FOOD
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RESEARCH

The potential source for composite flours as food ingredient from local grown crops

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Abstract

The market of composite flour is growing as consumer nowadays choosing a healthy diet as personal preference. The suitability of the composite flour for use as intermediate or finish food ingredients highly depends on its physicochemical properties and its nutritional value. In this study, four types of local fruit crops (particularly their seeds) namely *rambutan*, *cempedak*, *durian* and *nangka* were dried and ground into powder form. The physicochemical properties such as bulk density, pH, water absorption capacity (WAC), oil absorption capacity (OAC), foam stability (FS), foam capacity (FC) as well as gelatinization properties of these composite flour were studied. Mineral content and heavy metal analytes were also determined. Results for bulk density from the least to the higher amount was 0.54±0.00 g/mL, 0.57±0.00 g/mL, 0.58±0.01 g/mL, 0.66±0.00 g/mL , 0.70±0.00 g/mL and 0.72±0.00 g/mL for *rambutan* flour, *cempedak* flour, tapioca flour, *nangka* flour, wheat flour and *durian* flour, respectively. Both *cempedak* flour and *nangka* flour showed the lowest pH value (5.72±0.01, 5.73±0.00), followed by *rambutan* flour and *durian* flour (6.67±0.00, 6.90±0.00) which similar to that tapioca flour and wheat flour (6.65±0.1, 6.08±0.0), respectively. *Rambutan* flour, *cempedak* flour and wheat flours showed the highest value in% of foam stability meanwhile these composite flours showed the lowest value in% of foam capacity. Results for water absorption capacity (WAC) and oil absorption capacity (OAC) in a range of 6% to 42% and 8% to 12% respectively, however, durian flour obtained the highest value for WAC while the value for OAC was the lowest. All of the composite flour possesses gelling properties at 13% concentration except for *cempedak* flour which completely gels at 20% of concentration. *Rambutan* flour showed the highest mineral analyte particularly in Zinc (107.19±0.17) and Copper (14.22±0.27) followed by *nangka* flour [Zinc (64.20±0.32) and Copper (10.40±0.12)] and *durian* flour [Zinc (52.38±0.42) and Copper (7.97±0.05)]. Level of heavy metal toxicity was under risk for all types of composite flour.

1. Introduction

Composite flours are a mixture of different vegetable flours rich in starch or protein, with or without wheat flour, for certain group of bakery products and its definition by Anon *et al.* (2018) is "composite flours are a mixture of flours from tubers rich in starch (e.g. cassava, yam, sweet potato) and/or cereals (e.g. maize, rice, millet, buckwheat), with or without wheat flour". Wheat flour is commonly used as it contains gluten which is responsible for the elasticity of the dough, improving the texture of the baked products. Gluten contains 75-86% protein and the remaining nutrients are carbohydrate and lipid, held strongly within the gluten-protein matrix (Anon *et al.*, 2018).

There have been several studies conducted on fruits which have been combined with wheat flour to produce bakery products. A study done by Feili *et al.* (2014) reported that 5% substitution of the jackfruit rind flour gave the highest mark for overall acceptance compared to 10% and 15% substitution of jackfruit rind flour with wheat flour. Research by Papa Spada *et al.* (2018) reported that the jackfruit seed flour could be used in food preparation and has potential as cocoa powder substitute. Other studies conducted by Rohman (2017)

stated that rambutan seed is a potential source of flour which is rich in carbohydrate. Nevertheless, other sources used to produce composite flour are from fruits as they contain a significant amount of vitamins, minerals and antioxidant properties as well as low in sodium, fat and calories (Nurul Izzah *et al*., 2012). The recent development in food industries used gluten-free composite flours to produce food products that are more suitable to people who have celiac disease or other health-conscious individuals. A wide range of healthy, gluten-free alternatives to regular or wheat flour exists for people with celiac disease, non-celiac gluten sensitivity or those avoiding gluten for other reasons. The worldwide number of sufferers of coeliac disease has been predicted to increase resulting in a growing market for gluten-free cereal-based products (Lebwohl *et al*., 2017). Yet, the suitability of the composite flour to be used in the food as a food ingredient are highly depending on the functional properties such as bulk density, pH, moisture content, gelling concentration, gelatinization, water absorption capacity, oil absorption capacity and foam capacity and stability give effect to the texture of processed food. Functional properties are the intrinsic physicochemical properties that reflect the complex interaction between the composition, structure, confirmation and other food components which are associated (Chandra *et al.*, 2015).

