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The Physical and Functional Properties of Partially Defatted Coconut Testa Flour

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ABSTRACT

Coconut testa is an important byproduct of the coconut industry. In this study, particle size distribution, physical and functional properties of flour produced from partially coconut testa of four local cultivars namely san raman, gon thembili, ran thembili, TallxTall were compared with those of commercial hybrid (COM) using relevant procedures. Results showed that particle size distribution, physical and functional properties of flours of different coconut cultivars were varied significantly ($p<0.05$). The highest bulk density value was observed for SR (0.67 g/ml) while the lowest for TxT (0.54 g/ml) ($p<0.05$). Maximum swelling capacity (35.00 ml) and oil absorption capacity (142.67%) were recorded for COM while the least swelling capacity (20.67 ml) and oil absorption capacity (85.67%) were recorded for RT ($p<0.05$). The highest emulsion activity was found for COM (50.00%) while the least value recorded for SR (42.95) ($p<0.05$). The maximum emulsion stability was displayed by COM (54.86%) while the least emulsion stability was recorded for GT (27.51%) ($p<0.05$). The observed physical properties suggested that coconut testa flour of COM variety has certain advantages over others. It could be used for partial replacement with wheat flour for value addition leading to non-cereal based products.

Key words: *Agro-waste utilization, coconut byproducts, coconut testa, coconut testa flour, flour properties*

INTRODUCTION

Coconut (*Cocos nucifera* L.) is a tropical monocotyledon perennial crop belonging to the family arecaceae. The fruit of coconut has a number of sub-components, each of which finds beneficial uses to humankind. Among the different sub-component parts of the coconut, the white kernel is the most valuable part contributing to the highest economic value. The thin brown outer layer present adjacent to the hard shell covering the white kernel is called testa (Lima *et al*., 2015). According to previous studies, testa constitutes approximately 18% (w/w, wet basis) of the fresh coconut kernel weight (Marikkar and Madurapperuma, 2012). Often, testa is removed during the production of virgin coconut oil, desiccated coconut, coconut milk, and coconut milk powder due to the unappealing brown colour imparted on the finished products. According to current practice, removal of testa takes place after deshelling the coconut, done manually using paring knives (Marikkar and Madurapperuma, 2012). As the total annual production of coconut in Sri Lankan is in the range of 2500 – 3000 million coconuts (CDA, 2016), a considerable amount of testa is left under-utilized in the above-mentioned industries. The current utilization of testa is merely

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limited to the extraction of low-grade oil and using the residue for animal feed formulation. A number of past investigations have given focus to study the importance of testa as a source of bioactive compounds and associated health benefits (Marasinghe *et al*., 2019; Arivalagan *et al*., 2018; Appaiah *et al*., 2016; Geetha *et al*., 2016; Zhang *et al*., 2015). In a recent study, Adekola *et al*. (2017) compared the antioxidative and anti-diabetic activities of whole coconut testa with those of seed coats of selected beans. However, previous authors did not investigate the physical and functional properties of coconut testa flour produced out of residue coming from the cold-press mechanical oil extraction process, which involves low-temperature heating to protect severe burning or thermal degradation effects. This type of investigation would be beneficial because different food processing methods including oil extraction are known to bring changes to the bioactivities and functional properties of original raw materials. According to our literature search, an investigation into the physical and functional properties of the flour produced from residues of coconut testa has not been considered in most of the previous studies. Hence, the study aimed to compare the physical and functional properties of partially defatted coconut testa flour of four local coconut cultivars namely, san raman (SR), gon thembili (GT), ran thembili (RT), TallxTall (TxT) and commercial hybrid (COM) grown in Sri Lanka.

