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RESEARCH ARTICLE

Effect of cabinet tray drying method on physicochemical, nutritional and antioxidant status of dragon fruit (*Hylocereus polyrhizus*) powder: A comparative analysis on laboratory and commercial market sample

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Abstract

Dragon fruit (*Hylocereus polyrhizus*) belonging to the Cactaceae family, is gaining popularity in India as a minor tropical fruit crop. However, due to high perishability associated with dragon fruits, drying is one of the most effective viable methods for its long-term preservation. Spray and Drum drying are the two major expensive methods recognized for converting dragon fruit into powder. To overcome this, a low-cost tray drying process was attempted to produce dragon fruit powder with minimal additive incorporation and optimal free-flowing properties. The physico-chemical properties, mineral content and antioxidant activity of the laboratory-produced powder were evaluated and compared with a commercially available spray-dried red dragon fruit powder. The parameters analyzed included moisture content, water activity, whiteness index, total sugars, ascorbic acid, protein, total phenols, total betalains, antioxidant activity (Ferric Reducing Antioxidant Power; FRAP assay) and mineral content. Results of the data revealed that the laboratory sample demonstrated superior quality, with higher total sugars (26.69 %), protein (1.97 %), total phenols (576.56 mg GAE/100 g), total betalains (96.93 mg BCE/100 g) and FRAP activity (120.80 mg AEAC/100 g). The powder also exhibited the desirable storage properties such as lower moisture content (0.98 %), lower water activity (0.270) and low whiteness index (6.030). Experimental findings revealed that the laboratory produces dragon fruit powder was not only tagged as lower in production costs but also had significantly higher nutrient content, phytochemicals and antioxidant levels compared to the commercial sample.

Keywords: antioxidant activity; drying process; food colorant; mineral content; red dragon fruit

Introduction

Dragon fruit, commonly known as “Kamalam” in India, is botanically called *Hylocereus polyrhizus* of the family Cactaceae. This minor tropical fruit crop has recently gained popularity as “super fruit” due to its exceptional nutritional profile and health benefits. The vibrant red colour of *H. polyrhizus* (red dragon fruit) is attributed to betalains, the water-soluble nitrogen-containing pigments known for their potent antioxidant properties (1). Regular consumption of dragon fruit has been linked to a reduced risk of heart diseases, Type-II diabetes, low-density lipoprotein (LDL) cholesterol levels and certain cancers. (2). Despite these benefits, the utilization of the fruit is limited, as it is highly perishable and seasonal in nature

In the year 2020, it was reported that India's dragon fruit cultivation rapidly expanded by 3084 ha total area under cultivation and an estimated production of 12113 MT (3). Notably, more than 80 % of the orchards are less than three years old, reflecting the crop's nascent yet promising growth. Recognizing its commercial value, the Mission for Integrated Development of Horticulture (MIDH) implemented by the Ministry of Agriculture and Farmer's Welfare, Government of India has set an ambitious target of expanding dragon fruit cultivation to 50000 hectares in 2030 (4). However, the rapid expansion of cultivation produces market challenge, particularly an oversupply during peak harvest periods owing to crop brief flowering to maturity cycle (28-30 days). Due to market glut and increased production, the price of the dragon fruit has declined by more than 60 % over the past four years, with further reductions anticipated. To address this issue, value addition and product diversification have emerged as key strategies to stabilize prices and enhance profitability. Dragon fruit powder has gained significance among value-added products due to its versatility in various food preparations such as ice creams, milkshakes, juices, cakes, puddings and cookies. However, the commercial production of dragon fruit powder, particularly through spray or freeze

drying is characterized by high costs, primarily due to substantial investment requirements and the use of additives (20-40 %) that dilute the pulp content. In the current market, spray-dried dragon fruit powder is priced around 4000 ₹/kg, while freeze-dried powder commands a premium of 12000 to 15000 ₹/kg.

To overcome these challenges, this study aimed to develop a cost-effective alternative method for producing dragon fruit powder. The method seeks to lower production costs and reduce reliance on additives, thereby increasing the affordability and consumption of dragon fruit powder and providing a sustainable solution to the challenges faced by producers and consumers.

