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Effects of Drying Temperature on Bioactive Compounds Retention in Dragon Fruit (*Hylocereus undatus*) Peel Powder

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ABSTRACT

The dragon fruit peels are discarded despite the high content of bioactive components such as phenolic, flavonoid, betacyanin content, and antioxidant activity. Drying these peels to powder for use as an infusion might aid in its valorization. Therefore, this study aimed to assess effects of drying peels at three different temperatures (50°C, 60°C, and 70°C) on retention of bioactive compounds in the resulting powder. For this, dragon fruit peels were cut into 2.5 cm length and 3-3.5 mm thickness and dried at three temperatures until the moisture content reached around 5%. Then the dried peels were ground, and sieved through a 40-mesh size screen. Proximate analysis and bioactive components were determined for fresh and dried dragon peel powder prepared for infusion. A sensory evaluation of infusion was conducted by steeping 1.5 g of dried dragon fruit peel in 50 mL of hot water (90°C) for 5 minutes, using a 9-point hedonic scale. The results showed that peel dried at 50 °C retained significantly higher amounts of bioactive compounds with a total polyphenol content of 64.9 mg GAE/100g extract, total flavonoid content of 56.34 mg QE/100 g extract, and betacyanin content of 52.34 μg/100 g dry matter extract. Moreover, the extract of peel powder dried at 50 °C exhibited 77.37 % DPPH radical scavenging activity at a concentration of 2.8 mg/ml. In addition, sensory panelist significantly preferred the infusion prepared from the peels dried at 50 °C to those dried at other temperatures. This study suggests that processing dragon fruit peels into powder for infusion preparation is a viable strategy to reuse peels that would typically be discarded.

1. INTRODUCTION

Dragon fruit (*Hylocereus undatus*), is a fruit crop known as pitaya and mostly found in tropical subtropical region (Pavithra & Mini, 2023; Singh & Kumar, 2023). It is well known for its rich nutrient contents specially vitamin C, phosphorus, calcium and functional properties (Patwary et al., 2013). There are several varieties of dragon fruit. Most of them are categorised into three types (Figure 1) namely *Hylocereus undatus, Hylocereus polyrhizus, Selenicereus megalenthus* (Wakchaure et al., 2023). *Hylocereus undatus* is the most cultivated and consumed species of dragon fruit in south Asian countries (Lakshmeshwara et al., 2024; Panchal et al., 2018). Dragon fruits are mainly eaten fresh or made into juice, leaving the peel as the primary byproduct (Nurliyana et al., 2010). Dragon fruit peel, which makes up 30–35% of the fruit's weight, is largely discarded as waste and remains underutilized (Analianasari & Apriyani, 2018). Utilizing fruit residues like dragon fruit peels offers both environmental and economic advantages and can be used to produce herbal tea (Trimedona et al., 2020). To enable value addition and commercial use of dragon fruit's non-edible parts in food products, it is essential to assess their physico-chemical properties, antioxidant capacity, bioactive compounds, and related functional characteristics (Alam et al., 2023). The bioactive components of dragon fruit are sometimes affected by season, weather, cultural practices, water availability, transportation, handling, and storage

(Alam et al., 2023). According to Jamilah et al., (2011) fresh dragon fruit peel is composed primarily of water (92.65%) and fiber (up to 69.3% of total dietary fiber), with smaller amounts of protein (0.95%), lipid (0.10%), ash (0.10%), carbohydrates (6.20%), betacyanin (150.46 mg/100 g), and pectin (10.8%). Aside from moisture, fiber is the predominant component.

Dragon fruit peel infusion, made from the by-product of *Hylocereus undatus*, has been shown to possess significant antioxidant properties attributed to its high total phenolic approximately 223 mg GAE/100g , total flavonoid content at 39.50 mg QE/100g, betacyanin contents at 18.67 mg/100g and vitamin C content approximately 93.87 mg/100g (Hasan et al., 2025; Nishikito et al., 2023; Sari & Hardiyanti, 2013). Compared to green and black teas, dragon fruit peel infusion exhibits moderate phenolic content and antioxidant activity, making it a promising functional beverage (Sari & Hardiyanti, 2013). Nurliyana et al. (2010) observed the drying process in an oven at 70°C negatively affected the total phenolic compounds in the peels, the TPCs in the peels remained higher than those in the pulps. This work aimed to study effects of drying dragon fruit peels at different temperatures: 50°C, 60°C, and 70°C and evaluate the retention of bioactive components after drying. Additionally, sensory analysis of infusion, prepared from peel powder, was carried out to find the sensory acceptability using a 9-point hedonic rating scale.

