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EFFECT OF PHYSICOCHEMICAL PARAMETERS ON THE QUALITY OF SPRAY-DRIED MIXED BERRY JUICE POWDER USING MALTODEXTRIN AS A CARRIER AGENT

Lad P. A.*, V. P. Kad, K. J. Kamble, S. V. Salve, G. B. Yenge, G. N. Shelke and G. M. Chavan
Department of Agricultural Process Engineering, Dr. Annasaheb Shinde College of Agricultural Engineering and Technology, MPKV, Rahuri- 413722, Ahilyanagar, Maharashtra, India.
*Corresponding Author E-Mail: Ladpranoti7@Gmail.Com
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ABSTRACT

This study investigates the physicochemical and functional properties of spray-dried mixed berry powder using maltodextrin as a carrier agent. The powder exhibited a high powder recovery rate (59.64%) and low moisture content (2.26%), ensuring good shelf stability. Functional attributes such as solubility (95.10%), dispersibility (95.32%), and wettability (93.51 s) indicate excellent reconstitution behavior. The product also demonstrated favorable flow properties with a Hausner ratio of 1.45 and Carr's Index of 31.58. Notably, the powder had high total phenolic content (246.39 g GAE/100g), total anthocyanin content (208.92 mg/100g), and antioxidant activity (64.36%), confirming its nutritional potential. The color parameters (L*, a*, b*) suggested good color retention. Overall, the findings highlight the effectiveness of maltodextrin in producing high-quality, bioactive-rich berry powders through spray drying.
Keywords: Physicochemical and functional properties, Spray-dried mixed berry powder, Maltodextrin, Raspberries, Blueberries.

Introduction

Raspberries (*Rubus idaeus*) and blueberries (*Vaccinium corymbosum*) are widely recognized for their rich content of bioactive compounds, particularly anthocyanins, flavonoids, and phenolic acids, which contribute to their potent antioxidant properties (Skrovankova *et al.*, 2015). However, the high moisture content and perishable nature of these berries limit their shelf life and pose challenges for storage and transportation (Horvitz, S. 2017). Spray drying has emerged as an effective technique to convert fruit juices into stable, easy-to-handle powders, thereby extending shelf life and facilitating incorporation into various food products (Verma and Singh, 2013).

The spray drying process involves atomizing the juice into a hot drying medium, leading to rapid moisture evaporation and formation of powder particles. The high sugar and acid content in berry juices can result in low glass transition temperatures, causing stickiness and poor powder flowability (Muzaffar *et al.*, 2018). The properties of additives for spray drying in use are critical, as it has an influence on the process parameter and physico-chemical properties of spray drying (Lee *et al.*, 2018). To address these challenges, carrier agents like maltodextrin or gum arabic are typically added to the feed solution prior to atomization. These agents help produce free-flowing powders (Ferrari *et al.*, 2012). Spray drying fruit juices offers significant economic advantages, as converting them into a powdered form decreases their volume and packaging needs, simplifies handling and transportation, and extends their shelf life (Ferrari *et al.*, 2012).

The choice of carrier agent and its concentration are pivotal in preserving the antioxidant properties of berry powders. The growing demand for functional foods enriched with natural antioxidants, understanding the interplay between spray drying parameters and the quality of berry juice powders is essential. This study aims to systematically evaluate the effects of key physicochemical parameters on the quality attributes of spray-dried mixed raspberry and blueberry juice powders using maltodextrin as a carrier agent, thereby optimizing the process for industrial applications.

Material and Methods

At the Post-Harvest Technology Center of Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, India, mixed berry juice was prepared for use in subsequent drying experiments. Fresh raspberries (*Rubus idaeus*) and blueberries (*Vaccinium*) were procured from the pune market and stored under deep freezer −18°C until further use. Juice extraction was carried out by blending the fruits using a high-speed laboratory blender. The resulting pulp was filtered through a fine mesh sieve to remove seeds and coarse particles, yielding a clarified juice.

Formulation of Mixed Berry Juice Feed Solution

For the formulation of mixed berry juice, raspberry and blueberry juices were combined in equal proportions (1:1, v/v) to produce a standardized blend. The resulting juice was immediately stored at −18°C to preserve its physicochemical properties and inhibit microbial activity prior to further processing. The total soluble solids (TSS) content of the mixed berry juice was measured at 12.13°Brix. Maltodextrin was used as a carrier agent and added at a concentration of 15% (w/w) based on the juice weight to improve drying performance and stability (Hoa *et al.*, 2018). The juice–carrier mixture was homogenized using a magnetic stirrer (Model 2MLH, Remi Sales and Engineering Ltd., Mumbai, India) at 1000 rpm for 10 minutes to ensure a uniform feed solution suitable for drying.

