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Comparative Analysis of Spray Dried and Tray Dried Beetroot Powder used as a Raw Material for 3D Food Printing

Madhvi Sharma[1]*, Alok Dubey[2], Pratibha Parihar[1], S.S. Shukla[1] and Kiran Gupta[1]
[1]Department of Food Science and Technology, JNKVV, Jabalpur (Madhya Pradesh), India.
[2]Ministry of Food Processing Industries (New Delhi), India.

(Corresponding author: Madhvi Sharma)*
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ABSTRACT: This paper presents a detailed comparative analysis of Tray Dried Beetroot Powder (TBRP) and Spray Dried Beetroot Powder (SBRP), with a focus on their physical, biochemical and sensory properties for potential integration into 3D food printing. Comprehensive examination of physical, color and biochemical properties revealed that the spray-dried variant surpassed its tray-dried counterpart in terms of color values, betalain content, particle size and sensory evaluation, positioning it as a superior ingredient for 3D printing. The vibrant color enhanced the palatability of the printed product, while the smaller particle size ensured uniform mixing in the printing ink, preventing nozzle clogging. These findings contribute to a comprehensive understanding of the distinct characteristics of each powder type, aiding in informed decisions for their utilization in 3D food printing applications.

Keywords: Spray drying, Tray Drying, Beetroot powder, 3D food printing.

INTRODUCTION

In recent years, the field of 3D food printing has witnessed unprecedented attraction, with researchers exploring innovative materials to enhance the capabilities and applications of this cutting-edge technology. Among these materials, beetroot powder has emerged as a promising substrate due to its vibrant color, nutritional richness, and potential versatility in 3D food printing processes. Throughout history, traditional food drying methods like sun drying have evolved with the aid of modern technology to mitigate the impact of biochemical changes on nutritional value during the drying process. Common contemporary techniques encompass sun drying, tunnel drying, spray drying, drum drying, freeze-drying, microwave drying, and fluidized bed drying. Tray drying entails exposing small produce pieces to hot dry air or sunlight for ambient temperature storage, while spray drying rapidly transforms liquids or slurries into dry powder using hot gas and is a preferred method for thermally-sensitive materials like foods and pharmaceuticals. Fang *et al.* (2015) on the solubility and color stability of spray-dried powders offers crucial insights into the behavior of powders during reconstitution, an aspect essential for 3D food printing processes.

The present study conducts a comparative analysis between Tray Dried Beetroot Powder (TBRP) made using tray dryer model (Yukti, 322) and Spray Dried Beetroot Powder (SBRP) made using spray dryer (Model-SPD-D-111), evaluating their physical, biochemical, and sensory properties aiming is to provide valuable insights for the optimal utilization of these powders in 3D food printing applications as 3D food printing is a groundbreaking culinary technology that transforms digital designs into edible delights. Using additive manufacturing techniques, this process involves layering food materials to craft intricate and customized dishes as discussed by Dankar *et al.* (2018). The comparative analysis presented in this paper aims to contribute to the growing body of knowledge surrounding the utilization of beetroot powders in 3D food printing. By understanding the distinctive properties of TBRP and SBRP, researchers and practitioners can make informed decisions regarding their integration into 3D printing processes, ultimately advancing the field's capabilities and expanding the range of printable food materials.

MATERIALS AND METHODS

The study was conducted in Department of Food Science and Technology at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). Beetroots were procured from local vegetable market, Jabalpur. The beetroots utilized in the research were carefully selected at their optimal stage of maturity and were of substantial size. The chemicals and glasswares utilized in this investigation were sourced from reputable suppliers, including M/s British Drug House Mumbai, Qualigen Fine Chemicals, Glaxo-Smith Kline Pharmaceuticals Limited in Mumbai 400025, Thermo-Fisher Scientific India Pvt. Ltd. in 403404, B-Wing Delhi, and Fine Chemicals Limited in Ahmedabad – 380 006, India. Prior to use the freshly sorted beetroots were thoroughly washed, cleaned and were then utilized in the experiments conducted. Three replicates of each sample were used for analysis. The experiments were carried out as per the methods described in details in the following sections.