In general, Malaysian fruits such as *rambutan*, *nangka* and *cempedak* are abundant and it is becoming necessary to find a solution that could maximally utilize these crops through innovative product development. The need to fully utilize and reduce post-harvest losses of a local source is a major drawback to researchers in our country and also the lack of body of knowledge that adds to this issue. In addition, as there is an increasing demand using composite flours as a substitute for wheat flour for food products such as high-fibre bread, pasta, flakes and biscuits in commercial markets, the need to provide information on the scientific studies of composite flour is vital. For this purpose, the physicochemical properties of local grown fruits crops were studied. Adding up to the demand in composite flours with an adequate level of mineral and the toxicity level of heavy metal analytes, both analytes were also analyzed.

2. Materials and methods

Fresh and ripe fruits were bought from the market in Taman Universiti, Skudai, Johor**.** Wheat flour and tapioca flour were purchased from a grocery shop in Taman Universiti, Skudai and used as a benchmark**.**

2.1 Preparation of composite flours

The fresh fruits were washed before peeled to separate the seeds and its flesh. The seeds of each fruit were manually removed from pulp and washed to remove any adhering materials. The preparation of composite flours for each fruit was based on Menon *et al.,* (2014). Each of these samples was then dried in a hot air oven at 60°C for 6 to 8 hrs. The dried samples were then milled and the grounded flour samples were sieved at 100 μm mesh size to obtain fine texture flour. Lastly, samples were packaged in polyethylene bags and stored at room temperature for further use.

2.2 Bulk density

Bulk density was determined based on the method by Oladele and Aina (2007). A 10 mL graduated cylinder, previously tared, was gently filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 mL mark. Bulk density was calculated as the weight of sample per unit volume of sample (g/mL).

2.3 pH

The pH was measured by preparing a 10% (w/v) suspension of samples in distilled water. The suspension was mixed thoroughly and the pH was measured (Model Mi 150).

2.4 Moisture content

The moisture content of samples was determined according to AOAC standard procedures (AOAC, 1975).

2.5 Gelatinization

The flour sample (1 g) was weighed and transferred to 50 mL centrifuged tube followed by 10 mL of distilled water. The suspension was gradually heated in water bath until they form a solid gel. At complete gel formation, the respective temperature was measured and considered as its gelatinization temperature which is based on the method by Chandra and Samsher (2013).

2.6 Gelling concentration

Gelling concentration was done employing the method by Adebowale *et al.* (2005). Sample suspensions containing 1, 7, 13 and 20% (w/v) of flour concentration were prepared in 5mL distilled water. The mixtures were heated in a boiling water bath for 1 hr followed by rapid cooling under running cold tap water. The mixtures were allowed to further cool down for 2 hrs at 4°C. The least gelation concentration was determined as that concentration when the sample from the inverted test

tube did not fall down or slip.

2.7 Water absorption capacity (WAC)

WAC of flours was carried out using the modified method of Akanbi *et al.* (2009). About 2 g of the sample was suspended in 20 mL of distilled water in a centrifuge tube. The sample was then stirred for 30 s at every 10 mins interval by using a glass rod. After 5 intervals, the mixture was then centrifuged at 4000 rpm for 20 mins at 4°C. Then, the supernatant was gently decanted and the content of the tube was drained at 45° angle for 10 mins. The gel formed at the bottom of the centrifuge tube was then weighed. WAC was expressed as percentage increase of sample weight.

