Heliyon 7 (2021) e08292

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Microwave vacuum-dried durian flour and its application in biscuits

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ARTICLE INFO

Keywords:
Durio zibethinus Murr.
Dough
Cookies
Baking
Starch

ABSTRACT

Durian is one of most popular fruits due to its nutritional values and unique flavor. Durian products have been continuously developed to meet market needs. In this study, durian (*Durio zibethinus* Murr.) cv. 'Monthong' was subjected to microwave vacuum-drying at 1,200 W to produce durian flour for use in biscuits that are normally made from wheat flour. The microwave treatment induced starch gelatinization to a significant extent. As a result, compared to the wheat flour, the durian flour had lower viscosity, pasting temperature, gelatinization temperatures, and enthalpy of gelatinization but higher water absorption capacity. Dough properties including development time, dough stability, time to breakdown and the phase angle tangent of the durian dough were less than those of the wheat dough. The elastic modulus (G′) and viscous modulus (G″) of the durian dough were higher than for the wheat dough. All the tested durian doughs had higher G′ values than G″, indicating a viscoelastic structure. Substitution of wheat flour with durian flour should not exceed 50% to obtain reasonable dough properties and baking quality of durian biscuits.

1. Introduction

Durian (*Durio zibethinus* Murr.) is a fruit that is native to and extremely common throughout Southeast Asia, especially Thailand, Malaysia, Indonesia, the Philippines, and Cambodia. Durian from Thailand is recognized high quality and consequently, accurate identification of the geographical origin has become very important to ensure the authenticity of Thai durian (Zhou et al., 2021). Thailand produces around 1.1 million t of durian each year. Its export value on the global market was more than USD 2,000 million in 2020 (Office of Agricultural Economics, 2021). Durian and durian-based products are predicted to become even more popular with estimated global demand of more than USD 25 billion by 2030 (Durian Harvest, 2021), due to its unique flavor and high levels of nutritional, antioxidant, and bioactive compounds such as flavanols, anthocyanin, total carotenoids, and β-carotenoids. According to proximate composition analysis using standard AOAC methods reported by Charoenkiatkul et al. (2016), durian cv 'Monthong' contained 69.3 g moisture per 100 g fresh sample, 70.7 g carbohydrate per 100 g dry matter, 10.1g crude fat, 7.6 g protein per 100 g dry matter, 3.5 g ash per 100 g dry matter, and 8.0 g total dietary fiber per 100 g dry matter. Total sugar in the durian was 48.3 g per 100 g dry matter, consisting of sucrose (44.6 g per100 g dry matter), glucose (2.4 g per100 g dry matter), maltose (0.8 g per100 g dry matter), and fructose (0.5 g per100 g dry matter), as well as being a gluten-free ingredient. Thus, durian should be processed into flour to extend its shelf-life and improve it use in the development of various value-added durian products such as cake, cookies, pie filling, and biscuits.

For flour development, microwave vacuum-drying has been confirmed as a suitable method to increase the drying rate and reduce the drying time of durian by 98% compared with hot-air drying. In addition, microwave vacuum-drying could retain the color of flour close to that of fresh durian. However, the physiochemical properties of the starch in durian flour produced using hot-air drying were different from those resulting from microwave vacuum-drying. Generally, starch is changed from a crystalline to an amorphous structure during heating with some water to obtain starch gelatinization. Volumetric heating during microwave vacuum-drying produces starch with less crystallinity than from conventional drying. The starch granules from the microwave vacuum-drying appear broken and open, which may be responsible for the better rehydration than from the conventionally dried sample in the study by Bai-Ngew et al. (2015).

Wheat flour is commonly used to develop proper biscuit structure and texture, due to its available gluten. Many studies have replaced wheat flour by flours obtained from locally grown crops, as one way of balancing trade, with composite flours for dough-based products of particular interest. Noorfarahzilah et al. (2014) defined composite flour

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https://doi.org/10.1016/j.heliyon.2021.e08292
Received 18 July 2021; Received in revised form 7 September 2021; Accepted 27 October 2021

as a mixture of flours or starches intended to replace wheat flour totally or partially in bakery products. Many kinds of flours have been reported to successfully replace wheat flour in biscuits to increase the health benefits such as using fiber from whole barley flour (20–40%) (Aly et al., 2021) and resistant starch from annealed white sorghum starch (15–45%) (Cervini et al., 2021), and to improve flavor by adding roasted adzuki bean flour (Bi et al., 2021). However, the proportion of flour must be investigated because it can affect dough properties and product quality. For example, the addition of chestnut flour (0, 50, 80, and 100%) in a biscuit formulation tended to increase the water-binding capacity but reduce the viscous and elastic moduli of the biscuit dough. Up to 50% replacement with chestnut flour was recommended to maintain an acceptable biscuit quality (Paciulli et al., 2018). Knowledge of the dough properties from the composite flour is important for the development of specific bakery products.

