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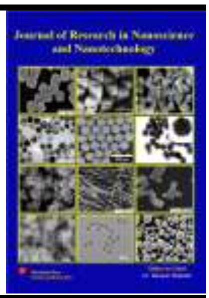

Effect of Particle Size on Physical Properties of Rambutan Seed Powder

So'bah Ahmad [1,*] and Rabiatul 'Adawiyah Sayuti [2]

[1] School of Industrial Technology, Faculty of Applied Sciences, Universiti Teknologi MARA, 40400 Shah Alam, Selangor, Malaysia
* Correspondence: sobah@uitm.edu.my
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ABSTRACT

Rambutan seed powder is derived from the crushing of dried seed of rambutan (*Nephelium lappaceum L.*) and it is promisingly used as an incorporating powder into food product. However, there is limited information on the effects of particle size on the handling and processing of rambutan seed powder in the industry. Therefore, a study was performed to determine the effects of particle sizes on physical properties of rambutan seeds powder. The physical properties measured moisture content, bulk and tapped density, as well as flowability characteristics. In this work, the powders were classified based on their mean diameter (d50) that ranged between less than 250 µm, between 250 µm and 750 µm and more than 750 µm. The fine rambutan seed powder (RSP) with particle 250 µm to 750 µm exhibited the best powder characteristics as it holds lowest moisture content, 5.42% and fair and passable flow properties, with Hausner ratio of 1.26 ± 1.20. The results indicated a significant impact of particle size on the cohesivity, where smaller particle size tended to decrease flowability and caused caking and agglomeration, which led to undesirable quality of food product.

Keywords:
Rambutan seed powder; Particle Size; Moisture Content; Carr's Index; Hausner Ratio

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1. Introduction

Nowadays, rambutan fruits generate a large amount of waste along with a notable cost of approximately 94,500 tons/year in Indonesia, Thailand, and Malaysia respectively [1,2]. Abundant of seed waste, diversifying of its functions, minimising management disposal cost, fighting for zero hunger as well as promoting good health and well- being have led to this study. Its diversifying functions of rambutan seed clearly seen in food industry due to its safe to consume as it contains no toxic and higher nutritional value [3]. In addition, the rambutan seed also contains 37.1% to 38.9% crude fat, 11.9% to 14.1% protein, 2.8% to 6.6% crude fibre, and 2.6% to 2.9% ash on a dry weight basis [3]. However, the main challenge is to convert the rambutan seed into an environmentally acceptable or sustainable substance ideal for industrial purposes [4]. A better understanding of the fruit seed stimulate its use and, as a result, the waste may be decreased [4].

Fruit wastes especially rambutan have high in moisture content and rich in biodegradable organic compounds, which causes an unpleasant odour to spread out during decomposition and resulting in a large amount of waste [5,6]. Long-term waste disposal into the ecosystem not just leads the greenhouse gas emissions during decomposition, and yet also serves as a breeding site for bacteria, pests, and mice, facilitating plague transmission [5].

Rambutan seeds are an industrial by-product that is considered waste; however, their utilisation is efficient to achieve a value-added product [7,8]. However, its application is still limited to unprocessed rambutan seed and subsequent processes of rambutan seed powder; hence it is needed to determine its physical properties for further application in food industry. For example, an application of rambutan seed powder as a new replacer of wheat flour in noodles that will assist in utilizing agricultural waste and preserving the environment.

The main significance of this research is a product development from agricultural waste where the rambutan seed is normally discarded as waste and not usually being consumed by people specifically in Malaysia. Hence, it can be diversified into a new replacer in food products. Besides, the study from other researcher found that dried seed possessed higher protein, fat, and carbohydrate values contrasted to fresh seed [7,8].

After direct consumption or industrial processing, the seeds are disposed of as a by-product that can lead to adverse effects on the environment and economic disruption if not treated efficaciously [9]. The prolong lifespan of food waste essential to the capability to convert rambutan seed to secondary supplies for the industry, minimising waste and encouraging recycling and reuse of waste to help conserve the environment, as well as establish a secure food chain and null food waste [9]. There has been a limited study of seed powder derived from rambutan seeds. Therefore, the objective of this study to investigate the effect of particle size on physical properties of rambutan seed powder to avoid wastage and fully utilise the rambutan seeds in the food industry.