2.8 Oil absorption capacity (OAC)

OAC of the flour samples was done by employing the method by Adebowale *et al.* (2005) with some modifications. About 1 g of the flour sample was added to the tube and weight (labelled B). 10 mL of canola oil was added to the test tube and weight (labelled C). The mixture of sample and oil were vortex for 1 minute and allowed to stand at room temperature for 10 mins then was centrifuged at 4000 rpm for 30 mins at 4°C. The supernatant (unabsorbed oil) was decanted and the tubes were allowed to drain at a 45° angle for about 10 mins and the residue weight (labelled D). The result was expressed as a percentage increase of the sample weight.

$$\% \ absorption = \frac{D - B}{C - B} \cdot 100$$

2.9 Foam capacity and stability

The foam capacity and foam stability were determined according to the method by Makri *et al.* (2005) with slight modification. About 1 g flour and 50 mL distilled water at room temperature were prepared in a calibrated centrifuge tube and whipped with a homogenizer for 5 mins to foam. The volume of foam at 30 s after whipping was expressed as foam capacity using the formula:

$$Foam \ capacity \ (\%) = \frac{volume \ of \ foam \ (ml)}{initial \ volume \ (ml) \ before \ homogenization} \times 100\%$$

After 1 hr whipping, the volume of foam was recorded to determine the foam stability as percent of initial foam volume.

$$Foam \ stability \ (\%) = \frac{volume \ of \ foam_{after \ 1 \ hour} - volume \ of \ foam_{after \ 30 \ seconds}}{volume \ of \ foam_{after \ 30 \ seconds}}$$

2.10 Mineral and heavy metal analytes determination (digestion procedure)

For the digestion of the samples, a representative of 1 g of dry weight sample is digested with 1 mL of 60% analytical grade Nitric acid (Sigma Aldrich, Germany) and ultrapure water (Hitachi, Japan). The digestate was heated using a hot plate under boiling temperature until white vapour appeared. The sample was then diluted with ultrapure water until it reached a 100-mL final volume. The sample is filtered using 0.25 nylon syringe filter and ready for Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) injection. For the precise quantification of heavy metal and mineral analytes, calibration against synthetic standards was used before running the sample. 1000 µg/kg multi-element standard was used from Perkin Elmer standard solution and diluted to 10, 20, 30, 50 µg/kg and 25 µg/kg as Quality Control (dissolved with 1% nitric acid (Sigma Aldrich, Germany). The data acquisition was done by ICP-MS Software (ELAN 6100, Perkin Elmer).

3. Results and discussion

3.1 Physicochemical properties of composite flours

Table 1 shows the data for the physicochemical properties of composite flours. In this study, the investigation of the physicochemical properties will provide information about the physical changes that may occur during the processing and development of food product. The parameter which discussed here includes bulk density, pH, moisture content, water absorption capacity (WAC), oil absorption capacity (OAC), foam stability and foam capacity. Bulk density measures flour heaviness, defined as the ratio of flour weight to volume (g/mL). This enables one to predict its characteristics and compressibility of a food product. This is supported by Oulai *et al.* (2014) as they reported that this parameter determines the suitability for flours to facilitate in particulate foods packaging to maximize packing density of the powder for the efficiency of transportation. Based on Table 1, bulk density of composite flours varied from 0.54±0.00 g/mL to 0.72±0.00 g/mL with *durian* seed flour showing the highest value of bulk density (0.72±0.00), while *rambutan* seed flour (0.54±0.00 g/ mL) showing the lowest value of bulk density. High bulk density of flour suggests the suitability for use in food preparations especially as a thickener in food products since it helps to reduce paste thickness which is an important factor in convalescent and child feeding (Chandra *et al.*, 2015).

The pH analysis of all composite flours was acidic varies from 5.72±0.10 to 6.90±0.10. Changes in pH values are directly related to the maturation stage of the fruits. Based on the result, d*urian* has the highest pH value while *cempedak* has the lowest pH value as in Table 1. Considering the low pH of the composite flours evaluated in this study, it has a low risk of food deterioration by microorganisms, enzymes or non-enzymatic reactions (Damasceno *et al.*, 2016).