Because durian is in high demand as a food product that contains a reasonably high starch content for flour development, this study aimed to determine the effect of substitution of wheat flour by durian flour on the composite flour properties, dough properties, and biscuit quality. Furthermore, the potential of the durian flour for the development of a durian biscuit was investigated.

2. Material and methods

2.1. Materials

Durian (*Durio zibethinus* Murr.) cv. 'Monthong' (104 days after full bloom) was purchased from a local supplier. The maturity of the durian was evaluated by skilled Thai workers and using the day count, characteristics of the fruit spines, tapping the fruit, and its colour and shape. Wheat flour with 10–11% protein (Kite brand, United Flour Mill Public Co., Ltd, Thailand) was purchased from a local supermarket.

2.2. Methods

2.2.1. Durian flour preparation

The durian flesh was taken from the fruit manually and cut in half to remove the seed. The edible part was cut into small pieces before grinding using a food processor (Combimax 600, Braun, USA) to obtain durian slurry. The durian slurry was poured into a block (255 × 380 mm) with 3 mm thickness and placed in a microwave vacuum oven (MarchCool, Bangkok, Thailand) at 1,200 W for 12 min (MD). The pressure and frequency were set at 13.33 kPa and 2,450 MHz, respectively. The dried durian slurry was finely ground using an ultra-centrifugal mill (Retsch model ZM100, Haan, Germany) and passed through a 100-mesh (0.149 mm) sieve. The durian flour samples were packed in aluminium foil bags and kept at 25 °C until use. The experiment was independently conducted with two replications.

2.2.2. Determination of flour composition

The components of the durian and wheat flours were determined using AOAC method (2000) for the moisture, fat, protein, fiber, ash, and carbohydrate contents. The fat content was analyzed using the continuous solvent extraction method with a Soxhlet fat-extraction apparatus. Crude protein was analyzed using the combustion method with a protein analyzer (Leco model FP528, St Joseph, MI, USA). The protein percentage was calculated by multiplying N by a factor of 6.25, with the carbohydrate content calculated by the difference from this amount. The starch content was determined using the glucoamylase method (AACC, 1995). The amylose content was determined using amperometric titration with a potassium iodate solution as described by Gibson et al. (1997).

2.2.3. Determination of physical properties of composite flour

Composite flours were prepared by substitution of wheat flour with the durian flour at 0, 25 (MD25), 50 (MD50), 75 (MD75), and 100%. Then, the composite flours were determined for their pasting properties, thermal characteristics, and physicochemical properties.

Determination of pasting properties of composite flour

The pasting properties of the composite flour slurry were determined using a Rapid Visco Analyzer (RVA; 4D, Parten Instruments Group, Hägersten, Sweden) according to AACC Method 76-21.01 (1995). The temperature time cycle consisted of initial heating at 50 °C for 1 min, continuous heating at a 12 °C/min rate to 95 °C, holding at 95 °C for 2.5 min, cooling at the same rate to 50 °C, and maintaining at 50 °C for 1.5 min. The recorded parameters were peak viscosity (PV), trough, final viscosity (FV), break down viscosity and set back viscosity.

Determination of thermal characteristics of composite flour

The thermal characteristics of the composite flour were analyzed using a differential scanning calorimeter (DSC 822e, Mettler-Toledo GmbH, Switzerland), following the method of (Bai-Ngew et al.,. 2015). The composite flour was mixed in distilled water (1:3 w/v) and allowed to disperse for 1 h at room temperature (25 °C) using a magnetic stirrer to ensure full hydration of the flour. The dispersion sample (16 mg) was packed into an aluminum pan and hermetically sealed before analysis. The DSC analyzer was calibrated using indium. An empty aluminum pan was used as a reference. Sample pans were heated at a rate of 5 °C/min from 25 to 100 °C. The onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c), and enthalpy of gelatinization (ΔH_{gel}) were calculated for the endotherms using the Star^e Software for thermal analysis® Ver.8.1. Three samples were measured and the average value was reported.

Determination of physicochemical properties of dough

Farinograph measurement

Farinograph measurements and evaluation of farinograms were carried out according to AACC Method 54-21 (1995). The farinogram data were analyzed using a Brabender farinograph (Farinograph®-E, Brabender®GmbH & Co.KG, Germany) with a 50 g sample. The dough mixing was carried out in a stainless-steel bowl with a mixing speed of 63 revolutions per minute at 30 °C. The water absorption capacity, dough development time, dough stability, and time to breakdown of the dough were recorded.

Determination of dough rheology

The dough sample was prepared using a mixer (Model 5K5SS, KitchenAid®, USA) with a spiral blade. From the titration curve obtained from the farinogram, the amount of water was determined, added and mixed with flour for 3 min. The oscillatory shear flow of the dough was analyzed using a rotational rheometer (Gemini 200 HR Nano, Malvern-Bohlin Instrument, UK). All measurements were carried out at 25 °C using 50 mm serrated parallel plates (PP50). The dough was placed between the plates with a 2 mm gap and the edges were trimmed. The dough sample was allowed to rest between the plates for 20 min before testing. The frequency sweep was set from 0.1 to 20 Hz with 0.1 % strain. The data of elastic modulus (G′), viscous modulus (G″), and phase angle tangent (tg $\delta = G''/G'$) were plotted against the frequency sweep in a double logarithmic diagram.

