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Analysis on Chemical and Physical Properties of Dried Sago Bagasse

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ABSTRACT

The uncontrollable of sago bagasse waste from sago industry production become an environmental issue as it just dumping directly into nearby rivers which can affect a river pollution if not treated well. As it still has about 70% starch content, it has a potential to be converted to the others value-added product such as animal feed. However, before it can be converted to others product, it should go through a drying process to reduce its higher moisture content (90 wt.%), as well to prevent any micro bacteria growth and for long lasting packaging. Thus, this study focused on the evaluation of drying process at T=70 and 80 °C on reducing of its final moisture content by using three drying approaches: fluidized bed dryer (FBD), micro-oven and direct sunlight drying. Then, these samples of dried sago were analysed to determine its properties of starch, fibre, and ash, as well to study its functional organic chemical group by using Fourier infrared transform (FTIR) method. The results show the reduction of sago water content by FBD shown a significant result as compared to others drying methods as the FBD method produces a good solid mixed between particles. Besides, the drying rate using the FBD was achieved in a shorter time within 30 min as compared to oven which within 2 hours and sunlight drying within 6 days to achieve similar final desired moisture content at 11 wt.%. The analysis on the starch properties using the FBD was also almost 75% more higher than oven, which is about 70% starch content. Moreover, the presence of starch was successful proven by the presence of acrylic acid at a wavelength of 1539.72 cm^{-1} for FBD sample by using FTIR. In addition, using the FBD, the sago waste can maintain its quality as an animal feed by reached a brightness level, W_l as compared to the slurry sago waste where the dried sago using FBD is 58.78%, meanwhile the fresh slurry sago waste is 93.31%. In conclusion, the sago drying in the FBD at T=80 °C was selected as the optimum drying condition as it had achieved a short drying rate for desired final 11 wt.% moisture content and resulted in better on the chemical and physical analysis.

Keywords: Sago bagasse; Fluidized bed dryer (FBD); Oven drying; Sun light drying; Starch

INTRODUCTION

Generally, sago species, *Metroxylon* grows in humid environments, including swampy areas and was believed to be one of the earliest harvested to obtain tree trunks to be processed to produce starch where a soil fertility plays an important role on the impact of sago tree harvesting time (Chong 2015). Most of the sago tree species grow in wet environments with humid temperatures of 29-32 °C (Rahman et al. 2020). Since sago trees have high adaptability to severe environments, then it does not require close monitoring (Rahman et al. 2020). According to National Commodity Policy 2011-2020, sago industry is a major contributor to the economic sector in Sarawak, Malaysia as almost half of the world's sago products are imported from Sarawak with an output of 190,000 tones. In fact, Malaysia also exported 25,000 tons of sago to ASEAN, Japan, Taiwan, and Australia in 2010 (Anon 2020). The results of study by sago (Nururrahmah et al. 2018), found that sago has a high carbohydrate content with a value of 84.7 grams of carbohydrate for every 100 grams of sago. The high carbohydrate content in sago starch has made it a daily food source in Southeast Asia. In the food industry sector, sago starch is an important raw material because it has the highest starch production capacity from cassava, rice or corn (Amin et al. 2019). This

is expected to increase the high demand for sago products in the future. Past study by (Mustafa Kamal et al. 2017) have proved the starch content of modern and traditional extraction plants are different in terms of moisture content, color, microstructure, particle size and infrared adsorbent. But, since the rapid growth of the sago industry, it has contributed to river pollution because of the dumping of sago waste directly into nearby rivers. This sago waste is a by -product resulting from the starch extraction process that is produced in large quantities from several factories in Malaysia (Bujang 2010). Most of this sago waste is disposed of in an untreated manner because the high moisture content in the sago waste has hindered the industry for the reuse of the sago waste (Jiwa Bakti 2020). In addition, the dumping of sago waste into the river also affects the production of effluent in the river which hinders the process of air aeration to aquatic life.