Spray Drying of Mixed Berry Juice

Mixed berry powder was produced using a laboratory-scale spray dryer (Model LU 222, Labultima, India). The juice–carrier feed solution was pumped into the drying chamber under optimized conditions, with an inlet temperature of 150°C, outlet temperature of 85°, and a feed flow rate of 500 mL/h. The resulting powder was collected using a cyclone separator and immediately sealed in airtight containers to prevent moisture absorption. For storage, the powder samples were vacuum-sealed in polyethylene pouches and placed in a desiccator containing silica gel at room temperature until quality evaluation. The physicochemical properties of the powder were analyzed to assess product quality. Evaluated parameters included powder yield, moisture content, bulk density, solubility, dispersibility, hygroscopicity, wettability, total phenolic content (TPC), antioxidant activity, and color characteristics.

Fig. 1 : Spray dryer

Fig. 2 : Mix berries juice Powder

Drying yield

Drying yield was calculated as the ratio of the solid mass collected from both the product collector and the main chamber of the spray dryer to the total solid mass initially fed into the system (Lee *et al.*, 2017).

Moisture content

The moisture content of the mix berries powder was calculated by using AOAC method (2005). Samples were weighed and dried in a vacuum oven at 70°C for 24 hours. Moisture content was calculated based on the difference between initial weight and final weight and expressed as percentage. The drying and weighing processes were repeated until constant weight was obtained.

$$\text{Moisture content (\%)} = \frac{\text{Initial weight final weight}}{\text{weight of sample}} \text{X100}$$

Bulk density

Bulk density was determined by transferring 20g of powder into a 100 mL graduated cylinder. The cylinder was then gently tapped by dropping it onto a rubber mat from a height of 15 cm, repeated 10 times to allow the powder to settle uniformly. Bulk density (g/cc) was calculated as the ratio of the powder mass to the final settled volume occupied in the cylinder (Do *et al.*, 2018).

$$\text{Bulk density (g/cc)} = \frac{\text{weight of sample at recorded volume (g)}}{\text{volume of sample (cc)}}$$

Tapped density

Tapped density was determined by using Tze *et al.*, 2012. After observing the initial volume, the cylinder was mechanically tapped, and volume was recorded until reached to constant volume. The tapped density is calculated by the following formula,

$$\text{Tapped density (g/cc)} = \frac{\text{Mass of powder}}{\text{Final tapped volume}}$$

Wettability

Wettability was assessed based on the method described by Ferrari *et al.* (2012), by recording the time taken for 1.0 g of powder placed on the surface of 400g of distilled water at 25°C to fully submerge.

Solubility

Solubility of the powder was determined following the method described by Santhalakshmy *et al.* (2015). One gram of powder was dispersed in 100 mL of distilled water and blended at 1550 rpm for 5 minutes. The mixture was then centrifuged at 3000 rpm for 5 minutes and left to settle undisturbed for 30 minutes. A 25 mL aliquot of the clear supernatant was transferred into pre-weighed Petri dishes and dried in a hot air oven at 105 °C for 5 hours. Solubility (%) was calculated based on the weight of the dried residue relative to the initial sample.

Dispersibility

Dispersibility was assessed using the method of Santhalakshmy *et al.* (2015). with slight modifications. One gram of powder was added to 10 mL of distilled water at 25°C in a 50 mL beaker and stirred vigorously with 25 full strokes in 15 seconds. The mixture was then passed through a 212 µm sieve, and the retained material was oven-dried at 105°C for 4 hours. Dispersibility (%) was calculated based on the recovered dry matter.

$$\text{Dispersibility (\%)} = (\frac{10+a)\times\%\,TS}{a\,x(100-b)} \times 100$$

Where a represents the weight of the powder sample (g), b is the moisture content of the powder (%), and %TS denotes the percentage of total solids in the reconstituted powder after

Hygroscopicity

Hygroscopicity was measured following the method of Kothakota *et al.* (2014) with slight modifications. Approximately 1g of powder was placed in a desiccator maintained at 25°C with a saturated NaCl solution, providing a relative humidity of 75.29%. After seven days, the samples were reweighed, and hygroscopicity was expressed as grams of moisture absorbed per 100g of dry solids (g/100g).