2.2.4. Development of durian biscuit from composite flour

Durian biscuit preparation

Durian biscuit samples were prepared using 100% durian flour and composite flours containing 25% (MD25), 50% (MD50), and 75% (MD75) durian flours. The formula of the durian biscuit dough was

Table 1. Pasting properties of wheat, durian, and composite flours.

Viscosity parameter	Composite flour				
	Wheat flour	MD25	MD50	MD75	Durian flour
Peak viscosity (RVU)	211.58 ± 2.84a	136.39 ± 3.18b	55.08 ± 0.73c	16.06 ± 3.31d	4.81 ± 0.99e
Trough (RVU)	141.16 ± 3.19a	78.75 ± 0.52b	32.05 ± 0.29c	12.2 ± 4.2d	2.42 ± 1.09e
Breakdown viscosity (RVU)	70.42 ± 1.53a	57.50 ± 2.67b	23.11 ± 0.67c	3.86 ± 0.96d	2.39 ± 0.67d
Final viscosity (RVU)	250.06 ± 3.61a	138.53 ± 2.33b	56.33 ± 0.55c	23.5 ± 4.5d	8.28 ± 0.82e
Setback viscosity (RVU)	108.89 ± 2.39a	59.78 ± 2.17b	24.28 ± 0.84c	11.27 ± 0.32d	5.86 ± 1.36e
Pasting temperature (°C)	67.18 ± 0.85a	67.23 ± 3.13a	65.65 ± 0.78a	58.50 ± 4.19b	50.8 ± 0.9c

[a-e] Values shown as mean ± standard deviation within the same row with different lowercase letters are significantly different ($P \leq 0.05$).

composed of flour, fine grain sugar (30 g per 100 g flour), unsalted butter (20 g per 100 g flour), sodium bicarbonate (0.5 g per 100 g flour), baking powder (0.3 g per 100 g flour), ammonium bicarbonate (1.0 g per 100 g flour), salt (1.0 g per 100 g flour), and water (25.0 g per 100 g flour). The sodium bicarbonate, ammonium bicarbonate, and salt were dissolved in the water at ambient temperature to prepare the solution. The butter was creamed with the sugar for 2 min and then with the solution for 5 min. The composite flour and baking powder were mixed with the previous mixture for 3 min to obtain dough. The dough was sheeted to a 3 mm thickness and cut into circular shapes using a 65 mm diameter cutter. The circular shapes were baked in a convective baking oven at 160 °C for 10 min, and then allowed to cool.

Determination of durian biscuit quality

The thickness and diameter of the durian biscuits were measured using a set of Vernier calipers. The specific volume of each biscuit was analyzed using a Volscan instrument (VSP600, Texture Technologies, Massachusetts, USA). The hardness of the durian biscuits was determined using a texture analyzer (Stable Micro System TA-XT2i, Surrey, UK) with a three-point bending rig (HDP/3PB). In addition, the biscuit texture was analyzed based on sound analysis using an acoustic envelope detector (A/RAED).

2.3. Statistical analysis

All experiments were conducted with 3 replications. Experimental data were analyzed using ANOVA in the statistical package SPSS® version 12.0 (SPSS (Thailand) Co., Ltd., Bangkok, Thailand). Duncan's multiple range test was used to carry out multiple comparisons of mean values and significance was tested at $p < 0.05$.

3. Results and discussion

3.1. Composition of flour

Based on the proximate composition analysis, the contents of moisture, fat, protein, crude fiber, ash, and carbohydrate of the microwave vacuum-dried durian flour were 5.56, 9.95, 7.92, 11.37, 3.31 and 66.73 g per 100 g dry matter, respectively. The composition of the flour from durian cv 'Monthong' in the current study was similar to that reported by Charoenkiatkul et al. (2016). In addition, in the current study, the starch content of the microwave vacuum-dried durian flour was 11.8% consisting of 99.3% amylopectin and 0.7% amylose. The ratio of amylopectin-to-amylose in the durian flour coincided with that reported in another study on the composition of the flour made from ripened and overripe durian cv 'Monthong' (Bai-Ngew et al., 2014). For the wheat flour, the contents of moisture, fat, protein, crude fiber, ash and carbohydrate were 11.60, 1.82, 11.20, 3.35, 0.50 and 74.9 g per 100 g dry matter, respectively, with 72.8% starch content consisting of 76.5% amylopectin and 23.5% amylose.