MATERIALS AND METHODS

Materials and Sampling

Fifty mature coconuts (12 months) from five different local cultivars (SR, RT, GT, TxT and COM) were collected from the varietal blocks of Coconut Research Institute of Sri Lanka, Lunuwila from August to October 2018. In the varietal blocks, fresh emerging bunches of each cultivar were earmarked for sampling after 12 months of maturity. Samples were subjected to 3 weeks of seasoning to make de-shelling easy. Coconuts seasoned for 3 weeks were de-husked manually and their hard shell was removed carefully. Coconut testa of the nuts peeled off manually were pulverized into medium size particles using a disintegrator (Unitex Engineers, Sri Lanka). Inter-particulate bonds of coconut testa can be broken down in this way. The disintegrated testa (moisture content of 42 to 45%) were oven-dried at 70°C using a cabinet-type dryer (Wessberg, Martin, Germany) for 8 h. Low-temperature drying was adopted to minimize severe burning or thermal degradation. Two kilograms of dried testa (medium size particles) of individual cultivar were then subjected to cold press oil extraction using a micro oil expeller (Komet DD85 machine, Germany). The residues left after oil extraction were ground into fine coconut testa flour (CTF) using a commercial grinder (Panasonic, Model: MK-MG 1000). The grounded flour samples were packed in low-density polyethylene (LDPE) bags and then stored at refrigerated (4°C) condition until further analyses. All chemicals used in this study were of analytical grade unless otherwise specified.

Methods

Particle size analysis: Analysis of flour particle size distribution was carried out according to Nishita and Bean (1982). CTF (50g) was sifted through 500, 420, 297, 150 and 63 µm sifters (500 µm sifter on the top and 63 µm sifter at the end), on a ro–tap type sieve shaker (Heiko Seisakusho, Japan) operated at 278 rpm for 15 min. After shaking, the weight of flour remained on each sifter was recorded. The weight of flour remained in each sifter was divided by the total weight of flour (50 g) to determine the percentage of flour retained on each sifter.

Determination of protein content: The protein contents of samples were determined according to a method described in the AOAC (2005) manual with a conversion factor of 6.25.

Bulk density: The bulk density (BD) was measured according to the method described by Okaka and Potter (1977) with some modifications. CTF (20g) was loaded in to a measuring cylinder (50 ml). The cylinder was constantly knocked until a consistent volume was attained. The bulk density was calculated as shown below:

$$Bulk\ density = Weight\ of\ flour\ (g) \div Volume\ of\ flour\ (ml)$$

Swelling capacity: The swelling capacity (SC) was performed according to the procedure described by Okaka and Potter (1977). Each sample of CTF was added into 100 ml measuring cylinder to fill up to 10 ml mark. A portion of distilled water was added up to 50 ml mark. The topmost of the measuring cylinder was firmly enclosed by the cap. The contents were mixed thoroughly by inverting the cylinder. After 2 min, the contents were inverted again and kept on a table without any motion for further 8 min. The volume of the flour was recorded after 8 min and reported as SC.

Water absorption capacity: The water absorption capacity (WAC) was measured according to the method described by Sosulski *et al*. (1976). A sample of CTF (1.0 g) was mixed with distilled water (10 ml) in a centrifuge tube and kept at 30°C ± 2°C for 30 min. The mixture was centrifuged (Beckman, USA) at 6000 rpm for 1 h. The weight of the paste was recorded after removing the supernatant. The WAC was expressed as the percentage of water absorbed per g of flour.

$$WAC = \frac{Final\ weight\ of\ paste\ (g) - Initial\ weight\ of\ flour (g)}{Initial\ weight\ of\ flour\ (g)} \times 100$$

Oil absorption capacity: The oil absorption capacity (OAC) was measured according to the method described by Sosulski el al. (1976). A sample of CTF (1.0 g) was mixed with soybean oil (specific gravity 0.9092) (10 ml) in a centrifuge tube and kept at 30°C ± 2°C for 30 min. The mixture was centrifuged (Beckman, USA) at 6000 rpm for 1 h. The weight of the paste was recorded after removing the supernatant. The OAC was expressed as the percentage of water absorbed per g of flour.

$$OAC = \frac{Final\ weight\ of\ paste\ (g) - Initial\ weight\ of\ flour\ (g)}{Initial\ weight\ of\ flour\ (g)} \times 100$$