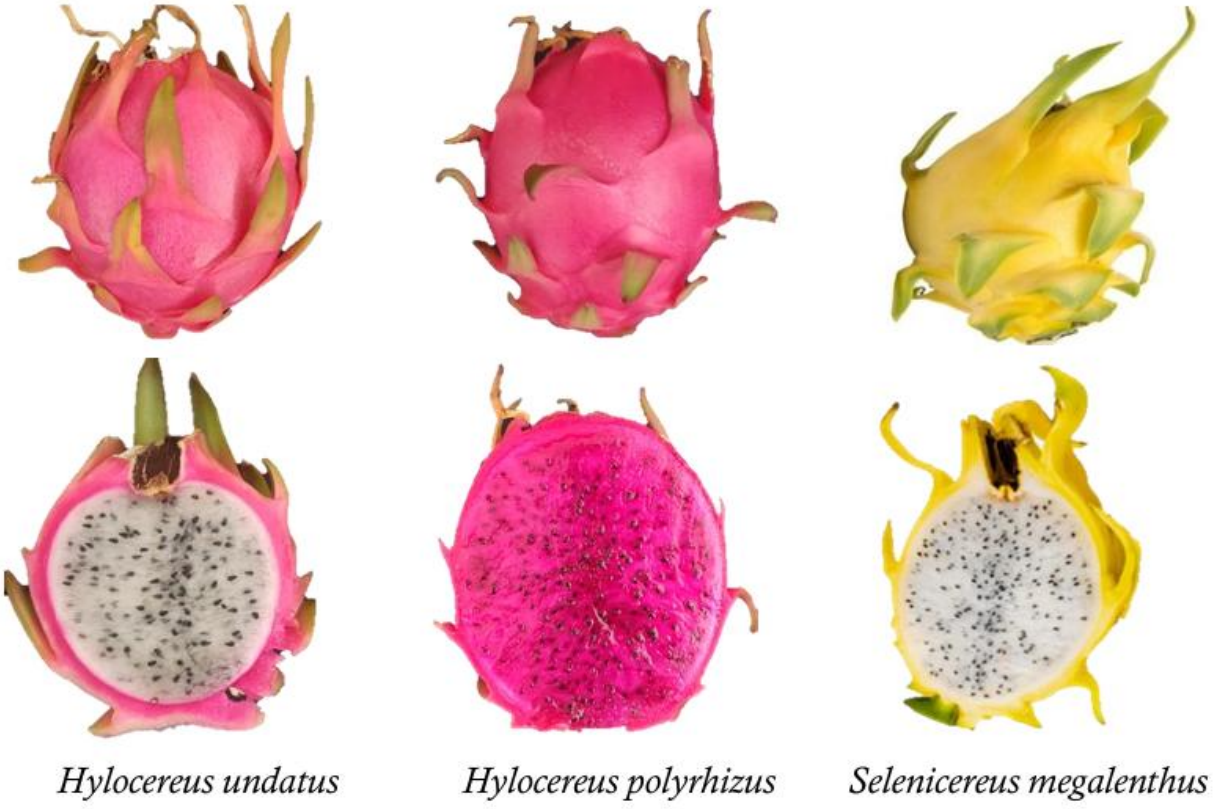

Figure 1
Three major categories of dragon fruit for commercial production (Source: Wakchaure et al., 2023).

2. MATERIALS AND METHODS

2.1 Material

White dragon fruit (*Hylocereus undatus*) were purchased from local market of Dharan, Nepal. Lab Grade Sodium Hydroxide Pellets, (Qualigens, Assay 98%), Oxalic acid (Qualigens, Assay 99.5%), Methyl blue and Phenolphthalein (Finar), Na_2CO_3 (Qualigens, Assay 99-101%), Folin-Ciocalteu phenol reagent (Sigma-Aldrich), Aluminium Chloride (Ultra Pure Lab Chem Industries LLP, Assay 98%), 2,2- Diphenyl-1-picrylhydrazyl (DPPH)- (Sigma-Aldrich), Gallic acid (Oxford, Assay 98%), Methanol Lab Grade (Fusion Biotech, Assay-99%), Sulhuric acid, (Qualigens, Assay 98%) were used.

2.2 Methods

2.2.1 Preparation of dragon fruit peel powder

Dragon fruit peel powder were prepared with minor modification procedure followed by Rotta et al., (2016). The dragon fruit free from any defects or damage were taken and subsequently washed in tap water. After manual separation of peel and pulp, about 450 g of peels were cut into 2.5 cm length and 3-3.5mm thickness. 150 g of peels were spread on trays of approximately $40\,cm \times 30\,cm$ without overlapping and dried at three temperatures in a cabinet dryer till moisture content dropped around 5%. A cabinet

dryer was operated at 31 ± 2°C and 53 ± 2% RH. The studies were conducted triplicates for 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) of 1.5 mm thickness and stored in room temperature (31 ± 2 °C). Dried dragon fruit peel was crushed in an electric blender after drying at various temperatures. The processed powder was tightly sealed in plastic bags to avoid moisture absorption. For further analysis, these bags were kept at room temperature of 31±2°C. The infusion was served by soaking 1.5 g of dried peel powder in 50 mL hot water and left for 5 min. The sensory analysis was done by 10 panelists using hedonic rating scale (9 = extremely like, 1 = extremely dislike).

2.2.2 Analytical Procedure

Determination of Moisture Content

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

Determination of Crude Fiber

The crude fiber of fresh dragon fruit peel and powder were determined described by Ranganna, (1986).

Determination of crude fat

Crude fat content of the samples was determined by solvent extraction method using Soxhlet apparatus described by Ranganna, (1986).

Determination of total ash

Total ash of fresh dragon fruit peel and powder were determined by drying ashing described by Ranganna, (1986).

The carbohydrate content of fresh dragon fruit peel and dried dragon fruit peel powder were determined by difference method described by Ranganna, (1986). The percentage of carbohydrates (nitrogen-free extract), was obtained from the difference of the subtraction of 100% minus the sum of the percentages of moisture, crude protein, crude fat, crude fiber and ash.

Determination of crude protein

The nitrogen content of fresh dragon fruit peel and powder were determined by using Kjeldahl digestion, distillation and titration method described by Ranganna, (1986). Conversion factor 6.25 was used to obtain the crude protein.

