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Production of spray dried jackfruit powder from enzymatic liquefied juice

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Abstract
This paper presents the enzymatic liquefaction process for jackfruit optimized with Pectinase. Spray drying process was carried out using different inlet temperatures (160-180 °C) and maltodextrin concentrations (15-25% w/w). Results indicated that the spray dried jackfruit powder produced at Jackfruit powder obtained at 180 °C inlet temperature and 25 per cent maltodextrin (T_9) recorded minimum moisture content, hygroscopicity in the fresh powder and also recorded highest solubility, recovery, carbohydrate and fat content. Desired flow property *viz.*, bulk density, tapped density, HR and CI were recorded in the 160 °C inlet temperature and 15 per cent maltodextrin (T_1) treatment combination.

Keywords: Jackfruit, enzymatic liquefaction, spray drying

1. Introduction
The Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the Moraceae family and consists of three parts: bulbs (32%), seeds (18%), and rind (50 per cent). The Western Ghats of southern India, Sri Lanka, and the rainforests of Malaysia, Indonesia, and the Philippines are where it originated. The jackfruit is the national fruit of Bangladesh and Sri Lanka, as well as the state fruit of Kerala and Tamil Nadu in India. Because it is cheap and plentiful during the season, the jackfruit plant is often referred to as "poor man's food."

India is the world's second-largest producer of the fruit and is known as the "Motherland of Jackfruit." The total area under jackfruit cultivation in India is approximately 1,02,552 ha, with an estimated 1,00,000 trees grown as an intercrop in other commercial crops (betel nut, coffee, pepper, and cardamom plantations) and in back yards throughout the country. It is widely farmed in Kerala state in India, and it was once thought to be a divine fruit. It is planted on 97,536 ha and produces 348 million fruits each year, with a productivity of 3,568 fruits per ha. It is grown all year in Karnataka, with a total planted area of 6,777 ha, a production of 2,31,568 tonnes, and a value of Rs. 6,951 (in lakh) every year.

The jackfruit tree thrives in tropical lowlands and is commonly farmed throughout the world's tropical regions. It produces the largest fruit of any tree, weighing up to 55 kilogrammes, measuring 90 centimetres in length and 50 centimetres in diameter. A mature jack tree bears about 200 fruits per year, with older trees giving up to 500 per year (Alagiapillai *et al.*, 1996) [3]. The fleshy petals of the immature fruit are eaten, and the jackfruit is a numerous fruit made of hundreds to thousands of separate blossoms.

The ripe jackfruit has a moisture level of 72.0 - 94.0 per cent. On a dry matter basis, the fat and ash contents were 0.3 per cent and 2.70 per cent, respectively. Carbohydrates (16-25.4 g/100 g), protein (1.2-1.9 g/100 g), and fat (0.1-0.4 g/100 g) are all present. The calculated calorific value was 382.79 kcal/100 g. Iron (0.5-1.1 mg/100 g), calcium (20-37 mg/100 g), sodium (2-41 mg/100 g), and manganese (27 mg/100 g) were all present in significant amounts in the ripe jackfruit. The titratable acidity and pH readings were 1.12 per cent and 5.78 respectively. The jackfruit seed flour has a high water absorption capacity (25 per cent), bulk density (0.80 g/cm^3), and fat absorption capacity (17.0 per cent) (Ranasinghe *et al.*, 2019) [22].

The therapeutic qualities of jackfruit are extensive. Vitamin A and flavonoid pigments such as xanthin, carotene-ß, cryptoxanthin, and lutein are found in modest concentrations in the fresh fruit. These chemicals are important in the antioxidant and visual processes of the body. Jackfruit is a strong source of antioxidant vitamin C, with 13.7 mg (or 23 per cent of the RDA) per serving (Mukprasirt and Sajjaanantakul, 2004) [17]. It's an uncommon fruit that's high in vitamins from the B-complex family. It is high in pyridoxine (vitamin B-6), riboflavin, niacin, and folic acid.