3.2. Pasting properties of flour

The pasting properties of the wheat flour, durian flour and the composite flour (a mixture of durian and wheat flours) are presented in Table 1. The wheat flour had higher values for pasting temperature and viscosity than the microwave vacuum-dried durian flour because of the higher starch content in the wheat flour than in the durian flour. In this study, the starch content in the durian flour was 11.8% whereas the starch content in wheat flour was 72.8%. By comparison, another study reported wheat flour contained a lower starch content (63.1%) and a peak viscosity of 199.5 cP which was much less than the peak viscosity of wheat flour (1,945.0 cP) containing a higher starch content (69.8%) (Li et al., 2020).

In addition, the durian flour in the current study was prepared using microwave vacuum-drying which is characterized by rapid processing. The high heating rate induces structural change in starch, with the crystalline structure of the starch being disorganized into an amorphous structure during heating and a high heating rate could increase the degree of disorganization. The starch granules appeared to have a broken and opened form (Bai-Ngew et al., 2015). Consequently, the pasting properties of the starch in the durian flour declined. This was consistent with Ma et al. (2016) who reported that a change in the starch granule structure could decrease peak viscosity, breakdown, final viscosity, and setback of the flour, resulting in the peak RVA viscosity of the 100% durian flour being very low. In addition, there was little change in the viscosity during the temperature change, indicating that the starch in the durian flour had already been gelatinized during the microwave vacuum drying.

Partially replacing the wheat flour with durian flour tended to decrease the pasting temperature and viscosity of the composite flour, compared with the wheat flour (Figure 1). Thus, the viscoelasticity of the composite flour decreased with an increase in the durian-to-wheat flour ratio.

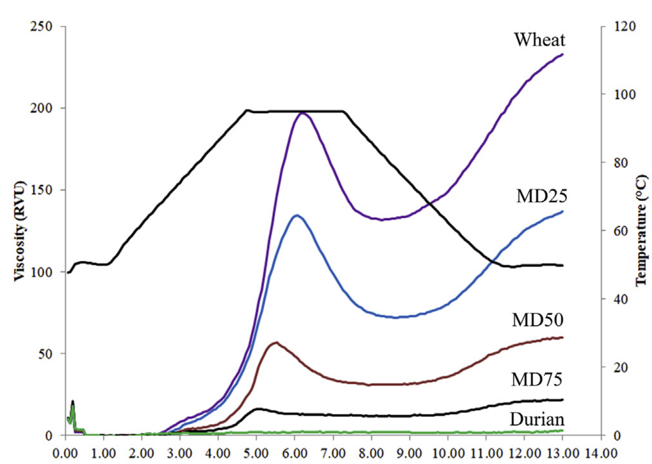

Figure 1. Pasting profiles of wheat, durian, and composite flours.

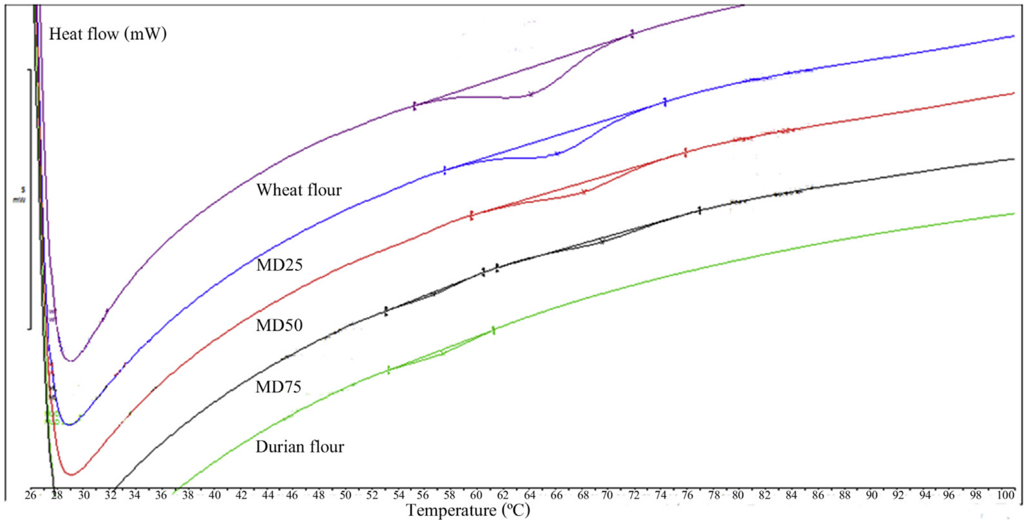

Figure 2. DSC thermograph of wheat flour, durian flour and composite flours.

3.3. Thermal properties of composite flour

From the DSC thermograph, the wheat and durian flours had a single endothermic curve whereas the replacement with durian flour at 25%, 50%, and 75% in the composite flours led to two endothermic peaks (Figure 2). The low T_p value corresponded to the gelatinization of the durian flour while the high T_p value reflected gelatinization of the wheat flour. The T_o value of the composite flour was the lowest observed value of T_o while the T_c value of the composite flour was the highest observed value of T_c. The thermogram of the composite flour was the sum of the two individual thermograms (Table 2).