Determination of Vitamin C

The vitamin C was determined by iodine titration method described by Suntornsuk et al., (2002) with slight modifications. Starch indicator solution was prepared by mixing 1g of starch with 100mL of boiling water. The solution must immediately remove from heat and left for cool. Each 25mL of infusion extract was transferred into a 250mL Erlenmeyer flask. 25mL of 2N sulfuric acid was added, mixed, diluted with 50mL distilled water and 3 mL starch indicator added. The solution was directly titrated with 0.01 N standardized iodine solution until the blue color had 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.

Extract preparation for the analysis of TPC, TFC, TTC and DPPH radical scavenging activity

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 Whatman No. 41 filter paper and the obtained filtrate were used for the analysis of TPC, TFC, TTC and DPPH radical scavenging activity.

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. 0.25 mL of extracted samples were measured into test tubes, then 1.3mL of 10-fold Folin-Ciocalteu's reagent and 3.75 mL 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. The total phenolic content was quantified using the standard curve and reported as mg gallic acid equivalents per 100 g crude extract), with all measurements were performed in triplicate.

Determination of the antioxidant activity

Antioxidant activity of fresh and dried dragon fruit peel powder prepared for infusion was determined using the DPPH radical scavenging method described by Panico et al. (2009) with slight modifications. The control infusion (A control) was made by adding 0.28 mL of DPPH solution (0.1 mM, in 80% methanol) to a 10 mL conical flask, and then diluting it with 0.944mL methanol to maintain volume. In the similar manner 0.28 mL of the DPPH solution and 0.28 mL of the test infusion (A sample) were used in the preparation and poured into a 10 mL conical flask and 0.944 mL methanol. The final extract concentration was 2.8 mg/ml. Following repeated inversions, the mixture was incubated for 30 min at an ambient temperature in dark. Following a 30-minute incubation of the tubes at room temperature in the dark, the absorbance of the mixture was measured at 517 nm using a UV-VIS spectrophotometer (Cary 60, Agilent, USA), with 80% methanol serving as the blank. The radical scavenging activity was estimated as a decrease in DPPH absorbance and was calculated using the following equation:

The percentage DPPH radical scavenging activity was calculated as follows:

$$\% \text{ radical scavenging activity} = \frac{\text{Absorbance control-Absorbance Sample}}{\text{Absorbance control}} \times 100$$

Determination of total flavonoid content

The total flavonoid content (TFC) of the of the fresh and dried peel powder were quantified by the aluminium chloride colorimetric method described by Zhishen et al., (1999) with minor modification. 2 mL of the extract was transferred into 10 mL volumetric flask. 0.3mL of 5% sodium nitrite solution was added to the flask, then let it rest for five min. 3 mL of a 10% $AlCl_3$ solution and allowed to stand for 5 min. after 5 min, 2 mL of 1 N NaOH was added and distilled water was added to maintain the volume of flask. The solution was thoroughly mixed, and its absorbance was measured against blank at 510 nm using UV-VIS spectrophotometer (Cary 60, Agilent, USA).
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).

Determination of total tannin content

The Folin-Ciocalteu method was applied to assess the tannin concentration in accordance with the methods described by Mythili et al., (2014). 0.1mL of the peel powder extract was added in 10 mL volumetric flask, and 7.5 mL of distilled water was added. In the same flask, 0.5mL of Folin-Ciocalteu reagent, 1 mL 35% Na_2CO_3 solution were added and volume was maintained using distilled water 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 against the blank with a UV-VIS spectrophotometer (Cary 60, Agilent, USA) set at 725nm.

Preparation of betacyanin extract and determination of betacyanin content

Methanol extractions were carried out to determine the betacyanin content in fresh and dried peel powder of dragon fruit prepared for infusion described by Priatni & Pradita, (2015) with minor modification. Quantification of betacyanin was done described by (Lim et al., 2011). 10 g macerated fresh dragon fruit peels and dried powder peels was weighed using analytical balance and 40 mL of methanol was added in a beaker. The extraction was carried out by maceration process for 24h in a refrigerator. The extract was then filtrated by using a Whatman No. 41 filter paper. The filtrate was stored in a refrigerator for further analysis. The absorbance of samples were measured at 538 nm using the UV-visible spectrophotometer and was used as a measure of degree of extraction. The absorbance reading was used to calculate the total betacyanin concentration and expressed $\mu g/100g$ of peel powder.

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

Where A= absorbance at 538 nm, L (path length) =1.0 cm
DF= dilution factor, V= volume of extract (mL)
W= weight of extracting material (g).
For betanin, mean molar absorptivity (E) = 65000 L $mol^{-1}cm^{-1}$ H_2O and molecular weight (MW) = 550g/mol.

Sensory analysis

The infusion prepared using the peel of *Hylocereus undatus* were analyzed for sensory evaluation using 9 point hedonic rating scale as described in Ranganna, (1986). 1 – dislike extremely and 9 – like extremely on sensory attributes like color, flavor, smell, taste, aftertaste and overall acceptability with the help of 10 semi-trained panelists including faculties and staffs who are familiar to green tea.

Statistical analysis

The triplicate data from each experiment analysis were subjected to one-way analysis of variance (ANOVA) using IBM SPSS Statistics version 27. Means were compared using Tukey's HSD at 5% level of significance. MS Excel 2016 was employed for general calculations, graphing, and diagram construction. All results were presented as mean ± standard deviation.

3. RESULT AND DISCUSSION

The present study was conducted to optimize the drying temperature for dragon fruit peel strips intended for infusion. Mature dragon fruits were purchased from the local market in Dharan. Some fresh dragon fruit peels were separated and stored in a refrigerator for subsequent chemical analysis. The remaining fruit peels were chopped with a knife to a uniform length and dried at different temperatures (50°C, 60°C, and 70°C) until the moisture content reached approximately 5%. The dried dragon fruit peels were then ground using a grinder and sieved through a 40-mesh sieve. Both the fresh dragon fruit peel and the dried peel powder were analyzed for proximate composition and bioactive compound content.