Spray drying is a method in which the liquid feed is atomized and pumped into the drying chamber. A stream of hot gas catches the droplets inside the drying chamber and transports them from the drying chamber to the product recovery system. Evaporation occurs in a matter of seconds when the relatively cool droplets come into contact with the heated gas (Krishnaiah *et al.*, 2014) [14]. Because of the low product temperature and quick drying time, spray drying is a good choice for heat-sensitive items like meals, dairy products, and fruit and vegetable juices (Roustapour *et al.*, 2009) [24].
Encapsulation of jackfruit powder has a higher potential for capturing thermo-sensitive bioactive chemicals. Furthermore, they take up less storage and transit space. Shelf-stable items that can be utilised in a variety of food preparations are achieved by reducing moisture content, water activity (a_w), and enzyme reactions (Roustapour *et al.*, 2009) [24].

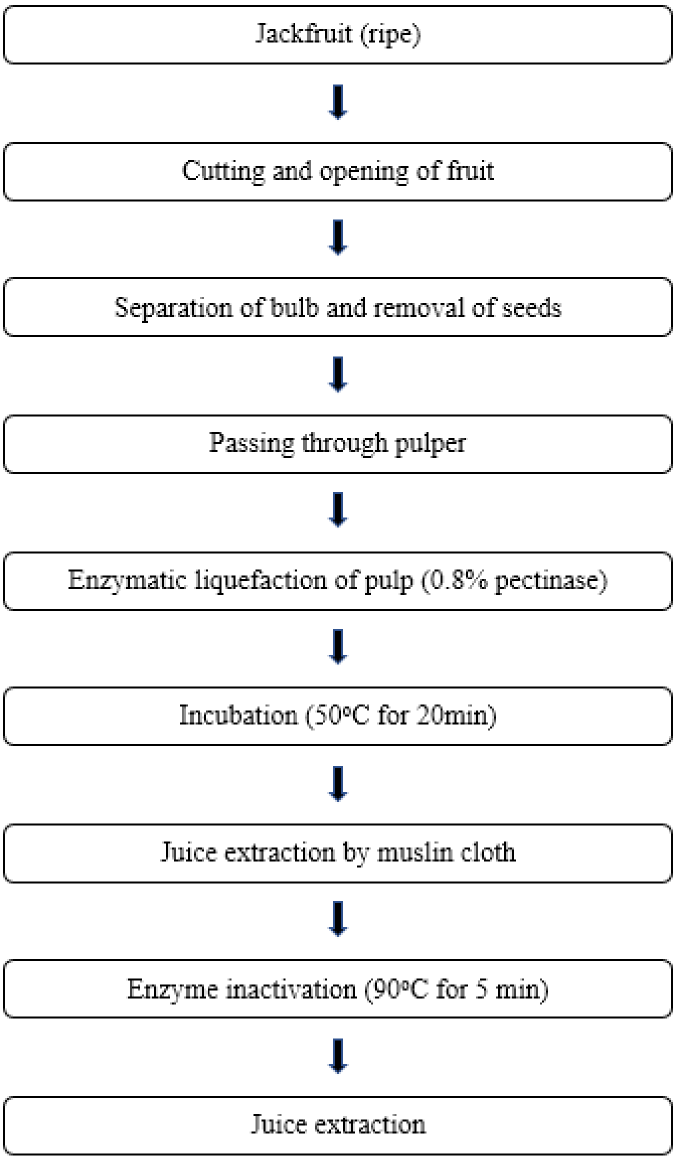
2. Materials and Methods

2.1 Jackfruit
Fresh jackfruits were obtained from the College of Horticulture, Kolar. Fruits that were uniform in size, shape, and maturity were chosen and delivered to the lab. Additional fruits were sliced and seeds were separated from the bulbs, then run through the pulper to make fine textured pulp, which was then packed in polythene covers and stored in a deep freezer (-18 °C) for later use.

2.2 Pectinase enzyme
The pectinase enzyme was used for extraction of juice, which was procured from Sri Durga Sales Corporation, Doddanna Industrial Estate, Peenya 2nd stage, Bengaluru – 560091, India.

2.3 Maltodextrin
Maltodextrin 10DE was used as carrier agent were procured from Sri Durga Sales Corporation, Doddanna Industrial Estate, Peenya 2nd stage, Bengaluru – 560091, India.

