Food Research 5 (4) : 374 - 381 (August 2021)
Journal homepage: http://www.myfoodresearch.com

FOOD
RESEARCH

Physicochemical and thermal properties of durian seed flour from three varieties of durian native of Sabah

Siti Faridah, M.A., Nur Atikah, M.R.L., Jau-Shya, L., Hasmadi, M., Mohd Rosni, S., Wolyna, P. and *Noorakmar, A.W.

Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, 88400, Kota Kinabalu, Sabah, Malaysia

Article history:
Received: 12 November 2020
Received in revised form: 17 January 2021
Accepted: 18 August 2021
Available Online: 28 August 2021

Keywords:
Durian,
Seeds,
Flour,
Physicochemical,
Thermal Properties

DOI:
https://doi.org/10.26656/fr.2017.5(4).659

Abstract

This study was aimed at assessing the physicochemical and thermal properties of flour, acquired from the seeds of three native Sabah durian species. The three durian species concerned are the Dalit, Sukang and Pulu. Flour deriving from the seeds of the dalit (DDSF), sukang (DSSF) and pulu (DPSF) durian species, were put through a physicochemical, pasting and thermal characteristics assessment process. The protein content in flours, derived from the seeds of durian native to Sabah, demonstrated a high capacity for the absorption of both water ($r = -0.855$, $p<0.01$), and oil ($r = 0.921$, $p<0.01$). DPSF, which holds the most protein content at 6.92%, demonstrated the lowest water absorption capacity, and greatest oil absorption capacity ($p<0.05$). Moreover, DPSF was observed to have the lowest swelling power, solubility and peak viscosity ($p<0.05$). In terms of pasting temperature, no outstanding disparities were detected between the three durian seed flours ($p>0.05$), but they were considered to have high pasting temperatures. The lowest setback viscosity ($p<0.05$) displayed by DPSF, is an indication that the following gelatinization, will quickly dissolve. Additionally, the enthalpy ΔH of DPSF revealed as 0.29 J/g ($p<0.05$) is deemed significantly low. This undertaking delves into the physicochemical and thermal characteristics of durian seed flour, to its use as composite flour.

1. Introduction

Durian, which is heralded 'the king of fruits' in Southeast Asia, comes from the Bombacaceae family and the Durio genus (Noor Raihana *et al*., 2015). There are a total of 23 species of durian spread throughout Malaysia. The lowland forests, of Peninsular Malaysia and Sabah, are homes to 13 different varieties of durian, while Sarawak is home to 16 varieties (Salma, 2011). However, out of these many durian species, only nine are suitable for human consumption. These edible varieties are the *D. dulcis* (lahong), *D. grandiflorus* (durian monyet), *D. graveolens* (dalit), *D. kinabaluensis*, *D. kutejensis* (lai), *D. lowianus* (durian daun), *D. oxleyanus* (durian sukang), *D. testudinarum* (durian kura-kura) and *D. zibethinus* (durian putih).

Among the durian species native to Sabah, the most well-known and most widely cultivated are the durian dalit, durian sukang and durian pulu. The flesh of the durian dalit varies in colour from yellow to a darker shade of yellow or orange, and from pink to red. According to Hanif *et al*. (2013), durian dalit holds roughly 13 fatty acid components, and a lesser saturated than unsaturated fatty acid content. While the colours of the durian pulu flesh are similar to those of the durian dalit, the thorns of the former are not as prickly. Durian Sukang comes with an intense aroma and flesh closely similar in appearance, to that of durian putih. However, the flavour of durian Sukang is on the tart side, and sweet (Salma, 2011). Generally, compared to durian Dalit and durian Pulu, durian Sukang comes in a smaller size, and with thorns less pointed.

The seeds of durian, which make up 20% to 25% of whole fruit, are regularly disposed of as agro-waste (Mohd Nazrul Hisham *et al*., 2012; Srianta *et al*., 2012). Previous investigations in this area have revealed that the seed of durians holds 6.6% moisture, 4.8% crude fibre, 0.4% fat, 7.6% protein, 3.8% ash, 76.8% carbohydrate, and 52.9% in overall dietary fibre content (Amiza and Roslan, 2009). Durian seed meal can be employed as an alternative to wheat flour or as a thickening agent during the manufacture of food products such as angkak (Srianta *et al*., 2012), pasta (Mirhosseini *et al*., 2015),

---

*Corresponding author.
Email: *aqemanur@ums.edu.my*

cake, cookies and soup (Amiza *et al*., 2004). A gum extracted, from *D. zibethinus* seed flour, demonstrated its capacity for exceptional water and oil absorption, as well as stability, when used in mayonnaise (Cornelia *et al*., 2015).

Of late, the feasibility of using the seeds of durians native to Sabah, as a substitute for composite flour, is drawing much attention. This undertaking focused on assessing the physicochemical and thermal properties of flour, generated from three separate durian varieties, cultivated in Sabah, Malaysia.