3.1 Proximate composition of fresh and dried dragon fruit peel

The proximate composition fresh dragon fruits peel and dried peel powder must be known before the peels are utilized to make infusion. Table 1 shows proximate composition of fresh and dried dragon fruit peel powder.

Table 1
Proximate Composition per 100g of fresh and dried dragon fruit peel powder

Parameters	Fresh dragon fruit peel *(*wet weight basis)	Dried dragon fruit peel powder *(dry* weight basis)
Moisture (%)	87.12 ± 0.22	5.13 ± 0.18
Ash (%)	2.22 ± 0.13	17.23 ± 0.32
Crude protein (%)	1.28 ± 0.45	9.93 ± 0.27
Crude fiber (%)	0.98 ±0.04	7.60 ± 0.06
Fat	3.26 ±0.04	25.31± 0.56
Carbohydrate (%)	5.16 ± 0.09	40.06 ± 0.20

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

Table 1 provides proximate composition dragon fruit peel in fresh and dried conditions. Moisture content of fresh dragon fruit peel was 87.12% which is less than the finding made by Alam et al., (2023) and Sari & Hardiyanti, (2013) who reported the moisture content of fresh peel 91.88% and 90.27% respectively. The result has a significant impact on

its shelf life and microbial activity of the powder. The ash content, crude protein, crude fiber, fat and carbohydrate were found as 2.22 %, 1.28%, 0.98%, 3.26 % and 5.16% respectively which were similar to the finding made by Alam et al., (2023) and by Sari & Hardiyanti, (2013). Low moisture content assures that peel powder in dried form can remain nutritious and edible for a long time without microbial growth, less susceptible to enzymes activities and chemical degradation. The relatively high amount of ash in the peel powder suggests that it contains a considerable quantity of minerals which implies that it is highly nutritious and may warrant its consideration for use in food formulation Low protein content ensures a tender and fluffy texture when used in food formulation. The powder is, therefore, ideal for pie dough, muffins, and some cookie batters (Cacatian & Guittap, 2018). The result suggests that the peel powder is recommended as a good source of food supplement for patients with cardiac problems or at risk with lipid-induced disorders (Oladele & Aina, 2007). It also contributes to the longer shelf life of the powder (Cacatian & Guittap, 2018). The slight variation in the proximate analysis may be due to the location, season, harvesting time and maturity (Alam et al., 2023).

3.2 Bioactive components in fresh dragon fruit peel

The results of the bioactive components obtained is shown in Table 2. Compared to the flesh, the peels of the red and white dragon fruit are better in scavenging free radicals. Extracts from dragon fruit peels have antioxidant qualities that reduce oxidative damage and harm (Sari & Hardiyanti, 2013). Dragon fruit contains betalain pigments, betacyanins and betaxanthins serves the antioxidants (Nguyen & Pirak, 2019).

Table 2
Bioactive components in fresh dragon fruit peel

Parameters	Values
Total phenolic content (mg GAE/100g extract)	134.3 ± 0.16
Total flavanoid content (mg QE/100g extract)	90.36 ±1.73
Total tannin content (mg TAE/100g extract)	360.12 ± 0.45
Antioxidant activity (%) (2.8mg/mL extract)	85.07 ± 0.20
Betacyanin content (**µg/100g** extract)	143.02 ± 1.43
Ascorbic acid (mg/100g extract)	90.34 ± 0.29

Values were the mean of three determinations ± standard deviation.

Analysis result showed that total phenolic content fresh dragon fruit peel was lower than findings reported by Sari & Hardiyanti, (2013). The amount of the flavonoid content was found lower than findings reported by Alam et al., (2023). DPPH radical scavenging activity of dragon fruit peel was higher than values reported by Le, (2022). Le, (2022) described the antioxidant activity of the peels was also higher than that of the pulps, which is in accordance with their phenolic contents. Analysis result of total betacyanin in methanol extract was lower than the value reported by Priatni & Pradita, (2015) who found the betacyanin content in methanol of fresh extract 531.45 µg/100g. The ascorbic acid content was found lower than value reported by Sari & Hardiyanti, (2013).

Table 3
Bioactive components of dried dragon fruit peel powder at various temperatures

Parameters	50°C	60°C	70°C
Total phenolic content (mg GAE/100g)	64.9 ± 0.83^{a}	43.6 ± 1.50^{b}	35.2 ± 1.88^{c}
Total flavonoid content (mg QE/100g)	56.34 ± 1.30^{a}	44.37 ± 0.90^{b}	31.74 ± 0.45^{c}
Antioxidant activity (%) (2.8mg/mL)	77.37 ± 0.84^{a}	69.33 ± 0.77^{c}	54.58 ± 1.25^{c}
Betacyanin content (µg/100g, dry matter)	52.34± 1.32^{a}	26.50 ± 0.89^{b}	20.19 ± 1.56^{c}

