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Effect of maltodextrin concentration and inlet air temperature on physical and reconstitution properties of spray dried fig (*Ficus carica*) powder

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Abstract
This study explored the impact of maltodextrin and inlet air temperature on the properties of spray dried fig pulp powder, identifying optimal conditions for production in terms of yield, physical and reconstitution properties. In this research, the focus was on understanding how two factors, maltodextrin (5%, 7.5% and 10.0%) and inlet temperature (140, 160 and 180 °C) of the air entering the spray dryer, affected the properties of spray dried fig pulp powder. The highest powder yield of 70.66% spray dried fig powder was obtained for 10% maltodextrin concentration and an inlet air temperature of 180 °C in the spray dryer. The best handling properties *i.e.*, flowability (Carr's index of 10.86 and Hausner ratio of 1.12) were optimized in 10% maltodextrin concentration at 180 °C spray dryer inlet air temperature. This combination resulted in favourable reconstitution properties of the fig powder, such as high solubility (96.05%), wettability (307.28 s) and dispersibility (84.93%).

Keywords: Maltodextrin concentration, inlet air temperature, spray dried fig, *Ficus carica*, powder

Introduction
The fig fruit (*Ficus carica* L.) has a rich historical background, with cultivation dating back to 3000-2000 BC in the Mediterranean region (Marpudi *et al.*, 2013) [13]. This nutritious fruit is packed with fiber, potassium, calcium, and iron, surpassing other fruits like apples, grapes, and strawberries in terms of nutritional content. However, fresh figs have a short shelf life due to their high metabolic activity and susceptibility to pathogen development. When harvested at full ripeness during the end of summer, fresh figs can only last for about two days under ambient temperatures (Hung *et al.*, 2011) [17]. The high fructose and glucose content of figs makes them suitable for natural sweeteners in food formulations. Damaged and deformed figs, which are not suitable for fresh consumption, find application in the industry as they can be converted into fig extract and fig powder. It is crucial to select extraction conditions that minimize heat damage to the nutrients and prevent temperature-dependent adverse reactions such as the Maillard reaction (Barbosa-Canovas and Juliano, 2005) [4]. The spray drying technique can also be utilized for fig extract, as it acts as a form of encapsulation, allowing for the production of healthy food products (Encina *et al.*, 2016) [8]. By converting fig extract into a powder, its storage stability is enhanced, enabling easier handling, transportation, and utilization in a variety of food applications. Overall, the ancient fig fruit holds great nutritional value and is prone to rapid deterioration. Due to existing challenges and lack of documents in the field of fig powder production as well as presence of strong demand for turning the ripened fig fruits into high value products, the spray drying can be a solution to this problem. This process preserves the nutritional integrity of figs while providing a versatile ingredient for the production of healthy and flavorful food products.

Materials and Methods
Materials
Fresh fig fruits (Turkey brown variety) were procured from the local market (Raichur, Karnataka, India) and stored in refrigerator until required for the experiment. The fully ripened fig fruits were selected for the development of spray dried powder. The maltodextrin used had a Dextrose Equivalent (DE) of 18–20, with a molecular weight of 1925±96 $g.mol^{-1}$.

Methods

Preparation of fig pulp

The fully ripened fig fruits were selected for the development of spray dried powder. The fruits were thoroughly washed with plain water to remove any adhering dust and dirt and subjected to a fruit mill to obtain the pulp. The obtained fruit pulp was mixed with water at the ratio of 1:1.5 and stored at 5 °C for 24 hours. After 24 hours, the pulp was sieved using mesh strainer and muslin cloth. The strained fig fruit pulp was further used for spray drying.

Spray drying of fig pulp

The spray dryer used was a pilot model of vertical co-current type (SMST- tall type, Science tech, Kolkata, India) with a water evaporating capacity of 1000 $mL.h^{-1}$ equipped with a rotary wheel atomizer operated at 18000 rpm and atomization flow of 2 $kg.cm^{-2}$. The spray drying of fig pulp was carried out using maltodextrin as an encapsulating agent at different concentrations (5%, 7.5% and 10.0%). Two to three drops of Tween-80 were also added to enhance the emulsifying and film forming properties. The resultant solution was mixed in a shear homogenizer for 5 minutes at 1500 rpm. The mixture was fed to spray dryer at a feed rate of 5 $mL.min^{-1}$ at different inlet air temperatures (140, 160 and 180 °C) and outlet temperature of 80 °C. The hot air was supplied to provide the latent heat for evaporation of water and consequently led to the formation of microcapsules. The spray dried powder was collected from the collecting chamber were then filled in PET pouches, sealed air tight and stored at refrigerated condition at 4 °C.