Emulsion activity: The emulsion activity (EA) was estimated according to the method of Yasumatsu *et al*. (1972). A sample of CTF (1.0 g), distilled water (10 ml), soybean oil (10 ml) were blended together in a calibrated centrifuge tube to prepare the emulsion. The prepared emulsion was centrifuged at 3000 rpm for 5 min. The EA was calculated as shown below:

$$EA = \frac{Height\ of\ the\ emulsified\ layer(cm)}{Total\ height\ of\ the\ mixture(cm)} \times 100$$

Emulsion stability: The emulsion stability (ES) was estimated according to the method of Yasumatsu *et al*. (1972). A sample of CTF (1.0 g), distilled water (10 ml), soybean oil (10 ml) were blended together in a centrifuge tube to prepare the emulsion. The prepared emulsion was heated at 80°C for 30 min in a water bath. The mixture was cooled under running tap water for 15 min and centrifuged at 3000 rpm for 15 min. The ES was calculated as shown below:

$$ES = \frac{Height\ of\ the\ emulsion\ layer(cm)}{Total\ height\ of\ the\ mixture(cm)} \times 100$$

Foam capacity: The foam capacity (FC) was determined according to the method described by Narayana and Narasinga (1982) with slight modification. A sample of CTF (1.0 g) was mixed with distilled water (50 ml) in a measuring cylinder. The foam was formed by shaking the mixture for 5 min. The volume of foam was recorded after 3 min while the foam was stabilized (volume of foam before whipping). The mixture was shaken again and the volume of foam was recorded after 30 sec (volume of foam after whipping). The FC was expressed as shown below:

$$FC = \frac{\text{Volume of foam after whipping (ml)} - \text{Volume of foam before whipping(ml)}}{\text{Volume of foam beore whipping (ml)}} \times 100$$

Foam stability: The foam stability (FS) was determined according to the method described by Narayana and Narasinga (1982) with slight modification. A sample of CTF (1.0 g) was mixed with distilled water (50 ml) in a measuring cylinder. The foam was formed by shaking the mixture for 5 min. The volume of foam was recorded after 3 min when the foam was stabilized (initial volume of foam). The contents were kept steady and volume of foam was recorded after 1 hr (final volume of foam). The FS was expressed as shown below:

$$FS = \frac{Initial\ volume\ of\ foam\ (ml)}{Final\ volume\ of\ foam(ml)} \times 100$$

Least gelation concentration: The least gelation concentration (LGC) was assessed using the procedure described by Coffman and Garcia (1977) with modification. The flour suspensions of 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and 30% (w/v) were prepared in distilled water (5 ml). The contents were heated in a water bath at 90°C for 1 h. The mixtures were cooled down under running tap water. The contents were further cooled at 10 ± 2°C for 2 h. The concentration at which the contents remained in the tube without moving when the tube was inverted was taken as the LGC.

Statistical Analysis

All results from analyses were expressed as the mean value ± standard deviation. Data were statistically analyzed by one-way analysis of variance (ANOVA) using Tukey's test of MINITAB (version 14) statistical package at 0.05 probability level.

RESULTS AND DISCUSSIONS

Particle size distribution

Particle size is one of the important characteristics of any flour that determines its functional attributes in product formulations. The particle size distribution of CTF of different coconut cultivars is depicted in Fig. 1. According to statistical analysis, significant relationships were existed [F (16, 50) = 6288.81, p = 0.0001] between cultivars and particle size distribution with few exceptions. For all cultivar types, no significant differences were noticed for particle size ranges of 63-150 μm and 150–297 μm, but a significant difference was noticed for the particle size range of 420–500 μm. SR and the rest of the cultivars displayed significant differences for the particle size range of 297–420 μm, meanwhile COM and TxT displayed significant differences for particle size range >500 μm.

