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Original Research Article

Production of *Artocarpus altilis* Spray Dried Powder: Its Physicochemical Characteristic and Pathogen Analysis

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Abstract: *Artocarpus altilis* (breadfruit) powder is attracting a lot of attention for its potential as a processed food ingredient incorporated into a variety of food option, due to its functional properties and nutrient dense. The objective of this research was to better understand the spray dried breadfruit's physical properties at laboratory and pilot scale and its thermal behaviour. Nutritional composition as well as its pathogen analysis were also determined. Prior to spray drying, physical properties of breadfruit puree were analysed. Thermal behaviour was tested via DSC while the test for nutritional composition based on AOAC (2000) Official Method and pathogen analysis based on BP (2008) standard protocol. The result for breadfruit puree for laboratory and pilot scale were as follows: 12.0 ± 1.3, 18.95 ± 2.3, 6.39 ± 0.20 and 25.7 ± 1.6, 36.67 ± 4.6, 6.25 ± 0.50 for viscosity (m.Pa.s), solid content (%) and pH, respectively. The physical properties of spray dried breadfruit for laboratory and pilot scale were as follows: 12.27 ± 1.14, 3.14 ± 0.74, 50.96 ± 1.78 and 61.0 ± 2.7, 3.02 ± 0.12, 8.74 ± 1.23, for yield (%), moisture content (%) and solubility (%), respectively. Thermal behaviour for spray dried breadfruit was 28.29°C ± 0.20. The nutritional composition determined were protein (1.7 ± 0.15 %w/w), crude fibre (5.02 ± 0.03 %w/w), fat (3.27 ± 0.11 %w/w), ash (3.80 ± 0.017 %w/w) and carbohydrate (86.90 ±0.03 %w/w). Pathogen analysis resulted in a safe level of Total Plate Count, Total Coliform Count, while *E. Coli*, *S. aureus*, *Salmonella*, *were* not detected.

Keywords: spray dried breadfruit, physical and thermal properties**,** nutritional and pathogen analysis

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1. Introduction

Breadfruit (*Artocarpus altilis*) also known as sukun in Malay is a traditional crop and a reliable staple food that originates from South Pacific countries (Liu *et al.*, 2020). Breadfruit trees are not only easy to grow, but they are also capable of bearing fruit in abundance. The fruits are highly nutritious, energy-rich, and contain large amounts of phytochemicals which exhibit significant antioxidant properties (Ragone, 2018; Zainol *et al.*, 2022). These compounds are beneficial in improving our health as they are often associated with the prevention of cardiovascular diseases, urinary tract infections and other chronic illnesses (Braga *et al*., 2019; Singh *et al.*, 2018). In addition, antioxidant activity and total phenolic content is an important measure to improve food quality and prolong shelf life without imposing any undesirable effects from the addition of synthetic chemical preservatives (Batiha *et al.*, 2021; Ramli *et al.*, 2020). Breadfruit can also be a source of dietary fibre whereby a fibre-rich diet aids in the regulation of blood sugar in diabetics, the reduction of unfavourable blood lipids (a risk factor for CVDs), and the management of weight. Besides providing essential minerals, breadfruit offers an alternative to gluten-free for those who are gluten intolerant, who are suffering from Type 2 Diabetes Mellitus, and other health-conscious individuals (Liu *et al.*, 2020; Ragone, 2018; Singh *et al.*, 2018; Zainol *et al.*, 2022). Gluten-free products are frequently expensive; therefore, high-yielding gluten-free flours, such as breadfruit flour, could be used to substitute or partially replace wheat in a variety of products instead of the present equivalents (Yazid *et al.*, 2018). Breadfruit also contains high resistant starch which is according to research, resistant starch offers numerous health benefits, including suppressing appetite and feeding the beneficial bacteria in the colon, so boosting the number and kind of bacteria (Ragone, 2018). The rheological behaviour of breadfruit starch has been studied extensively in food application. Based on rheological qualities, the stability of native and modified breadfruit starch has also been examined for use in emulsion and baking (Anwar, 2016). Physical modification of starch requires the employment of chemical or biological agents; nonetheless, physical modification of starch is commonly preferred in diet food products (Din *et al.*, 2018). By taking these properties of breadfruit powder into account, manufacturers can use them as a guideline in monitoring and modifying its process to fulfil the desired characteristics depending on its purposes.