2. Materials and Methods

2.1 Rambutan Seed Powder (RSP)

A 5 kg of rambutan seeds were washed with clean water to eliminate any impurities. Then the seeds were dried by cabinet-drying method at 60oC for 11 hours. The temperature and time for cabinet-drying were determined according to the method reported by Miranti and Wahini [10] with some modifications. Then, the brown shell of dried rambutan seed were dehusked manually. Rambutan dried seeds then were crushed into fine powder using a blender (CBL-S250PM). Then, granule of rambutan dried seed were passed through a sieve shaker (Sigma-Aldrich) to achieve uniform and consistent particle size less than 250 μm, between 250 μm and 750 μm and more than 750 μm (see Figure 1). The rambutan seed powder (RSP) with different particle size was stored at 24o C in high density polyethylene containers for physical properties analysis.

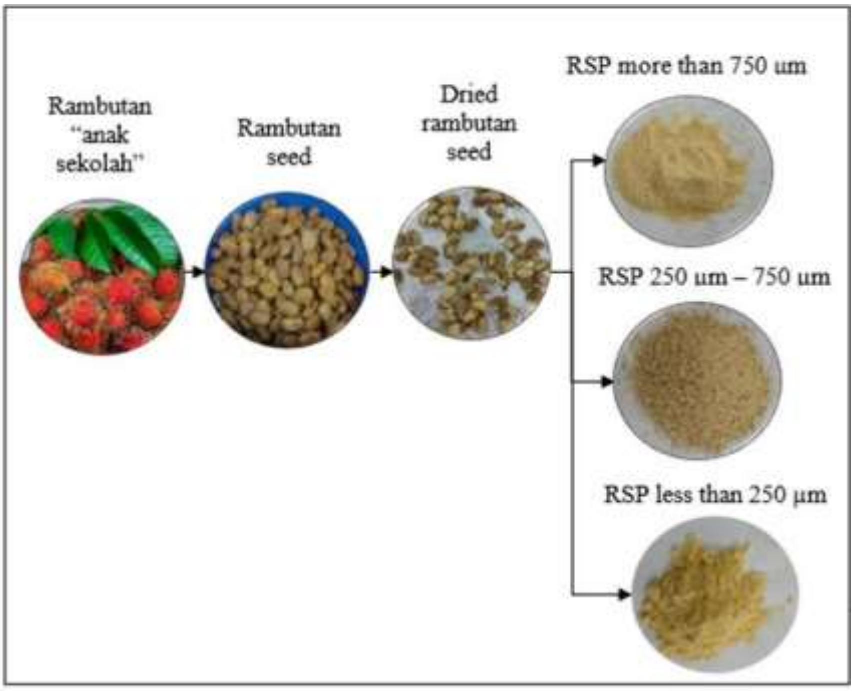

Fig. 1. Production of Rambutan seed powder (RSP)

2.2 Raw Material Properties
2.2.1 Moisture content

5 g of rambutan seed powder (RSP) from each particle sizes were determined using moisture analyser (Mettler-Toledo) [11]. A proper guideline was followed during handling the equipment. The sample were distributed evenly on the sample pan to allow a consistent drying process that can prevent from burn and uneven heating of sample [12]. During handling the sample, make sure to use spatula and avoid touching the sample with bare hands to avoid contamination. The drying parameter were set at a standard temperature of 150°C [12]. The analysis was repeated three times.

2.2.2 Bulk density

A 3 g of RSP (WRSP) was gradually filled into a 15 ml of graduated cylinder until it reached the 15 ml mark and weighed it [13]. The cylinder was moderately tapped to gather the which powder attached to the walls. The volume (Vβ) was recorded directly from the cylinder, then it was employed to calculate the bulk density using Eq. (1).

$$Bulk\ density, \rho\beta = \frac{W_{RSP}}{V_{\beta}} \tag{1}$$

where
W_{RSP}= Weight of rambutan seed powder
V_{β} = Volume of rambutan seed powder

2.2.3 Tapped density

A 3 g of RSP (WRSP) was gradually filled into a 15 ml of graduated cylinder until it reached the 15 ml mark and weighed it [13].The measuring cylinder was manually tapped 120 to 150 times 15 cm high on top of a rubber mat until the powder achieved a persistent volume (V_τ). The last tapped of the powder volume (cm3) were used to calculate powder tapped density using Eq. (2).