Material and methods

Sample preparation

Fresh red pulp dragon fruits (*H. polyrhizus*) were procured from the Indian Council of Agricultural Research - Indian Institute of Horticultural Research (ICAR-IIHR) farm at Hirehalli, Tumakuru district, Karnataka. The fruit was washed under clean running water and shade-dried to remove surface moisture. The pulp was separated from the peel, ground using a blender and analyzed for physico-chemical quality parameters. The homogenized pulp-additive mix was uniformly spread onto stainless steel trays and dried in a tray dryer at 60 ± 2 °C with an air velocity of 2 m/s for 16 hr. The dried, brittle sheets were ground into powder using a mixer grinder; this will be hereafter mentioned as lab samples (LS) (Plate 1). The commercial spray-dried red dragon fruit powder sample (CS) was procured from an e-commerce platform for the comparison of physico-chemical properties with LS.

Physicochemical analysis

The physicochemical properties *viz.*, moisture content, water activity, whiteness index, total sugars, protein content, fat content, total phenols, ash content, crude fiber, ascorbic acid, total betalain content, total antioxidant activity and mineral content in LS and CS of red dragon fruit powder were analyzed by following the below mentioned methodologies.

Moisture content

The moisture content of dragon fruit powder was determined using an infrared moisture analyzer (model: P1019319; make: A&D Company Limited, Japan). 1 g of the powder samples was placed in the moisture analyzer which automatically expressed the constant moisture in per cent.

Water activity

The water activity of dragon fruit powder was measured using a digital water activity meter (model: ms-1 aw, Switzerland; make: Novasia AG). One fourth volume of the container was filled with sample and it was closed with lid containing sensors and left undisturbed for three min. After stabilization, the water activity was displayed by digital water activity meter.

Whiteness index

The colour of dragon fruit powder was assessed in CIELAB method by using colorimeter (model: CR-10, Japan; make: Konica, Minolta) and the results were expressed as L^*, a^* and b^* values. Whiteness index (WI) was calculated according to the following formula:

$$WI = 100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2} \quad \text{(Eq. 1)}$$

Total sugars

The sugar content in the dragon fruit powder was determined following the Lane-Eynon titration method (5). Pre-weighed samples of dragon fruit powder (3 g) were homogenized using high pressure homogenizer (model: IKA T25 make: Digital ultra Turarax) with distilled water (DW) and the volume was adjusted to 100 mL using DW. Subsequently, 5 mL of lead acetate was added and left for 30 min. The precipitation of the lead solution was achieved by adding potassium oxalate and the final volume was adjusted to 150 mL with DW. The solution was then filtered through Whatman no. 1 filter paper and the clear filtrate was used for titration.

For the estimation of total sugars, the same filtrate was used. For this, 25 mL of filtered sample was transferred into a volumetric flask and 5 mL of concentrated HCl was added into it and left for 24 hr at room temperature. After that, a few drops of phenolphthalein indicator were added to the sample and sodium hydroxide (20 %) was used to neutralize the HCl. Light pink colour was the indication of complete neutralization of acid. Then, the final volume was made up to 50 mL with distilled water and titrated against Fehling's solution after adding a few drops of methylene blue

Plate 1. Image depicting the commercial and lab samples.

Note: The term "IIHR technology" appearing in the photograph should be interpreted as "Lab sample."

indicator. End point was judged by the change of blue colour into dark brick red colour.

Percentage of total sugars was calculated using the titre value in the following formula (4);

Total sugars (%) = (Factor x Volume made up)/ (Titre value × Weight of sample) × 100

Protein content

Protein content was estimated in dragon fruit powder using Folin phenol reagent method (6). One gram sample was homogenized with DW and the volume was made up to 25 mL. The sample was then centrifuged at 8000 rpm for 10 min and the supernatant was used for protein estimation. In dragon fruit powder, 1 mL of the supernatant was diluted with 9 mL of DW. The reaction mixture containing 1 mL of the extract and 5 mL of reagent C (mixture of reagent A (2 % Na_2CO_3 in 0.1 N NaOH) + reagent B (0.5 % $CuSO_4.5H_2O$ + sodium potassium tartrate) was mixed and kept for 10 min. Subsequently, 0.5 mL of Folin Ciocaltue Reagent (FCR) was added, mixed well and incubated at room temperature for 30 min in the dark. Absorbance was measured at 660 nm against the reagent blank. Protein present in the sample was calculated using a standard graph plotted using Bovine Serum Albumin and expressed in g/100 g. (Eq. 2)