2. Materials and methods

2.1 Raw materials

The Sabah districts of Menumbok, Tenghilan and Tamparuli were the sources of the Dalit, Sukang and Pulu durian species used for this investigation. These indigenous durians were harvested during the durian season from July to September. Each fruit weighed approximately 5 kg. Following the manual separation of the flesh from the seeds, sterile distilled water was used to meticulously cleanse the seeds. After the cleansing process, 1 kg of durian seeds was put in storage under a temperature of -20°C.

2.2 Preparation of flour

The preparing, of the Dalit, Sukang and Pulu durian seed flour, was following the procedure recommended by Mukprasirt and Sajjaanantakul (2004), albeit with minor alterations. The preparation procedure began with the lye-peeling of the seeds with 0.5% NaOH, for 30 mins, before they were rinsed with water. The seeds were then subjected to boiling (15 mins), and allowed to cool down at room temperature (30 mins), before the spermoderms were skinned off by hand. A mixer was used to chop up the cotyledons for 2 min and the resulting mash was dried in a cabinet dryer set at 60°C, until a reduced moisture content of 13% was attained. To finish the preparation process, a Mixer grinder (MX-AC210S, Panasonic, Japan) was employed to macerate the dried cotyledon mash, followed by straining at a mesh particle size of number 60. The resulting seed flour was kept in an air-tight container at room temperature for further analysis.

2.3 Chemical composition

The chemical composition was determined according to AOAC (2007) methods. To measure moisture content, the samples were subjected to drying overnight (105°C), until an invariable weight was attained. The Kjeldahl technique was used to establish protein content, the Soxhlet method using the Soxtec 2050 instrument (FOSS, Denmark) was employed to measure fat content, the crude fibre was determined using Fibretherm (Gerhardt, Denmark), ash content was acquired by computing the weight left behind after the overnight heating of the samples (at 550°C), and the carbohydrate content was computed by difference through the formula 100 - (g/100 g moisture + g/100 g protein + g/100 g fat + g/100 g crude fibre + g/100 g ash). All the samples were examined based on dry weight.

2.4 Water absorption capacity and oil absorption capacity

A centrifugal method, described by Tizazu and Emire (2010), was harnessed to establish the water absorption capacity and oil absorption capacity, of the flour samples. Around 2 g of the sample was mixed with 20 mL of distilled water (for water absorption capacity) and refined corn oil (for oil absorption capacity) using a vortex mixer for approximately 30 s. The samples were set aside for 30 mins at ambient temperature, before undergoing centrifugation for 10 mins at 2000×*g*. A 10 mL graduated cylinder was utilized to ascertain the volume of the supernatant. The density of water was taken at 1 g/mL, while the density of oil was taken at 0.944 g/mL.

2.5 Swelling power and solubility

The procedure employed by Ikegwu *et al*. (2010) was used to gauge swelling power and solubility. A weight of 1 g of the sample was introduced into a 50 mL centrifuge tube. Following the addition of approximately 30 mL of distilled into the centrifuge tube, a vortex mixer set at slow was used to merge the contents. The resulting slurry was subjected to heating in a water bath, at constant temperatures of 30, 40, 50, 60, 70, 80 and 90° C, for 15 mins. During this period, the sample was incessantly agitated, to deter the starch from bunching. To separate the gel and supernatant, the suspension was put through centrifugation for 10 mins at 3000×*g*. Subsequently, the aqueous supernatant was taken out and transferred into a dish, for investigations into the solubility pattern. The tube with the sediment was subjected to drying at 50°C for 30 mins and left to cool down before its weight was taken (w_2). A volume of 5 mL of supernatant liquid was introduced into an evaporating dish and dried to a stable weight in an oven set at 100°C, for 4 hrs. The solid derived from the drying process was then weighed (w_3). The centrifuge tube was weighed solely with the sample, prior to the addition of distilled water (w_1).

$$\text{Swelling power of sample(g/g)} = \frac{w_2 - w_1}{\text{weight of sample}}$$

$$\text{Solubility (\%)} = \frac{w_3}{\text{weight of sample}}$$

2.6 Pasting properties

In compliance with the approach employed by Kaur and Singh (2005), a rapid visco analyser (RVA) (Newport Scientific, Australia) was used to ascertain the pasting attributes. Following the placement of 3 g of flour sample (~10% moisture content) into a dry vacant canister, 25 mL of distilled water was added to the sample, bringing the total weight of the sample to 28 g. The solution was briskly stirred, and the canister was securely installed into the RVA. The slurry was subjected to heating at 50°C to 95°C, with a 7 min holding phase at 95°C, a cooling stage from 95°C to 50° C (6°C/min), followed by a 5 min holding phase at 50°C. Thermocline software was engaged for the interpretation of peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature from the pasting profile. The viscosity measurement was put across in centipoises (cP).

