PRODUCTION AND CHARACTERIZATION OF CASCARA POWDER FROM COFFEE PULP

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ABSTRACT: Despite being a waste product of the coffee industry, coffee pulp contains a range of valuable nutrients. With the increasing demand for coffee in the current market, the status quo presents an opportunity for its valorization into a food ingredient such as cascara flour. Hence, this study aimed to analyze the amylographic and nutritive properties of cascara to support its development as a product. Powdering of cascara was carried out with different grinding speed (scale 1, 2, and 3) and duration (1, 2, and 3 min) variations. It was found that finer particles were achieved with greater grinding speed and longer processing time. The powder within the size range of 0.074 - 0.149 mm possesses a lower gelatinization temperature and a higher maximum viscosity value than those of 0.149 - 0.177 mm, while also having a lower swelling power value. The amylose concentration present in the cascara powder was also relatively low (10.23%) compared to the market-available flour, which causes the cascara powder to possess a high gelatinization temperature (85 – 95 °C), low maximum viscosity (132.5 - 265 cP), and low swelling power (3.214 - 7.026 g water/ g starch). The cascara powder follows a dilatant time-independent non-Newtonian fluid characteristic. The cascara powder contains 61.7% carbohydrates, 9.902% protein, 20.95% fiber, and 528 mg of vitamin C per 100 g sample.

KEY WORDS: *Coffee pulp, Cascara powder, Amylographic properties, and Nutritional Value.*

1. INTRODUCTION

By 2020, 3 billion cups of coffee are consumed each day, implying an annual global revenue of 200 billion USD [1]. This market is expected to grow by 5.30% annually until 2025 [2]. From 2014, Indonesia has been holding the fourth largest market share, following Brazil, Vietnam, and Colombia, reaching a production capacity of 12.1 million bags annually by 2020 [3,4]. Unfortunately, from each coffee fruit produced, only 10% of the mass is taken as coffee bean and the rest, the pulp and husk, is discarded [5,6]. Hence, as the business grows in profit, the organic waste issue emerges.

The discarded coffee pulp and husk contain protein, carbohydrates, fiber, and minerals that are mostly underutilized by the coffee producers in Indonesia as most resort to only composting them to fertilize the crops [7,8]. Furthermore, Raharjani et al. [9] confirms the presence of substantial

number of bioactive phytochemicals within the pulp's extract. These phytochemicals have been studied to decrease the risk of non-communicable diseases [10]. These chemicals have been a lucrative topic of extraction for flavonoid and polyphenolic substances [11-13]. Despite of various studies that report on the content of cascara and its extraction methods, there are limited studies that assess the feasibility of direct product development from cascara and its relation to the choice of production process mechanism.

Cascara is considered as "whole food" by the EPSA Scientific Committee [14], which contains mostly carbohydrates and dietary fiber. Cascara has been developed into a beverage product for its caffeine content, of 424.4 mg per 100-gram, in Europe [15]. Iriondo-DeHond et al. [16] assessed the Maillard reaction in the drying stage of instant Cascara and concluded that the process results in low caffeine (10 mg/mL) and acrylamide levels (not detectable) along with notable increase of antioxidant substances which is safe for consumption of even pregnant women. They further suggested that the instant cascara is low fat (<1.5 g/100 mL), low sugar (0.02 - 0.05 g/100 mL), high in fiber, and source of potassium, magnesium, and vitamin C (6701 mg/100 g, 121.56 mg/100 g, 438.95 mg/100 g, respectively). On the other hand, several studies expressed the possibility of cascara powder being developed as a gluten-free powder alternative as it possesses similar properties as those of generic wheat flour for baking and cooking [17, 18]. Hence, this study was carried out to assess the feasibility of cascara to be developed as an alternative powder and to determine its physicochemical properties and nutritional value in relation to varying grinding speed and time of the powdering process.

2. METHODOLOGY

2.1. Preparation of raw materials

Dried cascara (Organic & Joy) from full-washed arabica coffee cherries used in this study were obtained from Surabaya, Indonesia. The dried cascara had an initial moisture content of 11.03% (as measured by a moisture analyzer) before powdered with a grinder and analyzed for its fundamental properties.