Fat content

Fat content was estimated in dragon fruit powder as per AOAC method as described by the (7). 5 g sample was taken in a beaker and a known volume of petroleum ether was added to it. The contents in the beaker were thoroughly mixed and allowed to rest until all the particles settled down. Subsequently, the clear solution of petroleum ether was drained into a pre-weighed beaker. This process was repeated for three to four times. The beaker containing the petroleum ether extractant was then left undisturbed at room temperature until the petroleum ether gets completely evaporated. The final weight of the beaker was measured using an electric weighing balance. The fat percent was calculated using the formula:

$$\text{Fat (\%)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Weight of the sample}} \times 100 \quad \text{(Eq. 3)}$$

Total phenols

Total polyphenol content in dragon fruit powder was determined by the Folin–Ciocalteu method (8) with slight modifications. 1 g of powder sample was crushed in 80 % ethanol. After homogenization, the final volume was adjusted to 20 mL with the same solvent and then centrifuged at 10000 rpm for 20 min at 4 °C. The supernatant (0.5 mL) was mixed with 0.2 mL of Folin-Ciocalteu reagent (diluted with DW in a 1:1 ratio) and 3.3 mL of DW. After 3 min, 1 mL of 20 % Na_2CO_3 solution was added and mixed thoroughly. The reaction mixture was incubated for 30 min in the dark. The absorbance of the sample was recorded at 760 nm using a spectrophotometer. Gallic acid was used to calibrate the standard curve. The total phenols were expressed as milligrams of gallic acid equivalent per 100 grams (mg GAE/100 g).

Ash content

Total ash content was determined by burning the dragon fruit powder in pre-weighed crucible in a muffle furnace at 500 °C for 6 hr (9). After burning the residue, ash weight was recorded and ash content was calculated using the formula;

$$\text{Total ash content (\%)} = \frac{\text{Weight of the ash (g)} \times 100}{\text{Weight of the sample (g)}} \quad \text{(Eq. 4)}$$

Crude fiber

For estimating crude fiber content in lab produced dragon fruit, sample of 5 gram was weighed. Sample was then mixed with 200 mL of H_2SO_4 (1.25 %) (9). The round bottom flask containing the sample was placed in a heating mantle for 30 min at 100 °C. Once heated, the substance was subsequently filtered through a muslin cloth and washed with 50 mL of distilled water. The residue obtained after filtration was added to a round bottom flask. It was then treated with 200 mL of sodium hydroxide solution (1.25 %) and boiled in a heating mantle for 30 min. It was again rinsed and filtered within a muslin cloth with hot distilled water. It was then finally washed with 25 mL of ethanol (95 %). The remaining substance was transferred into a crucible and the crucible containing the sample was subjected to oven drying at a temperature of 130 °C for duration of 2 hr (W2). Desiccator was used to cool the sample and then samples were weighed. It was subjected to heating in a muffle furnace at a temperature of 600 °C for a period of 30 min. Ashed samples were weighed after cooling in a desiccator (W3).

$$\text{Percentage of Crude fibre} = \frac{(W3-W1)\,(W2-W1) * 100}{W} \quad \text{(Eq. 5)}$$

Where

W = weight of the sample

W1 = weight of the crucible

W2 = weight of crucible after heating in hot air oven

W3 = weight of crucible containing ashed sample

Ascorbic acid

Ascorbic acid present in the fruit powder was estimated by the iodine titration method (10). To estimate the ascorbic acid present in dragon fruit powder, 2 g of powder was weighed, homogenized and the final volume was made up to 50 mL using distilled water. Then, 5 mL aliquot was taken and 1 mL of starch indicator was added to it. After mixing, the aliquot was titrated against iodine solution until the appearance of a dark blue or purple colour as the end point.

A stock solution of standard L-ascorbic acid was used to calculate the dye factor. The final result was calculated using the following formula and the result was expressed as mg/100 g.

