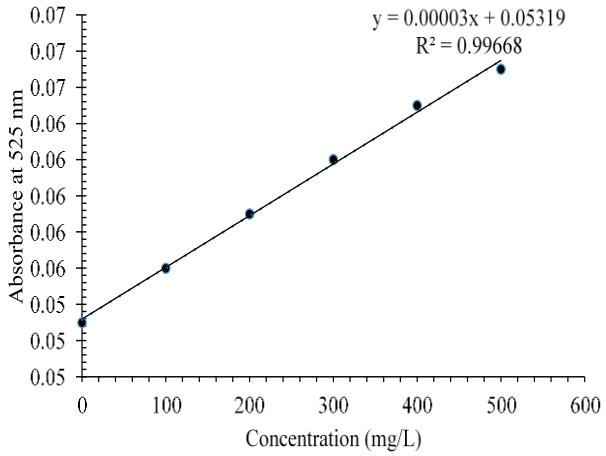


Photo gallery

Plate 1. Fresh dragon fruit peels

Plate 2. Dried dragon fruit peels

Plate 4. Crude fiber determination

Plate 5. Spectrophotometer analysis

Plate 6. Sensory analysis of dragon fruit peel tea