The moisture conditions of products are influenced by differences in variety, maturity and environmental conditions (Tortoe *et al.*, 2014). Analysis of moisture content in the food industry is fundamental for guaranteeing the final product quality. Based on Table 1, the moisture content of composite flours varied from the lowest value to the highest value; 5.64±0.10 to 11.91±0.20 respectively. It can be observed that composite flours from the fruit's seed gave lower values compared to the wheat flour and tapioca flour. Therefore, it can be concluded that composite flour from the seed such as *rambutan* (5.64±0.10), *durian* (8.18±1.60), *nangka* (8.66±0.00), and *cempedak* (8.68±1.70) have the tendency of longer storage and better shelf life compared to the wheat flour (11.80±0.10) and the tapioca flour (11.91±0.20).

Water absorption indicates (WAC) the ability of the flour to absorb and hold water to achieve desired consistency and create a quality end product. Based on Table 1, the WAC of sample tapioca flour was 6.00±0.30% while that of sample *durian was* 41.55±2.90%, indicating that *durian* flour has higher WAC. Therefore, it has a higher affinity for water which is informed by its lower moisture content. The ability of flour to absorb more water can improve the consistency and texture in food products. Increase in WAC is related to the fibre content due to increasing hydroxyl groups allowing more water interaction via hydrogen bonding (Chareonthaikij *et al.,* 2016). These results suggest lower WAC may be useful for food formulations such as partial wheat flour replacer for dough handling in baking and pastry products (Chen, 2016)

Oil absorption capacity (OAC) is the ability of the flour to absorb and retain oil and reflects the emulsifying capacity of the flour thus it will contribute to the flavour that gives mouthfeel and increases soft texture to the mouth (Oulai *et al*., 2014). Based on results in Table 1, the OAC of *rambutan* flour, *nangka* flour and *cempedak* flour are 10.74±0.50%, 10.39±1.70%, 11.83±0.20% respectively which is slightly similar to tapioca flour (10.68±0.20%). While *durian* flour and wheat flour having similar range value of OAC; (8.76±0.90%) and (8.84±0.20%) respectively. From the data, it is suggested that *durian* flour and the wheat flour will contribute less

mouthfeel and decrease the soft texture in the mouth. On the other hand, the lower value of OAC will contribute to a lower degree of rancidity during the storage period. The ability of OAC is related to its amino acid composition, protein conformation and surface polarity or hydrophobicity (Chandra *et al*., 2015).

Foam capacity (FC) of protein refers to the amount of interfacial area that can be created by the protein while foam stability (FS) is defined as the ability of the protein to stabilize against gravitational and mechanical stresses (Fennama, 1996). Results for FC and FS are presented in Table 1. The FC of composite flours are varied from 4.0 to 32.0%, with the highest FC was wheat flour (32.0%) while the lowest FC were tapioca flour, *durian* flour and *rambutan* flour (4.0%). On the other hand, the FS data are in the range from 0 to 100%. The highest foam stability was observed for *rambutan* (100%), followed by wheat flour (37.5%), *cempedak* (25.0%) and *nangka* (12.5%). Interestingly, both tapioca flour and *durian* flour showed no foam stability. There was an inverse in the relationship between foam capacity and stability. Flour with high foaming ability could form large air bubbles surrounded by thinner less flexible protein film (Chandra *et al*., 2015). This air bubbles probably easier to collapse and consequently lowered the foam stability (Jitngarmkusol *et al*., 2008). In order to improve texture and sensory properties, other processing aids are added, including emulsifiers, stabilizers and including food hydrocolloid (Moore *et al*., 2006)

3.2 Gelation properties of composite flours

Table 2 shows the gelatinization properties of composite flour. Gelatinization temperature of *rambutan* flour, *nangka* flour, *cempedak* flour and wheat flour (> 90°C) were slightly higher than that of *durian* flour and tapioca flour (< 85°C). Gelatinization temperature has been described as the point at which irreversible swelling of starch granules occur, resulting in the formation of a viscous paste. It is indicative of the minimum temperature required to cook starch/flour slurry and the energy costs involved (Chandar and Shamser, 2013). It was observed that (Table 2) only tapioca flour (82°C), *durian* flour (85°C) and *nangka* flour (95°C) possess complete gelatinization. This is probably due to the