2.2. Powdering of cascara

Powdering of cascara was carried out at 3 different speeds (scale 1, 2, 3) and 3 different processing durations (1, 2, 3 min) using a grinder (Turbo Heavy Duty EHM 8000). The powder was then sieved using mesh no. 20 (0.841 mm), 30 (0.595 mm), 80 (0.177 mm), 100 (0.149 mm), and 200 (0.074 mm).

2.3. Determination of moisture content

Moisture content analysis was caried out by placing 2 g of sample into a Moisture Analyzer HX204 (Mettler Toledo, Switzerland) set at 105 °C.

2.4. Determination of gelatinization temperature and viscosity

Viscosity and gelatinization temperature were measured using Brookfield's DVIII Ultra Rheometer with spindle type number 27 of speed 100 rpm. The powders used in this analysis were those that fall under the 0.149 - 0.177 mm and 0.074 - 0.149 mm ranges because the 0.595 - 0.841 mm range was unable to be measured by the rheometer. Gelatinization temperature was noted on 2 points, when the fluid's viscosity starts to rise and when the fluid reaches its maximum viscosity [19].

2.5. Determination of powder solubility and swelling power

Water solubility of the samples was determined by using the Kainuma method [20] and was calculated by using Eq. (1). Swelling power was determined by using the Leach method [21] and was calculated by using Eq. (2).

$$\%\ of\ solubility = \frac{Weight\ of\ soluble\ starch\ (g)}{Weight\ of\ the\ starch\ sample\ (dry\ basis)(g)} \quad (1)$$

$$Swelling\ Power = \frac{Weight\ of\ starch\ granules\ (g)}{Weight\ of\ the\ starch\ sample\ \times (1 - \%\ of\ solubility)} \quad (2)$$

2.6. Determination of rheological properties of cascara powder

A fluid's properties can generally be described as newton or non-Newtonian. The determination of this properties was done by using the procedures suggested by Hartanto [22]. The cascara powder was heated at 59 to 95 °C with a constant mixing rate of 100 rpm. When the sample reached its maximum viscosity, it formed a thick and homogenous mixture. Another sample of cascara powder was heated at the room temperature (27°C) with the same constant mixing rate as the control sample.

2.7. Determination of nutritional value

Carbohydrate, protein, and fiber content of the samples were determined using the Luff Schoorls method, Kjedahl method and gravimetric method following the procedure outlined by Indonesian National Standard 01-2981-1992 [23]. Concentration of vitamin C was determined using iodometry method according to the AOAC [24]. Concentration of carbohydrate, protein crude fiber and vitamin C were calculated by using Eq. (3) to Eq. (6).

$$\%\ of\ glucose\ = \frac{W1\ \times df}{W} \times 100\% \quad (3)$$

Where *W1* is glucose in every mL of sample (mg), *W* is the sample's mass (mg), and *df* is the dilution factor.

$$Protein\ concentration = \frac{NH_3\ \times Mr\ N \times cf}{W} \quad (4)$$

Where *cf* is the conversion factor (6.25) and *Mr N* is the molecular weight of *N* (14 g/mol).

$$\%\ of\ crude\ fiber = \frac{W_2}{W} \times 100\% \quad (5)$$

Where W_2 is the weight of sediments retained by the filter paper (g).

$$Vitamin\ C\ \left(\frac{mg}{100\ g}\right) = \frac{0.88\ \left(\frac{mg}{ml}\right) \times titrant\ volume\ \times df\ \times 100}{mass\ of\ sample\ (g)} \quad (6)$$

2.8. Determination of amylose and amylopectin concentration

Amylose and amylopectin concentrations were determined by using the method described by Apriyanto et al. [25] and calculated by using Eq. (7).

$$\%\ of\ Amylose = \frac{C\ \times V\ (mL) \times df\ \times 100\%}{mass\ of\ sample\ (mg)} \quad (7)$$

Where *C* is the amylose concentration from the standard curve (mg/mL) determined by a using a spectrophotometer at a wavelength of 625 nm, followed by an equation of standard curve from Ardiansyah et al. [26].