Breadfruit offers wide technological functionalities and nutrient dense which has a great potential when incorporated into a variety of food application. Some of the applications of breadfruit as food ingredient include breadfruit flour, infant formulas, pasta, biscuits, fermented foods, extruded products, and stiff porridge (Singh *et al.*, 2018). Although

breadfruit is healthy, it quickly deteriorates physiologically after harvesting. To reduce post-harvest losses and increase breadfruit utilization, the breadfruit can be turned into powder, which is more shelf stable. Breadfruit powder manufacture has opened the door for these fruits to be used into a wide range of food sectors.

The quality of the dehydrated products is influenced by drying techniques and the physicochemical transformations that transpire in tissues throughout the drying process. In particular, the dehydrating technique employed has an impact on various material properties, including but not limited to color, texture, density, porosity, and sorption characteristics. Prior research has been conducted to investigate the impact of different methods and process parameters on breadfruit drying. The studies aimed to gather data on the final product and determine the optimal operating conditions (Famurewa *et al.*, 2015; George *et al.*, 2017). Multiple dehydrating processes enable the economical production of convenient, high-quality goods in a timely manner and at competitive prices. Historically, breadfruit segments have been predominantly dried outdoors, directly in the sun. A study by Tanura *et al.*, (2018) suggested that by subjecting breadfruit to microwave drying, the moisture content of the sample was effectively decreased from 69.16% to 7.51% on a damp basis. Significant effects of microwave power variation and milling time variation were observed on the physical quality characteristics of breadfruit powders such as colour differences, bulk density, whiteness, gel consistency and water and oil absorption capacity. Conventional method of oven dried then grounded and spray drying of fruit materials into powder can help to prolong their shelf-life by reducing moisture content in fruits, as this inhibits microbial growth and enzymatic activity (Phing *et al.*, 2022; Tan *et al.*, 2022; Wong & Tan, 2017). Due to several advantages offer by spray drying as such to protect chemically sensitive bioactive compounds, spray dry has been used.

One of the topics that has received a lot of interest and still being explored is the processing of breadfruit powder and its application to diversify food supply with desired texture. Since there is lack of research and established data available for spray dried breadfruits powder, therefore, the aim of this research was to envisage the physicochemical characteristic of spray dried breadfruit powder. The properties of this breadfruit powder via lab scale to pilot scale processing were determined to have a better understanding and a comparable data for future processing and commercialization purposes. The results from their physical, nutritional, and pathogen analysis can be used as a complementary data to other processed food products. These finding will add value to local sources and rise significant

impact on product development intended for health-related consumers as well as suitable for general consumption.

2. Materials and Methods

2.1. Preparation of Breadfruit Purée

The breadfruits were purchased from the local supplier. Firstly, the fruits were cleaned and washed. The skin was peeled, and the core was removed from each fruit. 1 kg of the white meat was then cut into small pieces, and 1 L of filtered water was added prior to blending using a commercial blender (National, Malaysia). The blending speed was set to maximum blending, and the puree was filtered through 50-mesh sieve. The juice and the carrier agent (maltodextrin) in the ratio of 1:0.3 (w/w) were then homogenised at 8000 rpm using a rotor-stator homogenizer (Heidolph, Germany). 1 kg of juice (without water) equaled to 300 g of maltodextrin. The sample was spray dried at 180˚C inlet temperature using a laboratory scale spray dryer (Labultima, India). In comparison, the larger production scale was carried out on a pilot-scale homogenizer (250 L), filtered by the sieve and spray dried using a pilot-scale spray dryer (Preci, Japan) at 180˚C.