However, sago waste is suitable as a new product because the content of wet sago waste still has 60-70% starch which is suitable to be used as animal feed if treated properly. On the other hand, this sago residue is rich in nutrients that consists of starch and contains chemical compositions such as lignin, cellulose, and hemicellulose. These contents have potential as a renewable resource in producing useful products such as animal feed as it has nutritional value of protein and crude fiber (Wardono et al. 2021) and as addition material of ceramics due to its tensile strength (Lai et al. 2014). Before sago residue is converted to a new product, sago residue needs to go through a drying process to remove the amount of moisture to prevent bacterial growth and maintain product quality in terms of color, texture, and total polyphenol content. In addition, non-dried sago residue is potentially damaged quickly because of the microbes are easily formed on the fiber due to the high nutrient content in sago residue. There are several drying methods such as drying directly through the sun and through a technological dryer i.e., microwave. However, this method is less effective because it uses a lot of energy, and this sago residue is exposed to an unhealthy environment (Sunarti et al. 2012).

The previous study shows a fluidized bed dryer (FBD) shown some advantages on drying where it was widely used in the drying industry to dry wet solids such as to dry a coconut waste (Assawarachan 2013) black pepper (Chuwattanakul & Eiamsa-Ard 2019) and soybeans (Nitz & Taranto 2007). As the drying is an important process in the food industry, some of the material needs to be dried first i.e., at least 40 wt. %. In the drying process, the factor influencing the optimal drying rate of sago residue is important to reduce the drying time in a short time as well to maintain a quality of the sago residue (Daud 2008). Thus, this study will determine the effects of different drying technique; FBD, oven and direct sunlight on the chemical and physical properties of the dried sago residue.

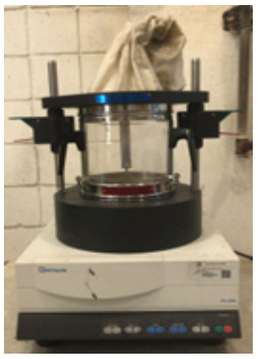
METHODOLOGY

A total of 10 kg of sago residue was obtained from Bor Giap Sdn. Bhd, Batu Pahat, Johor Bharu. Firstly, the sago residue was dried using different drying methods for further analysis on its chemical and physical properties. Samples of sago residue had been going through three drying methods; namely FBD and oven dryer operated at T=70 and 80 °C and under direct solar drying for 6 days to achieve a desired final moisture content of 10-11 d.b%. Once the dried sago sample was obtained, three chemical and two physical analyses were conducted.

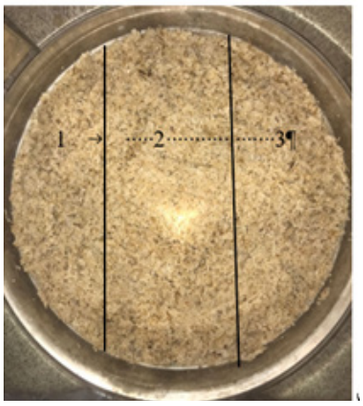
DRYING PROCESS VIA FBD, OVEN AND SUNLIGHT

In the drying process, 150 g wet sago residue were used for each drying process. The FBD machine; model Retsch TG 200 used has a diameter of 220 mm and a height of 520 mm including the filter bag. The temperature is set at T=70 and 80 °C with velocity of v_i=20 m/s. The sample was divided into three areas as shown in Figure 1 where (1) is taken from left position (1), (2) from middle position and (3) from right position.

During the drying process using the FBD and oven, the sago moisture content was measured for every 10 minutes time interval to determine the amount of water loss during the drying process. The process was repeated three times to obtain the average value of the final moisture content. For the solar drying process, initially, the sample was placed under sunlight direct at 10 am. The water content of the sago residue samples was recorded at 2 pm and 6 pm to obtain the total difference in water loss up to 11 wt.% water content.



(a)



(b)

FIGURE 1. (a) Model of FBD and (b) position of sample taken at (1) left, (2) center and (3) right area

ANALYSIS ON A CHEMICAL AND PHYSICAL PROPERTIES OF DRIED SAGO WASTE

Before proceeding to further analysis, the dried sago residue was ground to a fine powder and sieved using a 35-mesh sieve (500 µm) which was categorized as coarse powder to obtain a uniform and same size besides, to separate any contaminants. For each drying method, the sample has been analyzed using three chemical analyses; amylose and starch extraction, fiber and ash extraction and determine of an organic compound, meanwhile for two physical analyses; color testing and pore structure area of dried sago waste.