Hausner ratio and Carr index

Hausner ratio and Carr index was determined by Tze *et al.* (2012). Hausner ratio is a number that is correlated to the flowability of a powder or granular material. It is calculated by the formula below:

$$\text{Hausner ratio (HR)} = \frac{\rho_T}{\rho_B}$$

Carr index represents the compressibility of a powder. It is calculated by the following formula

$$\text{Carrs Index} = \frac{\rho_T - \rho_B}{\rho_B}$$

where, ρT =the tapped density; ρB =the bulk density

Total phenolic content

The total phenolic content was measured using the Folin–Ciocalteu colorimetric method, following the procedure of Do *et al.* (2018) with slight modifications. A 0.5 mL aliquot of the appropriately diluted extract was mixed with 2.5 mL of 0.2 N Folin–Ciocalteu reagent (Sigma-Aldrich, Steinheim, Germany) and allowed to react for 8 minutes. Subsequently, 2.0 mL of 7.5% sodium carbonate solution (Merck, Darmstadt, Germany) was added, and the mixture was incubated at room temperature (25 °C) for 30 minutes. The absorbance was then recorded at 760 nm using a UV–Visible spectrophotometer (Genesys 10S, Thermo Scientific, Madison, WI, USA). A standard calibration curve was prepared using gallic acid (0–50 µg/mL), and the TPC results were expressed as milligrams of gallic acid equivalents per gram of dry weight (mg GAE/g DW).

Color

The color of the spray-dried mix berries juice powder was measured by using Color meter Ferriari *et al.*, (2012). L* values shows (light\dark), a*values shows (red\green) and b*shows (yellow\blue) value were obtained.

Result and Discussion

Powder Recovery

Table 1. showed the powder recovery of mix berries juice powder was reported at 59.64%, which

often show a slightly wider recovery range, typically 51% to 75%, depending on drying conditions and carrier type. This variability is due to differences in the feed composition and drying parameters like inlet temperature and feed flow rate, which influence particle formation and adhesion losses. Maltodextrin is commonly used as a carrier to improve powder recovery by reducing stickiness due to sugars and acids in berries. Tonon *et al.* (2008) and Kha *et al.* (2010) observed similar recovery percentages for fruit powders using maltodextrin carriers.

Table 1 : Physico chemical properties of mix berry juice powder.

Characteristics	Treatment (Maltodextrin)
Powder Recovery. (%)	59.64±0.032
Moisture Content, (%)	2.26±0.036
Bulk Density, g/cc	0.31±0.010
Tapped Density, g/cc	0.45±0.015
Solubility, (%)	95.10±0.046
Wettability, s	93.51±0.017
Hygroscopicity,g/100g	23.18±0.042
Dispersibility, %	95.32±0.015
Hausner Ratio	1.45±0.015
Carr's Index	31.58±0.006
TPC, g GAE/100g	246.39±0.290
TAC (mg/100g)	208.92±0.029
AA, (%)	64.36±0.335
L* value	69.439±0.059 ^{c}
a* value	17.138±0.054
b* value	-2.062±0.032

Moisture Content

Moisture content plays a critical role in determining the quality of spray-dried powders, as it directly reflects the efficiency of the drying process. Additionally, a lower moisture level minimizes water's role as a plasticizer, thereby helping to maintain a higher glass transition temperature and enhancing the powder's stability (Ferrari *et al.*, 2012). The value of moisture content of spray dried mix berries juice powder was found 2.26% shown in Table 1. The results were within the desirable range for powders, promoting extended shelf life (Kothakota *et al.*, 2014). Spray-dried berry powders usually have moisture content between 2% and 4.5%, ensuring microbiological stability and shelf life (Mahdavi *et al.*, 2016). Moisture content affects powder flowability and reconstitution. Maltodextrin helps to reduce moisture by encapsulating the juice solids, protecting them from moisture absorption.

Bulk Density (g/cc)

Bulk density of mix berries juice powders was found 0.31±0.010 g/cc. indicated in Table 1. influenced by particle size and morphology. Higher bulk density powders occupy less volume, advantageous for packaging and transport (Mahdavi *et al.*, 2016). Maltodextrin addition generally increases bulk density by forming larger and more compact particles. Bulk density indicates the packaging and handling characteristics of the powder. Higher bulk density indicates a lower amount of air presented in the powder, which can help to prevent lipid oxidation during storage (Mahdi *et al.*, 2020).

Tapped Density (g/cc)

True density corresponds to the real solid density and does not consider the spaces between particles (Bhusari *et al.*, 2014). Tapped density of powders is an important factor influencing their packaging, transport, and sale, as it represents the mass of powder that can occupy a given container volume. Producing spray-dried powders with higher tapped density is beneficial because it allows for the use of smaller storage containers (Mahdi *et al.*, 2020). The value of tapped density was shown in Table 1. The value of tapped density of mix berries juice powder was found 0.45g/cc. Tapped density is higher than bulk density due to powder compaction. The gap between these values is used to calculate flow indices like Carr's Index and Hausner Ratio, which help assess flowability (Kothakota *et al.*, 2014)

Solubility (%)

Solubility is a critical functional property of spray-dried powders, reflecting how easily the powder dissolves in a solvent (Ali *et al.*, 2020). It can be seen from Table 1.the value of solubility of mix berries juice powder 95.10% indicates good reconstitution behavior, supported by maltodextrin's role in forming a porous matrix that facilitates rapid dissolution (Jaya & Das, 2004). The higher the solubility, the better the quality products. This high solubility is often attributed to the use of maltodextrin as a carrier agent, which is highly water-soluble due to its low molecular weight and hydrophilic nature. Good solubility also enhances the powder's usability in instant formulations and improves consumer acceptability by reducing lump formation (Ali *et al.*, 2020).