Ascorbic acid Content (mg/100 g) =

$$\frac{\text{Titrate value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Weight of sample} \times \text{Volume of sample taken}} \times 100 \quad \text{(Eq. 6)}$$

Total betalain content

For estimating total betalain content, a standard method was used (11) with a slight modification and expressed in mg BCE/100 g. For estimating the total betalain content in dragon fruit powder, 2 g of powder was ground with acidified methanol: water (1:1) solvent for colour extraction. Extracted sample volume was made up to 25 mL with acidified methanol: water (1:1) solution. Extracted sample was subsequently centrifuged at 8000 rpm for 10 min to get a clear extract. One mL of supernatant was mixed with 4 mL of methanol: water (1:1) solvent and was used to record the absorbance at 538 nm in a spectrophotometer against a blank reagent (acidified methanol: water [1:1]).

Total Antioxidant Activity (FRAP Assay)

The FRAP (Ferric Reducing Antioxidant Power) assay was conducted according to a standard protocol (12). Initially, 1 mL of the dragon fruit powder extract was diluted to 10 mL using 9 mL of deionized water (DW). For the assay, 0.2 µL of the diluted extract was mixed with 1.8 µL of freshly prepared FRAP reagent, which consisted of acetate buffer, $FeCl_3 \cdot 6H_2O$ and TPTZ (2,4,6-tripyridyl-s-triazine) in a 10:1:1 ratio. The reaction mixture was incubated for 30 minutes in the dark at room temperature, after which the absorbance was measured at 593 nm. A standard curve was generated using ascorbic acid and the results were expressed as milligrams of ascorbic acid equivalent (AEAC) per 100 g of sample

Mineral analysis

The mineral analysis of dragon fruit powder samples was carried out by means of the atomic absorption spectrophotometric method (Agilent 200 Series AAS).

Statistical analysis

The t-test for physico-chemical parameters of two variables (CS and LS) was analyzed using the WINDOSTAT 9.3 software at 1 % significance level to understand the statistically significant differences between the two respective means ($P \leq 0.01$) of various parameters.

Results and Discussion

Moisture content

Moisture content plays a pivotal role in determining the stability and shelf life of fruit powders (13). In the present study, the moisture content of commercial dragon fruit was found to be 4.93 %, which is slightly higher than that of lab sample at 4.47 % (Table 1). This could be attributed to higher water retention capacity of hydrocolloids (maltodextrin) in CS compared to hydrocolloids of LS (additive combination containing starch as principal ingredient). Furthermore, the drying method itself plays a significant role in moisture removal efficiency. Also, the prolonged exposure of LS formulation to high temperature (60 ± 2 °C) for a longer time (16 hr) results in thorough moisture evaporation. This contrasts with the rapid nature of spray drying, which uses high air velocities and short residence times, often resulting in poor moisture evaporation (14). The excessive use of maltodextrin and spray drying in mango powder production increase moisture content due to the formation of sticky powder during drying (15). This sticky behaviour can lead to incomplete moisture removal, which in turn increases the final moisture content of the powder that ultimately affects the shelf life of the fruit powder.

Table 1. Physical properties of commercial (CS) and lab samples (LS) of red dragon fruit powder

Samples	Moisture (%)	Water activity	Whiteness index
CS	4.93[a]	0.39[a]	27.70[a]
LS	4.47[b]	0.27[b]	6.03[b]
T-test values	0.21	0.02	3.70
SEm	0.02	0.03	0.41

(p ≥ 0.01) CS- commercial sample LS-lab sample (p ≥ 0.01) CS- commercial sample LS-lab sample (p ≥ 0.01) CS- commercial sample LS-lab sample (p ≥ 0.01) CS- commercial sample LS-lab sample

Water activity

Water activity is a critical factor that influences the stability and shelf life of food powders by determining the availability of free water for chemical and microbial reactions (16). In the present study, the LS exhibited a significantly lower water activity (0.27) compared to the CS (0.39). The lower water activity of the LS is attributed to both the drying methods and the use of additive, which enhanced the moisture removal during the drying process. This lower water activity can be explained by the optimized tray drying technique. Tray drying, which involves slower drying at moderate temperature is known to facilitate a more thorough evaporation of moisture, thereby resulting in lower residual water content and reduced water activity (14). In contrast, spray drying is the method used for producing commercial samples and typically involves shorter residence times and higher temperatures. This rapid process results in improper removal of internal moisture and leads to the retention of higher moisture levels, contributing to increased water activity (17). This finding aligns with previous studies (18) which reported that high-temperature spray drying may cause case hardening, trapping moisture inside particles.