2.7 Thermal properties

Gelatinization characteristics of the durian seed flours were measured by way of a differential scanning calorimeter (DSC) (Perkin Elmer, USA), furnished with a liquid nitrogen intracooler system. This approach is in keeping with that utilized by Kaur *et al*. (2007). A mass of 1 mg of the sample was placed in an aluminium pan, followed by the addition of distilled water weighing 3 mg. The pan was subsequently sealed securely and equilibrated at room temperature overnight. The pan holding the sample was then subjected to heat ranging from 30°C to 110°C, with the rate of heating set at 10°C/min. The thermogram was referred to for ascertaining the onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and enthalpy (ΔH). A procedure recommended by Vasanthan and Bhatty (1996) was employed to establish the gelatinization range (T_c-T_o).

2.8 Statistical analysis

The analysis was performed in triplicates. The SPSS version 20 (IBM, New York, USA) was used to perform the analysis of variance (ANOVA), and test of significance (through the Tukey procedure), with a confidence level of 95%. The same software was utilized for computing the Pearson correlation coefficients (r), for associations between the properties of the flours.

3. Results and discussion

3.1 Chemical composition

Table 1 exhibits the chemical composition of flours, deriving from seeds of native Sabah durians. As can be observed, the moisture content of the durian Sukang seed flour (DSSF) is significantly lowest ($p<0.05$) among the flours. The low moisture content level serves to enhance the stability of the flour, by inhibiting the growth of mould while reducing the occurrence of biochemical reactions (Omimawo and Akubor, 2012). The content of fat in DDSF (0.62%), DSSF (0.58%) and DPSF (0.74%) were less than that in jackfruit seed flour (0.99% to 2.19%) (Tulyathan *et al*., 2002; Mukprasirt and Sajjaanantakul, 2004) and bambara groundnut flour (6.18%) (Adegunwa *et al*., 2014). On the other hand, the content of fat in DDSF, DSSF and DPSF, is more than the content of fat in durian putih (*D. zibethinus*) (Mirhosseini *et al*., 2015).

As displayed in Table 1, the protein content of DSSF ($p<0.05$) is the least among the flours investigated. As such, its swelling power is more pronounced than that of DDSF and DPSF. This is portrayed in Table 1 and Figure 1. The protein content of DDSF, DSSF and DPSF, which ranges between 6.03% and 6.92% (Table 1), is roughly half the protein content in wheat flour (13.7%). This is an indication that flour derived from indigenous durian seed, is deficient in gluten, and therefore unsuitable for the making of bread (Amiza and Roslan, 2009). Though inapplicable in the bakery industry, durian seed flour may find its place in other areas, through its amalgamation with other types of flour.

Table 1. Chemical composition and functional properties of Sabah indigenous durian seed flours

Parameters	DDSF	DSSF	DPSF
Moisture (%)	10.75 ± 0.08^{a}	8.39 ± 0.10^{c}	10.10 ± 0.10^{b}
Fat (%)	0.62 ± 0.02^{b}*	0.58 ± 0.01^{c}*	0.74 ± 0.03^{a}*
Protein (%)	6.32 ± 0.16^{b}*	6.03 ± 0.09^{c}*	6.92 ± 0.27^{a}*
Ash (%)	4.68 ± 0.04^{a}*	4.06 ± 0.17^{c}*	4.42 ± 0.08^{b}*
Crude fibre (%)	3.22 ± 0.03^{a}*	2.83 ± 0.04^{b}*	2.62 ± 0.04^{c}*
Carbohydrate (%)	74.41 ± 0.22^{c}*	78.11 ± 0.10^{a}*	75.19 ± 0.20^{b}*
Water absorption capacity (g/g)	0.89 ± 0.04^{a}	0.91 ± 0.02^{a}	0.82 ± 0.01^{b}
Oil absorption capacity (g/g)	0.66 ± 0.02^{b}	0.62 ± 0.01^{c}	0.70 ± 0.01^{a}

*expressed as dry weight basis. Values are presented as mean±SD. Values with different superscripts within the same are significantly different ($p<0.05$). DDSF: durian dalit seed flour, DSSF: durian sukang seed flour, DPSF: durian pulu seed flour.