2.2 Measurement of Viscosity

400 mL of the solution in a 500 mL beaker was prepared accordingly. The viscometer (Brookfield, USA) was adjusted, and the spindle was positioned at the center of the sample container. Before the viscosity measurement, the spindle must be selected to be less than 100% of the torque range as displayed on the screen by trial and error. The analysis was done in triplicate for each sample.

2.3 Solid Content

The solid content of breadfruit juice was determined by oven drying (Okokon & Okokon, 2019). 50mL of the sample was transferred to a pre-weighed glass Petri dish and dried in the oven at 105ºC for 2-3 hours. The dry solid content was calculated as

$$\text{Solid content} = \frac{W_{\text{dried juice}} - W_{\text{petri dish}}}{W_{\text{initial juice+petri dish}}} \quad (1)$$

2.3 Moisture Content

Particle moisture content was obtained by a halogen moisture analyzer provided with balance MX-50 (A&D Instruments Ltd., Oxfordshire, United Kingdom). The sample (2 g)

was measured and evenly distributed across the entire aluminium plate. The sample was subsequently dried at 105ºC, and the results were expressed as a percentage of moisture. The analysis was done in triplicate for each sample.

2.4 Powder Yield

The powder yield was calculated as the percentage of the spray dryer recovery (kg) from the weight of sliced breadfruit (kg).

2.5 Solubility of Powder

The solubility of the breadfruit powder was determined according to the method from (Pudziuvelyte *et al.*, 2019) with some modifications. 1 g of sample was prepared, mixed with 25 mL distilled water, and stirred using a magnetic stirrer for 5 minutes. Subsequently, the sample was centrifuged for 10 minutes at 3000 x g at room temperature. 20 mL of supernatant was transferred to pre-weighed glass Petri dishes and dried in an oven at 105ºC for 5 hours. The solubility of the sample was calculated as

$$Solubility\ (\%) = \frac{W_{dried\ supernatant} - W_{petri\ dish}}{W_{analytical}} \quad (2)$$

$$W_{analytical} = \frac{W_{sample\ to\ be\ dried} - W_{powder}}{W_{powder} - W_{distilled\ water}} \quad (3)$$

2.6 Thermal Behavior Using Ddifferential Scanning Calorimeter (DSC) Analysis

The thermal behaviour of the breadfruit powder samples was determined using the differential scanning calorimeter (DSC), (Mettler Toledo DSC1). Using standard indium and sapphire, the instrument was calibrated towards heat flow and temperature. Fifteen milligrams of each sample were accurately weighed into the DSC aluminium sample and flowed using the pan and sealed with a lid while an empty pan with a lid was used as a reference. The process began by decreasing the temperature to -80 ºC at a heating rate of 10°C/min, followed by scanning from -80ºC to 80ºC at the same heating rate. Dry nitrogen gas was used as the purge gas with a flow rate of 50 mL/min (Amin *et al.*, 2017; Roshani *et al.*, 2021)

2.7 Nutritional Composition

The proximate analyses were performed to estimate the moisture, ash, fat, protein, and crude fiber composition of the breadfruit samples based on AOAC (2000) Official Method. Briefly, moisture was determined using the oven drying method at 100°C for at least

5 hours until a constant weight of the sample was obtained. Ash was represented by the total mineral or inorganic residue remaining after either ignition or complete oxidation of organic matter in foodstuff whereby the dry-ashing method was applied. The protein content has been determined on the basis of total nitrogen content using the Kjeldahl method. Fat content was extracted using a non-polar solvent through the Soxhlet extraction method. The carbohydrate content of the sample was calculated by difference. The calculation of the energy value (kCal) of the sample was as followed:

$$\text{Energy (in kCal)} = 4\times \text{(Proteins and carbohydrates mass in grams)} + 9\times \text{(mass of fat in grams)} \quad (4)$$