Whiteness index

Colour is a key sensory attribute that significantly influences the visual appeal and consumer acceptance of fruit powders (19). In the present study, the whiteness value of LS was notably influenced by the concentration of the additive. LS recorded the lowest whiteness value (6.030), indicating a higher fruit content and a lower level of additive. In contrast CS, exhibited a substantially higher whiteness value (27.70). This difference is primarily due to the dilution effect caused by the light-coloured additive, which increases the lightness of the final product as its concentration rises.

A direct correlation was observed between increasing additive concentration and elevated whiteness values, indicating reduced fruit content. The intense red pigmentation of dragon fruit pulp, when contrasted with the white additive, produced a light purple hue in CS due to its higher additive concentration. These findings are consistent with previous research (20), where increasing maltodextrin concentration in spray-dried sumac extract powder similarly led to higher whiteness values.

Total sugars

The total sugars showed a notable difference between the LS and CS. The CS had a total sugar content of 26.69 %, which is significantly lower than the LS i.e., 39.81 % (Table 2). This disparity is attributed to the higher fruit pulp content and lower additive levels in the LS. In contrast, the CS is lower in sugar, likely resulting from the dilution effect of additives. Trends in sugar content due to additive incorporation have been identified in sweet potato flour and persimmon puree powder (21) and (22). And these reports also corroborate the present findings.

Protein content

The protein content in the LS (3.30 %) was significantly higher than in the CS (1.97 %). This difference can be attributed to the lower incorporation of additives in the LS, which retained a higher proportion of fruit pulp and thus preserved the protein content. In contrast, the CS had lower protein content due to the dilution effect caused by a higher concentration of non-protein additives, which is commonly used to improve drying efficiency, reduce stickiness and enhance flowability. Since these additives contain negligible protein, their increased proportion reduced the overall protein concentration in the final product. Similar findings have been reported in other fruit powders, where the incorporation of carrier agents led to a reduction in protein content. The substitution of protein-rich fruit solids with maltodextrin causes a decline in protein content during the spray drying of gac fruit (23). A reduction in protein content in mango powder with the inclusion of carriers like gum arabic and maltodextrin has been reported (18).

Fat content

The amount of fat present in fruit powder is an important factor that affects their nutritional profile, especially regarding beneficial lipids as well as their storage longevity and resistance to spoilage. In the present study, fat content was non-traceable in both the CS and LS (0.00 %, 0.02 % respectively). This finding aligns with the natural compositional characteristics of dragon fruit pulp, which inherently contains negligible levels of lipids (24). The limited fat content present in dragon fruit is primarily localized within its seeds (25). These seeds are a source of beneficial polyunsaturated fatty acids like linoleic acid, which is known for its nutritional and functional health benefits.

Crude fiber

Crude fiber refers to the indigestible portion of plant-based foods and resists enzymatic breakdown in the human gastrointestinal tract. In the present study, the crude fiber content in LS showed a significantly higher result (2.60 %). While, in CS no trace of crude fiber was detected (*i.e.*, 0.00).

Table 2. Chemical properties of commercial (CS) and lab samples (LS) of red dragon fruit powder

Samples	Total Sugars(%)	Protein(%)	Fat (%)	Ash (%)	Crude fibre (%)
CS	26.69^{b}	1.97^{b}	0.00^{b}	0.00^{b}	0.00^{b}
LS	39.81^{a}	3.30^{a}	0.02^{a}	3.00^{a}	2.60^{a}
T-test values	2.23	0.14	0.00	0.51	0.25
SEm	0.25	0.01	0.00	0.05	0.029

($p \geq 0.01$) CS- commercial sample LS-lab sample

Ascorbic acid

Ascorbic acid is one of the antioxidant agents present in food products which contribute towards the antioxidant activity. There was no significant difference ($P \geq 0.01$) in ascorbic acid content of CS and the LS (Table 3). The ascorbic acid content of both the dragon fruit powder samples showed similar results (43 mg/100 g).