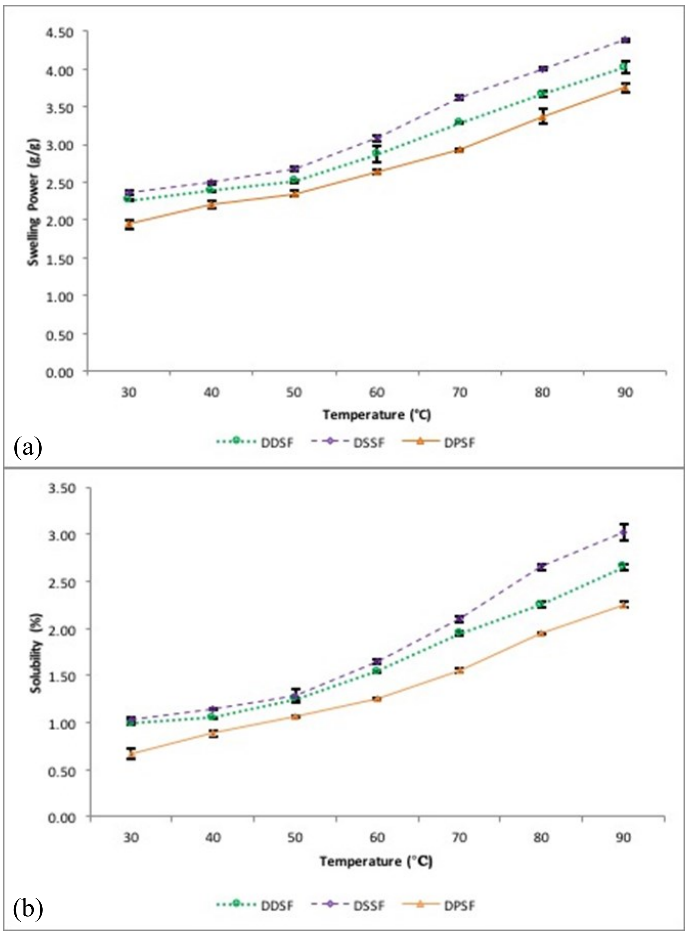

Figure 1. Effect of temperature on (a) swelling power and (b) solubility of indigenous durian seed flours.

3.2 Water absorption capacity and oil absorption capacity

Among the most essential functional qualities of flour, is its capacity for absorbing water and swelling, to enhance the consistency of food (Adepeju *et al*., 2011). As displayed in Table 1, the capacity to absorb water (0.91 g/g) is greater in DSSF than in the other flours. This could be attributed to its depleted fat content, which contributes towards a higher capacity for the absorption of water (Shevkani *et al*., 2014). Besides that, water absorption capacity was also enhanced by moisture and high crude fibre content (Akubor *et al*., 2013). At the same time, the oil absorption capacity plays a key role in flavour retention, enhancing delectableness, as well as in prolonging the shelf life of bakery and meat products (Adebowale and Lawal, 2004). In comparison to lentil (Kaur and Sandhu, 2010), field pea and pigeon flours (Kaur *et al*., 2007), the oil absorption capacity of DDSF, DSSF and DPSF is deemed inferior. As portrayed in Table 1, the oil absorption capacity of DPSF ($p<0.05$) is superior to that of DDSF and DSSF.

As illustrated in Table 2, protein content is strongly correlated to water absorption capacity, with r = -0.855 ($p<0.01$). Differences in protein, as well as carbohydrate portions, contribute towards disparities in the water absorption capacity in flours (Kaur and Sandhu, 2010). It has been revealed, that the water absorption capacity of jackfruit seed (Tulyathan *et al*., 2002; Chowdhury *et al*., 2012) and African star apple kernel flour (Akubor *et al*., 2013), is superior to that of the indigenous durian seed flours under investigation.

Table 2. Pearson correlation coefficients between various physicochemical and thermal properties of Sabah indigenous

Parameters	Protein	SP	PV	T_c-T_o
OAC	0.921**	-	-	-
Solubility	-0.888**	0.986**	-	-
WAC	-0.855**	0.940**	0.918**	-
PT	0.441	0.479	-0.407	-
ΔH	-0.919**	0.948**	0.974**	0.400

** $p< 0.01$. OAC: Oil Absorption Capacity, WAC: Water Absorption Capacity, PT: Pasting Temperature, SP: Swelling Power, PV: Peak Viscosity, T_c-T_o: range of gelatinisation, ΔH: enthalpy

The capacity of flour, for oil absorption, is determined by intrinsic factors that include amino acid composition, protein conformation and surface polarity or hydrophobicity (Chandra and Samsher, 2013). The hydrophobicity of proteins in flour enhances the binding of lipids, which consequently influences the oil absorption capacity of the flour. As shown in Table 2, a positive correlation was exhibited between protein content and the oil absorption capacity of indigenous durian seed flours (r = 0.921, $p<0.01$). This is verified by the fact that DPSF, with the highest protein content (6.92 %), is also superior to DDSF and DSSF in terms of oil absorption capacity (0.70 g/g).

3.3 Swelling power and solubility

As shown in Figure 1, as the temperature climbed from 30°C to 90°C, the swelling power and solubility of the indigenous durian seed flours were enhanced. Also, as displayed in Table 2, the solubility of flour enhances in tandem with the increase in swelling power. In terms of swelling power (Figure 1a) and solubility (Figure 1b), DSSF claims top spot in both these areas. The swelling power of DDSF, DSSF and DPSF was revealed to be greater than tiger nut flour (Oladele and Aina, 2007), but lesser than jackfruit seed flour (Mukprasirt and Sajjaanantakul, 2004). As illustrated in Figure 1, the swelling power and solubility of DDSF, DSSF and DPSF peaked, when the temperature reached 80°C. Ikegwu *et al*. (2010) stated that swelling power and solubility are greatest, at temperatures ranging between 80°C and 95° C.