ANALYSIS ON A STARCH EXTRACTION, FIBER, ASH AND ORGANIC COMPOUNDS GROUP

For analysis of starch content, a hydrothermal (HT) method was used to extract starch from sago residue. Each 4 g of sago residue sample from the FBD and oven drying were mixed with distilled water into 500 ml conical flask. The hydrothermal process was performed at T=115°C for 15 min using autoclave technology. Then, pH of the extraction solution was modified to 6.5 by using 0.25 M Ca (OH)2 reagent. Next, the solution was filtered by using a 150-mesh filter cloth before went through oven drying process at T=60 °C for 48 hours. Once the starch product has been dried, it was sieved using 100 mesh filter to reduce a size of a starch powder. The starch solid was diluted into 1% solution for analysis on UV-vis spectrophotometer at 610 nm wavelength.

For fiber and ash analysis, each 2g of sago residue sample from the FBD and oven were prepared and mixed with 0.128 M H_2SO_4 and 0.313 M NaOH separately in a conical flask. Next, the sample was heated by using a heating plate for 30 minutes and then filtered using a filter cloth. After that, 200 ml of hot water with H2SO4 conical flask was flowed to the filtered sample. Finally, a weight of the product of the wet fiber solid was measured as shown in Figure 2. This product was mixed with a solution of 0.313 M NaOH into a new conical flask and then was heated on a heating plate for 30 minutes. 300 ml of hot distilled water mixed with a NaOH conical flask was flowed to product to wash out and remove NaOH residue. The final product resulted was placed in a crucible and heated using a hot air oven at T=180 °C for 2 hours before weighted it after cooling down. For analysis of ash content, the product was further dried by using a muffle furnace with a crucible and lid for two hours at T=550 °C. Finally, the weight of product of ash was measured.

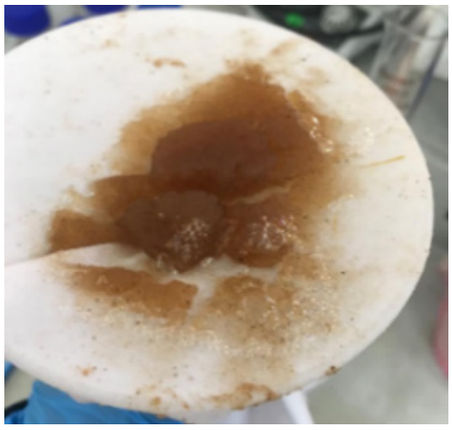


FIGURE 2. Product of fibre after filtering process.

Fourier transform infrared (FTIR) is used to validate the existence of starch content on the dried sago sample. The product of sample was analyzed in a form of coarse powder with 500 µm size. The FTIR analysis is set at wavelengths of 500 cm^{-1} up to 4000cm^{-1} which are categorized as mid-wavelength region that is suitable for functional group analysis in organic samples.

ANALYSIS OF COLOR TESTING AND PORE STRUCTURE AREA OF DRIED SAGO WASTE

For color test analysis, color dilution was performed for dry and wet samples of sago residue to see the difference in color change in terms of brownness and whiteness of the samples by using Nix model color detection technology. This machine will produce the values of Hunter parameter which involved of L^*, b^* and a^* to determine the sample value of a light or dark level after drying process. This analysis was performed to distinguish a color level of sago residue that closest to a fresh color of sago residue based on a white color value, W1 and a total brownness of a

sample, *E* (Sensor 2017). For pore analysis, BET machine was used to observe a pore area of dried sago in a micro centrifugal tube.

RESULT AND DISCUSSION

DRYING RATE OF SAGO MOISTURE CONTENT USING FBD, OVEN AND SUNLIGHT

The drying process of sago residue was studied using FBD, oven drying, and solar drying to reduce its moisture content to 11 wt.% with an initial moisture content of 84 wt.%. The sago bagasse dried by using FBD was simulated at T=70 and T=80 °C with a constant velocity of 20 m/s. Figure 3 shows a distribution profile of the moisture content of sago bagasse that decreases exponentially with increasing time for all sample positions. It shows drying in FBD at T=70 °C does not achieve optimal drying for water content for animal feed. The moisture content in the 30th minute reached a moisture content of 12.33 wt.% for the middle position sample, 18.32 wt.% for the right position sample and 12.61wt.% for the left position sample in FBD. As for animal feed, the appropriate moisture content required is not more than 11.5 wt.% (Alengadan 2013).