The presence of two endothermic peaks indicated that the durian and wheat flours in the composite flour were independently gelatinized. In this study, the gelatinization temperature and enthalpy of the durian flour was lower than for the wheat flour, indicating the low structural stability and crystallinity of the microwave vacuum-dried durian flour, compared with the wheat flour. Variation in transition temperatures among flours may be related to variation in the degree of crystallinity. Generally, the degree of crystallinity of wheat flour (30%) (Saiah et al.,. 2007) seemed to be less than that of the durian flour. The degree of crystallinity of the durian flour from hot-air drying and microwave vacuum-drying were 18–22% and 4–8%, respectively. The crystallinity of the durian flour decreased due to either the increasing air temperature in the case of hot-air drying or the increasing microwave power in the case of microwave vacuum-drying (Bai-Ngew et al., 2015). Therefore, the wheat flour could have greater structural stability than the durian flour as the starch granules in the former were more resistant to gelatinization, resulting in a high transition temperature.

In this study, starch in the durian flour was pre-gelatinized during the microwave vacuum-drying. The endothermic curve of the durian flour was very low in the range 50.68–61.27 °C with low enthalpy (2.18 J/g starch). The partial substitution of the wheat flour by durian flour decreased the values for T_o, T_p, T_c., and ΔH compared to wheat flour only, resulting in less energy being required for starch gelatinization of the composite flour during baking compared with the 100% wheat flour. However, the composite flour with low ratios of durian flour such as

Table 2. Differential scanning calorimetric data of wheat, durian, and composite flours.

Flour		Gelatinization characteristic				
		T_o (°C)	T_{p1} (°C)	T_{p2} (°C)	T_c (°C)	ΔH (J/g dry starch)
Wheat flour		56.80 ± 0.15	-	62.90 ± 0.25	68.17 ± 0.23	14.12 ± 1.52
Composite	MD25	58.16 ± 1.49	-	65.06 ± 0.14	71.43 ± 2.28	12.43 ± 0.08
	MD50	58.52 ± 0.96	-	66.91 ± 0.23	74.17 ± 1.25	12.38 ± 0.35
	MD75	51.3 ± 0.3	55.38 ± 0.14	68.49 ± 0.18	74.74 ± 0.98	12.24 ± 0.35
Durian flour		50.68 ± 0.86	56.11 ± 0.27	-	61.27 ± 0.75	2.18 ± 0.01

Values shown as mean ± standard deviation.

Table 3. Farinograph of doughs from wheat, durian, and composite flours.

Flour		Water absorption (%)	Development time (min)	Stability (min)	Tolerance Index (FU)	Breakdown (min)
Wheat flour		54.80 ± 0.74d	7.77 ± 1.24a	13.55 ± 1.73a	21.25 ± 4.11d	14.87 ± 2.41a
Composite flour	MD25	56.05 ± 0.07c	1.73 ± 0.21b	5.75 ± 0.07b	125.00 ± 1.41ab	6.80 ± 0.42b
	MD50	56.4 ± 0.3c	1.3 ± 0.3b	0.6 ± 0.2c	107.3 ± 28.4b	1.7 ± 0.4d
	MD75	59.70 ± 0.62b	1.83 ± 0.15b	0.96 ± 0.25c	136.7 ± 12.5a	2.53 ± 0.31c
Durian flour		63.05 ± 0.07a	1.75 ± 0.07b	0.95 ± 0.07c	88.50 ± 0.71c	2.55 ± 0.07c

[a-d] Values shown as mean ± standard deviation within the same column with different lowercase letters are significantly different ($P \leq 0.05$).

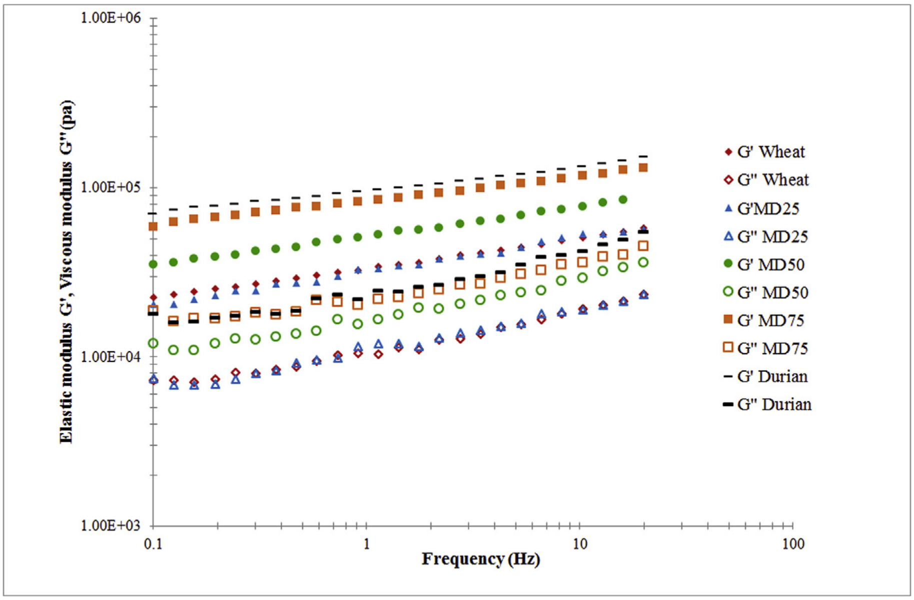

Figure 3. Moduli of doughs from wheat, durian, and composite flours.