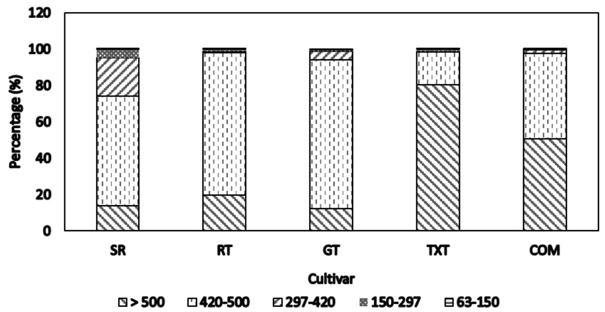

Figure 1. Particle size distribution of coconut testa flour of different coconut cultivars

Generally, the particle size distribution of flours would be influenced by the nature of grinding used in flour making process (Suntharalingam and Ravindran, 1993). This could be probably because the sieving process is affected by flour constraints (intrinsic) as well as sieve constraints such as aperture opening, rate, direction of movement of sieve,

sieve cloth etc. According to Wang and Flores (2000), the observed particle size distribution of wheat flour would have some influence on its physicochemical properties. In a subsequent study, De la Hera *et al*. (2013) found that the particle size heterogeneity of rice flour affected its hydration properties. For instance, rice flour hydration properties were increased with the reduction of particle size. In another study involving lentil flour, Ahmed *et al*. (2016) noticed that the decrease in the magnitude of particles influenced considerably the constitution, but it did not affect the water retention ability. In coconut kernel flour, the increase in the magnitude of flour particles tended to decrease the oil absorption capacity but enhanced the swelling and water absorption capacities (Dat *et al*., 2017). Enhanced WAC would favor more water to be absorbed by the flour matrices, which in turn would result in increased SC. According to Guillon and Champ (2000), modification of microstructure of particles caused by grinding would lead to altered OAC and hydration attributes of flour. For instance, the reduction of particle size by grinding leads to alteration of the structure of carbohydrate matrices in flour. This causes a reduction in water absorption by particles, which ultimately leads to modification of the hydration properties of flour.

Functional properties

The data presented in Table 1 compares various properties of coconut testa flour. Generally, assessment of functional characteristics of CTF would be useful to predict the effects of the addition of a new source of protein, carbohydrate, fat, and fiber to a specific food system (Chandra *et al*., 2013). This could also be valuable information for investigators engaged in coconut breeding programs.

The bulk density of flours would depend on factors such as particle size distribution, density and initial moisture content of flour. According to Table 1, bulk density of CTF of

Functional Property	Cultivar				
	SR	RT	GT	TxT	COM
Bulk density (g/ml)	0.67 ± 0.00^{c}	0.59 ± 0.00^{b}	0.55 ± 0.00^{a}	0.54 ± 0.00^{a}	0.65 ± 0.01^{c}
Swelling capacity (ml)	29.67 ± 1.53^{b}	20.67 ± 3.06^{a}	31.33 ± 1.15^{b,c}	29.00 ± 1.73^{b}	35.00 ± 1.73^{c}
Water absorption capacity (%)	320.00 ± 6.08^{d}	194.33 ± 10.69^{a}	238.67 ± 14.29^{b}	215.00 ± 7.21^{a,b}	275.00 ± 11.53^{c}
Oil absorption capacity (%)	124 ± 3^{c}	85.67 ± 7.02^{a}	127.33 ± 3.21^{c}	97.33 ± 3.21^{b}	142.67 ± 2.52^{d}
Emulsion activity (%)	42.95 ± 1.11^{a}	48.72 ± 1.11^{b,c}	45.51 ± 1.11^{a,b}	48.72 ± 1.11^{b,c}	50.00 ± 1.92^{c}
Emulsion stability (%)	43.24 ± 2.15^{c}	28.86 ± 1.03^{a,b}	27.51 ± 0.89^{a}	34.23 ± 3.28^{b}	54.86 ± 2.85^{d}
Foam capacity (%)	23.33 ± 2.89^{a}	28.67 ± 7.51^{b}	50.00 ± 0.00^{b}	41.11 ± 8.39^{b}	31.67 ± 16.07^{b}
Foam stability (%)	93.33 ± 11.55^{b}	0.00 ± 0.00^{a}	15.00 ± 8.66^{a}	17.78 ± 13.47^{a}	83.33 ± 14.43^{b}
Least gelation concentration (% , w/v)	12.00 ± 0.00^{a}	26.00 ± 0.00^{e}	22.00 ± 0.00^{d}	18.00 ± 0.00^{c}	16.00 ± 0.00^{b}

Each value in the table represents the mean ± standard deviations (SD) from three replicates. Means within each row bearing different superscripts are significantly ($p < 0.05$) different.