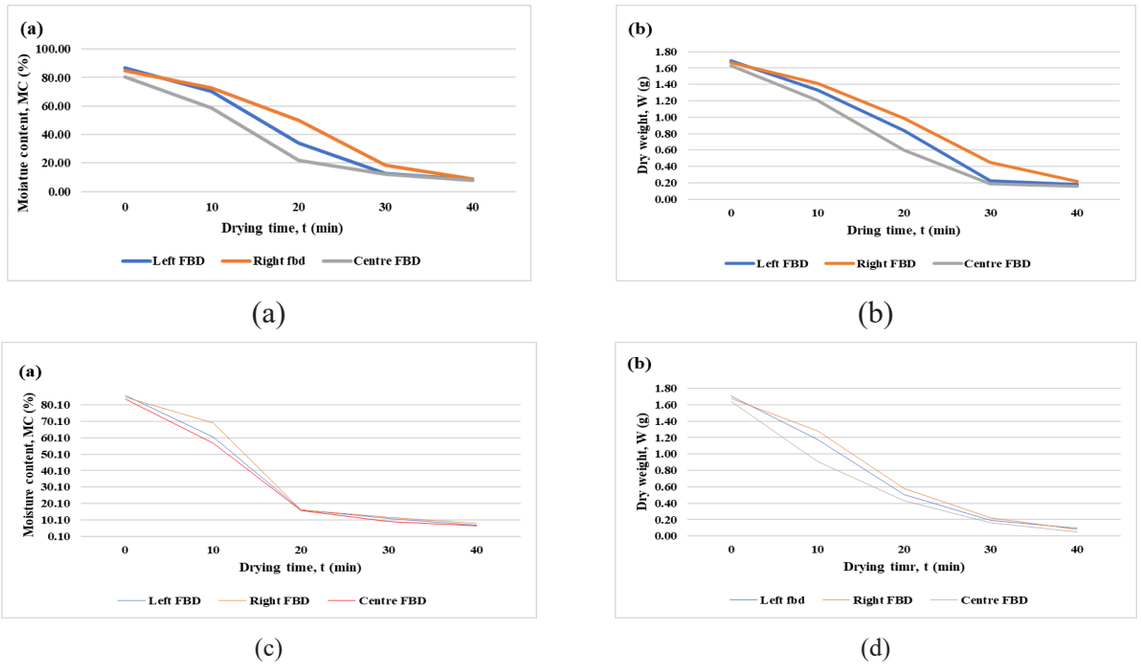
Meanwhile, with supply the hot air at T=80 °C, it shows the moisture content in the 30th minute had reached a moisture content of 9.23 wt.% for the middle position, 11.84 wt.% for the right position and 10.87 wt.% for the left position that fulfilled the required final moisture content for animal feed used. Besides, the unbalanced heat transfer distribution between the left, right and center positions in FBD is due to the symmetrical heat transfer occurring only in the central region of the drying cylinder in the FBD (Khoshtaghaza et al. 2014). This is due to the solid or sample moving randomly resulting in high inertia among the solids and achieving a good mixing during the fluid process (Daud 2008).

At first, both drying methods have initial moisture content of sago residue at 84.02 wt.% at 70 °C and 85 wt.% at 80 °C. It can be observed that the drying in FBD at 80 °C dries faster than at 70 °C. Although both temperatures reach the same drying time of 40 minutes but drying at 80 °C achieves optimal drying which reaches a water content of 10.64 wt.% where the water content in the sample is less than 11.5 wt.% is the ideal water content to analyze the sample organic for animal feed. In addition, it was found that the moisture content in sago residue decreased in parallel until the 60th minute. From the 70th minute, there are slightly significant differences in sago residue water content at 70 °C and 80 °C where it had achieved 12.02 wt.% and 18.44 wt.% for 70 °C and 80 °C, respectively. This indicates sago bagasse that dried in the oven at 80 °C had achieved an optimal drying condition as compared to oven drying at 70 °C. Overall, the water content will decrease in parallel with the increase in drying time but tends to be constant with the increase in oven drying time.