While heading the list for protein content (Table 1), DPSF is at the bottom for swelling power (Figure 1a) and solubility (Figure 1b). The lack of swelling power and solubility of DPSF could be attributed to the profound bonding strength in its protein-amylose complexes. According to Shimelis *et al*. (2006), the attraction of opposite charges, which occurs between protein and starch complexes during gelatinization, hampers the swelling process. In the context of swelling, starch can be separated into four categories: high swelling, moderate swelling, restricted swelling and highly restricted swelling (Ikegwu *et al*., 2010). Accordingly, the lower the swelling power value, the more restricted the swelling of indigenous durian seed flours.

3.4 Pasting properties

According to the RVA results exhibited in Table 3, in terms of pasting profile (Figure 2), there are significant differences ($p<0.05$) between the three indigenous durian seed flours considered for this undertaking. Gelatinization is defined as the alterations that occur during the heating of a starch and water combination. These alterations include the swelling of granules, rise in viscosity, and increased clearness and solubility of the slurry, as well as the decline in anisotropy (Ikegwu *et al*., 2010). The minimum temperature required for the cooking of flour samples is referred to as the pasting temperature (Shimelis *et al*., 2006). According to the results acquired, the pasting temperatures of DDSF, DSSF and DPSF, are not significantly different (Table 3). As portrayed in Table 2, the pasting temperature is correlated to protein content and swelling power. An elevated quantity of protein encourages protein-starch interactions, which serve to diminish the swelling of starch. This situation triggers a climb in the pasting temperature (Liu *et al*., 2007).

While the pasting temperatures of the three indigenous flours are not much different, their peak viscosities differ significantly, with DPSF at 1266 cP (the lowest), DDSF at 1750 cP, and DSSF at 1927 cP. Peak viscosity refers to the capacity of starch with regards to water absorption (Ikegwu *et al*., 2010). Table 2 shows a positive correlation in that both parameters ($r = 0.918$, $p<0.01$). The peak viscosity of all three indigenous durian seed flours were above those of pea, chickpea (Chung *et al*., 2008) and lentil flours (Kaur and Sandhu, 2010). The raised peak viscosity of DDSF, DSSF and DPSF is an indication that they are applicable for the manufacture of high gel strength products (Ikegwu *et al*., 2010).

According to Adebowale *et al*. (2005), flours with a high breakdown viscosity, have a low tolerance for heat and shear stress, during cooking. As displayed in Table 3, the breakdown viscosity for the indigenous durian seed flours stretches from 179.00 to 357.67 cP. The results, from an investigation conducted by Shevkani *et al*. (2014), revealed that the relationship between protein content, and breakdown viscosity, is detrimental in nature. The results from our study indicate that DPSF has a greater protein content (Table 1), and a lower breakdown viscosity (Table 3) than DDSF and DSSF. Besides that, the stability of flour products hinges on breakdown viscosity (Kaur and Singh, 2005).

Oloyede *et al*. (2016) observed that during cooling, flours with a low content of amylose, demonstrated a low setback viscosity, as well as low retrogradation (Falade and Christopher, 2015). DPSF demonstrated a lower setback viscosity, as well as lower retrogradation, in comparison to DDSF and DSSF (Table 3).

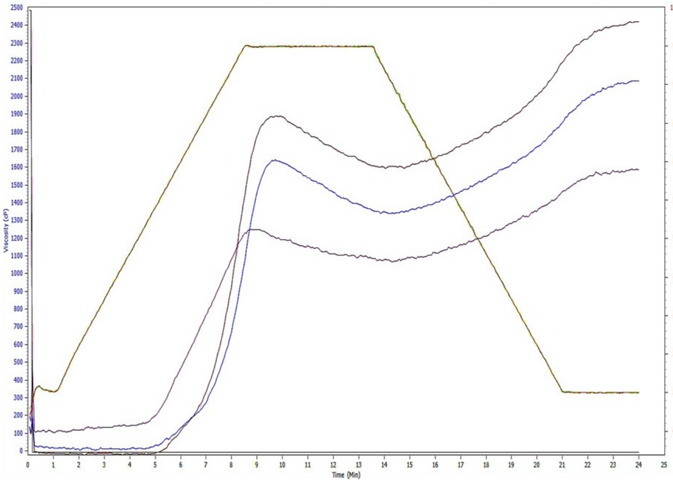

Figure 2. Pasting profile of indigenous durian seed flours

3.5 Thermal properties

Gelatinization is when starch particles heated in excess water, go through an ordered-disordered transition (Mukprasirt and Sajjaanantakul, 2004). The obvious disparities in gelatinization activities among DDSF, DSSF and DPSF ($p<0.05$) are exhibited in Table 4.