3. RESULTS

3.1. Determination of particle size distribution and water content

The particle size distribution yielded from different powdering time and grinding speed variations is presented in Table 1 and the code for each particle size range is shown in Table 2. Based on the results presented in Table 1, the powder made by speed 1 within 1 min has the largest accumulation of the largest particle size range (M595), amounting to a total of 74.7% of the total sample mass. The second largest particle size range (M149) is mostly accumulated within the powder resulted from speed 3 within 2 min, amounting to a total of 32.5% (w/w). Lastly, the smallest particle size is mostly retained within the mixture of powder resulting from speed 3 and 3 min of process time, amounting to a total of 43.6% (w/w). On the other hand, it can be seen that the moisture content is retained less in the final product as the process time and grinding speed increasing (1 min with speed 1 having the highest, and 3 min with speed 3 having the least).

3.2. Determination of gelatinization temperature and viscosity

Table 3 presents the gelatinization temperature and maximum viscosity of powder as per the previous speed and duration variations. It is found that most powder samples of M149 have a higher gelatinization temperature compared to that of M074 while that of the M074 range has a higher maximum viscosity than that of the M149. A comparison of the gelatinization temperature and maximum viscosity of different types of powder is presented in Table 4.

Table 1: Particle size distribution and water content of cascara powder

Grinding speed scale	Duration (min)	Particle size (mm)	Moisture content (%)	Amount of powder retained on mesh (%)
1	1	0.595 - 0.841	10.7 ± 0.02	74.7 ± 0.01
		0.149 - 0.177		14.5 ± 0.09
		0.074 - 0.149		10.7 ± 0.07
2	1	0.595 - 0.841	10.6 ± 0.05	68.1 ± 0.01
		0.149 - 0.177		16.7 ± 0.08
		0.074 - 0.149		11.8 ± 0.03
3	1	0.595 - 0.841	10.4 ± 0.09	59.5 ± 0.03
		0.149 - 0.177		19.1 ± 0.04
		0.074 - 0.149		12.6 ± 0.02
1	2	0.595 - 0.841	10.5 ± 0.01	53.1 ± 0.08
		0.149 - 0.177		23.2 ± 0.07
		0.074 - 0.149		21.7 ± 0.07
2	2	0.595 - 0.841	10.3 ± 0.02	51.5 ± 0.09
		0.149 - 0.177		23.67 ± 0.09
		0.074 - 0.149		24.74 ± 0.04
3	2	0.595 - 0.841	9.1 ± 0.02	41.28 ± 0.08
		0.149 - 0.177		32.4 ± 0.08
		0.074 - 0.149		29.0 ± 0.02
1	3	0.595 - 0.841	8.8 ± 0.07	39.0 ± 0.05
		0.149 - 0.177		28.2 ± 0.05
		0.074 - 0.149		32.7 ± 0.07
2	3	0.595 - 0.841	8.8 ± 0.03	37.4 ± 0.07
		0.149 - 0.177		26.6 ± 0.08
		0.074 - 0.149		35.8 ± 0.05
3	3	0.595 - 0.841	8.7 ± 0.01	35.4 ± 0.04
		0.149 - 0.177		21.0 ± 0.09
		0.074 - 0.149		43.6 ± 0.06

Table 2: Sample code based on particle size range

Particle Size	Code
0.595-0.841	M595
0.177-0.595	M177
0.149-0.177	M149
0.074-0.149	M074

3.3. Determination of gelatinization temperature and viscosity

Table 3 presents the gelatinization temperature and maximum viscosity of powder as per the previous speed and duration variations. It is found that most powder samples of M149 have a higher gelatinization temperature compared to that of M074 while that of the M074 range has a higher maximum viscosity than that of the M149. A comparison of the gelatinization temperature and maximum viscosity of different types of powder is presented in Table 4.