Analysis of spray dried powder properties

Powder yield

The powder yield of spray dried fig powder was determined as the mass percentage of final product compared to the mass of total solids measured in the feed solution (Sarabandi *et al*. 2019) [15].

Moisture content

The moisture content of spray dried fig powder was determined by following AOAC (2005, Method No. 945.43) using hot air oven (Kemi, KOS.6FD, Perumbavoor, India). Three grams of powder was kept in a pre-dried moisture box. The mass of the sample was recorded as W_1. The box was placed in hot air oven maintained at 100±2 °C for 8 h. After drying, the box was kept in the desiccator and then weighed. The mass of the dried sample was recorded as W_2. The moisture content of the sample was calculated by using the following equation (Wankhade *et al.*, 2012) [15].

$$\text{Moisture content (\% d.b.)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,
W_1 = Initial weight of sample, g
W_2 = Final weight of sample, g

Water activity

The water activity of spray dried fig powder was measured by Rotronic Hygrolab water activity analyzer (a_w-HP23, Bengaluru, India). Before measuring the water activity of powder, the instrument was tested for its accuracy to minimize the error by measuring the water activity of the distilled water. If the water activity for distilled water recorded one, then the instrument was said to be calibrated. The sample under test was kept in sample cup (2 g of sample) which was provided with water activity meter. The sensor was placed on the sample cup by firmly closing in such a way that the air should not enter into the sample cup. The reading was directly displayed on the water activity meter and was taken as water activity of the sample.

Colour values

The colour values of the spray dried fig powder were measured by $L*$, $a*$ and $b*$ indices using Hunter's lab colourimeter (Premier colourscan, Colour Flex EZ; Mumbai, India) and using CIELAB scale at 10° observer with D_{65} illuminant. Ten grams of sample was taken in a cylindrical glass sample cup (6.35 cm dia. × 4 cm deep) and placed at the light port (3.175 cm dia.). The colour values of $L*$, $a*$ and $b*$ were observed and recorded.

Bulk density

The bulk density (loose and tapped bulk density) of spray dried fig powder was measured using the procedure described by Al-Kahtani and Hassan (1990) [2]. Approximately,
1 g of spray dried fig powder was freely poured into a 5 mL glass graduated cylinder (readable at 1 mL) without tapping and disturbance, and this was measured as loose bulk density ($g.ml^{-1}$) and the same sample was repeatedly tapped manually by lifting and dropping the cylinder under its own weight to measure tapped bulk density ($g.ml^{-1}$).

$$\text{Loose bulk denisty } (g.cc^{-1}) = \frac{\text{Weight of powder } (g)}{\text{Bulk powder volume (cc)}}$$

$$\text{Tapped bulk denisty } (g.cc^{-1}) = \frac{\text{Weight of powder } (g)}{\text{Tapped powder volume (cc)}}$$

Flowability and Cohesiveness

The spray dried fig powders were evaluated for their flowability and cohesiveness in terms of Carr's index (CI) and Hausner ratio (HR), respectively according to formula based on loose and tapped bulk density.

$$\text{Carr's Index (\%)} = \frac{\text{Tapped bulk density}(g.cc^{-1}) - \text{Loose bulk density}(g.cc^{-1})}{\text{Tapped bulk density}(g.cc^{-1})} \times 100$$

$$\text{Hausner ratio} = \frac{\text{Tapped bulk density } (g.cc^{-1})}{\text{Loose bulk density } (g.cc^{-1})}$$

Reconstitution properties of spray dried fig powder

Solubility

The solubility of the microencapsulated powder was assessed using the method described by Al-Kahtani and Hassan (1990) [2]. 1 gram of the spray dried powder was placed in a 50 mL beaker, and 10 mL of distilled water at a temperature of 30±2 °C was added. The suspension was intermittently stirred for 30 minutes and then centrifuged at 9000 rpm for 10 minutes. The supernatant was carefully transferred into an evaporating dish and dried in a hot air oven at 105±2 °C for 4 hours. This drying and weighing process was repeated until a constant weight was achieved. The samples were then removed from the oven, cooled in a desiccator, and weighed. The determination of solubility was performed three times for the spray dried powder, and the average value obtained from these measurements was considered as the solubility of the spray dried powder.

$$\text{Solubility (\%)} = \frac{m_2}{m_1} \times 100$$

Where,
m_1 = Initial weight of sample, g
m_2 = Final weight of sample, g

Wettability
The wettability is characterized as the rehydration ability of a powder in water. The capacity of the microcapsules to mix with water is one of the most important reconstitution properties. Wettability of the microencapsulated powder was determined. The powder samples (0.1 g) were sprinkled over the surface of 100 mL of distilled water at 20 °C (water bath) in a 200 mL beaker without agitation. The time it took until the last powder particles submerged was recorded and used for a relative comparison of the extent of wettability between the samples.