Table 3. Pasting properties of Sabah indigenous durian seed flours

Parameters	DDSF	DSSF	DPSF
Pasting Temperature (°C)	77.52±2.49^{a}	76.35±2.18^{a}	80.60±4.73^{a}
Peak Viscosity (cP)	1750.67±111.55^{a}	1927.00±72.92^{a}	1266.00±46.87^{b}
Breakdown (cP)	309.00±53.25^{a}	357.67±58.35^{a}	179.00±5.00^{b}
Setback Viscosity (cP)	793.00±69.54^{a}	810.67±52.44^{a}	530.67±22.30^{b}

Values are presented as mean±SD. Values with different superscripts within the same are significantly different ($p<0.05$). DDSF: durian dalit seed flour, DSSF: durian sukang seed flour, DPSF: durian pulu seed flour.

Table 4. Thermal properties of Sabah indigenous durian seed flours

Parameters	DDSF	DSSF	DPSF
T_o (°C)	70.87 ± 0.06^{a}	67.03 ± 0.53^{b}	67.95 ± 0.56^{b}
T_p (°C)	75.15 ± 0.36^{a}	72.94 ± 0.69^{b}	72.24 ± 0.63^{b}
T_c (°C)	$78.84 \pm 1.08^{a,b}$	79.19 ± 0.38^{a}	77.39 ± 0.29^{b}
T_c-T_o(°C)	7.97 ± 1.03^{b}	12.16 ± 0.15^{a}	9.44 ± 0.55^{b}
ΔH (J/g)	0.77 ± 0.06^{b}	0.92 ± 0.07^{a}	0.29 ± 0.01^{c}

Values are presented as mean±SD. Values with different superscripts within the same are significantly different ($p<0.05$). DDSF: durian dalit seed flour, DSSF: durian sukang seed flour, DPSF: durian pulu seed flour, To: onset temperature, Tp: peak temperature, Tc: conclusion temperature, ΔH: enthalpy.

The onset temperature (T_o) is associated with the depletion of birefringence, during the gelatinization process (Mukprasirt and Sajjaanantakul, 2004). During our investigation, the highest onset temperature (T_o) ($p<0.05$) exhibited by DDSF, suggests that in comparison to the other flours, its gelatinization can be expected to be more demanding. The T_o of DDSF, DSSF and DPSF, which stretched between 67.03°C and 70.87°C, is comparatively greater than those of jackfruit seed flour (63.43°C) flour (Mukprasirt and Sajjaanantakul, 2004) and chickpea flour (65.4°C – 67.9°C) (Kaur and Singh, 2005).

The peak temperature (T_p) relates to the stability of starch crystallites, upon their exposure to heat (Aprianita *et al*., 2009). An elevated T_p value is indicative of highly resistant and stable starch. The highest T_p was credited to DDSF, which indicates that the stability, and heat resistance levels of its starch, is superior to those of DSSF and DPSF ($p<0.05$). The disparities, in gelling temperatures between flours, can be put down to variations in the size, shape and distribution of starch granules in flours, as well as differences in the internal arrangement of starch fractions within the granule (Kaur and Singh, 2005).

The enthalpy of gelatinization (ΔH) for DDSF, DSSF and DPSF were observed to be considerably dissimilar ($p<0.05$), which related to characteristics of the starch granule, including crystallinity and granule size (Bogracheva *et al*., 2006). Bhupender *et al*. (2013) suggested that starch with a depleted ΔH needs a lesser amount of energy to gelatinize. This also applies in reverse order. According to the results derived through our investigation, the ΔH of DPSF is the lowest among the indigenous durian seed flours. As such, in terms of gelatinization, DPSF will require a lesser amount of energy than DDSF and DSSF ($p<0.05$). Moreover, as can be observed in Table 2, there is a strong correlation between ΔH with protein ($r = -0.919$) and swelling power ($r = 0.948$).

The gelatinization range (T_c-T_o) of DSSF is very much greater ($p<0.05$) than that of DDSF and DPSF. This is illustrated in Table 4. And as the gelatinization range (T_c-T_o) is constructively linked to ΔH (Table 2), it follows that for the gelatinization of starch, DSSF will require more energy than DDSF and DPSF. In contrast, DPSF, with the lowest T_c and ΔH (Table 4) among the indigenous flours, dissolves easily when gelatinized.

4. Conclusion

Durian Pulu Seed Flour (DPSF) had the highest capacity for oil absorption, but with the lowest water absorption capacity, swelling power, solubility, peak viscosity, breakdown viscosity, and setback viscosity. As DPSF is responsive to heat, it requires less energy to gelatinize, while dissolving easily when gelatinized, due to its low ΔH and T_c. Durian Sukang Seed Flour (DSSF) demonstrated a high-water absorption capacity, swelling power, solubility and gelatinization range (T_c-T_o), with low protein content. As for Durian Dalit Seed Flour (DDSF), its high T_o and T_p rendered gelatinization difficult, as its starch is less susceptible to heat.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The research work was funded by the Ministry of Higher Education Malaysia under Research Acculturation Grant Scheme (RAGs), project no. RAG0038-STWN-2013.