Table 1. Physicochemical properties of composite flours

Sample	Bulk Density (g/mL)	Foam		pH value	% Moisture Content	Water Absorption Capacity		Oil Absorption Capacity	
		% Capacity	% Stability			% weight increase	% water absorbed	% weight increase	% oil absorbed
Rambutan	0.54±0.00	4	100	6.67±0.00	5.64±0.10	92.71±0.90	10.16±0.10	90.39±4.10	10.74±0.50
Durian	0.72±0.00	4	0	6.90±0.10	8.18±1.60	450.13±3.10	41.55±2.90	72.90±3.30	8.76±0.90
Nangka	0.66±0.00	16	12.5	5.73±0.00	8.66±0.00	257.66±3.40	27.12±0.60	87.81±3.90	10.39±1.70
Cempedak	0.57±0.00	8	25	5.72±0.10	8.69±1.70	304.25±3.50	31.73±4.00	94.89±2.20	11.83±0.20
Wheat	0.70±0.00	32	37.5	6.08±0.00	11.81±0.10	151.56±3.90	17.01±0.20	69.37±2.90	8.84±0.50
Tapioca	0.58±0.10	4	0	6.65±0.10	11.91±0.20	53.95±2.40	6.00±0.30	88.20±3.40	10.68±0.20

Table 2. Gelatinization properties of composite flours

Gelling	1%	7%	13%	20%	Gelatinization
Rambutan	No gel observed	Slightly gelling observed	Gelling observed	Gelling observed	95°C (slightly gel)
Durian	Slightly gelling observed	Slightly gelling observed	Gelling observed	Gelling observed	85°C (gel)
Nangka	No gel observed	Gelling observed	Gelling observed	Gelling observed	95° C (gel)
Cempedak	No gel observed	Slightly gelling observed	Slightly gelling observed	Gelling observed	95°C (slightly gel)
Wheat	No gel observed	Gelling observed	Gelling observed	Gelling observed	95°C (slightly gel)
Tapioca	Slightly gelling observed	Slightly gelling observed	Gelling observed	Gelling observed	82° C (gel)

higher amount of amylose and a greater degree of retrogradation which is caused by amylose-lipid complex in the granules being broken by heating (Chandar and Shamser, 2013).

Gelation is an aggregation of the denatured molecule and the ability of the protein to form gels and provide a structural matrix for holding water, flavours, sugars and food ingredients which is useful in food applications. Index of gelation (LGC) is observed from the characteristics of elasticity, viscosity and plasticity. The lower the gelation concentration, the better the gelating ability of protein ingredient (Akintayo *et al.*, 1999) which results in the swelling ability of the flour is enhanced (Kaushal *et al.*, 2012). All the samples completely formed gel at concentration 13% except for the *cempedak* flour which formed gel completely at the highest concentration of 20%. This suggested that *cempedak* flour contain the lowest starch components which result in low thermal degradation of starch during the processing. This might be associated with the gelatinization ability of globulin ratio in flour (Wani *et al.,* 2012). Meanwhile, wheat flour and *nangka* flour formed gel completely earlier than other samples which is at concentration 7%. Therefore, flours with least gelation concentration are reported to be good thickening agents and hence, are not suitable for infant formulation since it requires more dilution (Appiah *et al.,* 2011).

3.3 Essential mineral and heavy metal analytes determination in composite flours

Table 3 shows the essential mineral analytes of composite flour. Eleven mineral analytes were detected from the ICP-MS spectrometry. Among them, eight mineral analytes were at minimum detection (ppm) which were Cr, Ni, Ag, Be, Co, V, Se and Sr for all the composite flours. Al and Zn were the two mineral analytes that exist in a large amount in all composite flours. However, *rambutan* flours contained the highest amount of all analytes compared to the *durian* flours, the *nangka* flours and the *cempedak* flours. These analytes although exist in a minute quantity, they are important in maintaining many homeostatic mechanisms including efficiency of immune system as well as cell proliferation and genome stability (Bier *et al.,* 2015). In addition, these minerals are required in a small quantity in our body. On the other hand, in this study, the heavy metal analytes of flours were also determined. Figure 1 shows the heavy metal analytes detected in the composite flour. Only three heavy metal analytes were detected in all composite flours namely Arsenic (As), Lead (Pb) and Cadmium (Cd). As in Figure 1, Pb contributes the highest amount of heavy metal analytes in all the