Dispersibility
Dispersibility is the ability to disperse in water by gentle stirring. This means the microencapsulated powder should integrate into single primary particles. The dispersibility of microencapsulated powder was measured according to the method reported by (Jaya and Das, 2004; Fonseca *et al*., 2011) [12, 19]. One gram of microencapsulated powder was stirred with 10 mL of water at 30±2 °C in 50 mL beaker. Stirring was carried out to make 25 complete back and forth movements across the whole diameter of the beaker for 15 s. The reconstituted microencapsulated powder was then poured through the sieve of 150 µ size (Taylor series 100 mesh). The dry matter of the filtered spray dried powder was estimated by measuring its moisture content using an oven at 105 °C for 7 h (Santhalakshmy *et al*., 2015) [14]. Determination of dispersibility was carried out thrice for spray dried powder and the average value was considered for dispersibility of spray dried powder.

$$\text{Dispersibility (\%)} = \frac{(w + a)S_p}{aS_j}$$

Where,
a = Amount of powder used, g
w = Weight of water taken for reconstitution, g
S_p = Total solid present in encapsulated powder, %
S_j = Dry matter present in encapsulated powder after it has been passed through the sieve, %

Statistical Analysis
In the study, all experiments were conducted in triplicate, and the mean values were recorded. Factorial completely randomized design (FCRD) was employed to analyze the data. Analysis of variance (ANOVA) was performed to determine the statistical significance of the terms in the quadratic equation for each response variable. The experimental design was facilitated using the design-expert software. Thirteen responses, including powder yield, moisture content, colour values (*L*, a*, b**), water activity, bulk density, Carr's index, Hausner ratio, solubility, wettability, and dispersibility, were selected as dependent variables. The experiments were randomized, and statistical significance was assessed with a confidence level of 95%.

Results and Conclusions
Powder Yield
The findings demonstrated a positive correlation between powder yield and both maltodextrin concentration and inlet air temperature. The peak powder yield of 70.66% was achieved with a maltodextrin concentration of 10% and an inlet air temperature of 180 °C, while the lowest yield of 54.32% was recorded with 5% maltodextrin concentration at an inlet air temperature of 140 °C. This outcome could be attributed to the higher maltodextrin content in the feed, which potentially enhanced powder recovery, as observed in previous studies by Shrestha *et al*. (2007) [20], and Sharifi *et al*. (2015) [21]. Furthermore, the elevation of inlet air temperature seemed to contribute to improved heat and mass transfer efficiency, facilitating quicker water removal and reducing particle adhesion to the dryer walls. This effect aligns with similar observations made by Tonon *et al*. (2008) [16] and Tolun *et al*. (2016) [22], who investigated the spray-drying of acai and grape polyphenol, respectively.