Total Betalain content

Betalains are water-soluble, nitrogen-containing pigments predominantly present in red and purple varieties of dragon fruit. These pigments are known for their vibrant colouration and potential health benefits. Analysis of the data revealed a significantly lower betalain content in the CS (1.88 mg BCE/100 g) compared to LS (96.93 mg BCE/100 g). This substantial reduction in betalain content in CS can be attributed to the higher incorporation of additives and low fruit content during the drying process, which dilutes the pigment concentration. Furthermore, betacyanin compounds are highly heat-sensitive and prone to degradation when exposed to prolonged temperatures above 60 °C, owing to the instability of molecular structure (26). This degradation likely exacerbates the reduction in betalain levels in CS where elevated temperatures are typically employed in spray drying process. Due to the thermal sensitivity of these pigments and dilution effects of additives, significant losses in betalain content in spray-dried dragon fruit powders have been obtained (27).

Total phenols

Total Phenolic Content (TPC) of dragon fruit is largely attributed to its rich composition of polyphenolic compounds, which are renowned for their potent antioxidant properties. Key phenolic acids identified in dragon fruit include gallic acid, ferulic acid, *p*-coumaric acid and vanillic acid. A significant difference was observed between the CS and LS. The CS exhibited a markedly lower TPC (91.08 mg GAE/100 g) compared to the LS (576.56 mg GAE/100 g). This pronounced decline of TPC in CS is likely due to the dilution effect caused by the incorporation of higher quantities of additives during the spray-drying process to facilitate efficient drying (31). The excessive use of additives dilutes the concentration of phenolic compounds in the final product, thereby reducing its antioxidant potential. These findings align with previous studies that reported similar reductions in TPC amongst various dried fruit powders. Significant decreases in TPC have been documented in dried fruit powders of sumac, dragon fruit, blueberry, raspberry, cactus peel and bael fruit, respectively (20, 27-31).

Table 3. Antioxidant and phenolic properties of commercial (CS) and lab samples (LS) of red dragon fruit powder

Samples	Ascorbic acid (mg/100 g)	Betalains (mg BCE/100 g)	Total phenolic compound (mg GAE/100 g)	FRAP activity (mg AEAC/100 g)
CS	43	1.88^{b}	91.08^{b}	20.94^{b}
LS	43	96.93^{a}	576.56^{a}	120.80^{a}
T-test values	NS	5.19	61.51	20.15
SEm	0.35	0.58	6.91	2.26

($p \geq 0.01$) CS- commercial sample LS-lab sample

Total antioxidant activity (FRAP assay)

The Ferric Reducing Antioxidant Power assay, is a method used to measure the total antioxidant capacity of a sample by assessing its ability to reduce ferric (Fe^{3+}) ions to ferrous (Fe^{2+}) ions. In this study, the FRAP value (120.80 mg AEAC/100g) of LS was significantly higher than that of the CS (20.94 mg AEAC/100g).The reduced FRAP value observed in CS can be attributed to the loss of phenolic compounds such as gallic acid, caffeic acid and *p*-coumaric acid due to high temperature processing. This degradation is likely exacerbated by the incorporation of larger quantities of additives, which are predominantly complex carbohydrates with minimal antioxidant activity. The dilution effect caused by these additives diminishes the overall concentration of bioactive compounds, resulting in reduced antioxidant potential. Various other works also substantiates the present findings. In pitaya powder the tenfold decrease in its antioxidant content was due to the high level of additives in the pulp during processing (32). In spray-dried lemon juice powder, the excessive use of additives contributed to a significant reduction in antioxidant activity (33).