$$Trapped\ density, \rho\tau = \frac{W_{RSP}}{V_\tau} \times 100\% \quad (2)$$

where:
W_{RSP} = Weight of rambutan seed powder
V_τ = Volume of rambutan seed powder after tapping

2.2.4 Flowability and cohesiveness

The flowability and cohesiveness of the RSF were measured in conditions of the Carr's Index (CI) and Hausner ratio (HR) [14]. The CI and HR were calculated using Eq. (3) and Eq. (4) respectively.

$$CI = \frac{\rho_\tau - \rho_\beta}{\rho_\tau} \times 100\% \quad (3)$$

$$HR = \frac{\rho_\tau}{\rho_\tau} \times 100\% \quad (4)$$

where:
ρ_τ is the tapped density (g/cm3)
ρ_β is the mass of sediment (g/cm3)

2.3 Statistical Analysis

All results of measurements were performed at triplicate for raw material properties analysis. All the recorded data was expressed as the mean values ± standard deviation (SD) and the data was analysed using IBM SPSS Statistics 28.0 (SPSS Inc, Chicago, USA). Differences between treatments were assessed by one-way analysis of variance (ANOVA) using Tukey Test and was considered statistically significant at P ≤ 0.05, with 95% confident interval and 5% acceptable error.

3. Results and Discussion

3.1 Effect of Particle Sizes on Physical Properties
3.1.1 Moisture content

The result of the moisture content of RSP of different particle sizes is presented in Table 1. Particle size 250 μm – 750 μm has the lowest moisture content (5.42%) compared to particle size more than 750 μm (5.81%) and particle size less than 250 μm (7.68%). All three particle sizes of RSP were significantly different (P ≤ 0.05) between each other. As mentioned by Bhandari [15], a powder with high surface area per volume has potential to be hygroscopic where it has high degree of moisture absorption. High surface area here can be considered that the size of particle size is small; therefore, it may be the explanation why RSP with particle size less than 250 μm has the highest moisture content. Also mentioned by Bhandari [15], the powder's capacity to maintain its physical and chemical properties is typically obstructed by increased moisture absorption. The results for RSP moisture content that obtained in this study were corresponds with other literatures where non defatted rambutan seed flour and grape seed powder has moisture range (6.30% to 9.20%) [16,17]. Whereas, the study from Jahurul *et al.,* [3], the moisture content of oven- and freeze-dried rambutan seed powders were found to be 8.33 and 8.46%, respectively. Besides, the most significant factors affecting the moisture content of fruit powders are the used of drying processes and their operation setting whereas, the main problems that are significantly impacted by drying procedures are drying time and product quality [18].

Moisture content of RSP at different particle sizes determination is crucial in order to analyse the stability of powder and storage [13,19]. Also mentioned by Aziz *et al.,* [18], moisture content is another indicator of drying effectiveness; for powder to be microbiologically safe, it should be less than 5%. Hence, in order for RSP to achieve less than 5% for the moisture content, the parameters during drying process such as temperature and time should be altered. Furthermore, Saha *et al.,* [20], stated that increase in density at relatively large particle sizes able to deliver sufficient operating force to rearrange particles, in addition to the particles being more compatible at higher moisture levels.

Table 1
Raw material properties of rambutan seed powder (RSP)

Physical and mechanical propertiesof powder	Particle sizes of RSP		
	More than 750 μm	250 μm – 750 μm	Less than 250 μm
Moisture content (%)	5.81 ± 0.15[b]	5.42 ± 0.19[a]	7.68 ± 0.14[c]
Bulk density (g/cm^3)	0.57 ± 0.00[c]	0.44 ± 0.25[b]	0.37 ± 0.01[a]
Tapped density (g/cm^3)	0.57 ± 0.16[b]	0.55 ± 0.25[b]	0.51 ± 0.13[a]
CI (%)	9.74 ± 0.16[a]	23.84 ± 0.43[b]	27.35 ± 1.47[c]
HR	1.00 ± 0.08[a]	1.26 ± 1.20[a]	1.38 ± 0.03[a]

3.1.2 Bulk and tapped density

Based on Table 1, particle size more than 750 μm revealed the highest bulk (0.57 g/m3) and tapped density (0.57 g/m3). Then followed by bulk (0.44 g/m3, 0.37 g/m3) and tapped density (0.55 g/m3, 0.51 g/m3) for 250 μm – 750 μm particle size and less than 250 μm particle size, respectively.