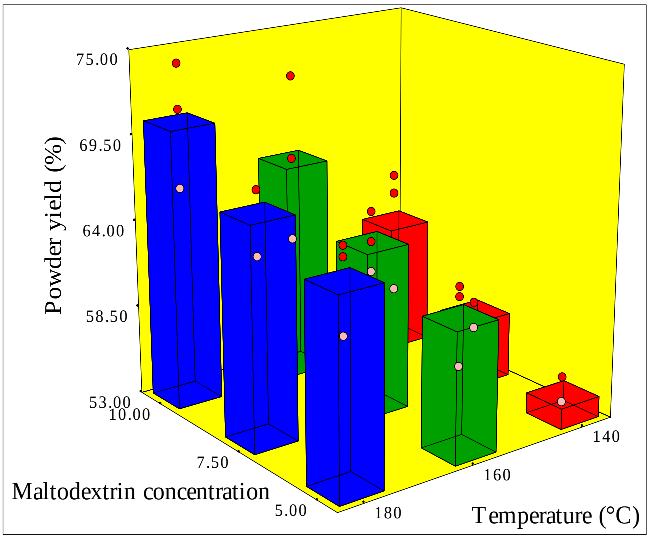
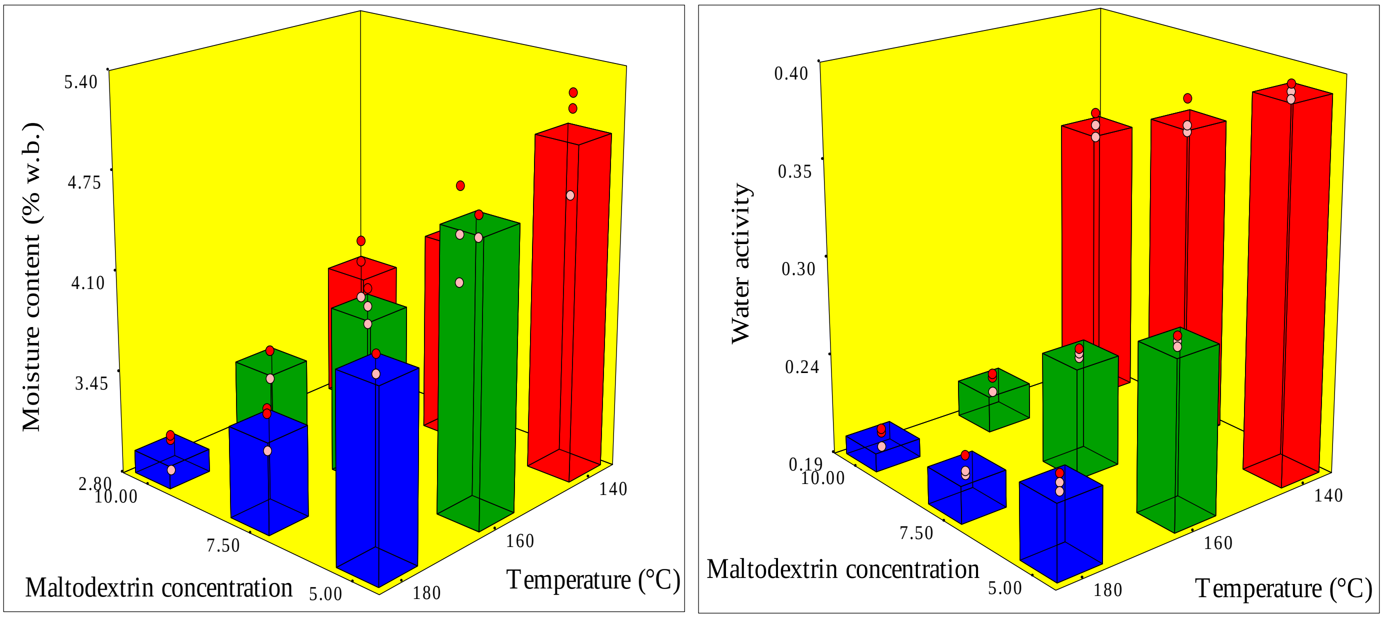


Fig 1: Effect of maltodextrin concentrations and inlet air temperatures on powder yield of spray dried fig powder

Moisture content
The results revealed a direct relationship between powder yield and both maltodextrin concentration and inlet air temperature. The highest powder yield, reaching 70.66%, was attained when using a maltodextrin concentration of 10% and an inlet air temperature of 180 °C. Conversely, the lowest yield of 54.32% was observed with 5% maltodextrin concentration at an inlet air temperature of 140 °C. This outcome could be attributed to the greater maltodextrin content in the feed, which is known to enhance powder recovery, a phenomenon supported by prior research conducted by Shrestha *et al*. (2007) [20], and Sharifi *et al*. (2015) [21]. Moreover, the elevation of the inlet air temperature seemed to foster improved heat and mass transfer efficiency, leading to faster water removal and reduced particle adhesion to the dryer walls. This trend aligns with similar observations made by Tonon *et al*. (2008) [16] and Tolun *et al*. (2016) [22], whose investigations focused on the spray-drying of acai and grape polyphenols, respectively.

Water activity

It was noticed that the water activity was found lowest using higher maltodextrin concentrations. This might be due to the ability of maltodextrin to reduce reactant mobility. Moreover, adding maltodextrin might prevent the change of the state from powder to a 'Sorption gel' (Chronakis, 1998) [6].