Figure 4 shows a comparison of the distribution profile of moisture content using three methods of dryings; FBD, oven and solar drying at 70 °C and 80 °C. Drying of sago residue using FBD only took 40 minutes to achieve 12% w.t final moisture content, which is faster than oven drying, that took around 120 minutes and solar drying took about seven days to achieve similar desired final moisture content. Overall, the FBD drying achieved optimal drying at a faster drying time of 10.65 wt.% within 30 minutes as compared to oven drying, 12.01 wt.% within 110 minutes and on the fifth day by solar drying to reach a moisture content of 9.53 wt.%. Each drying method resulted different value as it depended on the efficiency of each drying equipment. In this study, FBD drying at 80 °C is the shortest drying taken to achieve 11.5 wt.% as compared to the others drying methods. Table 1 summarized the averaged moisture content before and after the drying process using three methods of dryings: FBD, oven and solar drying in the first 30 minutes of drying process. It shows FBD achieved the faster and optimum drying time which is within 30 minutes as compared to the others drying methods.

TABLE 1. The averaged moisture content (MC) before and after the drying process in the first 30th minutes

	Before (Initial MC) (wt.%)	After 30 minutes drying (wt.%)
FBD	82.5	10.65
Oven	82.8	15.2
Solar	82.6	76.5



(a) (b)

(c) (d)

FIGURE 3. Moisture content and dry weight versus drying time at different position sample in the FBD for T=70 °C (a) and (b) and at T=80 °C (c) and (d), respectively

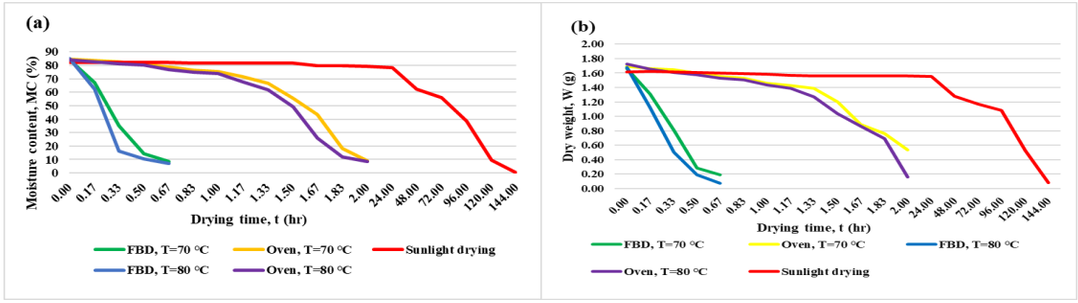


FIGURE 4 The comparison of the distribution profile of moisture content using three methods of dryings; FBD, oven and solar drying at (a) 70 °C and (b) 80 °C.

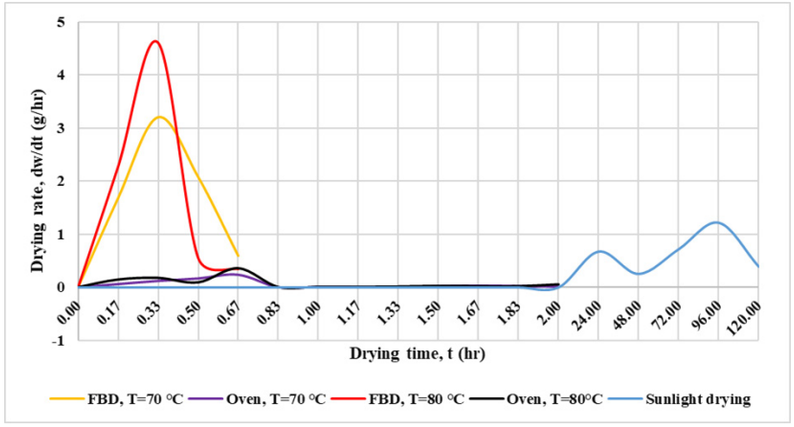


FIGURE 5 Average drying rate for FBD, oven drying at T=80 °C and under direct solar drying.

Figure 5 shows the averaged drying rates for FBD, oven drying at T=80 °C and under direct solar drying. It was found that the FBD drying at T=80 °C had achieved a higher and faster drying rate which at 4.60 g/h. It is because the FBD has a good mass and heat transfer rate due to good particle contact between the solid sample and the dry air (Daud 2008). The FBD drying shows a different drying rate on the first 0.67th hour, whereas oven drying, and solar drying did not show any significant change in drying rate from 0.83rd hour to 2nd hour. However, the oven drying rate has shown a slightly significant change in drying rate with sun drying at within the first 0.83rd hour. It was found that the drying rate of sago residue increased by using different velocities, but the decrease in drying rate was not significant at different temperatures.