2.8 Microbial Load Analysis

2.8.1 Total plate count (pour plate method)

1 g of sample was dissolved in 9 ml of buffered sodium chloride-peptone solution pH 7.0, and 9 mL of sterile diluents were prepared in universal bottles. 1 ml of the first dilution was transferred into next dilution blank. Dilutions up to 10^{-5} were prepared accordingly. 1 mL of the dilution was transferred into a petri dish and 20 ml of soybean casein digest agar medium that was previously melted and cooled to approximately 45°C was added to each petri dish. The plates containing agar were left to solidify at room temperature. Positive control was performed by inoculating with reference culture and was performed as per test procedure. Blank media was treated as negative control. Then, the plates were incubated for 5 days at 30-35°C and the results were recorded.

2.8.2 Total coliform count

1 g of sample to be examined was dissolved in 9 ml of buffered sodium chloride-peptone solution. If the product is known to have antimicrobial activity, an activating agent may be added to the diluent. pH of samples was adjusted to about pH 7. Several dilution bottles were prepared as needed, each containing 9 ml of sterile diluent. The solution was thoroughly mixed by using vortex over a period of about 12 seconds.1 ml of the first dilution was transferred into next dilution blank. Dilutions were prepared up to 10^{-6} and 1 ml was transferred for each dilution into petri dishes with 20 ml of Sabouraud Dextrose Agar Medium at not more than 45^{o}C. The agar was allowed to solidify at room temperature and both positive and negative control was also prepared. The culture plates were then incubated at 20–25^{o}C for 5 days.

2.8.3 Detection of Escherichia coli

1 g of the product was used to inoculate the corresponding bacterial species in 9 ml of Casein Soya Bean Digest Broth and was incubated at 30 to 35°C for 18 to 24 hrs. After incubation the Casein Soya Bean Digest Broth was shaken thoroughly. Then 1ml from Casein Soya Bean Digest Broth was transferred into 100 ml of MacConkey Broth and incubated at 42-44°C for 18–24 hrs. By mean of an inoculating loop, bacterial suspension was sub-cultured from the MacConkey Broth onto the MacConkey Agar and incubated at 35–37°C for 18–72 hrs. Presence of *E. coli* was spotted with pink colonies pink-red colonies. Gram negative rod was observed through gram staining. Uninoculated media was treated as negative control.

2.8.4 Detection of Salmonella species

10 g of sample to be examined was dissolved into 90 ml Casein Soy Bean Digest Broth, homogenized and incubated at 30–35°C for 18 to 24 hrs. After incubation, 0.1 ml of Casein Soy Bean Digest Broth culture was pipetted into 10 ml of Rappaport Vassiliadis *Salmonella* enrichment broth and incubated at 30–35°C for 18 to 24 hrs. By means of an inoculating loop, enrichment culture was streaked from Rappaport Vassiliadis *Salmonella* enrichment broth on Xylose Lysine Deoxycholate Agar. The culture plates were then incubated at 30 to 35°C for 18 to 48 hrs. Both positive and negative control was prepared according to test procedure. The probable presence of *Salmonella* is indicated by the growth of cultures having well developed red colonies, with or without black centres.

2.8.6 Detection of Staphylococcus aureus

10 ml of samples was dissolved in buffered sodium chloride-peptone solution pH 7.0 and were diluted too tenfold. Then 10ml of samples were inoculated into 100 ml of casein soy bean digest broth, homogenized, and incubated at 37°C for 18 to 48hrs. The medium was then subcultured on the surface of Baird-Parker Agar (BPA). The agar was then incubated at 37°C for 18 to 72 hrs together with its control. Upon examination, if there was a growth of black colonies surrounded by clear zone, Gram staining will be performed. If Gram-positive cocci were spotted, therefore the assay was proceeded with further confirmation tests. Both positive and negative control was performed as per test procedure