Table 3: Gelatinization temperature and maximum viscosity measurement results of cascara powder

Scale of grinding Speed	Duration (min)	Gelatinization Temperature (°C) M149	Gelatinization Temperature (°C) M074	Maximum Viscosity (cP) M149	Maximum Viscosity (cP) M074
1	1	90-95	85-90	132.5	280
2		90-95	85-90	200	225
3		90-95	85-90	180	155
1		90-95	85-90	250	170
2	2	90-95	85-90	245	135
3		90-95	85-90	250	265
1		85-90	90-95	180	145
2	3	90-95	90-95	197.5	145
3		90-95	85-90	142.5	250

Table 4: Comparison of gelatinization temperature and maximum viscosity of different types of powder

Types of Powder	Gelatinization Temperature (°C)	Maximum Viscosity (cP)	Source
Cascara	80-95	132.5-26.5	this study
Wheat Flour	82.38	2874	[27, 28]
Tapioca Starch	59-70	3402	[29, 30]
Corn Flour	61-72	3847	[29, 31]
Rice Powder	85.39	2338	[29, 32]

3.4. Determination of swelling power

The determination of the swelling power of cascara powder different particle size is presented in Table 5. A comparison of cascara powder's swelling powder and other powders is presented in Table 6.

Table 5: Swelling power of cascara powder at different powdering speeds and durations

Scale of Grinding Speed	Duration (min)	Swelling Power (g water / g powder) M595	M149	M074
1		7.02 ± 0.006	5.78 ± 0.009	5.12 ± 0.008
2	1	6.50± 0.007	5.68 ± 0.004	4.90 ± 0.001
3		6.35 ± 0.006	5.45 ± 0.009	4.63 ± 0.006
1		6.26 ± 0.001	4.96 ± 0.004	4.55 ± 0.002
2	2	6.22 ± 0.006	5.49 ± 0.001	4.31 ± 0.006
3		6.58 ± 0.008	5.10 ± 0.005	4.25 ± 0.001
1		6.20 ± 0.008	5.13 ± 0.006	4.07 ± 0.001
2	3	5.91 ± 0.009	5.03 ± 0.001	3.75 ± 0.005
3		5.66 ± 0.005	4.97 ± 0.001	3.21 ± 0.004

3.5. Determination of nutritional value

The comparison of carbohydrate contents for different powders is presented in Table 7. Table 8 presents a crude fiber concentration comparison of cascara powder and other flour. The result of protein concentration analysis is that cascara powder contains 9.902% protein, which is

considerably higher compared to other powders presented in Table 9. For vitamin C concentration determination, it is found that the cascara powder contains 528 mg vitamin C per 100 grams of cascara.

Table 6: Comparison of cascara powder's swelling power with other powders

Types of Powder	Swelling Power (g/g)	Source
Cascara	3.2-7.0	This study
Wheat Flour	4.5-7.9	[33, 34]
Tapioca Starch	13.8	[35]
Corn Flour	13.7-20.7	[36]
Rice Powder	6.4-9.0	[37]

Table 7: Carbohydrate concentrations in different types of powder

Types of Powder	Carbohydrate (%)	Source
Cascara	61.7	This study
Wheat Flour	69.0	[38]
Tapioca Starch	89.3	[29]
Corn Flour	74.2	[39]
Rice Powder	80	[40]

Table 8: Fiber contents of different types of powder

Types of Powder	Fiber (%)	Source
Cascara	20.95	This study
Wheat Flour	1.1-2.21	[41]
Tapioca Starch	2	[42]
Corn Flour	3.12	[39]
Rice Powder	0.61	[38]

Table 9: Protein concentrations of different types of powder

Types of Powder	Protein (%)	Source
Cascara	9.9	This study
Wheat Flour	8-12	[43]
Tapioca Starch	1.59	[29]
Corn Flour	8.7	[39]
Rice Powder	5.2-6.8	[44]

3.6. Determination of amylose and amylopectin concentrations

The results of amylose and amylopectin analysis are presented in Tables 10 and 11, respectively. The comparison of amylose content in cascara powder compared to generic flour is presented in Table 11.