CHEMICAL ANALYSIS ON THE DRIED SAGO BAGASSE

STARCH EXTRACTION

Before running the physical and chemical analysis on the dried sago bagasse, some extraction to obtain the pure content of starch, fiber and ash was prepared. After that, the result of starch extraction was diluted using a suitable solvent based on the solubility of the sample in a solvent that is between polar or non-polar solvent. Then, the dilute starch solution was analyzed using FTIR test and spectrophotometer analysis to observe the light absorption of the dilute solution at a wavelength of 610 nm.

From the starch extraction, it was found a starch yield content extracted from the dried FBD sample was slightly higher; 75% as compared to the oven drying sample; 70%. Then, the starch solution obtained was analyzed using spectrophotometer analysis and qualitative starch calculation based on the amylose content in the starch. The content of amylose and amylopectin in starch is influenced by the type, age, and conditions of the process. Additionally, the quality of animal feed containing starch is strongly influenced by the level of amylose and amylopectin content due to the role of amylose and amylopectin in a process of gelatinization, retrogradation and functional characteristics of the starch. The iodine solution was used to detect the presence of amylose in the starch content as it can combine with amylose caused by straight bond structure (Subroto 2020).

Figure 6 shows the Absorbance, AU (%) curve versus starch concentration, C (g/ml) of (a) FBD and (b) oven using UV-vis spectrophotometer drying, that was analyzed using a Dash Dr 3900 at a wavelength of 610 nm to obtain the value of R2. It was found that the R2 value for the FBD sample are 98% significantly with the relationship between amylose and absorption at 610 nm as compared to the oven drying sample at 91%. The amylose content (AC) in starch content was determined by using the equation (1) where it has been proved that this model achieved higher amylose content accuracy than other models (Ronoubigouwa et al. 2015).

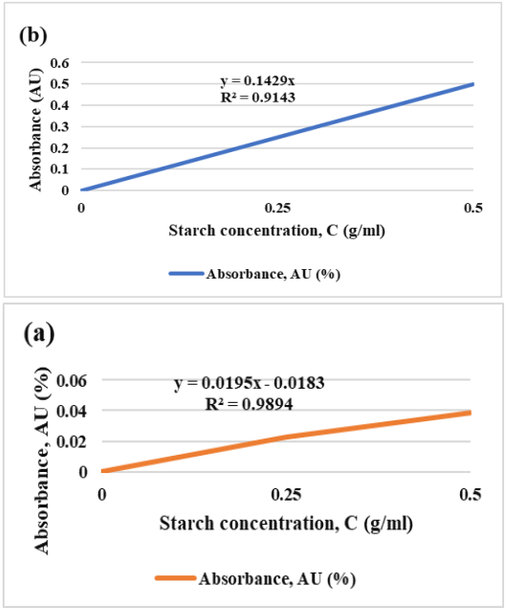


FIGURE 6 Absorbance starch by using uv-vis spectrophotometer for (a) FBD and (b) oven

The results show the percentage of amylose content in the FBD sample is slightly higher than the oven drying sample where it obtained 33.86% for FBD and 32.53% for oven drying. This is due to the amylose content increasing with temperature for which enzymes such as a-amylose, b-amylose, glucoamylase and pullulase are very active at high temperatures. in decomposing the amylose wall content in starch (Correia & Beirão-Da-Costa 2012).

$$AC\ (\%) = 5.83539 + 1.4175 \times \ln(\text{abs } 610)^2 \quad (1)$$

FIBER AND ASH CONTENT

For fiber and ash content analysis, it was found that the FBD samples achieved lower crude fiber than oven drying of which 10.76 wt.% crude fiber for FBD and 11.44 wt.% for oven drying. For ash analysis, both FDB and oven drying samples resulted almost similar content with 42.74g and 42.75g, respectively after incineration process.