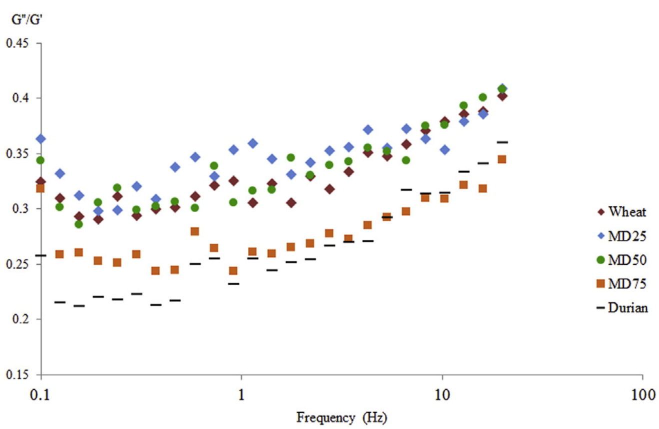

Figure 4. Values of tg δ for doughs from wheat, durian, and composite flours.

MD25 and MD50 did not produce two endothermic peaks. The unnoticeable endothermic peak of durian flour was possibly due to very low enthalpy from the small amount of durian flour.

3.4. Physicochemical properties of dough

Substitution of wheat flour with durian flour significantly affected the dough mixing behavior based on the farinograph results (Table 3). The water absorption of 100% wheat flour was 54.80%. Similar water absorption of wheat flour was reported by Mohammed et al. (2014). Water absorption of the durian flour was 63.05% and was significantly higher than for the wheat flour because the durian flour had fiber compounds that could increase water absorption. The greater number of hydroxyl groups in the fiber structure allowed more water interaction through hydrogen boding (Sudha et al., 2007). Ajila et al. (2008) reported that fiber from mango peel powder was incorporated into wheat flour used for biscuit making, resulting in increased water absorption.

The water absorption of the composite flour was in the range 56.05–59.70%. There was increased water absorption when the ratio of the durian flour in the composite flour increased. Although the durian flour had significantly higher water absorption, it had a higher mixing

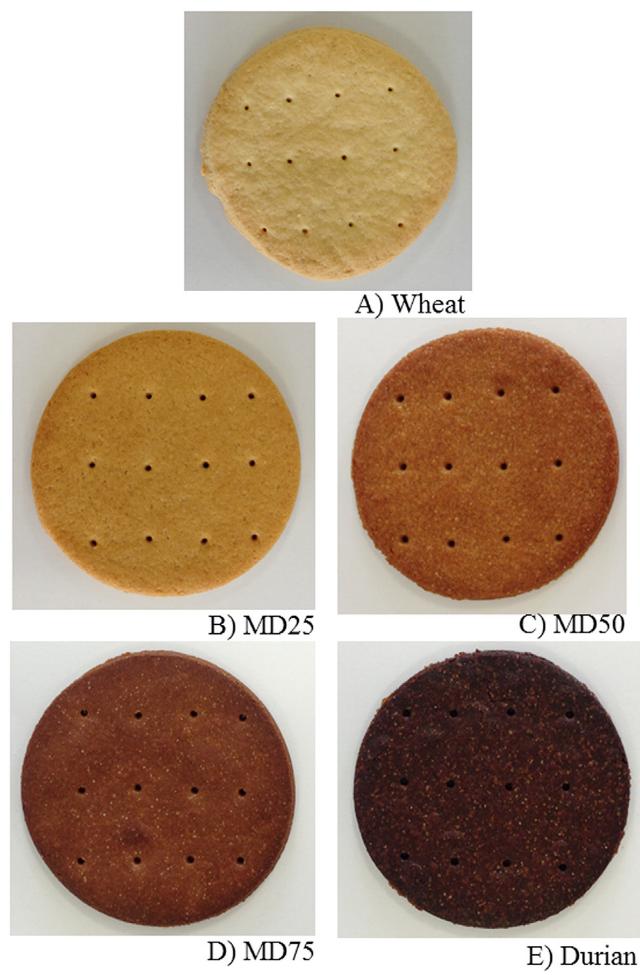

Figure 5. Appearance of biscuits from various flours: A) wheat, B) MD25, C) MD50, D) MD75 and E) durian.

Table 4. Quality of biscuits from wheat, durian, and composite flours.