Table 10: Concentration of amylose for different particle sizes of cascara powder

Grinding speed scale	Duration (min)	Concentration of Amylose (%)		
		M595	M149	M074
1	1	0.57 ± 0.003	2.21 ± 0.008	2.87 ± 0.009
2		0.90 ± 0.002	2.54 ± 0.008	0.57 ± 0.003
3		1.88 ± 0.009	2.21 ± 0.008	3.54 ± 0.001
1	2	2.21 ± 0.002	3.87 ± 0.002	4.20 ± 0.004
2		0.57 ± 0.003	1.23 ± 0.001	2.87 ± 0.009
3		3.87 ± 0.003	5.53 ± 0.005	7.20 ± 0.006
1	3	2.54 ± 0.008	2.87 ± 0.009	6.87 ± 0.001
2		0.57 ± 0.003	1.88 ± 0.009	6.20 ± 0.002
3		0.24 ± 0.005	2.54 ± 0.008	10.23 ± 0.007

Table 11: Concentration of amylopectin for different particle size of cascara powder

Grinding Speed Scale	Duration (min)	Concentration of Amylopectin (%)		
		M595	M149	M074
1	1	61.12 ± 0.006	59.48 ± 0.001	58.82 ± 0.001
2		60.79 ± 0.008	59.15 ± 0.001	61.12 ± 0.006
3		59.81 ± 0.001	59.48 ± 0.001	58.15 ± 0.008
1	2	59.48 ± 0.001	57.82 ± 0.007	57.49 ± 0.005
2		61.12 ± 0.006	60.46 ± 0.009	58.82 ± 0.001
3		57.82 ± 0.007	56.16 ± 0.004	54.49 ± 0.004
1	3	59.15 ± 0.001	58.82 ± 0.001	54.82 ± 0.008
2		61.12 ± 0.006	59.81 ± 0.001	55.49 ± 0.007
3		61.45 ± 0.004	59.15 ± 0.001	51.46 ± 0.003

Table 12: Comparison of amylose concentration between different types of powder

Types of Powder	Amylose concentration (%)	Source
Cascara	10.23 ± 0.007	This study
Wheat Flour	20.0	[27]
Tapioca Starch	22-28	[45]
Corn Flour	16.9-21.3	[36]
Rice Powder	26.58	[46]

3.7. Fluid characteristics of cascara powder

The change of the powder's viscosity over temperature is presented in Fig. 1. Generally, all samples experience a rise in viscosity value as temperature increases with constant mixing rate of 100 rpm. With the grinding speed of 1 for 1 min presented by Fig. 1(a), the viscosity of sample M149 experienced a small rise in viscosity value throughout the change in temperature from 45-95 °C, having a maximum of 132.5 cP. Whereas, after a small change of viscosity throughout 45-85°C sample M074 experienced a significant rise of viscosity at temperature 85-95°C with the maximum value of 280 cP. Hence, sample M074 possesses larger change in viscosity value compared to M149.

Samples of grinding speed of 2 for 1 min presented by Fig. 1(b) presents a significant rise in viscosity at 85-95°C for sample M074, giving a maximum of 225 cP, and 90-95°C for sample M149, giving a maximum of 200 cP. Thus, sample M074 possesses a larger maximum viscosity

compared to sample M149. Fig. 1(c) shows an exponential rise of viscosity value of sample M074 at 75-95°C, showing a maximum of 245 cP. On the other hand, sample M149 had an increase in viscosity value from 90-95°C, with the maximum being 180 cP. Sample M149 on Fig. 1(d) shows a steady rise in viscosity value with the increase in temperature from 65-90°C and an abrupt change from 90-95°C, showing a maximum of 250 cP.