Table 1. Functional properties of coconut testa flour of different coconut cultivars

different cultivars varied from 0.54 to 0.67 g/ml; the highest value being observed for SR (0.67 ± 0.00 g/ml), followed by COM (0.65 ± 0.01 g/ml) and RT (0.59 ± 0.00 g/ml). The bulk density of SR was significantly higher than that of COM ($p<0.05$). The bulk density of GT and TxT were similar ($p>0.05$) but significantly ($p<0.05$) lower than those of SR, RT, and COM. In fact, bulk density values of CTF were slightly higher than that of coconut kernel flour (0.51 ± 0.02 g/ml) as reported previously by Igbabul *et al*. (2014). In another study, Chandra and Samsher (2013) found that the bulk density of rice flours (0.914±0.01 g/cc) was comparatively higher than that of wheat flour (0.762 ± 0.00 g/cc). Packing requirements and handling of materials during wet processing are usually affected by the bulk density of flour (Abioye *et al*., 2011). Hence, during packaging and transportation, higher bulk density is desirable as it can reduce the cost significantly. From a product development point of view, flours with high bulk density are preferable as food thickeners (Chandra *et al*., 2015) while those with low bulk density such as CTF of TxT (0.54 g/ml) would be suitable for preparing infant foods.

The swelling capacity is the maximum volume a flour sample can occupy as a result of water absorption. This water absorption continues until a colloidal suspension is formed. The volume expansion would be stopped as a result of prevention of water absorption which is caused by intermolecular forces present among swelled molecules (Adetuyi *et al*., 2009). According to a previous report, the SC of flour is generally affected by particle size, varietal differences and processing methods (Chandra and Samsher, 2013). The data presented in Table 1 compared the swelling capacity of CTF of local coconut cultivars, which was varied from 20.67 to 35 ml. The maximum value was recorded for COM (35.00 ± 1.73 ml), followed by GT (31.33 ± 1.15 ml) and SR (29.67 ± 1.53 ml). The least value was recorded for RT (20.67 ± 3.06 ml) which was significantly ($p<0.05$) lower than those of other cultivars. The swelling capacity values of SR (29.67 ± 1.53 ml), GT (31.33 ± 1.15 ml) and TXT (29.00 ± 1.73 ml) were similar but significantly ($p < 0.05$) lower than that of COM (35.00 ± 1.73 ml). According to a previous study by Dat *et al*. (2017), the swelling capacity of coconut kernel flour was found to range from 10.31 to 13.45 ml, which was lower than those of CTF found in the present study. Likewise, swelling capacity values of CTF of the present study were higher than those of wheat (17.60 ± 1.85 ml) and rice flours (15.20 ± 0.84 ml) as reported by Chandra and Samsher (2013).

The water absorption capacity (WAC) is a parameter, which determines the amount of water to be added during food processing. The flour with high water absorption may have more hydrophilic constituents such as polysaccharides (Chandra *et al*., 2015). According to Table 1, WAC values of different cultivars were ranged from 194.33 to 320%; maximum being recorded for SR (320.00 ± 6.08%), followed by COM (275.00 ± 11.53%) and GT (238.67 ± 14.29%). The WAC of TXT and RT were more or less similar ($p>0.05$), but significantly ($p<0.05$) lower than those of SR, COM, and GT. There was no statistically significant ($p>0.05$) difference between WAC of GT and TXT ($p<0.05$), but the values were significantly ($p<0.05$) lower than those of SR and COM. WAC of SR was significantly higher than that of COM ($p<0.05$). In an attempt to assess the effect of flour particle size on functional properties of coconut kernel flour, Dat *et al*. (2017) observed a higher WAC value (7.91 to 11.88 g/ g of flour) for coconut kernel flour compared to those of CTF observed in this study. However, WAC of CTF of different cultivars were higher than those of flours such as wheat (140 ± 12.25%) and rice (192 ± 10.95%) as reported by Chandra and Samsher (2013). In fact, higher WAC values for CTF suggests its suitability for the preparation of foods such as sausages, soups and baked products (Aremu *et al*., 2007).