The physical properties of Tray Dried Beetroot Powder (TBRP) and Spray Dried Beetroot Powder (SBRP) were assessed through various parameters following established methodologies. Bulk density (ρb) and true density were calculated according to Majzoobi *et al*. (2012). Porosity (P) was estimated using the formula as described by Krokida and Maroulis (2000).

Porosity(P)=(ρb−ρt)/ρb,

Particle size analysis was conducted using a particle size analyzer (PSA 1190), Color values were determined using a Hunter Lab Color Flex Spectro-colorimeter (Model – Color Flex EZ) under D65/100 illuminant conditions. The pH was measured using a pH meter, and solubility was evaluated to understand the dissolution characteristics. For the biochemical analysis, established AOAC (Association of Official Analytical Collaboration), 2012 were employed, ensuring comprehensive and standardized assessment of the powders' composition. Sensory analysis was conducted according to Amerine *et al*. (1965), allowing for a qualitative evaluation of the perceptual attributes, including color, taste, flavor, aftertaste, mouthfeel, and overall acceptability.

RESULT AND DISCUSSION

In the exploration titled "Comparative Analysis of Spray Dried and Tray Dried Beetroot Powder: Physicochemical, Nutritional and Sensory Profiling," systematically essential parameters were investigated to unveil the diverse characteristics of tray-dried beetroot powder (TBRP) and spray-dried beetroot powder (SBRP).

A. Physical properties of TBRP and SBRP

As per Table 1, the bulk density (BD) of TBRP (0.455±0.0004 g/cm³) displayed a significant difference from SBRP (0.632±0.0008 g/cm³), indicating variations in the packing arrangement of particles. True density similarly differed, with TBRP exhibiting a higher value (1.566±0.033 g/cm³) compared to SBRP (1.206±0.185 g/cm³). Further distinctions were observed in porosity and particle size, as TBRP demonstrated higher porosity (70.94±0.64%) and a larger particle size (267±12.76 microns) than SBRP (64.167±0.142% and 64±5.8 microns, respectively). The color analysis, encompassing L*, a*, b*, and ΔE* values, unveiled notable differences between the two drying methods. Additionally, SBRP displayed superior solubility (97.43±4.6%) compared to TBRP (42.76±2.2%), underscoring the impact of drying techniques on both physicochemical and sensory attributes. The presence of an encapsulating agent was exclusive to SBRP, introducing a distinctive element to the formulation. This comprehensive analysis contributes valuable insights into the nuanced characteristics of TBRP and SBRP, offering essential considerations for the development of beetroot-based products.

B. Biochemical properties of TBRP and SBRP

In the nutritional analysis of tray-dried beetroot powder (TBRP) and spray-dried beetroot powder (SBRP), notable differences were observed. TBRP displayed lower moisture (6.5±0.16%) and higher protein (4.54±0.64%) compared to SBRP (8.023±0.34% and 1.03±0.042%, respectively).

Table 1: Physical properties of TBRP and SBRP.

Sr. No.	Parameters		Units	TBRP	SBRP
1.	BD		g/cm^3	0.455±0.0004	0.632±0.0008
2.	True density		g/cm^3	1.566±0.033	1.206±0.185
3.	Porosity		%	70.94±0.64	64.167±0.142
4.	Particle size		Microns	267±12.76	64±5.8
5.	Color	L*		27.72±1.52	56.32±4.56
		a*		47.6±2.53	54.68±3.66
		b*		14.4±0.78	19.53±1.52
		ΔE*		0.34	0.23
6.	pH			6.5±0.2	6.2±0.22
7.	Solubility		%	42.76±2.2	97.43±4.6
8.	Encapsulating agent		%	-	20%
9.	Time/temp for drying			45°C for 10 hours	480 ml/hr at 155°C
TBRP = Tray dried beetroot powder; SBRP= Spray dried beetroot powder					

Table 2: Biochemical properties of TBRP and SBRP.