2.4 Extraction of Jackfruit juice



2.5 Development of spray-dried jackfruit powder
T_1: 160 °C Inlet temperature + 15% Maltodextrin
T_2: 160 °C Inlet temperature + 20% Maltodextrin
T_3: 160 °C Inlet temperature + 25% Maltodextrin
T_4: 170 °C Inlet temperature + 15% Maltodextrin
T_5: 170 °C Inlet temperature + 20% Maltodextrin
T_6: 170 °C Inlet temperature + 25% Maltodextrin
T_7: 180 °C Inlet temperature + 15% Maltodextrin

T_8: 180 °C Inlet temperature + 20% Maltodextrin
T_9: 180 °C Inlet temperature + 25% Maltodextrin
Note: Feed flow rate at 2 ml/min and outlet temperature of 85 °C were kept constant

2.6 Spray drying process
In contact with heated air, spray drying converts small liquid droplets into dried powder. Because rapid evaporation keeps droplet temperatures low, that high drying air temperatures can be used without compromising product quality. In comparison to most other drying methods, the droplet drying time in spray drying is quite short. There are several types of dryers that employ hot air flow to dry goods, including constant bed dryers, fluidized bed dryers, and microwave dryers. The most prevalent type of drier is the spray dryer.

2.7 Analytical methods
2.7.1 Moisture content and water activity
A moisture analyser was used to determine the moisture level of jackfruit powder. Two grams of material were placed in a sample petri-dish and dried in an electric moisture analyser until the moisture content remained constant and was expressed in percentage. Water activity of jackfruit powder was determined by digital water activity meter. One fourth volume of the container was filled with sample and it was closed with lid containing sensors and left three minutes for undisturbed. After stabilizing the water activity was displayed by digital water activity meter.

2.7.2 Carbohydrate
The phenol sulphuric acid technique was used to determine the total carbohydrate content. A known amount of jackfruit powder (0.2g) was cooked for 1 hour in 2ml of 2N HCL. The extract was then neutralised with an appropriate amount of Na_2CO_3 before being filtered and incubated at room temperature overnight. The volume was increased to 50ml the next day, and a 0.2 ml aliquot was taken. After that, 5 per cent phenol (1 mL) and 5 mL sulphuric acid (5 mL) were added to it and thoroughly mixed before being incubated for 20 minutes at 490nm (Masuko *et al*., 2005) [16].

Calculation
Absorbance corresponds to 0.1ml of the sample = ‘x’ mg of glucose

$$\text{Total carbohydrate (\%)} = \frac{\text{‘x’}}{0.10} \times 100$$

2.7.3 Protein
Total protein content of the sample was determined by Lowry’s method (Lowry *et al*., 1951) [15]. The known weight of jackfruit powder (0.2g) was submerged in distilled water overnight. Next day the volume was made up to 20 ml and one ml aliquot was taken. Later 5ml of Reagent C (Reagent A+ Reagent B in 50:1) and 0.5 ml of FC Reagent (Diluted with water 1:1) were added, shaken well before incubating in dark for 30 min. and absorbance was read at 660 nm.

Reagent A: 50 ml of 2% Na_2CO_3 in 0.1N NaOH + 1ml $CuSO_4$

Reagent B: 50 mg of $CuSO_4.5H_2O$ in 10 ml of 1% NaK Tartarate

$$\text{Total protein (\%)} = \frac{\text{OD 660 x Std. value (mg) x Total vol. of extract}}{\text{Assay volume x wt. of the sample (g) x 1000}} \times 100$$

2.7.4 Hygroscopicity
Cai and Corke (2000) [6] proposed a method for determining hygroscopicity, which was modified. 1g of sample was placed in a container containing saturated NaCl solution at 25^0 C. (75.29 per cent RH). After one week, the samples were weighed, and the hygroscopicity was measured in grams of absorbed moisture per 100 grams of dry matter.

2.7.5 Solubility
The powder's solubility was determined using the Eastman and Moore (1984) [9] method. The powder's moisture content was measured. One gram of powder was mixed with 100 millilitres of distilled water. This solution was transferred to experimental tubes, centrifuged for 5 minutes at 3000 rpm, and allowed to settle for 30 minutes. A 25 mL aliquot of the supernatant was placed to pre-weighed petri dishes and oven dried for 5 hours at 105 °C. The weight difference was used to calculate the solubility (per centage).

2.7.5 Titratable acidity
A known volume of sample (5 ml) was taken and increased to 25 ml, from which 10 ml was extracted and titrated against the standard NaOH using phenolphthalein indicator. The appearance of a faint pink colour was designated as the finish line. The value was calculated using citric acid as a percentage of the titratable acidity of pulp and powder (Patil *et al*., 2014).