Flour		Diameter (mm)	Height (mm)	Specific volume (ml/g)	Sound analysis (dB)
Control		56.99 ± 1.29b	6.94 ± 0.35a	1.78 ± 0.06a	86.61 ± 1.27a
Composite flour	MD25	63.35 ± 0.48a	4.82 ± 0.04b	1.49 ± 0.08b	88.77 ± 0.96a
	MD50	62.81 ± 0.22a	3.96 ± 0.17c	1.11 ± 0.11c	86.64 ± 4.09a
	MD75	63.20 ± 0.29a	3.80 ± 0.22c	1.08 ± 0.05c	78 ± 5 b
Durian flour		63.83 ± 0.14a	3.8 ± 0.2c	0.97 ± 0.05c	75.08 ± 4.01b

[a-c] Values shown as mean ± standard deviation within the same column with different lowercase letters are significantly different ($P \leq 0.05$).

tolerance index and lower stability than the wheat flour. Furthermore, it required a short time to develop and breakdown dough, compared with the wheat flour. Consequently, dough from the durian flour was softer than for wheat flour which might have been due to a lack of gluten and the high content of damaged starch from the rapid heating rate during the microwave vacuum-drying. Increasing the content of damaged starch from 9.3 to 30 % increased the bread dough weakness from 53 to 82 Fainograph unit (Ma et al., 2016). The increase in the durian flour ratio in the composite flour reduced the time for dough development and breakdown. This could be explained by the decrease in the concentration of wheat gluten in the composite flour. This was supported by Koca and Anil (2007) who reported decreased water absorption and increased stability when wheat flour was partially replaced by flaxseed flour. Therefore, the dough strength was significantly degraded by increasing the ratio of durian flour in the current study.

Considering the rheological properties of the dough, there were variations in G' *and* G'' with the frequency sweep from 0.1 to 20 Hz for doughs made from wheat flour, composite flour, and durian flour, as shown in Figure 3. For all doughs, the values of G' and G'' increased with an increase in the frequency, with G' always higher than G''. Thus, all dough had a viscoelastic structure. The durian doughs had higher G' and G'' values than the wheat dough. Therefore, the G' and G'' values of dough made from the composite flour were likely to be higher than for dough made from wheat flour, with the exception of the composite flour MD25