Wettability (s)

Wettability reflects the initial hydration of the powder on water contact. Table 1. shows the values of wettability of mix berries juice powder and was found 93.51 seconds. It is relatively high. It is directly affected by the molecular interactions between the two phases Sarabandi *et al*., 2014.

Hygroscopicity (g/100g)

Hygroscopicity refers to a material's tendency to absorb moisture when exposed to environments with high relative humidity (Kothakota *et al*.,2014). In general, a powder is considered to be of good quality when it exhibits low hygroscopicity, minimal moisture content, reduced caking tendency, and high solubility (Bhusari *et al*., 2014). Hygroscopicity indicates the powder's tendency to absorb moisture. A value of hygroscopicity was observed 23.18 g/100g given in Table 1. Suggests that the powder is highly moisture-sensitive and requires controlled humidity conditions during storage. Maltodextrin helps reduce hygroscopicity due to its low affinity for water Ferrari *et al*., (2012).

Dispersibility (%)

High dispersibility implies that the powder can be easily mixed with water without forming lumps. This is essential for consumer satisfaction, especially in instant beverage formulations (Kothakota *et al*., 2014). Table 1. indicates the value of dispersibility of mix berries juice powder using maltodextrin as carrier agent. The value of dispersibility was found 95.32%.

Flowability

Flowability is a key characteristic of dried powders and is commonly evaluated using the Carr Index (CI). A higher Carr Index value signifies lower flowability, meaning the powder is more likely to resist smooth and free movement Santhalakshmy (*et al*., 2015). The Hausner Ratio provides insight into powder flowability. The observed value of Hausner ratio and Carr index given in the Table 1. The Hausner ratio of spray dried mix berries powder was found 1.45. A value above 1.25 indicates poor flow, which may be due to fine particle size and cohesive forces among particles (Carr, 1965). Carr's Index corroborates flowability issues when values exceed 25%. The Carr index was found 31.58% suggests limited flow, common in fine, hygroscopic dairy powders (Jaya & Das, 2004).

Total Phenolic Content (g GAE/100g)

Phenolic compounds are natural substances found in plants that act as powerful antioxidants and offer several health benefits. Because of their strong antioxidant effects, researchers often measure both the total phenolic content and antioxidant activity when studying the antioxidant properties of foods or plant-based products (Bhusari *et al*., 2014). The value of TPC was observed (246.39 g GAE/100g) shown in Table 1. The spray-dried powder suggests excellent retention of phenolic antioxidants from the original fruit or juice, reflecting optimized processing conditions. High TPC indicates good retention of bioactive compounds. Although some phenolics are sensitive to heat, spray drying with maltodextrin preserves these compounds by encapsulation (Bains *et al*., 2013).

Antioxidant Activity (%)

Antioxidant activity reflects the actual radical scavenging potential of retained phenolics. Antioxidant activity reflects the powder's ability to scavenge or neutralize free radicals, which are harmful to cells and contribute to aging and disease. Table 1. shows the values of antioxidant activity. The value of AA was found 64.36%, implies strong protective effects and is a desirable trait in functional foods and nutraceuticals. This property is typically correlated with high TPC and TAC values. (Tonon *et al*., 2008).

Color

Color is one of the important quality attributes as it reflects the sensory attractiveness and the quality of powders. The L* value indicates the powder's lightness. Higher values are associated with a whiter appearance, which is often preferred in dairy-based products (Sharma *et al*., 2012). A positive a* value denotes redness, which might arise due to Maillard browning during drying or pigment concentration. This is typical for fermented and protein-rich products undergoing thermal treatment (Kothakota *et al*., 2014). The negative b* value indicates a bluish tint, possibly due to protein interactions and drying effects. Such a shift is minor and does not impact consumer acceptability (Tonon *et al*., 2008). The value of L* a* and b* was illustrate in the Table 1. The L* a* and b* value was observed 69.439, 17.138 and -2.062 respectively.

Conclusion

The use of maltodextrin as a carrier in spray drying of mixed berry juice yielded a powder with excellent physical, functional, and nutritional properties. The high solubility and dispersibility make it ideal for instant beverage applications, while low moisture content and favorable flow indices support good storage stability. The significant presence of phenolics and strong antioxidant activity, enhances the functional value of the powder. These results suggest that maltodextrin-based spray drying is a promising technique for producing stable and nutritionally rich fruit powders suitable for food and nutraceutical industries.

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