Whereas M074 shows a steady decrease in viscosity from 45-85°C, an increase in viscosity only until 85-95°C, reaching a maximum of 170 cP. Sample M149 on Fig. 1(e) shows a steady rise in viscosity value with the increase in temperature from 55-90°C and an abrupt change from 90-95°C, showing a maximum of 245 cP. Whereas M074 shows a small and steady increase from 45-80°C with a larger change at 80-95°C, reaching a maximum of 135 cP. Sample M149 on Fig. 1(f) shows a steady rise in viscosity value with the increase in temperature from 45-90°C and an abrupt change from 90-95°C, reaching a maximum of 250 cP. Whereas M074 shows a steady increase in viscosity from 55-90°C with a larger change at 90-95°C, reaching a maximum of 265 cP.

Fig. 1(g) shows an inconsistent trend of viscosity change of sample M149 where there's an increase from 45-70°C and a decrease from 70-85°C. A significant rise of viscosity value happens from 85-95°C, reaching a maximum of 180 cP. Whereas M074 shows a steady increase from 45-95°C, reaching a maximum of 155 cP. Fig. 1(h) shows a steady increase of viscosity value of sample M149 from 60-90°C and a significant change from 90-95°C, reaching a maximum of 197.5 cP. Whereas M074 shows a steady increase from 45-95°C, reaching a maximum of 145 cP. Sample M149 on Fig. 1(i) shows a generally steady rise in viscosity value with throughout 45-95°C, reaching a maximum of 142.5 cP. Whereas M074 shows a small and steady increase from 45-80 ^{o}C with a significant rise at 85-95°C, reaching a maximum of 250 cP.

4. DISCUSSION

4.1. Effects of grinding speed and powdering time on particle size distribution

It is shown in Table 1 that as grinding speed and powdering time increases, the cascara powder particle size gets smaller. This is parallel to the findings of Deng and Manther [47] on the correlation between the grinding speed and the amount of time used in the process to the output particle size. This phenomenon accounts for the increasing probability of impact as grinding speed and process time increase. Another factor that may affect the particle size distribution in the powdering process is the cascara's plasticity that is influenced by the drying of the sample.

From Table 1, the grinding speed and processing time affect the moisture content within the powder. As the grinding speed and the processing time increases, the lower the moisture content of the final product will be. This observation can be explained by the fact that some of the kinetic energy produced by the grinding is converted into heat energy that is transferred into water molecules in the powder and is then converted back into kinetic energy in the removal and vaporization of the water molecules. This is consistent with the findings reported by Deng and Manther [47], according to which the highest grinding speed with the longest processing period results in the greatest accumulation of heat energy in the system. The analysis presents that all powder possesses moisture content of less than 14% and hence by that parameter alone, cascara powder may have the potential to be a flour alternative [48].