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{N. of NaOH} \times \text{Vol. made up} \times \text{Eq. weight of acid}}{\text{Vol. of the sample} \times \text{Weight or vol. of sample taken} \times 1000} \times 100$$

2.7.6 Ascorbic acid
Ascorbic acid content was estimated titrimetrically using 2,6-dichlorophenol indophenol dye as per the AOAC procedure. The powder was diluted with four per cent oxalic acid. 10 ml of aliquot was titrated against 2,6-dichlorophenol indophenol. The results are expressed as mg ascorbic acid per 100ml of juice.

$$\text{Ascorbic acid (mg/100 ml)} = \frac{\text{Ascorbic acid in standard} \times TV_2 \times \text{Vol. made up} \times 100}{\text{Aliquot taken} \times TV_1 \times \text{Weight of sample}}$$

2.7.7 Bulk density
Bulk density is measured by adding 2 g of powder into a 10 ml empty dry cylinder and the bulk density is determined by based on the following formula:

$$\text{Bulk density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (cm}^3\text{)}}$$

2.7.8 Tapped density
Tapped density is the ratio of the mass of the powder to the volume occupied by the powder after it has been tapped for a definite period of time.

$$\text{Tapped density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (cm}^3\text{)}}$$

2.7.9 Carr's index
It is an indication of the compressibility of a powder and is calculated by the formula,

$$\text{CI} = \frac{\text{Tapped density} - \text{bulk density}}{\text{Tapped density}} \times 100$$

2.7.10 Hausner ratio
Hausner ratio is the measure of the flow of a powder and is calculated as,

$$\text{HR} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

2.7.11 Colour
A Lovibond colour metre (Lovibond RT300, Portable spectrophotometer, Tintometer Limited, Salisbury, UK) with an 8mm aperture was used to measure the colour. The instrument was set to 10o observer and D 65 main illuminant. The black and white tiles given were used to calibrate the equipment. Lovibond units *L** (lightness/darkness), *a** (redness/greenness), and *b** (yellowness/blueness) were used to express colour. The lens of a colour reader was put over specific cuvettes containing juice to obtain these values. For each treatment, measurements were taken in triplicate.

2.7.12 Statistical analysis
The data was interpreted according to Panse and Sukhatme's guidelines (1967) [19]. The p = 0.01 significance level was employed in the 'F' test. Wherever the 'F' test was significant, critical difference values were determined.

3. Results and Discussion
3.1 Moisture content and water activity
In freshly collected powder, the maximum moisture content of 3.65 per cent was detected in the treatment T_1 while minimum value of 3.13 per cent was observed in treatment T_9. It is clear from the statistics that when the temperature and MD concentration rise, the moisture per cent decreases. As the drying temperature and MD content increased, the moisture content of the product decreased. This could be because the high drying air temperature caused a high temperature gradient at the surface of the feed drops, which accelerated the heat transfer rate. This was according to Weerachet *et al.* (2010) [29] in in pineapple juice, Tze *et al.* (2012) [28] in pitaya fruit, Quek *et al.* (2007) [21] in water melon juice powder.
The treatment T_1 had maximum water activity of 0.35. The lowest water activity was noted in treatments T_9. This might be due to previous reports at higher total solids content, a rapid drying was occurred and hence powder with low water activity was produced. This was in agreement with Tonan *et al.* (2009) [27] acai fruit juice powder, Tze *et al.* (2012) [28] pitaya fruit juice powder, Zaini (2009) [30] in mango fruit juice powder.

Table 1: Effect of treatments on water activity of spray dried jackfruit powder

Treatments	Water activity (a_w)	Moisture (%)
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	0.35	3.65
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	0.31	3.22
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	0.28	3.19
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	0.33	3.58
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	0.28	3.20
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	0.25	3.16
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	0.29	3.45
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	0.24	3.17
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	0.22	3.13
Mean	0.28	3.31
S.Em±	0.01	0.03
C.D. @ 1%	0.02	0.11

3.2 Carbohydrate and Protein
Table 2 shows the Carbohydrate content of jackfruit powder. The obtained results showed a highly significant difference between the treatments. However the mean carbohydrate content of the treatments ranges from 51.13 to 56.78 per cent. The treatment T_9 (180 °C Inlet temperature + 25% Maltodextrin) had maximum carbohydrate of 56.78 per cent. T_1 -160 °C Inlet temperature + 15% Maltodextrin (51.13 per cent) had lowest content of carbohydrate.