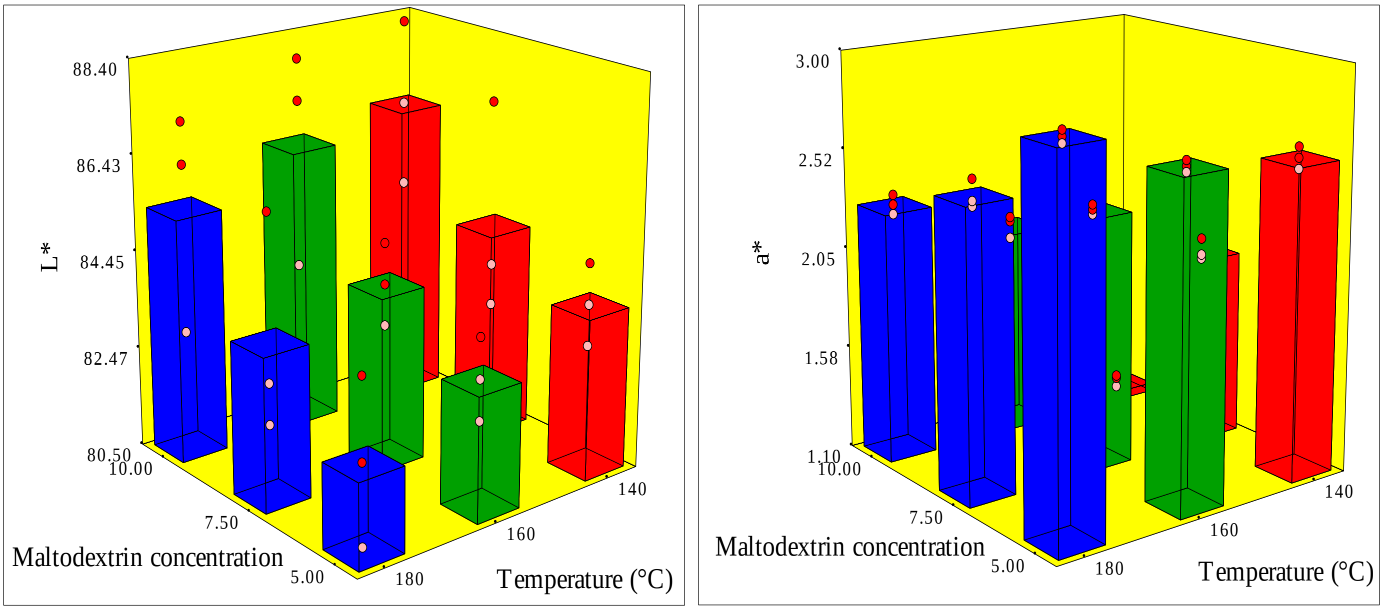


A) B)

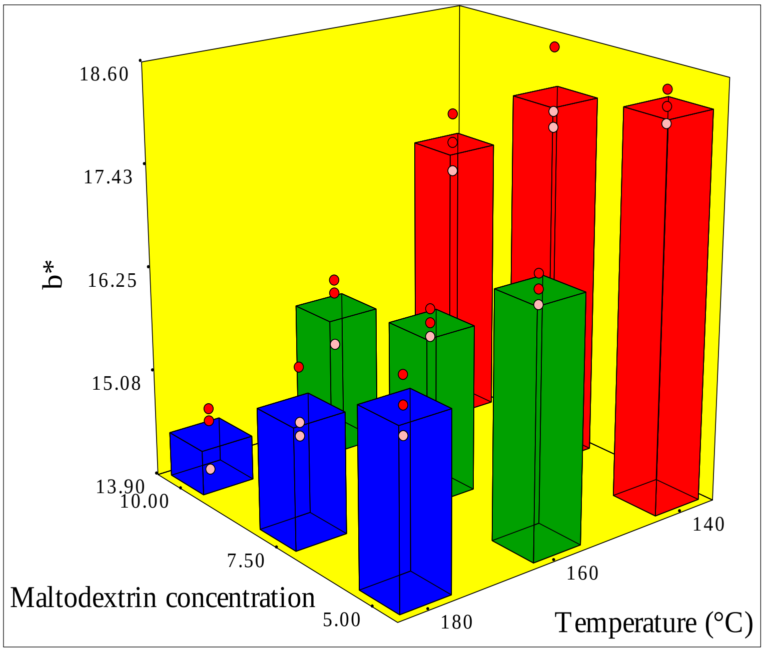
Fig 2: Effect of maltodextrin concentrations and inlet air temperatures on (a) moisture content and (b) water activity of spray dried fig powder

Colour values

It was observed from fig.3 (a) that increase in the inlet air temperature (140 to 180 °C) resulted decrease in *L** value of the spray dried fig powder. This implies that the colour of the powder became little darker at higher drying temperature. It might be because of non-enzymatic browning during spray drying. It was observed that increase in the inlet air temperature resulted in increase in *a** value during spray drying. This might be due to higher *a** value in the lower concentration of Maltodextrin. From the fig.3 (c), it was observed that increase in the inlet air temperature resulted in decrease in *b** value of the encapsulated powder. This might have been due to the degradation of colour of the spray dried samples at higher temperature.