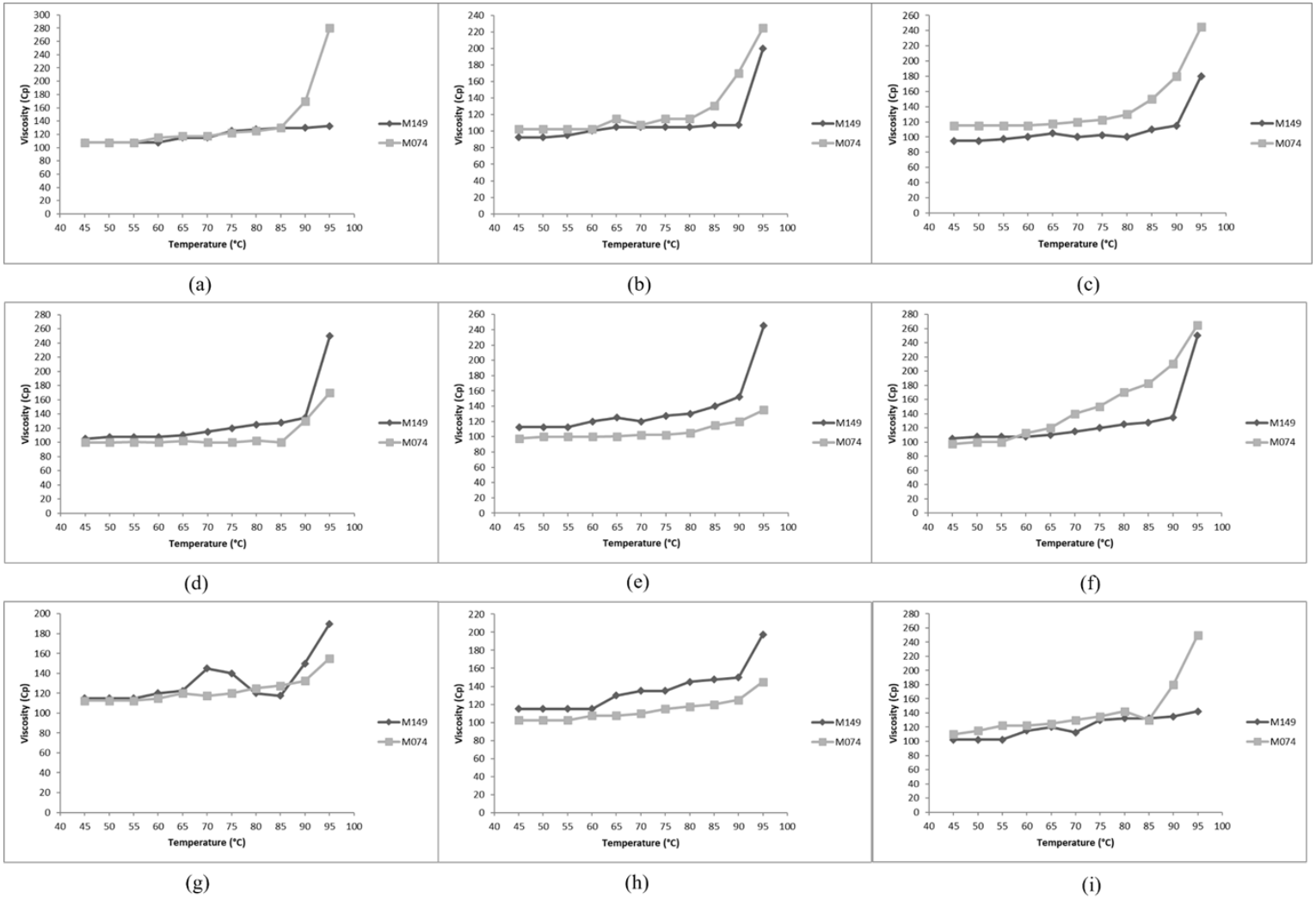

Fig. 1. Viscosity profile over temperature for (a) blender speed 1 for 1 min, (b), blender speed 2 for 1 min (c), blender speed 3 for 1 min (d) blender speed 1 for 2 min, (e) blender speed 2 for 2 min, (f) blender speed 3 for 2 min, (g) blender speed 1 for 3 min, (h blender speed 2 for 3 min), (i) blender speed 3 for 3 min.

4.2. Effects of particle size on gelatinization temperature and viscosity

The findings of this study presented in Table 2 are aligned with the findings of Muhandri [49], in which larger powder particles results in a more difficult gelatinization process and possess higher viscosity. In most industrial processes, materials with lower gelatinization temperature are preferred as it implies faster cooking process and hence lower energy consumption [50]. This study also finds that cascara powder possesses similar maximum viscosity ranges to commercial wheat and rice flour. However, the maximum viscosity of the powder is significantly less than that of the others. This may imply that cascara powder may be utilized for foods that have a non-rigid consistency, such as sweet sauces [50].

4.3. Effects of particle size on swelling power

Based on the findings presented by Table 4, generally, the cascara powder in this study possesses a swelling power within the range of 3.214 - 7.026 g/g. Samples of smaller particles present a lower swelling power compared to those composed of larger particles. This is because hydrogen bonds in smaller starch particles strengthen as the size of the starch molecules decreases, resulting in a decrease in water absorption capacity [51]. Furthermore, as the moisture content in the powder decreases with the increase in grinding speed and duration in the powdering stage, the swelling power decreases as well. This may be caused by the decrease in space between the neighboring solid molecules after powdering. Hence, there is less space for water droplets to enter the intermolecular bonds of granules [52]. It is also found that the gelatinization temperature is proportional to the swelling power and inversely proportional to the maximum viscosity. At a low gelatinization temperature, the powder will be easier to gelatinize, hence the viscosity will be high. In that case, hydrogen bonds that attract water will be scarce, thereby reducing the swelling power [53].