Mineral content

The mineral content, *viz.*, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) of CS and LS red dragon fruit powders is given in Fig. 1, 2. A significant variation was observed between the mineral content of two samples. Results showed significantly higher levels of N (1.46 %), P (0.121 %), K (1.72 %), Ca (0.71 %), Mg (0.45 %), S (0.09 %), Fe (22.54 ppm), Mn (11.30 ppm), Zn (13.18 ppm) and Cu (5.18 ppm) in LS compared to those of CS, which exhibited a mineral concentration of 0.08 % (N), 0.045 % (P), 0.73 % (K), 0.189 % (Ca), 0.410 % (Mg), 0.051 % (S), 21.80 ppm (Fe), 2.36 ppm (Mn), 1.20 ppm (Zn) and 1.09 ppm (Cu), respectively. The higher mineral content in the LS can be attributed to the minimal incorporation of additives during the drying process. In contrast, the lower mineral levels in CS are likely due to the dilution effect caused by the excessive addition of non-mineral-rich carriers. These additives, lack significant mineral content thereby diluting the overall mineral concentration in the final product. Similar observations have been reported in previous studies. An increase in maltodextrin levels causes a reduction in the mineral content of sweet potato flour (21). In

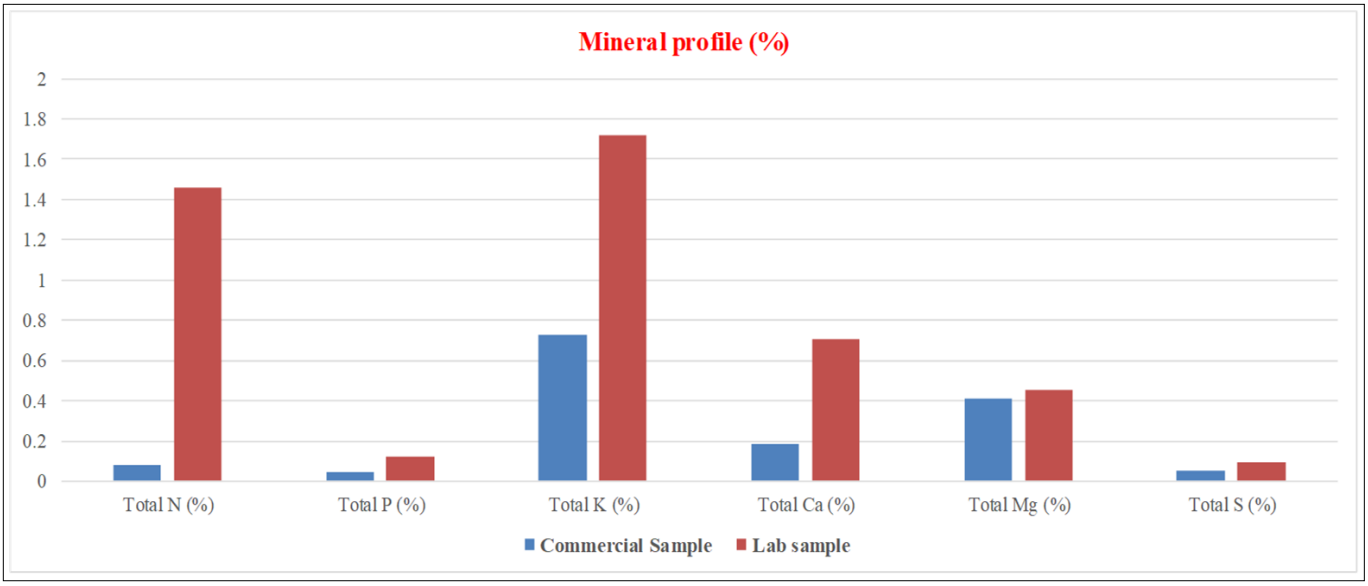

Fig. 1. Mineral content (%) of commercial and lab red dragon fruit powder samples.