A) B)

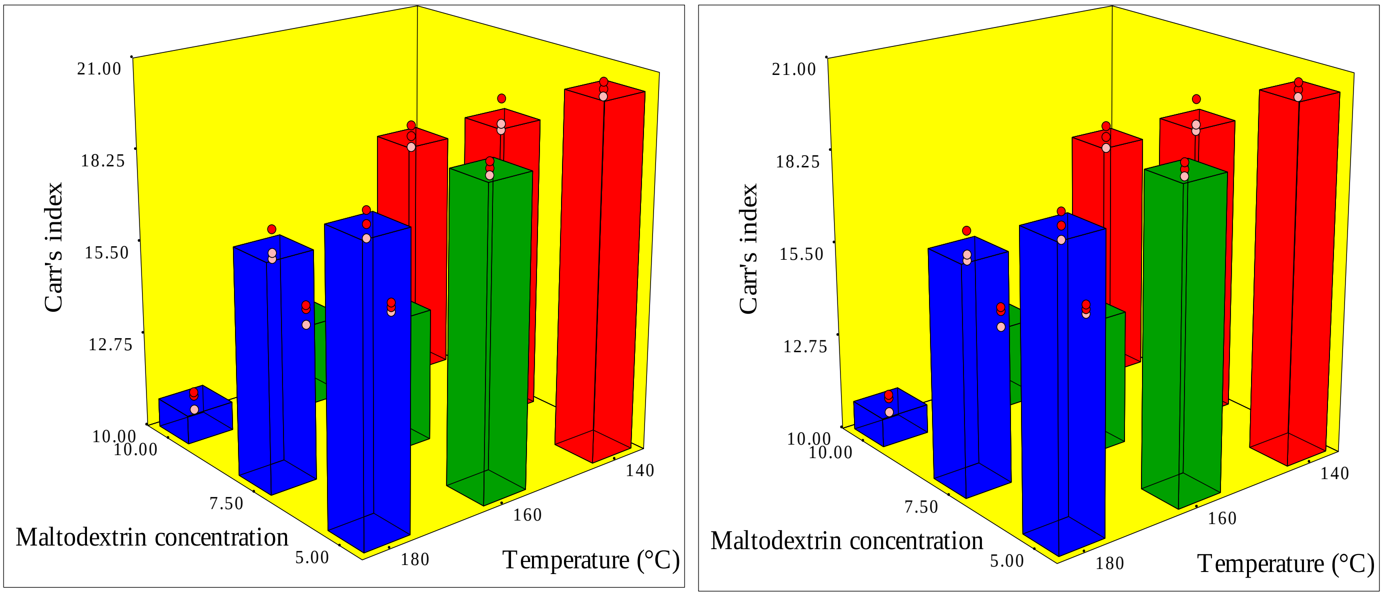


C)

Fig 3: Effect of maltodextrin concentrations and inlet air temperatures on (a) *L** value, (b) *a** value and (c) *b** value of spray dried fig powder

Flowability and Cohesiveness

The data revealed that the most elevated Carr's index value of 20.46 was registered when employing 5% maltodextrin at an inlet air temperature of 140 °C. In contrast, the lowest Carr's index value of 10.86 was observed when 10% maltodextrin was used as the coating material, coupled with an inlet air temperature of 180 °C. A higher Carr's index value typically implies inadequate flowability (Santhalakshmy *et al.*, 2015) [14]. Furthermore, a noticeable trend emerged: an increase in the inlet air temperature led to a reduction in both the Carr's index and the Hausner ratio of the spray-dried powder. This phenomenon could be explained by the fact that higher inlet air temperature enhances the driving force for moisture elimination, thereby accelerating the rate of heat transfer from the hot air to the particles (Goula and Adamopoulos, 2008; Asun *et al.*, 2016) [10, 3].