Table 2 shows the protein content of jackfruit powder. The obtained results showed a significant difference between the treatments. However the mean protein content of the treatments ranges from 3.47 to 3.68 per cent. The treatment T_1 (160 °C Inlet temperature + 15% Maltodextrin) had maximum protein content of 3.68 per cent. T_9 -180 °C Inlet temperature + 25% Maltodextrin (3.47 per cent) had lowest content of protein.

Table 2: Effect of treatments on carbohydrate and protein of spray dried jackfruit powder

Treatments	Carbohydrate (%)	Protein (%)
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	51.13	3.68
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	52.36	3.62
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	54.15	3.57
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	52.20	3.65
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	53.68	3.57
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	55.42	3.51
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	53.34	3.58
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	55.10	3.51
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	56.78	3.47
Mean	53.79	3.57
S.Em±	0.01	0.01
C.D. @ 1%	0.03	0.03

3.3 Hygroscopicity

The treatment T_1 had maximum hygroscopicity of 41.45 per cent. T_9 (39.24 per cent) had lowest content of hygroscopicity. As the maltodextrin concentration increased hygroscopicity of powder is decreased this may be due to low hygroscopicity of maltodextrin, which can affect the existing affinity towards moisture absorption in the product. Increase in temperature decreases the hygroscopicity this may be due to the higher the inlet temperature resulted in lower moisture content and the lower moisture content indicates lower hygroscopicity. Same results were also found by Rodrigues-Hernandez *et al*. (2005), Santhalakshmy *et al*. (2015) [25] in jamun juice powder and Shwetha (2016) [26] in custard apple juice powder.

3.4 Solubility

The treatment T_9 had maximum solubility of 99.12 per cent. T_1 (98.51 per cent) had lowest content of solubility. The increase in maltodextrin concentration resulted in an increase in the spray dried jackfruit powder's solubility. Low moisture content appears to be connected with high solubility (Goula and Adamopoulos, 2008) [12], since the lower the moisture content, the less sticky the powder is and the greater the surface area in contact with the rehydration water. Avila *et al*. (2015) [4], De Oliveira *et al*. (2009), and Bakar *et al*. (2010) [5] all reported similar findings.

When the temperature of the incoming air increased, the solubility of the spray dried jackfruit powder increased. This could be because incoming air temperature has an effect on residual moisture content. The higher the solubility of powder, the lower the moisture content of the powder. Furthermore, raising the drying air temperature causes an increase in particle size and, as a result, a reduction in the time it takes for the powder to dissolve (Goula and Adamopoulos, 2008) [12]. Abadio *et al*. (2004) [1] reported similar results in spray drying pineapple juice.

Table 3: Effect of treatments on hygroscopicity and solubility of spray dried jackfruit powder

Treatments	Hygroscopicity (%)	Solubility (%)
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	41.45	98.51
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	40.81	98.64
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	39.89	98.73
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	41.31	98.67
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	40.62	98.79
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	39.73	98.91
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	40.15	98.86
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	39.84	98.97
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	39.24	99.12
Mean	40.34	98.80
S.Em±	0.04	0.01
C.D. @ 1%	0.18	0.02

3.5 Titratable acidity and Ascorbic acid

Titratable acidity articulated in terms of citric acid varies with a range of 0.21 to 0.41per cent in jackfruit powder. Maximum per cent acidity of 0.41 per cent was seen in T_1- 160 °C inlet temperature + 15 per cent maltodextrin whereas, minimum value of 0.21 per cent was observed in T_9 -180 °C inlet temperature + 25 per cent maltodextrin. From this outcome it was clear that higher the inlet temperature acidity was found to decrease. This result was similar in case of jamun juice powder, (Santhalakshmy *et al*., 2015) [25].

Ascorbic acid is one of the important parameters from the nutritional point of view. It is an important antioxidant which contributes to the antioxidant activity of the powder. As ascorbic acid is heat liable and water soluble, their retention can be perceived only 25-30 per cent after spray drying.