Sr. No.	Parameters/ Contents	Units	TBRP	SBRP
1.	Moisture	%	6.5±0.16	8.023±0.34
2.	Protein	%	11.54±0.64	1.03±0.042
3.	Crude Fat	%	-	-
4.	Total Ash	%	4.03±0.54	1.325±0.4
5.	Carbohydrates	%	64.232±2.2	87.195±3.4
6.	Gluten	%	-	-
7.	Damaged starch	%	-	-
8.	Crude Fiber	%	12.46±0.54	1.84±0.42
9.	Betalains	mg/g DM	68.6±3.2	95.2±1.84
10.	TSS	°Brix	11.5±0.52	15±0.48
TBRP= Tray dried beetroot powder ; SBRP= Spray dried beetroot powder				

Table 3: Sensory comparison of TBRP and SBRP.

Sr. No.	Parameters	TBRP	SBRP
1.	Color	7	9.5
2.	Taste	7	8.5
3.	Flavor	6.5	8.5
4.	After taste	7	9
5.	Mouthfeel	6.5	9
6.	Overall acceptability	7	9
TBRP= Tray dried beetroot powder; SBRP= Spray dried beetroot powder			

Total ash content varied significantly, with TBRP at 4.03±0.54% and SBRP at 1.325±0.4%. Carbohydrate composition showed substantial differences, with TBRP at 64.232±2.2% and SBRP at 87.195±3.4%. Crude fiber content also differed notably, with TBRP at 12.46±0.54% and SBRP at 1.84±0.42%. Betalain concentration in TBRP was 68.6±3.2 mg/g DM, while SBRP had a higher concentration of 95.2±1.84 mg/g DM. TSS content was slightly higher in SBRP (15±0.48 °Brix) compared to TBRP (11.5±0.52 °Brix). These results showed similarity with the ones reported by Smith *et al.*, (2017). This concise nutritional analysis highlights significant variations in key constituents, providing essential insights for the development of beetroot-based products with desired nutritional attributes (Table 2).

C. Sensory comparison of TBRP and SBRP

In the sensory evaluation, spray-dried beetroot powder (SBRP) demonstrated superior preferences across various attributes compared to tray-dried beetroot powder (TBRP). SBRP received higher scores for color (9.5), taste (8.5), flavor (8.5), aftertaste (9), mouthfeel (9), and overall acceptability (9) (Table 3). TBRP, while still scoring favorably, obtained lower ratings in each category (ranging from 6.5 to 7).

These findings suggest a clear preference for the sensory qualities of SBRP, emphasizing its potential as a more appealing option in terms of taste, color, and overall acceptability. Results were in line with the findings reported by Johnson and Patel (2019).

CONCLUSIONS

In conclusion, this research sheds light on the intricate differences between spray-dried beetroot powder (SBRP) and tray-dried beetroot powder (TBRP) across physicochemical, nutritional, and sensory dimensions for their suitability in 3D food printing applications. Physically, SBRP demonstrated superior solubility, essential for 3D printing applications, and outperformed TBRP in sensory evaluations, scoring higher across various parameters such as color, taste, flavor, aftertaste, mouthfeel, and overall acceptability. The color analysis showcased vibrant and distinct characteristics in SBRP. Nutritionally, both the powders exhibited variations in moisture, protein, total ash, carbohydrates, and betalain content, highlighting the impact of drying methods on nutritional composition. Sensory evaluation revealed a clear preference for SBRP, evident in color, taste, flavor, aftertaste, mouthfeel, and overall acceptability. These findings contribute valuable insights for the development of beetroot-based products, emphasizing the importance of selecting appropriate drying methods based on desired characteristics. The understanding presented in this study serves as a valuable resource for researchers and food technologists seeking to optimize beetroot powder production for enhanced quality and consumer acceptance.

FUTURE SCOPE

This research significantly contributes to the field by providing valuable insights into the suitability of Tray Dried Beetroot Powder and Spray Dried Beetroot Powder for 3D food printing. The enhanced properties of the spray-dried variant make it a promising choice for creating visually appealing and sensorily satisfying printed food products.

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Conflict of Interest. None.

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