3. Results and Discussion

3.1 Physical Properties of Breadfruit Powder for Laboratory and Pilot Scale

The characteristics of the feeding solution and breadfruit powder are shown in Table 1. The viscosity has a direct relationship with the solid content in the feeding solution. Using a highspeed homogenizer during the pilot-scale production improved the homogenization

process, resulting in a greater solid content of the feeding material. Eventually, the viscosity of the two feeding materials was adequate for the spray drying process, which needed less than 40 mPa.s (Hernandez *et al.*, 2015). Meanwhile, the greater powder yield on the pilot-scale suggested that the breadfruit powder was recovered more efficiently. It demonstrated that the pilot-scale spray dryer is more reliable than the laboratory-scale spray dryer. Furthermore, the increasing solid content in the feeding materials enhanced the concentration of the feeding material, resulting in better breadfruit powder recovery. The drying medium has a large influence on product recovery in the spray dryer. In this case, higher concentration reduced the residue buildup and material losses in the pilot scale cyclone, increasing the powder yield (Goula & Adamopoulos, 2003). When utilizing either type of spray dryer, the moisture level of the powder did not change considerably. Both samples had an acceptable moisture content range, which had to be less than 10% (Einhorn-Stoll, U. 2018). Powder reconstitution parameters such as solubility showed the powder's ability to dissolve in water (Fournaise *et al.*, 2016). Following the results, both spray drying processes produced breadfruit powder with a low solubility (approximately 50 %).

Table 1. Physical properties of breadfruit in liquid and powder form

Processing activities	**Laboratory scale**	**Pilot scale**
Homogenizer		
Liquid:		
Viscosity (mPa.s)	12.0 ± 1.3	25.7 ± 1.6
Solid content (%)	18.95 ± 2.3	36.67 ± 4.6
pH	6.39 ± 0.20	6.25 ± 0.50
Spray dryer	**Laboratory scale**	**Pilot scale**
Powder:		
Yield (%)	12.27 ± 1.14	61.0 ± 2.7
Moisture content (%)	3.14 ± 0.74	3.02 ± 0.12
Solubility (%)	50.96 ± 1.78	48.74 ± 1.23

3.2 *Thermal Behaviour of Breadfruit Spray Dried Powder from Pilot Scale Activity*

Fosr this s section DSC analysis is important in analysing the thermal behaviour of spray-dried breadfruit powder samples. Figure 2 summarise the thermodynamic properties of the samples. Based on Figure 2, the optimum melting point was at 28.29 ± 0.20°C (A1°C) and 2.37 J/g for ΔH.