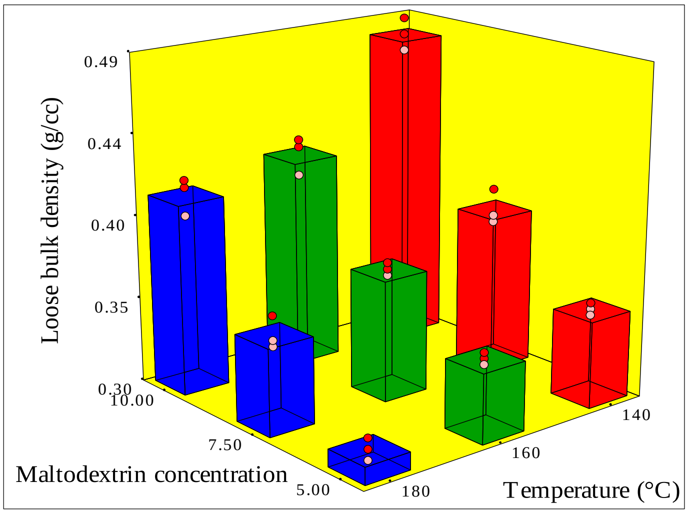


A) B)

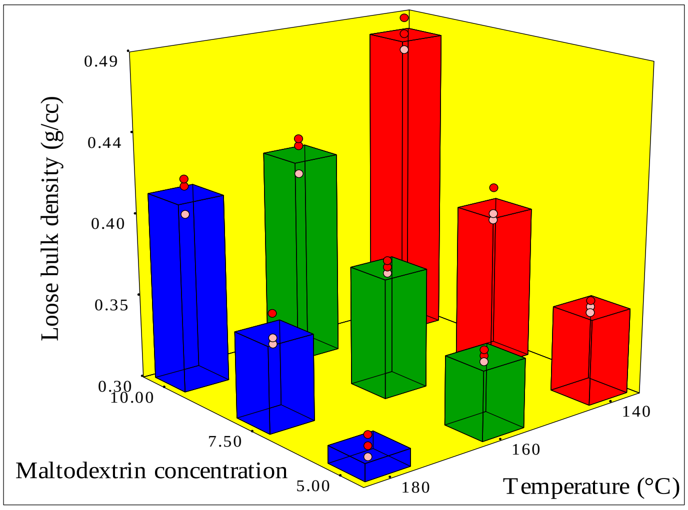
Fig 4: Effect of maltodextrin concentrations and inlet air temperatures on (a) Carr's index (b) Hausner ratio of spray dried fig powder

Bulk Density

From the studies, it was noticed that the loose bulk density and tapped bulk density was found lowest using 5% maltodextrin concentration. This effect might be attributed to the fact that maltodextrin addition minimizes thermoplastic particles from sticking. In addition, maltodextrin may cause an increase in the volume of air trapped in the particles, as maltodextrin is a skin-forming material. Generally, an increase in the volume of trapped air causes a decrease in the apparent density of the particles and this apparent density primarily determines the powder bulk density (Goula and Adamopoulos, 2010) [10].



A)



B)

Fig 5: Effect of maltodextrin concentrations and inlet air temperatures on (a) loose bulk density and (b) tapped bulk density of spray dried fig powder

Reconstitution properties of spray dried fig powder

The effect of spray drying processing conditions *viz.*, concentrations of coating materials (5.00, 7.50 and 10.00%) and inlet air temperature (140, 160 and 180 °C) on reconstitution properties is shown in the table 1.

Table 1: Effect of coating materials and spray dryer inlet air temperatures on reconstitution properties of spray dried fig powder

Maltodextrin concentration (%)	Inlet air temperature (°C)	Solubility (%)	Wettability (s)	Dispersibility (%)
5.00	140	85.72	267.21	77.73
5.00	160	87.44	282.52	78.26
5.00	180	89.78	289.18	79.05
7.50	140	90.72	278.43	80.78
7.50	160	91.56	291.26	82.19
7.50	180	92.13	298.33	83.32
10.00	140	93.09	284.48	84.21
10.00	160	93.67	304.51	84.65
10.00	180	96.05	307.28	84.93
S.D		1.95	6.38	1.75
Mean		91.13	289.24	81.68
R^2		0.80	0.85	0.79
CD @ 1%		2.15	2.20	2.14

Solubility: It was observed that, increase in the inlet air temperature results in increase in solubility of the encapsulated powder. This was due to the effect of inlet air temperature on residual moisture content. The lower the powder moisture content, the more soluble is the powder. In addition, increasing the drying air temperature generally produces an increase in particle size, and so, a decrease in time required for the powder to dissolve (Goula and Adamopoulos, 2008) [10].