Generally, the water absorption of flour is influenced by its protein content and hemicellulose level. As stated by Narayana and Narasinga (1982), polar amino acid residues of proteins attracts more water molecules. Hence, flours with high protein content might absorb more water than those with low protein contents. As shown in Fig. 2, crude protein contents of

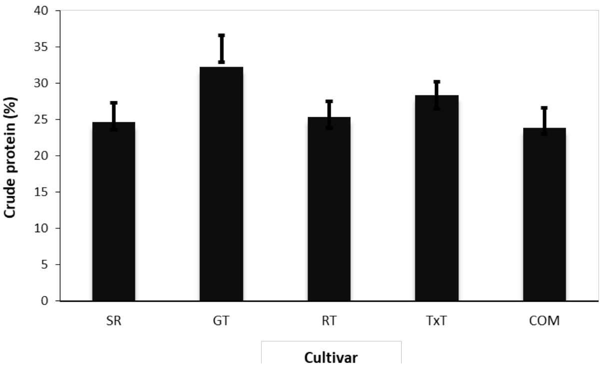

Figure 2. Crude protein content of coconut testa flour of different coconut cultivars

CTF of this study were comparably higher than those of wheat and rice flours as reported by other researchers. However, a statistically significant correlation was not found ($p>0.05$) between crude protein contents and WAC of CTF among different coconut cultivars. Perhaps, the differences in the amount of polar amino acids and conformational characteristics of proteins may be attributed to varied values of WAC among different cultivars (Narayana and Narasinga, 1982). Swelling of crude fiber might occur after absorbing water and expands the volume of flour further (Narayana and Narasinga, 1982). These might also contribute to the increased WAC of CTF when compared to other flour types such as wheat and rice.

Oil absorption capacity (OAC) contributes to improving palatability as well as the preservation of flavor. According to Table 1, OAC values of CTF were ranged from 85.67 to 142.67%; the maximum being recorded for COM (142.67 ± 2.52%), followed by GT (127.33 ± 3.21%) and SR (124 ± 3%). The least OAC was recorded for RT (85.67 ± 7.02%), which was significantly ($p<0.05$) lower than those of all other cultivars. The OAC value of GT (127.33 ± 3.21%) and SR (124 ± 3%) were not statistically different ($p>0.05$), but significantly ($p<0.05$) higher than those of TxT (97.33 ± 3.21%) and RT (85.67 ± 7.02%). The OAC of COM (142.67 ± 2.52%) was significantly higher than that of either GT (127.33 ± 3.21%) or SR (124 ± 3%) ($p<0.05$). In a previous study, Dat *et al*. (2017) observed a higher OAC value (3.28 to 3.93 g/g of flour) for coconut kernel flour compared to those of CTF of this study. Chandra and Samsher (2013) reported the OAC of wheat flour (146 ± 8.94%) which was higher than those of CTF used in the present study. In contrast, the OAC of rice flour (124) was found to be higher than those of cultivars namely RT and TxT. The variation in chemical composition among these flours was attributed to the differences in OAC values. For instance, hydrophobic interactions would be formed between non-polar side chains of amino acids and hydrocarbon chains of lipids, leading to the enhancement of OAC (Jitngarmkusol *et al*., 2008). Hence, the protein content and nature of amino acids present are important determinants of OAC of flours. High OAC of CTF of local cultivars would make them suitable for the preparation of food such as whipped toppings, sausages and bakery products where fat absorption is necessary (Aremu *et al*., 2007).