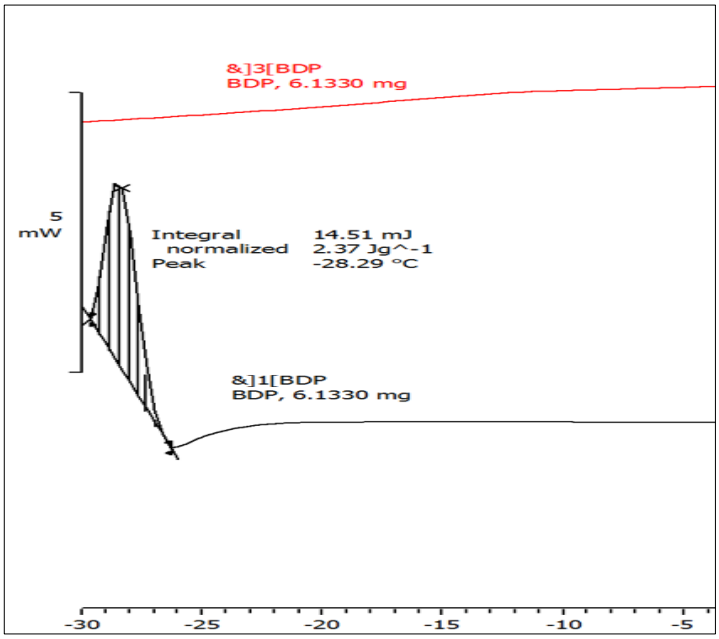

Figure 2. DSC thermogram of breadfruit spray dried powder

3.3 Nutritional Composition Breadfruit Spray Dried Powder from Pilot Scale Activity

Nutritional composition analysis is an important index to determine and classify nutritional values such as carbohydrates, protein, and fat content in a sample (Kabeer *et al.*, 2022; Rana *et al.*, 2018). Table 6 depict the composition of nutritional values in the breadfruit samples obtained from the analysis. The values for protein, ash, crude fiber, fat, and carbohydrate for breadfruit powder was 1.7 ± 0.15 %w/w, 3.80 ± 0.01 %w/w, 5.02 ± 0.03 % w/w, 3.27 ± 0.11 %w/w, respectively. Carbohydrates, fat and protein are categorized under macronutrients and body need these nutritive components for energy and maintain body structure and systems. Benefit of this spray dried breadfruit include increased intake of fiber and low in fat and these benefit for weight management.

Table 2. Nutritional composition of spray dried breadfruit

Parameters	Results % w/w
Protein	1.7 ± 0.15
Ash	3.80 ± 0.01
Crude Fiber	5.02 ± 0.03
Fat	3.27 ± 0.11
Carbohydrate	86.90 ± 0.03

3.4 Microbial Load Analysis Breadfruit Spray Dried Powder from Pilot Scale Activity

Five tests were conducted to determine viable values of bacteria in the spray dried breadfruit. The following tests were therefore completed: total plate count (TPC) and total

coliform count, a test for *Staphylococcus aureus,* a test for *Salmonella Ssp.,* and lastly a test for *Escherichia coli.* As illustrate in Table 3. In general, these sample was determined under the clause ready to eat food (RTE) which the method was based on USA Food and Drug Administration Bacteriological Analytical Manual 8th edition. Based on this standard, it provides information about the quality of the spray dried breadfruit as being satisfactory, acceptable, unsatisfactory or even potential hazardous and information related to hygiene and processing activity. Aside from that, the product's shelf life could be predicted by its microbiological quality.

Table 3. Microbial load analysis of spray dried breadfruit

Parameter	Unit	Result	Conclusion
Total Plate Count (TPC)	Cfu / g	2.1×10^4	Satisfactory
Total Coliform count	Cfu / g	5.8×10^2	Acceptable
Staphylococcus aureus	Cfu / g	ND < 10	Satisfactory
Salmonella spp.	Per 25 g	Absent	Satisfactory
Escherichia coli	Cfu / g	ND < 10	Satisfactory

Overall, the results depicted in Table 3 indicates that the spray dried breadfruit were of a good quality. The results of pathogen analysis herein showed that spray dried breadfruit was clear from pathogenic bacteria which namely as *Salmonella Ssp*. while Escherichia coli. and Staphylococcus aureus detected at a minimum level as shown in Table 3 and is categorized as satisfactory. Results for TPC is satisfactory while results for total coliform count showed acceptable quality. Although growth was observed in the agar, it is normal that some contamination during the processing stages would be encounter. It is suggested that this was due to contamination during and/or after preparation of the materials. Cross contamination can be influenced by the food management practices that consumers employ, and there is a growing concern regarding the improvement of such behaviours (Jeannie *et al.*, 2015). In practice, it is impossible to totally prevent contamination from the environment and by the food handlers; however, it is possible to minimise the risk by practising good hygiene.

4. Conclusions

This study shows that breadfruit powder obtained using spray dry contribute a useful information on its physicochemical characteristic such as its solubility, moisture content, thermal behaviour, crude fibre, protein, and fat content as well as its carbohydrate content. Apparently, both laboratory and pilot scale produced powder with acceptable moisture content, while the yield obtained from the pilot scale recovered more efficiently. Powder obtained from pilot scale shows promising value of nutrition, furthermore, the results from pathogen analysis indicate that this material is of a good quality and can be consumed. This

is one of the most important requirements which need to be assessed prior to initiating tests involving humans such as sensory assessment. Indeed, conducting of in-vivo studies should help to investigate efficacy and digestibility, which will ultimately determine its potential as a functional food, whereby breadfruit usage in food product development is being broadened.

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