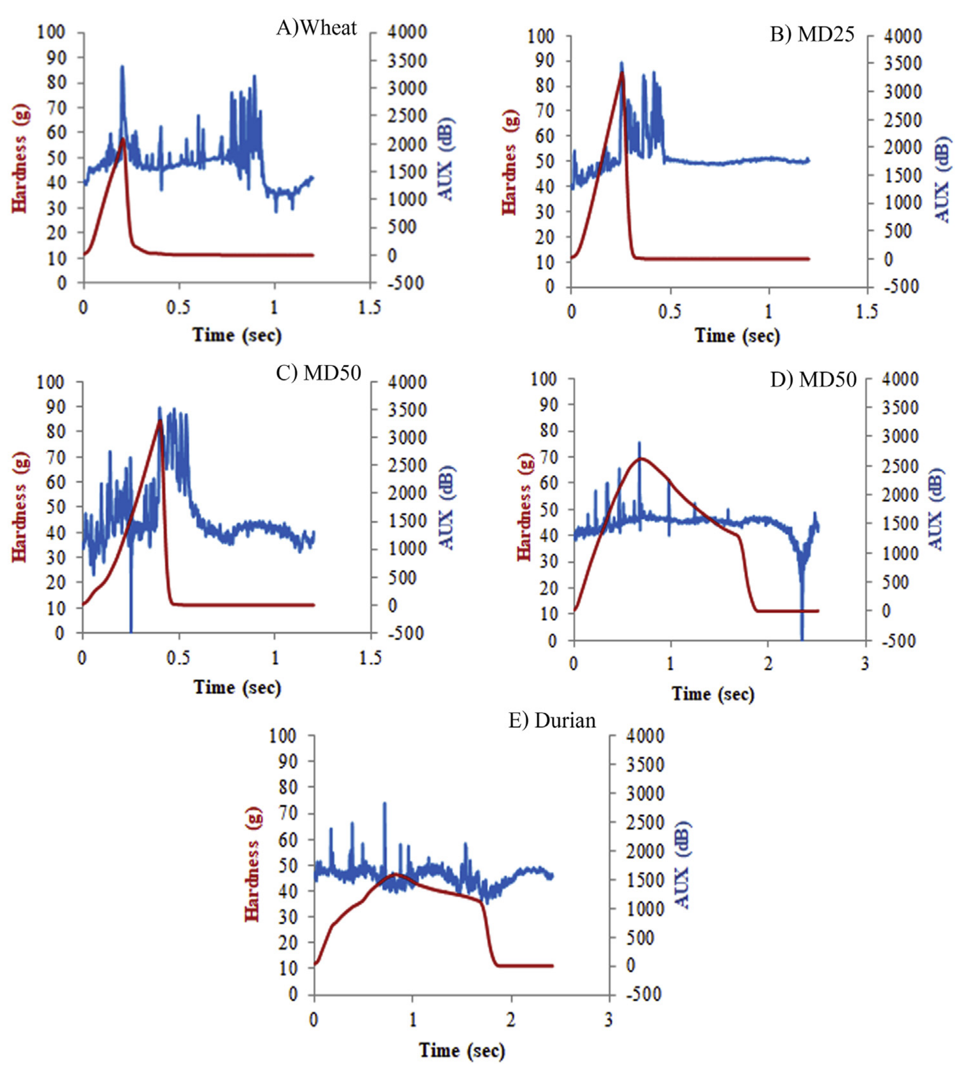

Figure 6. Texture profile and sound analysis of biscuits from various flours: A) wheat, B) MD25, C) MD50, D) MD75 and E) durian.

whose properties were similar to those of the wheat flour. This might have been due to the variation in starch-gluten interaction in the dough and the amount of damaged starch in the flours. The starch granules in dough act as a filler that reinforces gluten and produces strong bonds to increase the modulus.

The phase angle tangent (tg δ) is the ratio of viscous-to-elastic behavior and plays an important role in the rheology of polysaccharides. In this study, tg δ reduced with increasing frequency, reaching its minimum value when the frequency increased to 0.2 Hz (Figure 4). The decrease in tg δ indicated the development of some elastic networks. When the frequency increased to 20 Hz, tg δ increased again. This indicated better resistance of the material to deformation. However, the tg δ values of all doughs were less than 1, which confirmed that the elastic properties of the composite dough and durian dough predominated over the viscous properties (Hesso et al., 2015). Although durian flour is gluten-free, its high amylopectin content could help to maintain the elastic properties of durian dough compared to the viscous properties. In another study, gluten-free dough was successfully developed for bread by replacing wheat flour by a mixture of waxy starch and regular starch of corn and potato. The presence of waxy starch (high amylopectin starch) could increase the values of storage and loss moduli of the gluten-free bread dough (Witczak et al., 2019). In the current study, to obtain the same range of rheological properties as the wheat dough, durian flour could replace the wheat flour by 25–50%.

3.5. Quality of durian biscuits from composite flours

Wheat biscuits are much lighter than biscuits containing durian flour due to the high sugar content in durian (17.45–51.70%) (Ali et al., 2020) that could enhance Maillard and caramelization reactions during baking at high temperature (Figure 5). An increase in the durian flour ratio produced biscuits appearing a darker color. In addition, the wheat biscuits had a smaller diameter, were thicker than the durian biscuits. All the durian biscuits had similar diameters, but different thicknesses (Table 4). The increase in the amount of durian flour added reduced the dough expansion vertically due to the increased weakness of the dough that resulted in a significant decrease in the specific volume of the dough. In addition, biscuit hardness was reduced with the increased added durian flour (Figure 6). The formation of an amylose network determined the initial texture of biscuits. The amylose content in the composite samples was reduced with the increased durian flour because i) the overall starch level was lower and ii) there was virtually no amylose in the durian flour.

The sound analysis measured in decibels (dB) using the stable micro system acoustic envelope detector, the increased amount of durian flour reduced the sound intensity. This was confirmed by the biscuits containing high amounts of durian flour, such as MD75 and 100% durian flour, being soft and sticky. With the same ratios of other ingredients, wheat biscuits would have a sound intensity value of 86.61 ± 1.27 db. In addition, the sound profile patterns of MD25 and MD50 were similar to those of wheat biscuits. Therefore, 25–50% durian flour could be used in the composite flour to produce durian biscuits with a similar crispy texture to the regular biscuit. This was in agreement with the findings for dough properties where the substitution of wheat flour with durian flour up to 50% still provided comparable dough properties to the wheat flour.

4. Conclusion

Durian flour was prepared using rapid heating in a microwave vacuum-dryer and used to replace wheat flour to develop composite flours containing 0%, 25%, 50%, 75%, or 100% durian flour. The durian flour had lower values for viscosity, pasting temperature, gelatinization temperatures (T_o, T_p and T_c), and ΔH_{gel} but a higher water absorption capacity than the wheat flour. Dough properties (development time, dough stability, time to breakdown, and tg δ) of the durian dough were less than those of the wheat dough. However, the values for G′ and G″ of the durian dough were higher than for the wheat dough. To obtain reasonable dough properties for dough-based products, the amount of durian flour in the composite flour should not exceed 50%. Substitution of wheat flour by up to 50% durian flour was confirmed for its potential to produce durian biscuits with comparable texture to the regular biscuit.

Declarations

Author contribution statement

Bai-Ngew, S.: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Therdthai, N.: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Zhou, W.: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Funding statement

This work was supported by The Kasetsart University Research and Development Institute (KURDI), Bangkok, Thailand (104.57).

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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