ORGANIC COMPOUND BY FTIR

The existence of starch content on the wet and dried sago sample sago samples in the FBD and oven drying was identified using a Fourier infrared spectrum as shown in Figure 7. It was found that the spectra between the two samples are close to each other. Both samples showed high and wide peaks in the range of 3000 cm^{-1} to 3600 cm^{-1} due to the stretch ability of the OH group for FBD sample at 3346 cm^{-1} and for oven sample at 3344.58 cm^{-1}. Whereas a peak at around 2930 cm^{-1} for which both samples fell at a peak of 2930.76 cm^{-1} proved the CH stretch. The presence of absorbed water in both samples was also identified at a peak of 1640 cm^{-1} for FBD sample and 1613.01 cm^{-1} for oven sample. The finger range for sago residue is wide starting at the apex of 1100 cm^{-1} up to 990 cm^{-1} featuring stretching characteristics of C-O bonds in the C-O-C bonds and C-OH bonds in the glycosidic group. These two samples did not show significant peak differences but can be distinguished through peaks for the presence of triple lignin which is in between 1503 cm^{-1}, 1456 cm^{-1} and 1427 cm^{-1}. For the FBD sample, triple lignin could be identified at 1427cm^{-1} and for oven drying at 1426.31 cm^{-1}. In addition, the presence of peaks ranged from 1550 cm^{-1} to 1400 cm^{-1} which were bound by C=O bonds for acrylic acid. Acrylic acid can prove the presence of starch in the sample because acrylic acid is connected to the starch for which the FBD is at a peak of 1539.72 cm^{-1} (Yacob et al. 2003).

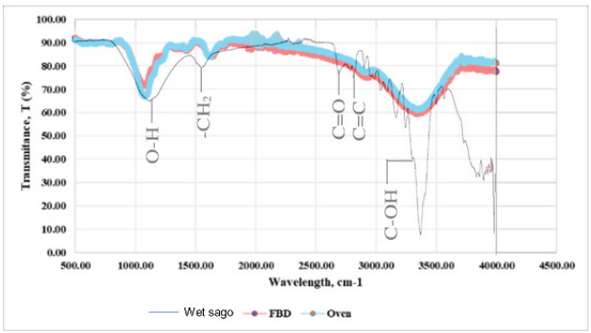


FIGURE 7 FTIR spectrum on sago waste before and after dried by using FBD and oven.

Overall, the functional group for the sago samples did not show significant changes despite the use of different temperatures. The less significant difference in FTIR spectra for these FBD and oven drying samples was due to the presence of some uncontrollable errors. Among them, the particle size of sago residue can affect the reading of the FTIR spectrum. For this study, the particle size of sago residue used was 500 µm which is under the category of fine particles (Margenot et al. 2016). Nevertheless, the largest influence of sample quantity in sieve analysis is the sieve with a large load. If a large sample load is used in the sifting process, particles can be trapped in the snare and hinder the sifting process. Thus, small particles cannot pass through the sieve and the measured size distribution can be considered too coarse (Margenot et al. 2016).

PHYSICAL ANALYSIS ON THE DRIED SAGO BAGASSE

COLOR TEST

The formation of browns in dried foods was measured by using a color meter which is usually suppressed using Hunter's color parameters, in terms of brightness, '*L*', redness, 'a' and yellowness, '*b*'. The 'L' parameter measures the brightness of the sample from (*L*=0) black to (*L*=100) white. The 'a' and 'b' parameters were measured from -60 to +60. For '*a*', the degree of measurement is from reddish green, while '*b*' is from blue to yellow. The total color change, *E* is calculated in each color change for the parameters *L, *a* and **b*. This is because, calculating the total color change, *E* more accurately evaluates the drying effect of sago residue than the three individual color parameters, namely *L, *a* and **b* (Baini & Langrish 2009). Equation (2) was used to measure the level of white, W1 samples before and after FBD and oven (Yadav et al. 2006). The initial color of the sago residue before the drying process was also measured and its value was used to calculate the total color change after drying using Equation (3) (Baini & Langrish 2009).

$$W_1 = 100 - \sqrt{(100 - L)^2 + a^2 + b^2} \qquad (2)$$

$$E = \sqrt{(L_o - L)^2 + (a_o - a)^2 + (b_o - b)^2} \qquad (2)$$

Table 2 shows the color test result of browning analysis; E where the FBD sample is quite lower than the oven drying. The browning value of the oven drying is slightly higher may be related to the moisture content of which water is one of the components in the Millar's reaction which can produce the brown color compounds such as melanoidin. The loss rate of moisture content in the oven drying sample is lower which means, the oven dryer has high moisture content at low drying rate as compared to FBD which achieves low moisture content at high and short drying rate. This feature can explain the oven dryer more browning; E is found in sago residue with high moisture content. Meanwhile, the difference in white value of sago residue samples using FBD and oven dryer

was very significant before it was dried. The white value results, W_i shows darker samples at low drying rates, for which the drying rate of the FBD is higher and shorter than the oven dryer. Visible, the oven sample is darker, L than the FBD sample. In conclusion, a sample of the oven dryer had achieved a lower drying rate showed darker, L and more brownish, E as compared to the FBD which achieved higher and shorter drying rate. This shows that the drying of sago residue samples using the FBD is more suitable for the drying process of animal feed manufacturing in maintaining the quality of the product.