In jackfruit powder, the ascorbic acid content ranges from 9.27 to 12.38 mg/100 g. Among the various treatments highest ascorbic acid retention was verified in the treatment T_1 -160 °C inlet temperature with 15 per cent maltodextrin (12.38 mg/100 g) whereas, significantly least ascorbic acid content in jackfruit powder was documented in the treatment T_9 - 180 °C inlet temperature with 25 per cent maltodextrin (12.38 mg/100 g).

A decreasing trend was observed in ascorbic acid content with increase in maltodextrin concentration. It was also observed that increase in inlet temperature leads to decrease in the ascorbic acid content of jackfruit powder. This might be due to heat reactions that have reduced the ascorbic acid content.

Table 4: Effect of treatments on titratable acidity and ascorbic acid of spray dried jackfruit powder

Treatments	Titratable acidity (%)	Ascorbic acid (mg/100g)
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	0.41	12.38
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	0.37	11.03
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	0.31	9.74
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	0.38	12.07
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	0.32	11.45
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	0.26	10.63
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	0.33	11.51
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	0.27	10.66
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	0.21	9.27
Mean	0.32	10.97
S.Em±	0.01	0.01
C.D. @ 1%	0.03	0.04

3.6 Bulk density and Tapped density

Table 5 shows the bulk density of jackfruit powder. The obtained results showed a significant difference between the treatments. However the mean bulk density of the treatments ranges from 0.41 to 0.66 per cent. The treatment T_1 had maximum bulk density of 0.66 g/cm^3. T_9 - 0.41 g/cm^3 had lowest content of bulk density. The mean tapped density of the treatments ranges from 0.49 to 0.86 g/cm^3. The treatment T_1 had maximum tapped density of 0.86 g/cm^3 and T_9 - 0.49 g/cm^3 had lowest content of tapped density.

As the concentration of maltodextrin rises, the bulk density and tapped density fall. This action could be explained by the fact that maltodextrin prevents thermoplastic particles from staying together. Furthermore, because maltodextrin is a skin-forming substance, it may induce an increase in the volume of air trapped in the particles. The apparent density of the particles decreases as the volume of trapped air increases, and this apparent density is what defines the powder bulk density solubility.

The bulk density and tapped density of the spray dried jackfruit powder falls as the inlet air temperature rises. This could be because the dry powder has a faster evaporation rate and a more porous or fractured structure, meaning that the droplets shrink less and the powder has a lower density (Fazaeli *et al*., 2012) [10]. These findings were consistent with Chegini and Ghobadian's (2005) [7] findings for spray dried orange juice powder.

Table 5: Effect of treatments on bulk density and tapped density of spray dried jackfruit powder

Treatments	Bulk density (g/cm^3)	Tapped density (g/cm^3)
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	0.66	0.86
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	0.57	0.71
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	0.48	0.59
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	0.61	0.77
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	0.52	0.65
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	0.44	0.53
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	0.56	0.70
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	0.48	0.59
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	0.41	0.49
Mean	0.53	0.65
S.Em±	0.01	0.01
C.D. @ 1%	0.03	0.02

3.7 Carr's index and Hausner ratio

Flowability is an important property for dried particles and was expressed as the Carr's index (CI) and Hausner ratio (HR). The higher value of the carr's index indicates poor flowability (Santhalakshmy *et al*., 2015) [25]. The Carr's index of the spray dried jackfruit powder ranged from 0.16 to 0.23. The treatment T_1 (160 °C Inlet temperature + 15% Maltodextrin) had maximum Carr's index of 0.23. T_9 -180 °C Inlet temperature + 25% Maltodextrin (0.16) had lowest content of Carr's index. In terms of handling properties, the spray dried jackfruit juice powder were considered as "excellent" to "passable" powders by their Carr's index.

The amount of empirical relationship between flowability characteristics of the powders and the results by the parameter Hausner ratio tests according to the Jinapong *et al*. (2008) was expressed by the amount less than 1.18, 1.19-1.25, 1.3-1.5 and greater than 1.6 indicates for the excellent, good, passable and very poor flow properties respectively. The mean Hausner ratio of the treatments ranges from 1.20 to 1.30. The treatment T_1 (160 °C Inlet temperature + 15% Maltodextrin) had maximum Hausner ratio of 1.30. T_9 -180 °C Inlet temperature + 25% Maltodextrin (1.20) had lowest content of Hausner ratio. In present study the spray dried jackfruit powder indicates flow property from "excellent" to "passable".