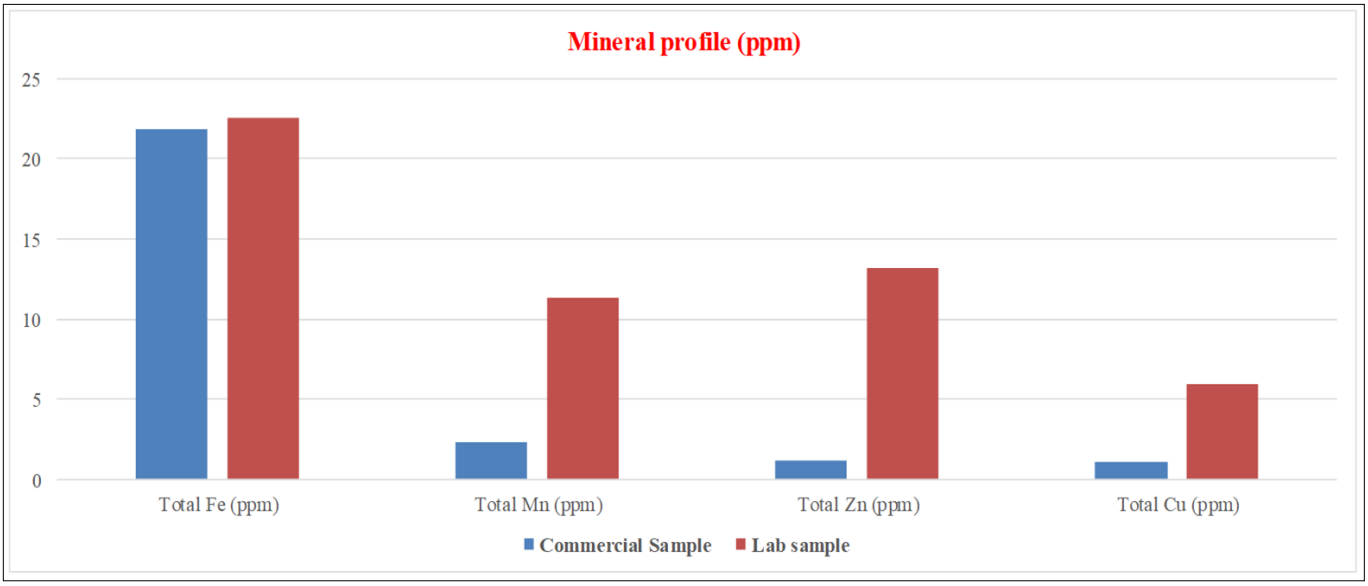

Fig. 2. Mineral content (ppm) of commercial and lab red dragon fruit powder samples.

spray-dried gac fruit powder, the higher levels of maltodextrin concentrations reduced mineral levels, which are due to the decreased proportion of fruit solids (23). Analogous effects were exhibited by spray-dried dragon fruit and cherry tomato powders (27, 34).

Ash content

The ash content serves as an indicator of the total mineral residue in a fruit powder, reflecting its mineral composition and nutritional quality. In this study, the ash content of the CS and LS was determined as 0.0 % and 3.0 % on a dry weight basis, respectively. Notably, no ash content was detected in the CS. This absence of detectable ash content in the CS can be attributed to the dilution effect caused using additives, which are inherently low in ash and mineral content. As the proportion of these additives increases in relation to the fruit pulp during processing, a diminution occurs in the mineral concentration of the resulting powder, which reduces the ash content. Similar findings have been reported in the literature. A significant decline in the ash content of sweet potato flour with increasing levels of maltodextrin during processing has been observed (21). The incorporation of maltodextrin into gac fruit powder during spray drying has substantially reduced its ash content (23).

Conclusion

The experimental findings indicate that the red dragon fruit powder produced by tray drying contains significantly higher levels of bioactive compounds including protein, fat, crude fiber, pigments, phenols, antioxidant activity and minerals compared to commercially available red dragon fruit powder. This enhanced nutritional profile is attributed to the inclusion of dragon fruit seeds and mucilage, the components which are typically discarded during conventional spray drying. Additionally, the use of tray drying to produce red dragon fruit powder offers a cost effective and simple alternative, making it particularly viable for small scale enterprises. The powder produced from tray drying holds significant potential as a natural colourant and nutritional additive in health, wellness, food and confectionary industries. Overall, this method demonstrates clear advantages over existing production techniques in terms of nutritional value, economic feasibility and scalability, therefore, making it a promising option for broader application.

Authors' contributions

TH and KP have done the data collection, analysis and interpretation of results and draft manuscript preparation. CKN contributed to study conception and design, supervision of the experiment, validation of results, project administration and funding acquisition. PP was involved in the drafting of the manuscript or revising, review, supervision and validation. GK and TRR performed the analysis, interpretation of results and provided resources for the experiment.

Compliance with ethical standards

Competing Interests: The author(s) declare(s) that they have no competing interests

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Availability of data and material: The data that support the findings of this study are available on request from the corresponding author.

Ethical issue : None

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