The emulsion activity (EA) of CTF of different coconut cultivars are given in Table 1. The EA of different coconut cultivars were ranged from 42.95 to 50.00%. The highest EA was reported for COM (50.00 ± 1.92%), followed by TxT (48.72 ± 1.11%) and RT (48.72 ± 1.11%). The emulsion activity of RT (48.720 ± 1.109%), TXT (48.720 ± 1.109%) and COM (50.00 ± 1.92%) were not statistically different ($p> 0.05$), but significantly ($p< 0.05$) higher than that of SR (42.95 ± 1.11%). The emulsion activity of GT (45.510 ± 1.109%) and SR (42.950 ± 1.109%) were more or less similar ($p>0.05$). The emulsion capacities reported for coconut kernel flour (50.00 ± 0.20%) (Igbabul *et al*., 2014), wheat (43.88 ± 4.119%) and rice flours (41.48 ± 1.842%) (Chandra and Samsher, 2013) were somewhat similar to those of CTF samples of local cultivars. Emulsifying properties are usually influenced by the hydrophobicity of proteins in the flour. Owing to their surface-active properties, proteins are able to form electrostatic repulsions on the surface of oil droplets and stabilize the emulsion (Kushal *et al*., 2012). Solubility and conformational stability of proteins are generally attributed to variations in the emulsifying activity of proteins (Kushal *et al.,* 2012). Flours with the least protein solubility might display the least emulsification activity but the highest emulsifying stability (Kushal *et al*., 2012). According to Peyrano *et al*. (2016), the state of proteins (native/denatured) also affects emulsification properties; native proteins isolated from yellow cowpea showed higher emulsification activity compared to denatured ones. Researchers suggested that compositional changes in proteins and non-protein components such as carbohydrates might contribute collectively to emulsifying characteristics of flours (Kushal *et al*., 2012).

The emulsion stability (ES) of CTF of local coconut cultivars are compared as shown in Table 1. The ES of CTF were ranged from 27.51 to 54.86%; the maximum ES value being recorded for COM (54.86 ± 2.85%), followed by SR (43.24 ± 2.15%) and TXT (34.23 ± 3.28%). The mean ES values of GT (27.51 ± 0.85%) and RT (28.86 ± 1.03%) were not statistically different ($p>0.05$), but significantly lower than those of the rest. ES could be enhanced by the existence of soluble proteins in food systems (Kushal *et al*., 2012). The ES was significantly enhanced when firm globular protein molecules, which were impervious to physical distortion, involved in the formation of an adhesive layer in emulsions (Kaushal *et al*., 2012). High EA and ES are generally desired in food preparations such as comminuted meat products, salad dressings, frozen desserts and mayonnaise. The high ES of CTF from COM indicates its suitability for preparation of food such as cakes, soups and sausages where stability of emulsion is required. ES of CTF from local coconut cultivars were comparably similar to those of wheat (38.38 ± 4.79%) and rice flours (37.31 ± 5.41%) (Chandra and Samsher, 2013).

Foam is a colloid of small gas bubbles surrounded by a thin liquid layer trapped in a liquid or solid medium. The extent of the area of an air-water interface that can be formed by proteins is referred to as foam capacity (FC) (Chandra *et al*., 2015). The FC of CTF of local coconut cultivars are compared with that of commercial hybrid as depicted in Table 1. The FC (%) of GT (50.00 ± 0.00), TxT (41.11 ± 8.39) COM (31.67 ± 16.07) and RT (28.67 ± 7.51) were more or less similar ($p>0.05$), but significantly ($p<0.05$) higher than that of SR (23.33 ± 2.89). Previously, Chandra and Samsher (2013) reported FC values for wheat (12.92 ± 5.03%) and rice flours (3.52 ± 0.89%), which were comparably lower than those of CTF of this study. This is attributed to low protein content in wheat flour (16%) and rice flour (9.1%) when compared to the protein content of CTF (23.82-32.22%) (Fig. 2). Previously, Yasumatsu *et al*. (1972) observed the association between FC and water-soluble nitrogen content in soybean products. FC of a food material also depends on its pH, type of proteins, processing method, surface tension, viscosity etc. According to Oladele and Aina (2007), foam capacity could be influenced by solubilized protein content and polar and non-polar lipid content of flour. Soluble proteins might reduce the surface tension at the gas-water interface and form a continual sticky layer throughout the gas bubbles (Kaushal *et al*., 2012). It is believed that the arrangement of protein molecules also affects the FC of flours. Stretchy proteins would give well foaming ability while greatly organized globular proteins would result in low FC (Baljeet *et al*., 2010).