Table 6: Effect of treatments on carr's index and hausner ratio of spray dried jackfruit powder

Treatments	Carr's index	Hausner ratio
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	0.23	1.30
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	0.20	1.25
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	0.19	1.23
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	0.21	1.26
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	0.20	1.25
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	0.17	1.20
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	0.20	1.25
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	0.19	1.23
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	0.16	1.20
Mean	0.19	1.24
S.Em±	0.43	0.01
C.D. @ 1%	1.7	0.02

3.8 Colour

The data pertaining to changes in colour values of jackfruit powder was measured by Lovibond colour meter in terms of *L** (light-dark), *a** (red-green) and *b** (yellow-blue) and were depicted in table 7.

The treatment T_3 (160 °C Inlet temperature + 25% Maltodextrin) had maximum *L** value of 87.49. T_7 -180 °C Inlet temperature + 15% Maltodextrin (84.85) had lowest *L** value. The mean *L** value ranges from 84.85 to 87.49. The results shown that *L** values of spray dried jackfruit powder increased with increased in the concentration of the maltodextrin. The high concentration of maltodextrin resulted in whiteness of the powder. Increased in the inlet temperature resulted in decrease in *L** value of the powder. It means the colour of the powder becomes darker ay higher inlet air temperature. Similar results were reported in spray dried karonda powder by Abhilasha (2019) [2] and in spray dried watermelon juice powder by Oberoi and Sogi (2015) [18].

The treatment T_7 (180 °C Inlet temperature + 15% Maltodextrin) had maximum *a** value of 1.03. T_3 -160 °C Inlet temperature + 25% Maltodextrin (0.68) had lowest *a** value. The mean *a** value ranges from 0.68 to 1.03. From the results it can be noticed that increase in the concentration of maltodextrin reduces the redness of powder. Increase in the inlet air temperature results in increased *a** value of the spray dried jackfruit powder. It may be results of some non-enzymatic browning reaction such as caramelization and millard reactions during the spray drying. Similar results were reported by Ferrari *et al*. (2012) [11] for spray drying of blackberry.

The treatment T_7 (180 °C Inlet temperature + 15% Maltodextrin) had maximum *b** value of 32.56, followed by T_8 (31.71). T_3 -160 °C Inlet temperature + 25% Maltodextrin (23.78) had lowest *b** value, followed by T_2 (24.15). The mean *b** value ranges from 23.78 to 32.56.

Table 7: Effect of treatments on colour of spray dried jackfruit powder

Treatments	*L**	*a**	*b**
T_1 -160 °C Inlet temperature+ 15% Maltodextrin	86.59	0.85	25.89
T_2 -160 °C Inlet temperature+ 20% Maltodextrin	86.98	0.75	24.15
T_3 -160 °C Inlet temperature+ 25% Maltodextrin	87.49	0.68	23.78
T_4 -170 °C Inlet temperature+ 15% Maltodextrin	85.42	0.93	30.81
T_5 -170 °C Inlet temperature+ 20% Maltodextrin	85.78	0.87	29.77
T_6 -170 °C Inlet temperature+ 25% Maltodextrin	86.31	0.76	29.04
T_7 -180 °C Inlet temperature+ 15% Maltodextrin	84.85	1.03	32.56
T_8 -180 °C Inlet temperature+ 20% Maltodextrin	85.23	0.97	31.71
T_9 -180 °C Inlet temperature+ 25% Maltodextrin	85.94	0.83	31.24
Mean	86.06	0.85	28.77
S.Em±	0.01	0.01	0.01
C.D. @ 1%	0.02	0.05	0.02

4. Conclusion

The present study describes the possibility of producing spray dried jackfruit powder with the aid of enzymatic liquefaction. Jackfruit powder obtained at 180^o C inlet temperature and 25 per cent maltodextrin (T_9) recorded minimum moisture content, hygroscopicity in the fresh powder and also recorded highest solubility, recovery, carbohydrate and fat content. Desired flow property *viz.*, bulk density, tapped density, HR and CI were recorded in the 160 °C inlet temperature and 15 per cent maltodextrin (T_1) treatment combination. The results obtained indicate that good quality of jackfruit powder can be produced by spray drying, which demonstrate a great potential for the uses of such powders in the food industry.

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