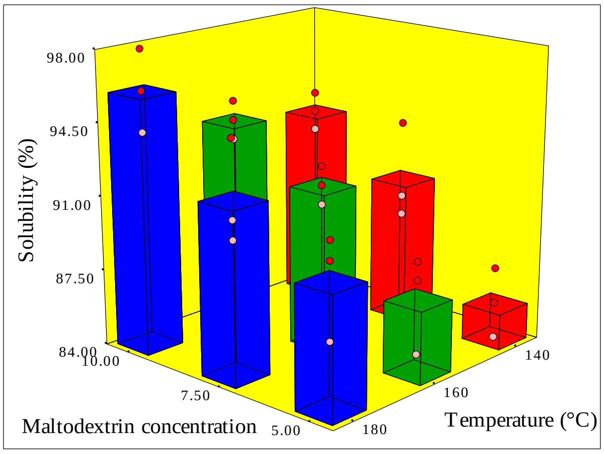


Fig 6: Effect of maltodextrin concentrations and inlet air temperatures on solubility of spray dried fig powder

Wettability

With the increase in inlet air temperature, wettability time was found to decrease which could be attributed to the decreased moisture content of the product that the powder absorbs water and wet the surface fast. It might also be due to porous structure and lower particle size of the powder (Chegini and Ghobadian, 2005) [5].

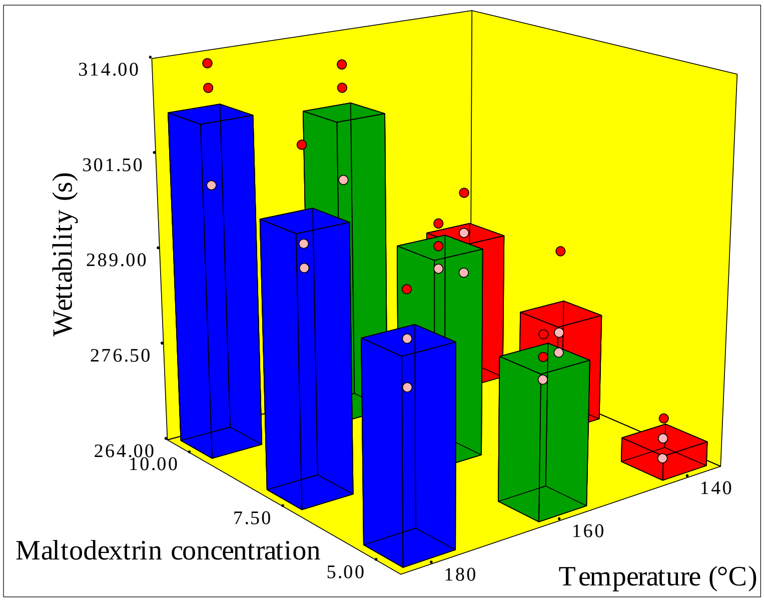


Fig 7: Effect of maltodextrin concentrations and inlet air temperatures on wettability of spray dried fig powder

Dispersibility

From the results, it was observed that increase in the inlet air temperature results in increased in dispersibility of the spray dried powder. The higher temperature gave a better porous structure after drying, generally as a result of a significantly reduced processing time. This has been shown to improve the reconstitution properties of food products (Ekpong *et al.*, 2016) [7].

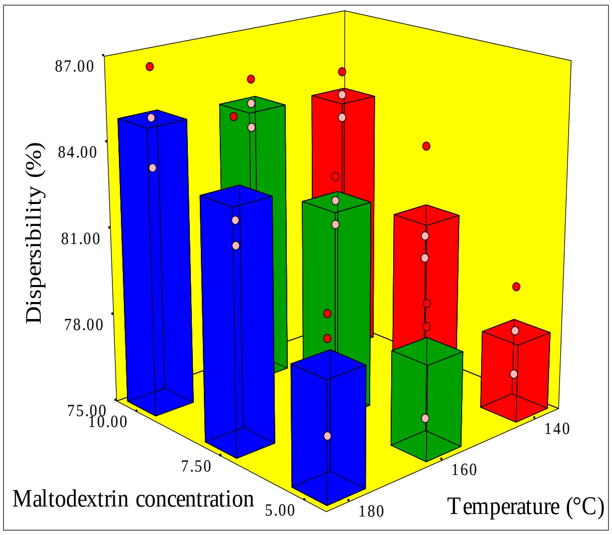


Fig 8: Effect of maltodextrin concentrations and inlet air temperatures on dispersibility of spray dried fig powder

Conclusions

The present investigation concludes that the inlet temperature of spray dryer 180 °C gave highest powder yield as compared to other temperatures and had significant effects on physicochemical properties. Addition of maltodextrin improved the solubility of spray dried fig powder. The best processing conditions for the powder production and colour characteristics used an inlet temperature of 180 °C and 10% maltodextrin concentration. The results obtained during the present investigation indicate that good quality powders with optimum moisture content and water activity can be produced by spray drying, which demonstrates the great potential for the use of such powders in the food industry.

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