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

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

Phenolic compounds are linked to the prevention of oxidative stress-related diseases like cancer and cardiovascular issues, they may protect organisms from harm because of their antioxidant tendency. Table 3 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 result was found by Kondareddy et al., (2021), and reported that the decrease in total phenolic content is due to longer drying time at higher temperature which could increase in oxidation of phenolic compounds. These results follow the similar pattern on drying the citrus peel on microwave (Ghanem et al., 2012). Drying to higher temperature involves longer extraction hours and heat-sensitive bioactive components to degrade (Nguyen & Pirak, 2019). 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 could 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). TFC content of dried samples was found lower than fresh samples as shown in Table 3 which might be due to slight differences between samples (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). Antioxidants present in dragon fruit peel, lowers the cholesterol levels and which is beneficial for people with hepatic steatosis, insulin resistance, and obesity (Rahmah et

al., 2022). The reactivity phenol moiety (hydroxyl group on aromatic ring) of phenolic causes the antioxidant activity. They are capable of scavenging free radicals by donating electrons or hydrogen (Ajila et al., 2007). The antioxidant activity of fresh dragon fruit peel was found to be 85.07 ± 0.20%. According to Nurliyana et al., (2010), the antioxidant activity found to be 87.02% which was slightly higher than obtained value. The antioxidant activity of dried dragon fruit peel powder was found lower than fresh 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 were significant differences among the fresh and dried samples. Antioxidant activity and polyphenol concentration are affected by drying temperature (Suryaningsih et al., 2021). 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. The BC content of fresh dragon fruit was found to be 143.02 ± 1.43 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 infusion at 50°C, 60°C and 70°C were found similar to result conducted by dos Santos et al., (2014). 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).

3.4 Sensory Evaluation of Dragon Fruit Peel Infusion

The peel infusion was subjected to semi trained panelist using a 9-point hedonic rating test for sensory evaluation. The sensory analysis of three peel infusion was carried out which were coded A, B and C that are produced by drying at 50°C, 60°C and 70°C respectively. Panelists rated the color and appearance of infusion A higher than the infusion B and C counterparts shown in Figure 2. Statistical analysis showed that there was significant difference ($p>0.05$) infusion A with infusion B and C. As the drying temperature increases, the betacyanin content decreases which might be the cause for the decrement in mean sensory score of samples according to color and appearance. Similar results was found by Tan et al., (2023) for green tea infusion in which infusions showed no significant difference for the sensory parameters of color and appearance. The color of the dragon fruit comes from the betalain pigments, betacyanins and betaxanthins which are also known as antioxidants (Nguyen & Pirak, 2019). Statistical analysis revealed a significant difference in terms of aroma and taste on infusion A with infusion B and C shown in Figure 3 and Figure 4. Panelists rated the aroma of infusion A slightly higher than the infusion B and C counterparts, which tended to lose volatiles at elevated temperatures. This aligns with the fact that mild drying minimizes loss of aroma compounds (Gautam & Abdul, 2020). 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. Taste scores dropped notably at higher temperatures for infusion A, then B and C respectively. This might be due to drying at high temperature degrade desirable flavor molecules and increase bitterness or off-flavors (Ilmannafian et al., 2024). Infusion A obtained the highest mean score among the three samples in terms of mouthfeel shown in Figure 5. Statistically samples were significant different. Mouthfeel trends mirrored taste and aroma: peels dried at 50 °C yielded a smoother mouthfeel, likely due to reduced fiber hardening and minimized formation of astringent phenolics (Gautam & Abdul, 2020; Ilmannafian et al., 2024). Combining these sensory attributes, 50 °C dried infusions were most preferred overall shown in Figure 6.

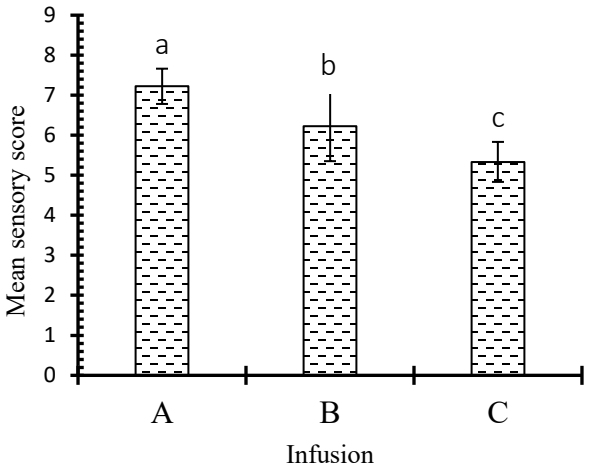

Figure 2
Sensory evaluation on color and appearance of infusion

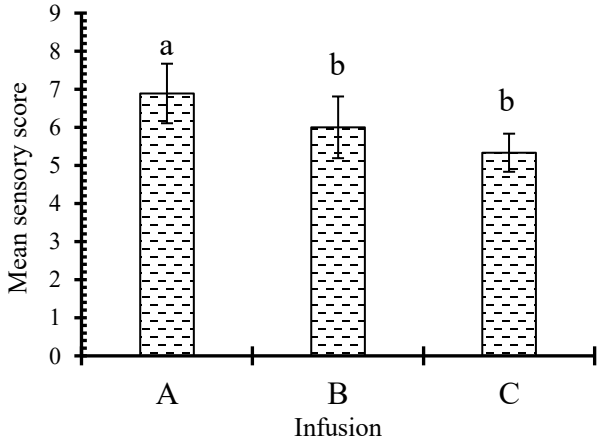

Figure 3
Sensory evaluation on aroma of infusion

Higher temperatures i.e., 60 °C and 70 °C caused gradual sensory deterioration in terms of taste and mouthfeel that highlights heat sensitivity of flavor volatiles and texture-contributing compounds. The score of overall acceptance was similar to Sari & Hardiyanti, (2013) for dragon fruit peel infusion made by partially fermented process where infusion at 50°C was found to be best among the samples.