The foam stability (FS) is defined as the capability of proteins to maintain the foam against gravitational and physical forces

(Chandra *et al.*, 2015). The FS of CTF of local coconut cultivars are compared with that of commercial hybrid as shown in Table 1. The FS (%) of SR (93.33 ± 11.55) and COM (83.33 ± 14.43) were more or less similar (p> 0.05), but significantly (p< 0.05) higher than that of RT (0.00 ± 0.00), GT (15.00 ± 8.66) and TxT (17.78 ± 13.47). Previously, Chandra and Samsher (2013) reported the FS values for wheat (1.94±0.048 %) and rice flours (0.98 ± 0.00%), which were considerably lower than those of CTF of all cultivars except RT. In CTF of RT, there was hardly any foam that could be seen after one hour. Air from small bubbles disperse into larger bubbles due to high pressure inside small bubbles compared to larger ones or the atmospheric pressure from the surrounding. Hence, this phenomenon would decrease the stability of the foam. FS can be reduced by draining liquid or through the foam layer due to gravity. Instability of liquid layer between bubbles would cause a combination of bubbles leading to reduction of foam. According to Jitngarmkusol *et al.* (2008), an inverse correlation existed between FC and FS. Bulky gas bubbles bordered by skinny, less stretchy protein layers can be formed due to high FC of flours. These gas bubbles can be easily broken due to the instability of the liquid layer. This results in low FS in flours with high FC. Food ingredients with good FC and FS are used in bakery products and whipping toppings (Aremu *et al.*, 2007).

The least gelation concentration (LGC) which is used as a measurement of gelation capacity is the lowest protein concentration upon which the gel is retained in the tube without slipping when a tube is inverted (Aremu *et al.*, 2007). The LGC of CTF of local coconut cultivars are compared with that of commercial hybrid as shown in Table 1. The LGC of CTF were ranged from 12 to 26% (w/v); maximum being recorded for RT (26 ± 0.00%), followed by GT (22 ± 0.00%) and TxT (18 ± 0.00%). The LGC of each variety was significantly (p<0.05) different from each other and decreased in the order of RT>GT>TxT>COM>SR. A lower LGC implies a better ability to forming gels by the protein component of the flour. The LGC values of CTF found in this study were remarkably higher than those of wheat (8%) and rice (6%) as reported previously (Chandra and Samsher, 2013). Differences in gelation properties among different legume flours were attributed to differences in the distribution of proteins, lipids, and carbohydrates (Adebowale and Maliki, 2011). According to Kaushal *et al.* (2012), the gelation ability of flours is affected by the competition between proteins and starch to water absorption. Gelation properties are attributed to protein type present in the system but not to protein quality (Adebowale and Maliki, 2011). Gelation properties could be affected by interactions among chemical constituents of the flour. When protein concentration is increased by adding more flour, thermodynamic attractions between protein and water molecules are reduced leading to increased synergistic effects between proteins that leads to enhanced gelation (Aremu *et al.*, 2007). The gel forming ability of a food ingredient is important in food applications as well as new product developments. The gel provides a physical medium to retain water, sugars, flavors, and other nutrients in a food system (Aremu *et al.*, 2007). Owing to its binding properties, flours with low LGC such as CTF, particularly from SR variety may provide consistency in food preparations such as semi-solid beverages (Ogunlakin *et al.*, 2012). Flours with low LGC are useful for the preparation of foods such as sauce, puddings etc where thickening and gelling are desired (Chandra *et al.*, 2015).

CONCLUSIONS

This study investigated the physical and functional properties and particle size distribution of CTF of five local coconut cultivars. Significant relationships were existed between cultivars and particle size distribution with few exceptions. Among all cultivars, COM hybrid was found to display the highest values for EA, ES, SC and OAC. The observed differences in particle size and functional properties would make them suitable for different applications. Information of this kind would be beneficial not only for product development activities but also for those who are engaged in plant breeding.

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