References

Adebowale, A.A., Sanni, L.O. and Awonorin, S.O. (2005). Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. *Food Science Technology International*, 11(5), 373–382. https://doi.org/10.1177/1082013205058531

Adebowale, K.O. and Lawal, O.S. (2004). Comparative study of the functional properties of bambara groundnut (*Voandzeia subterranean*), jack bean (*Canavalia ensiformins*) and mucuna bean (*Mucuna pruriens*) flours. *Food Research International*, 37(4), 355-365. https://doi.org/10.1016/j.foodres.2004.01.009

Adegunwa, M.O., Adebowale, A.A., Bakare, H.A. and Kalejaiye, K.K. (2014). Effects of treatments on the antinutritional factors and functional properties of bambara groundnut (*Vigna subterranea*) flour. *Journal of Food Processing and Preservation*, 38(4), 1875–1881. https://doi.org/10.1111/jfpp.12159

Adepeju, A.B., Gbadamosi, S.O., Adeniran, A.H. and Omobuwajo, T.O. (2011). Functional and pasting characteristics of breadfruit (*Artocarpus altilis*) flours. *African Journal of Food Science*, 5(9), 529–535.

Akubor, P.I., Yusuf, D. and Obiegunam, J.E. (2013). Proximate composition and some functional properties of flour from the kernel of African star apple (*Chrysophyllum albidum*). *International Journal of Agricultural Policy and Research*, 1(3), 62–66.

Amiza, M.A. and Roslan, A. (2009). Proximate composition and pasting properties of durian (*Durio zibethinus*) seed flour. *International Journal of Postharvest Technology and Innovation*, 1(4), 367–375. https://doi.org/10.1504/IJPTI.2009.030685

Amiza, M.A., Aziz, Y., Ong, B.C., Wong., V.L. and Pang, A.M. (2004). CHIEF: Cheap high fibre flour from local fruit seed. Expo Science, Technology and Innovation 2004. PWTC. Kuala Lumpur.

AOAC. (2007). Official Methods of Analysis. 18th Ed., Washington, D.C., USA: Association of Official Analytical Chemists.

Aprianita, A., Purwandari, U., Watson, B. and Vasiljevic, T. (2009). Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. *International Food Research Journal*, 16(4), 507–520.

Bhupender, S.K., Rajneesh, B. and Baljeet, S.Y. (2013). Physicochemical, functional, thermal and pasting properties of starches isolated from pearl millet cultivars. *International Food Research Journal*, 20 (4), 1555–1561.

Bogracheva, T.Y., Meares, C. and Hedley, C.L. (2006). The effect of heating on the thermodynamic characteristics of potato starch. *Carbohydrate Polymers*, 63(3), 323–330. https://doi.org/10.1016/j.carbpol.2005.08.065

Chandra, S. and Samsher. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, 8(38), 4849–4852. https://doi.org/10.5897/AJAR2013.6905

Chowdhury, A.R., Bhattacharyya, A.K. and Chattopadhyay, P. (2012). Study on functional properties of raw blended jackfruit seed flour (a non-conventional source) for food application. *Indian Journal of Natural Products and Resources*, 3(3), 347–353.

Chung, H.J., Liu, Q., Hoover, R., Warkentin, T.D. and Vandenberg, B. (2008). *In vitro* starch digestibility, expected glycemic index, and thermal and pasting properties of flours from pea, lentil and chickpea cultivars. *Food Chemistry*, 111(2), 316–321. https://doi.org/10.1016/j.foodchem.2008.03.062

Cornelia, M., Siratantri, T. and Prawita, R. (2015). The utilization of extract durian (*Durio zibethinus L.*) seed gum as an emulsifier in vegan mayonnaise. *Procedia Food Science*, 3, 1–18. https://doi.org/10.1016/j.profoo.2015.01.001

Falade, K.O. and Christopher, A.S. (2015). Physical, functional, pasting and thermal properties of flours and starches of six Nigerian rice cultivars. *Food Hydrocolloids*, 44, 478–490. https://doi.org/10.1016/j.foodhyd.2014.10.005

Ikegwu, O.J., Okechukwu, P.E. and Ekumankana, E.O. (2010). Physico-chemical and pasting characteristics of flour and starch from achi *Brachystegia eurycoma* seed. *Journal of Food Technology*, 8(2), 58–66. https://doi.org/10.3923/jftech.2010.58.66

Kaur, M. and Sandhu, K.S. (2010). Functional, thermal and pasting characteristics of flours from different lentil (*Lens culinaris*) cultivars. *Journal of Food Science and Technology*, 47(3), 273–278. https://doi.org/10.1007/s13197-010-0042-0