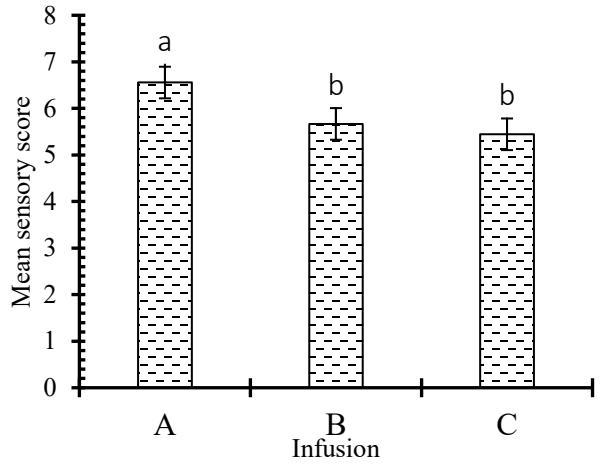

Figure 4
Sensory evaluation on taste of infusion

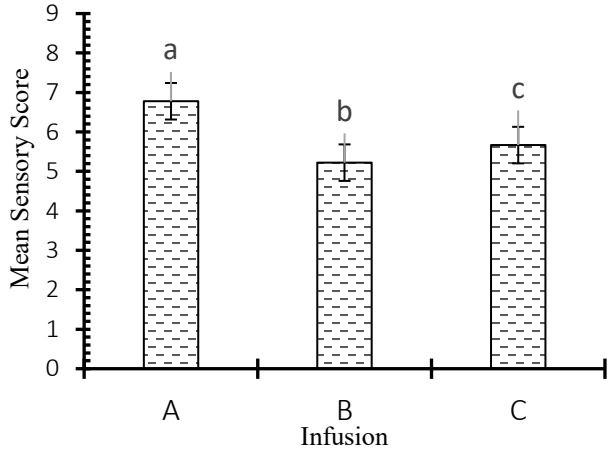

Figure 5
Sensory evaluation on mouthfeel of infusion

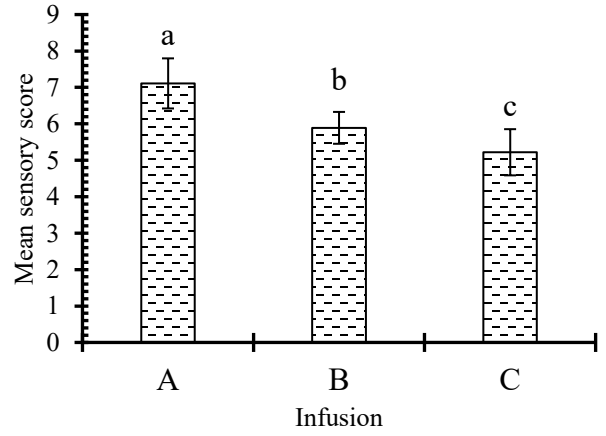

Figure 6
Sensory evaluation on overall acceptability of infusion

Also, the score for overall acceptance for avocado infusion for peel dried at 57.5°C was found to be best infusion (Pokhrel, 2023). The score of overall acceptance was similar to Tan et al., (2023) for green infusion. According to the overall acceptability test Rotta et al., (2016), the panelists who also demonstrated intent to acquire a new product if it were to be sold did not reject the dehydrated avocado peel infusion.

4. CONCLUSION

Drying dragon fruit peel at 50 °C maximizes the retention of bioactive compound and antioxidant activity, making it highly suitable for industrial applications as a functional ingredient. This approach supports sustainability, offers health benefits, and ensures consumer acceptability, while future research should address the long-term safety and efficacy of peel-based infusions and products.

CONFLICTS OF INTEREST

The authors report no conflicts of interest for this research work.

REFERENCES

Ajila, C. M., Naidu, K. A., Bhat, S. G. & Rao, U. J. S. P. (2007). Bioactive compounds and antioxidant potential of mango peel extract. *Food Chemistry*, *105*(3), 982–988. https://doi.org/10.1016/j.foodchem.2007.04.052

Alam, M., Biswas, M., Ahmed, J., Hosain, M. A., Alam, A., Khan, M. H. H. & Molla, M. M. (2023). Physico-chemical properties, antioxidant activity and bioactive compounds in edible and non-edible portions of dragon fruit cultivars native to Bangladesh. *Food Research*, *7*(4), 194–203. https://doi.org/10.26656/FR.2017.7(4).243

Analianasari & Apriyani, M. (2018). Characteristics of Frozen Yoghurt Enriched with Red Dragon Fruit Skin Extracts (Hylocereus polyrhizus). *Journal of Physics: Conference Series*, *953*(1). https://doi.org/10.1088/1742-6596/953/1/012036

Cacatian, S. B. & Guittap, L. . J. V. (2018). Production, Proximate Analysis and Functional Properties of Dragon Fruit Peel Powder. *International Journal of Ecology and Conservation*, *25*(March), 1–17.