Table 3. Mineral analytes detected in composite flour

Mineral analytes	Concentration mean (ppm)			
	Durian	Rambutan	Nangka	Cempedak
Aluminium , Al	23.74±0.58	47.13±0.48	10.35±0.28	41.37±0.05
Chromium, Cr	2.12±0.08	1.39±0.09	1.79±0.01	1.69±0.01
Nickel, Ni	1.05±0.00	2.81±0.12	0.78±0.01	0.48±0.00
Silver, Ag	0.03±0.00	0.07±0.00	0.05±0.00	0.11±0.00
Beryllium, Be	0.01±0.00	0.07±0.00	0.01±0.00	0.01±0.00
Cobalt, Co	0.17±0.02	0.07±0.01	0.03±0.00	0.03±0.00
Vanadium, V	0.01±0.00	0.07±0.01	0.00±0.00	0.00±0.00
Copper, Cu	7.99±0.05	14.22±0.28	10.40±0.12	5.24±0.00
Selenium, Se	0.06±0.00	0.15±0.02	0.09±0.00	0.10±0.00
Strontium, Sr	2.47±0.06	6.08±0.01	5.20±0.14	2.41±0.01
Zink, Zn	52.38±0.42	107.39±0.17	64.23±0.32	29.61±0.03

composite flours while the other two heavy metal (As and Cd) were detected at the minimum level. The detection of Pb, Cd and As is vital as these heavy metal analytes can lead to adverse effects, although they are only present in small quantity. From the data obtained (Figure 1), these three heavy metal analytes were detected to be below the maximum admissible limit (LMA) in the composite flours. The LMA of these heavy metal is Pb (1 mg/kg), LMA of As (0.02mg/kg) and LMA of Cd (0.05 mg/kg)(Malaysian Food Regulation 1985). In general, all the composite flours were without risk of contamination
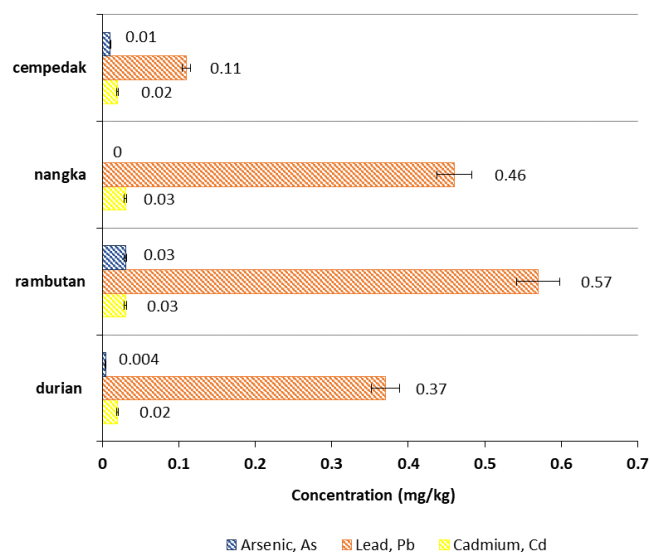

Figure 1. Heavy metal analytes detected in composite flours (n=3)

5. Conclusion

Each composite flours has extinguished characteristic that enables the incorporation of the composite flours into new food product formulation. Protein gelation is vital in the preparation and acceptability of many foods, including vegetables and other products while foaming stability is useful in the food system such as confectionery products. Other properties such as WAC, OAC, pH and bulk density investigated in this study showed promising data and proposed that the composite flour from local are an ideal raw material to be utilized as semi and/or intermediate finish products in various food products and beverages. In addition, mineral analytes determined in these composite flour will add value to the products. All results obtained confirmed that the composite flours are safe to consume.

Conflict of interest

The authors declare is no conflict of interest.

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