Kaur, M. and Singh, N. (2005). Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum L.*) cultivars. *Food Chemistry*, 91(3), 403–411. https://doi.org/10.1016/j.foodchem.2004.06.015

Kaur, M., Sandhu, K.S. and Singh, N. (2007). Comparative study of the functional, thermal and pasting properties of flours from different field pea (*Pisum sativum L.*) and pigeon pea (*Cajanus cajan L.*) cultivars. *Food Chemistry*, 104(1), 259–267. https://doi.org/10.1016/j.foodchem.2006.11.037

Liu, Q., Gu, Z., Donner, E., Tetlow, I. and Emes, M. (2007). Investigation of digestibility In vitro and physicochemical properties of A- and B-type starch from soft and hard wheat flour. *Cereal Chemistry*, 84 (1), 15–21. https://doi.org/10.1094/CCHEM-84-1-0015

Mirhosseini, H., Abdul Rashid, N.F., Tabatabaee Amid, B., Cheong, K.W., Kazemi, M. and Zulkurnain, M. (2015). Effect of partial replacement of cornflour with durian seed flour and pumpkin flour on cooking yield, texture properties, and sensory attributes of gluten-free pasta. *LWT - Food Science and Technology*, 63(1), 184–190. https://doi.org/10.1016/j.lwt.2015.03.078

Mohd Hanif, N., Noor Qhairul Izreen, M.N., Hasmadi, M. (2013). Komposisi proksimat dan komponen asid lemak Durian Kuning (*Durio graveolens*) Sabah. *Sains Malaysiana*, 42(9), 1283–1288.

Mohd Nazrul Hisham, D., Mohd Lip, J., Suri, R., Mohamed Shafit, H., Kharis, Z., Shazlin, K., Normah, A. and Nurul Nabilah, M.F. (2012). Agrowaste: Phytosterol from durian seed. *World Academy of Science, Engineering and Technology*, 69(9), 72–75.

Mukprasirt, A. and Sajjaanantakul, K. (2004). Physico-chemical properties of flour and starch from jackfruit seeds (*Artocarpus heterophyllus Lam.*) compared with modified starches. *International Journal of Food Science and Technology*, 39(3), 271–276. https://doi.org/10.1111/j.1365-2621.2004.00781.x

Noor Raihana, A.R., Marikkar, J.M.N., Amin, I. and Shuhaimi, M. (2015). A Review on food values of selected tropical fruits' seeds. *International Journal of Food Properties*, 18(11), 2380–2392. https://doi.org/10.1080/10942912.2014.980946

Oladele, A.K. and Aina, J.O. (2007). Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*). *African Journal of Biotechnology*, 6(21), 2473–2476. https://doi.org/10.5897/AJB2007.000-2391

Oloyede, O.O., James, S., Ocheme, O.B., Chinma, C.E. and Akpa, V.E. (2016). Effects of fermentation time on the functional and pasting properties of defatted *Moringa oleifera* seed flour. *Food Science and Nutrition*, 4(1), 89-95. https://doi.org/10.1002/fsn3.262

Omimawo, I.A. and Akubor, P.I. (2012). Food Chemistry (Integrated Approach with Biochemical background). Nigeria: Joytal printing press.

Salma, I. (2011). Durio of Malaysia. Serdang, Malaysia: Malaysian Agricultural Research and Development Institute (MARDI).

Shevkani, K., Singh, N., Kaur, A. and Rana, J.C. (2014). Physicochemical, pasting, and functional properties of amaranth seed flours: effects of lipids removal. *Journal of Food Science*, 79(7), 1271–1277. https://doi.org/10.1111/1750-3841.12493

Shimelis, E., Meaza, M. and Rakhsit, S. (2006). Physico-chemical properties, pasting behaviour and functional characteristics of flour and starches from improved bean (*Phaseolus vulgaris L.*) varieties grown in East Africa. *Agricultural Engineering International*, 8, 1–18.

Srianta, I., Hendrawan, B., Kusumawati, N. and Blanc, P.J. (2012). Study on durian seed as a new substrate for Angkak production. *International Food Research Journal*, 19(3), 941–945.

Tizazu, H. and Emire, S. (2010). Chemical composition, physicochemical and functional properties of lupin (*Lupinus albus*) seeds grown in Ethiopia. *African Journal of Food Agriculture Nutrition and Development*, 10(8), 3029–3046. https://doi.org/10.4314/ajfand.v10i8.60895

Tulyathan, V., Tananuwong, K., Songjinda, P. and Jaiboon, N. (2002). Some physicochemical properties of jackfruit (*Artocarpus heterophyllus Lam*) seed flour and starch. *Science Asia*, 28, 37–41. https://doi.org/10.2306/scienceasia1513-1874.2002.28.037

Vasanthan, T. and Bhatty, R.S. (1996). Physicochemical properties of small and large granule starches of waxy, regular, and high amylose barleys. *Cereal Chemistry*, 73(2), 199–207.