Chaaban, H., Ioannou, I., Chebil, L., Slimane, M., Gérardin, C., Paris, C., Charbonnel, C., Chekir, L. & Ghoul, M. (2017). Effect of heat processing on thermal stability and antioxidant activity of six flavonoids. *Journal of Food Processing and Preservation*, *41*(5), 1–12. https://doi.org/10.1111/jfpp.13203

Dos Santos, C. M., de Abreu, C. M. P., Freire, J. M., Queiroz, E. de R. & Mendonça, M. M. (2014). Chemical characterization of the flour of peel and seed from two papaya cultivars. *Food Science and Technology*, *34*(2), 353–357. https://doi.org/10.1590/fst.2014.0048

Gautam, A. & Abdul, S. (2020). Comparative study of different drying techniques of dragon fruit peel. *Journal of Pharmacognosy and Phytochemistry*, *9*(4), 280–283. www.phytojournal.com

Ghanem, N., Mihoubi, D., Kechaou, N. & Mihoubi, N. B. (2012). Microwave dehydration of three citrus peel cultivars: Effect on water and oil retention capacities, color, shrinkage and total phenols content. *Industrial Crops and Products*, *40*(1), 167–177. https://doi.org/10.1016/j.indcrop.2012.03.009

Hasan, M. N., Islam, T., Shil, K. C., Saha, S., Satter, M. A. & Amin, M. Z. (2025). Bioactivity profiling of dragon peel (Hylocereus spp.) extracts and molecular docking against inflammatory protein tumor necrosis factor-alpha (TNF-α). *Food Chemistry Advances*, *7*(June), 101027. https://doi.org/10.1016/j.focha.2025.101027

Herbach, K. M., Stintzing, F. C. & Carle, R. (2006). Stability and color changes of thermally treated betanin, phyllocactin, and hylocerenin solutions. *Journal of Agricultural and Food Chemistry*, *54*(2), 390–398. https://doi.org/10.1021/jf051854b

Ilmannafian, A. G., Kiptiah, M. & Darmawan, M. I. (2024). The Effect of

Drying Methods on The Quality of Dragon Fruit Skin Tea. *Agroindustrial Journal*, *11*(1), 1. https://doi.org/10.22146/aij.v11i1.90154

Jamilah, B., Shu, C. E., Kharidah, M., Dzulkifly, M. A. & Noranizan, A. (2011). Physico-chemical characteristics of red pitaya (Hylocereus polyrhizus) peel. *International Food Research Journal*, *18*(1), 279–286.

Kondareddy, R., Sivakumaran, N., Radha Krishnan, K., Nayak, P. K., Sahu, F. M. & Singha, S. (2021). Performance evaluation and economic analysis of modified solar dryer with thermal energy storage for drying of blood fruit (Haematocarpus validus). *Journal of Food Processing and Preservation*, *45*(9). https://doi.org/10.1111/jfpp.15653

Lakshmeshwara, S., Jain, S., Manasa, S., Singh, A., Imchen, A., Prasad, P. V. S., Raizada, O. & Yadav, V. (2024). A Review on New Approaches in Dragon Fruit Production, Nutraceutical Insights and Morphological Dynamics. *Journal of Advances in Biology & Biotechnology*, *27*(5), 853–862. https://doi.org/10.9734/jabb/2024/v27i5847

Le, N. L. (2022). *Functional compounds in dragon fruit peels and their potential health benefits: a review*. *57*(5), 2571–2580. https://doi.org/10.1111/ijfs.15111

Lim, S. D., Yusof, Y. A., Chin, N. L., Talib, R. A., Endan, J. & Aziz, M. G. (2011). Effect of extraction parameters on the yield of betacyanins from pitaya fruit (Hylocereus polyrhizus) pulps. *Journal of Food, Agriculture & Environment*, *9*(2), 158–162. http://www.isfae.org/scientificjournal.php

Mrkìc, V., Cocci, E., Dalla Rosa, M. & Sacchetti, G. (2006). Effect of drying conditions on bioactive compounds and antioxidant activity of broccoli (Brassica oleracea L.). *Journal of the Science of Food and Agriculture*, *86*(10), 1559–1566. https://doi.org/10.1002/jsfa.2554

Mythili, K., Umamaheswara Reddy, C., Chamundeeswari, D. & Manna, P. K. (2014). Determination of Total Phenol, Alkaloid, Flavonoid and Tannin in Different Extracts of Calanthe Triplicata. *Journal of Pharmacognosy and Phytochemistry*, *2*(4), 41–47.

Nguyen, B. M. N. & Pirak, T. (2019). Physicochemical properties and antioxidant activities of white dragon fruit peel pectin extracted with conventional and ultrasound-assisted extraction. *Cogent Food and Agriculture*, *5*(1). https://doi.org/10.1080/23311932.2019.1633076

Nishikito, D. F., Borges, A. C. A., Laurindo, L. F., Otoboni, A. M. M. B., Direito, R., Goulart, R. de A., Nicolau, C. C. T., Fiorini, A. M. R., Sinatora, R. V. & Barbalho, S. M. (2023). Anti-Inflammatory, Antioxidant, and Other Health Effects of Dragon Fruit and Potential Delivery Systems for Its Bioactive Compounds. *Pharmaceutics*, *15*(1).

Nurliyana, R., Syed Zahir, I., Mustapha Suleiman, K., Aisyah, M. R. & Kamarul Rahim, K. (2010). Antioxidant study of pulps and peels of dragon fruits: A comparative study. *International Food Research Journal*, *17*(2), 367–375.

Oladele, A. K. & Aina, J. O. (2007). Chemical composition and functional properties of flour produced from two varieties of tigernut (Cyperus esculentus). *African Journal of Biotechnology*, *6*(21), 2473–2476. https://doi.org/10.5897/AJB2007.000-2391

Panchal, J. ., Gaikwad, R. ., Dhemre, J. & Chavan, U. . (2018). Studies on preparation and storage of jelly from dragon fruit (Hylocereus undatus). *Journal of Pharmacognosy and Phytochemistry*, *7*(4), 2648–2655.