4.4. Effects of amylose and amylopectin concentration on physicochemical properties of cascara powder

The highest amylose concentration presented by Table 10 is 10.23 %. The comparison of amylose concentration between different powders is presented in Table 6. It is found that amylose in cascara powder is substantially less than that of commercial flours. Amylose content is proportional to fluid viscosity and the ease of gelatinization [54]. This is because, in low concentration, amylose is difficult to expel out of starch granules. Hence, this finding supports the previous in which viscosity of cascara powder is low (132.5-265 cP) and low gelatinization temperature. On the other hand, amylose concentration is inversely proportional to the swelling power of the powder as amylose blocks water from entering the starch granules by forming a complex with starch and lipid molecules [55]. Hence, a high swelling power of 7.026 g/g found through this research with the low amylose concentration can be justified.

The previous also implies that the amylopectin concentration in cascara powder is higher compared to others. As amylose contributes to the rigidity of a processed product, while amylopectin contributes to the gooeyness of a material, cascara powder may be considered as a basis for food products needing a low-rising and gooey texture such as sauces [50].

4.5. Nutritional values of cascara powder

Based on Table 6, it is found that cascara powder has a relatively low concentration of carbohydrates compared to the other powders, although very close to that of wheat powder. This implies that cascara powder may be an alternative to a low-carb flour product used in controlled diets. As seen in Table 7, cascara powder possesses around 7 - 20 times more fiber than the other powders. To the physicochemical properties of the powder, high crude fiber concentration contributes to the low viscosity of the cascara powder mixture as they possess high water absorption capacity. As a food product, high fiber content is beneficial in the prevention of digestive and cardiovascular disorders, as well as mammary gland and colon cancer [58]. Furthermore, fibers may help with dietary programs that focuses on weight loss [55]. Considering this fact, cascara may be a contender on the nutritional side for its gluten-free, low carb, and high fiber content. Compared to the currently available dietary powders, that are mainly made from almond, quinoa, brown rice, and whole wheat, cascara may have the upper hand in the supply chain as it is always readily available from the waste of coffee production.

As presented in Table 8, the cascara powder used in this study contains 9.9 % protein, which is considerably higher than most commercial flour. Tjahjadi [55] suggested that this is a competitive advantage of cascara powder as the higher the protein content in a powder, the more it is regarded as possessing high nutritional value. This study found that cascara powder possesses high vitamin C concentration. This becomes a unique selling proposition for cascara powder as the other powders do not contain vitamin C [56].

4.6. Fluid characteristics of cascara powder

Fig. 1 presents an incremental change in viscosity value of powder mixture as temperature increases. This implies that cascara powder is not a pseudoplastic non-Newtonian fluid that supposedly decreases in viscosity as it is given shear stress [57]. All in all, based on the parallel finding by Widjanarko [31], it can be inferred that cascara powder is most likely a dilatant time-independent non-Newtonian fluid as the viscosity thickens with the increase of shear stress.

5. CONCLUSIONS

The finer the particle size of cascara powder, the lower its gelatinization temperature and swelling power, and the greater its maximum viscosity would be. Cascara powder is found to follow the characteristics of a dilatant time-independent non-Newtonian fluid. The cascara powder used in this study contains 10.23 % amylose, which contributes to high gelatinization temperature (80-95°C), low maximum viscosity (132.5 - 26.5 cP), and a considerably higher swelling power (3.21 - 7.03 g/g) compared to the other commercially available powders. Meanwhile, it contains 61.7% carbohydrates, 9.9% protein, 20.9% fiber, and 528 mg/100 g of vitamin C. Hence this study concludes that cascara is potential to be used as a low-carb, gluten-free, high vitamin dietary ingredient.

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