TABLE 2. Final color parameter on drying sago waste

Final color parameter on drying sago waste					
	W_1	E	L	a	b
Before dry	93.31	0	58.89	-0.86	1.69
FBD	58.78	0.24	49.27	-0.99	1.89
Oven	48.04	13.57	58.84	-0.17	11.23

BET ANALYSIS

The surface area of the sago bagasse can be determined through the absorption of nitrogen on the sample using the BET method which is in the relative pressure range of 0.05 to 0.3 (Zhang 2020). Figure 8 shows the results for the pore surface area of sago residue before and after drying using a FBD and an oven dryer. It was found that the surface area of sago residue by using a FBD is higher than that of drying using an oven dryer. This is because it is possible that the rate of total water loss in the sample contributes to the increase in the total surface area of the sample (Zhang 2020). They found that the drying method on the surface area of BET samples gradually increases with the degree of hydration of a sample or the amount of moisture content lost. Such a tendency can be expected, as surface area is associated primarily with increasing C-S-H amounts with age due to continuous hydration. This also leads to an increase in the volume of the gel pores which is a major contributor to the surface area of BET. The surface area of the BET area of the oven dryer is quite lower because of the carbonization of the air which is distributed in the oven. This risk can be avoided by passing nitrogen gas ventilation through a small bottle with a sample at a temperature of 60 °C (Zhang 2020). It can be concluded that the high amount of water loss or hydration of a sample affects the surface area of BET pores. Additionally, the general expectation of an increase in the pore surface area of BET samples provides a better microstructure. In conclusion, the samples dried using a fluidized layer dryer achieved a better BET pore surface area and were close to the wet samples of sago residue compared to the oven dryer samples.

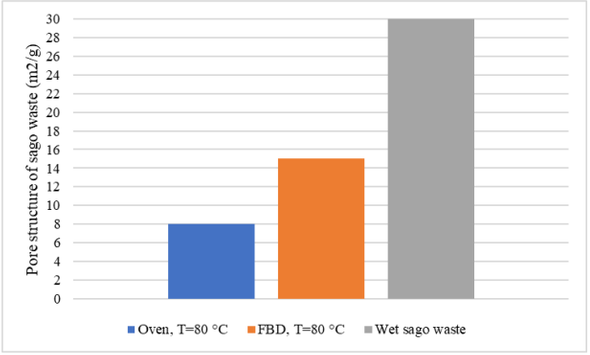


FIGURE 8 Pore structure analysis of the sago from the BET test

CONCLUSION

The effects of different drying on the chemical and physical analysis of sago residue were studied by using the FBD, oven drying and solar drying. The FBD drying at 80 °C has achieved optimum condition and shorter drying rate than the oven dryer and solar dryer in achieving the desired final moisture content for animal feed production which at 11 wt.%. For the quantitative characterization of sago residue starch, the FBD sample had achieved a higher starch and amilo content than the oven dryer as the amylose content increases with increasing temperature. in decomposing the amylose wall content in the starch. Next, the oven dryer achieves a higher fiber content than the fluidized layer dryer. In addition, the results of the organic group using FTIR also proved the presence of starch in the sample through acrylic acid at peak of 1539.72cm^{-1}. Next, the color test results for the FBD sample had achieved a total whiteness of W1 that was close to the wet sago samples and has a lower amount of browning as compared to the oven dryer. For pore surface area analysis using BET, FBD sample is slightly higher than oven dryers as the high amount of water loss or hydration of a sample affects the surface where an increase in the pore surface area of BET samples provides a better microstructure. In conclusion, the sago drying in the FBD at T=80 °C was selected as the optimum drying condition as it had achieved a short drying rate for desired final 11 wt.% moisture content and resulted in better on the chemical and physical analysis.

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DECLARATION OF COMPETING INTEREST

None

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