Panico, A. M., Garufi, F., Nitto, S., Di Mauro, R., Longhitano, R. C., Magrì, G., Catalfo, A., Serrentino, M. E. & De Guidi, G. (2009). Antioxidant activity and phenolic content of strawberry genotypes from fragaria x ananassa. *Pharmaceutical Biology*, *47*(3), 203–208. https://doi.org/10.1080/13880200802462337

Patwary, M. A., Rahman, M., Barua, H., Sarkar, S. & Alam, M. S. (2013). Study on the Growth and Development of two Dragon Fruit (Hylocereus undatus) Genotypes. *The Agriculturists*, *11*(2), 52–57. https://doi.org/10.3329/agric.v11i2.17487

Pavithra, K. J. & Mini, C. (2023). Development and Quality Evaluation of Dragon Fruit (Hylocereus undatus) based Blended RTS Beverages. *Asian Journal of Dairy and Food Research*, *42*(1), 110–116. https://doi.org/10.18805/ajdfr.DR-1847

Pokhrel, B. (2023). *Optimization of dryinng temperature and size of strips for avocado peel tea infusion*. Tribhuvan University.

Priatni, S. & Pradita, A. (2015). Stability Study of Betacyanin Extract from Red Dragon Fruit (Hylocereus Polyrhizus) Peels. *Procedia Chemistry*, *16*, 438–444. https://doi.org/10.1016/j.proche.2015.12.076

Rahmah, L., Ansori, A. N. M., Choiriyah, N. A., Iskandar, H. T., Hadiwirawan, G. Y., Rebezov, M. & Gorelik, O. (2022). Substitution of Dragon Fruit Peels on Vitamin C, Water content, and Fiber in Milk Pie to improve human health. *Research Journal of Pharmacy and Technology*, *15*(8), 3690–3696. https://doi.org/10.52711/0974-360X.2022.00619

Ranganna, S. (1986). *Handbook of Analysis and Quality Control for Friuts and Vegetable Products* (Second). Tata McGraw-Hill Publishing Company limited.

Réblová, Z. (2012). Effect of temperature on the antioxidant activity of phenolic acids. *Czech Journal of Food Sciences*, *30*(2), 171–177. https://doi.org/10.17221/57/2011-cjfs

Rotta, E. M., de Morais, D. R., Biondo, P. B. F., dos Santos, V. J., Matsushita, M. & Visentainer, J. V. (2016). Use of avocado peel (Persea americana) in tea formulation: a functional product containing phenolic compounds with antioxidant activity. *Acta Scientiarum - Technology*, *38*(1), 23–29. https://doi.org/10.4025/actascitechnol.v38i1.27397

Sari, A. R. & Hardiyanti, R. (2013). Antioxidant Level and Sensory of Dragon Fruit (Hylocereus undatus) Peel Tea Infusion Made by Partially Fermented Process. */Agroindustrial Journal*, *2*(1), 63–68.

Šeruga, M., Novak, I. & Jakobek, L. (2011). Determination of polyphenols content and antioxidant activity of some red wines by differential pulse voltammetry, HPLC and spectrophotometric methods. *Food Chemistry*, *124*(3), 1208–1216. https://doi.org/10.1016/j.foodchem.2010.07.047

Singh, S. & Kumar, S. (2023). A Review on Nutritional, Medicinal and Bio-active Compound of Dragon Fruit Hylocereus polyrhizus (F.A.C. Weber) Britton & Rose. *International Journal of Biochemistry Research & Review*, *32*(5), 57–67. https://doi.org/10.9734/ijbcrr/2023/v32i5817

Suntornsuk, L., Gritsanapun, W., Nilkamhank, S. & Paochom, A. (2002). Quantitation of vitamin C content in herbal juice using direct titration. *Journal of Pharmaceutical and Biomedical Analysis*, *28*(5), 849–855. https://doi.org/10.1016/S0731-7085(01)00661-6

Suryaningsih, S., Muslim, B. & Djali, M. (2021). The antioxidant activity of roselle and dragon fruit peel functional drink in free radical inhibition. *Journal of Physics: Conference Series*, *1836*(1). https://doi.org/10.1088/1742-6596/1836/1/012069

Taharuddin, N. H., Jumaidin, R., Mansor, M. R., Hazrati, K. Z., Tarique, J., Asyraf, M. R. M. & Razman, M. R. (2023). Unlocking the Potential of Lignocellulosic Biomass Dragon Fruit (Hylocereus polyrhizus) in Bioplastics, Biocomposites and Various Commercial Applications. *Polymers*, *15*(12). https://doi.org/10.3390/polym15122654

Tan, H. L., Ojukwu, M., Lee, L. X. & Mat Easa, A. (2023). Quality characteristics of green Tea's infusion as influenced by brands and

types of brewing water. *Heliyon*, *9*(2), e12638. https://doi.org/10.1016/j.heliyon.2022.e12638

Trimedona, N., Rahzarni, R., Syahrul, S., Muchrida, Y. & Roza, I. (2020). Antioxidant Properties of Herbal Tea Prepared from Red Dragon Fruit Peel with The Addition of Ginger. *Journal of Applied Agricultural Science and Technology*, *4*(2), 181–188. https://doi.org/10.32530/jaast.v4i2.179

Wakchaure, G. ., Chodhari, J. D., Kukde, R. B. & Reddy, K. S. (2023). Postharvest Technology of Dragon Fruit. In *ICAR–National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra* (Issue August).

Zhishen, J., Mengcheng, T. & Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. In *Food Chemistry, 64*(4), 555–559). https://doi.org/10.1016/S0308-8146(98)00102-2