According to Das *et al.,* [21] high bulk density can improve the weight of mango kernel flour supplemented foods without altering the volume as it is defined as the mass of the particles that occupies a unit volume of a bed [18]. Besides, higher bulk density is preferable for easier dispersibility and reduced paste thickness, however low bulk density of flour is a valuable physical characteristic when assessing transportation and storability [22]. Hence, it indicated that, RSP with particle size more than 750 μm may be easy to disperse and the thickness paste may be reduced. Also mentioned by Ritika *et al.,* [23] bulk density of flours may alter the uniformity or texture of the noodles; due to the fact that the coarse-particle flour yielded a thick result with little or no puffiness. Hence, RSP with more than 750 μm may not suitable to be incorporated into noodles [23]. The tapped density based on this result was higher than bulk density as tapping allowed the smaller particles to occupy the voids between larger particulates and reach a dense packing condition [13]. Overall, the results showed that there is a significant difference between three particle sizes for bulk density. While for tapped density results showed that there is no significant different between particle size (750 μm) and (250 μm – 750 μm).

Furthermore, the protein composition, preparation, treatment, and storage of the sample were also may influenced by the bulk density. According to Eiamwat *et al.*, [16] alkaline-treated defatted rambutan seed flour, showed that the bulk density value was 0.65 g/m3. Therefore, rambutan seed powder in this research might has high protein composition compared to previous research based on bulk density volume.

3.1.3 Carr's index (CI), Hausner ratio (HR) and Flowability

Dried particles powder has two important properties; flowability and cohesiveness [18]. The Carr index (CI) is used to represent the powder's compressibility. Higher CI values representing poor flowability and high compressibility [18]. Besides, Aziz *et al.*, [18] mentioned that powder cohesiveness is classified using the Hausner ratio (HR), which is a good indicator of powder consistency and flowability. The lower the cohesiveness the greater a powder's flowability.

Based on the results obtained, particle size with less than 250 μm found to be the highest and for both CI (27.35%) and HR (1.38) value. For particle sizes of 250 μm – 750 μm and more than 750 μm, presented 23.84%, 9.74% for CI and 1.26, 1.00 for HR value, respectively. According to Agarwal *et al.*, [24], particle size with less than 250 μm showed poor flow properties due to the high value of CI and HR values. For 250 μm – 750 μm particle size demonstrated fair and passable flow properties while for particle size more than 750 μm, revealed the excellent flow properties. In the case of this three range particle sizes, as the particle size increase the value of CI and HR values increase, which suggest good flowability. However, the results obtained were not corresponds with literature from Camacho *et al.*, [25] where the range of CI and HR values of orange powder were between 0.203 to 0.108 and between 1.12 to 1.255, respectively whereby these values showed the excellent and good flowability. These may be due to the high fat and protein content of rambutan seed.

As mentioned by Hadjittofis *et al.*, [26] inter-particulate interactions such as adhesion/cohesion, frictional forces, and mechanical forces owing to interlocking affect the flow of powder particles. A variety of many other factors may also impact powder flowability [26]. For instance, particle size and distribution, particle shape and distribution, porosity, density, moisture content, surface composition, and powder substances. Based on result obtained, there is a significant difference ($P \leq 0.05$) between all three-group range of particle sizes in terms of CI values; however, there is no significant difference ($P \leq 0.05$) between all three-group range of particle sizes in terms of HR values.

4. Conclusions

Rambutan seed powder with particle 250 μm to 750 μm was chosen to be the best powder characteristics incorporating for food industry application as it holds lowest moisture content 5.42%, fair and passable flow properties, with Hausner ratio of 1.26 ± 1.20. The knowledge of these powder properties is needed for sufficient equipment design and performance prediction; hence the flow problems will not be occurred. Also, the typical problems such as caking, and agglomeration affected the food powder quality.

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