Physicochemical and Sensory Properties of Waffle Incorporated With Date Seed (*Phoenix dactylifera L.*) Flour

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Abstract. This study investigates the feasibility of utilizing date seed flour (DSF) as a partial substitute for wheat flour (WF) in waffles production. The research focuses on evaluating the physicochemical properties of DSF and the impact of 5% and 10% DSF substitution on the physicochemical and sensory attributes of waffles. Physicochemical analyses revealed that DSF has significantly lower moisture content (10.21±0.17%) and water activity (0.56±0.03), but higher ash (0.66±0.03%) and magnesium (18.35±0.25 mg/100g) levels compared to WF. DSF also exhibited a darker colour (lower L and higher a and b values), and greater radical scavenging activity (70.03±2.92%) than WF. Waffles substituted with 5% DSF showed significantly higher protein (10.85±0.21%), calcium (178.80±4.21%), and magnesium (9.56±0.35%) content than the control waffles made from WF. Importantly, the incorporation of DSF did not negatively affect the textural characteristics of the waffles. Sensory evaluation results indicated no significant differences in texture, taste, or overall acceptability between DSF-substituted waffles and the control (waffle made from WF). These findings suggest that DSF can effectively replace WF in waffle production, enhancing nutritional value while maintaining quality, and contributing to sustainable food production by utilizing date seeds that are otherwise discarded.

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1 Introduction

Date palm (*Phoenix dactylifera* L.) is the most widely cultivated fruit crop in dry and semiarid regions due to its high nutritional value and environmental benefits. It can thrive in arid, hot, and dry climates, in alkaline and salty soils. While date palms can endure extreme summer temperatures up to 50℃ and brief frosts down to 5℃, they grow best in temperatures ranging from 21℃ to 27℃, with an overall tolerance range of 13℃ to 28℃ [1-3]. There are over 2000 globally recognized date types, including Khalas and Medjool, each with unique attributes. Different maturity stages—Hanabauk, Kimri, Khalal, Rutab, and Tamr—indicate various uses at different moisture levels. Date fruits, ellipsoid in shape, have a fleshy pericarp and an oblong, grooved seed with a firm endosperm and small embryo, ranging in colour from deep red to yellowish based on species and ripening stage [4-6]. Date fruits, are rich in sugars, fiber, minerals, and vitamins. They contain 75% sugars, 5–15% fiber, and essential minerals like manganese, phosphorus, magnesium, and iron [7, 8].

Oman, Libya, Iraq, Egypt, UAE, Saudi Arabia, Pakistan, Sudan, Tunisia, and Algeria are the world's main producers of date palms. The top four producers— Iraq, Saudi Arabia/UAE, Egypt, and Iran— together produce 9,656,378 tons of dry, semi-dry, and soft date fruit varieties [7, 9]. The rising global harvest of dates benefits the financial market, with consumption expected to reach 13,482.48 k-tons by 2025. Production nearly doubled to over 8.5 million tons in 2018, and the number of cultivating countries grew from 23 in 1960 to 37 in 2020 [10-12]. In 2018, global date production reached 8.52 million tons, with 852,000 tons of date seeds, representing 10% of the fruit mass. As production grows, date seed waste increases, emphasizing the need for its utilization in the food industry. While date seed flour has been used in baked goods [13-16], its use in waffles from the Deglet Noor variety at the tamr stage has not yet been studied [17].

Date seeds account for 10 to 15% of the fruit's mass, varying by variety, and their composition differs among types. Studies show that date seeds are a natural source of protein, minerals, antioxidants, phenolic components, and dietary fiber [1], [13], [18]. Hence it is important to study the properties of the date seed powder and how it affects the waffles properties when incorporated. Studies on date seed flour (DSF) preparation involve various methods. Hassan's [16] cleaned date seeds, roasted the seeds at 60–70°C for 4 hours and 180°C for 1 hour, then blended them into a fine powder. Elgindy [19] oven dried date seeds at 30°C for 48 hours, crushed with a pestle and mortar, blended, sieved, and stored the DSF at 4°C. Najjar *et al.*'s [13] soaked date seeds in water for 6 hours, air-dried for 3 days, ground, sieved to remove particles larger than 250 μm, and stored the DSF at −20°C. Omar *et al.* [20] oven dried date seeds at 50°C, milled, sieved through a 60-mesh sieve, and preserved the DSF at 4°C.

Studies show that incorporating 2.5% to 10% date seed flour (DSF) enhances baked goods properties. Texture and antioxidant activity in muffin improved with 2.5% DSF hydrolysates incorporation [14]. In another study it is reported that 7.5% DSF addition in cookies made cookies dark and crispy [13]. Jahan *et al.* [15] reported increased fiber in bread with 1 to 10% DSF substitution. Omar *et al.* [20] found 10% DSF incorporation is optimal for white loaf quality, while Hassan's [16] found cakes which was supplemented with 10% to 40% DSF had improved volume and shelf life, though 40% DSF inclusion affected cake's colour. Moderate DSF levels which is less than 10% offered best results in the baked goods.

Discarding date seeds wastes valuable nutrients like fiber, minerals, and phenolic compounds. Utilizing the date seeds supports sustainability and meets consumer demand for eco-friendly products [1], [10], [21]. This research aimed to explore the feasibility of using DSF in waffle production by evaluating physicochemical properties of date seed flour

(DSF) along with the physicochemical and sensory properties of waffles substituted with 5 and 10% DSF. The study seeks to determine whether DSF can effectively replace wheat flour (WF) without compromising the quality of the waffles.

2 Materials and Methods

2.1 Materials

The dates utilized in this research were Deglet Noor dates in their dry tamr stage, sourced from Kuantan, Pahang, Malaysia.

2.2 Date seed flour (DSF) production

The seeds were separated from flesh and then soaked in tap water to remove remaining flesh, and oven dried (SFCN-302, Finetech) at 60°C for 3 hours. They were then ground, sieved through a 500-micron sieve, and stored at 4°C in a zip-lock bag until analysis [20].

2.3 Preparation of waffles substituted with DSF

Waffles were prepared with 5% and 10% date seed flour (DSF) substitution, following [22] and [23]. Control waffles comprised 50.3% milk, 25.2% wheat flour, ,10% sugar, 8% butter, 3.6% egg yolk, 2% baking powder, 0.8% vanilla essence and 0.1% salt. Butter and sugar were creamed, then combined with egg yolk and vanilla. Flour, salt, and milk were added gradually, with baking powder incorporated last. The batter was cooked in a greased waffle maker for 9 minutes, then cooled for 30 minutes, sealed, and stored at 4ºC until analysis. For DSF waffles, 5% and 10% DSF were substituted the wheat flour.

2.4 Experimental design

Analyses on date seed flour (DSF) and waffles substituted with 5% and 10% DSF were conducted as illustrated in the Figure 1.

2.4.1 Sensory analysis

During the sensory evaluation, 30 untrained panellist which is students from Universiti Teknologi MARA Cawangan Negeri Sembilan, Kampus Kuala Pilah tested the waffle samples. The ethical statement for the study was applied from Universiti Teknologi MARA Research Ethics Committee with ethics approval code REC/1027/2024 and informed consent was obtained from each subject before they participate in this study. Subjects confirmed not having any known wheat-related consumption disorder. All participants were recognized as regular waffle consumers, consuming baked products at least once to thrice times per month.

Panellist received a slice of sample from each formulation and were asked (with vocal and written instruction) to evaluate the preference in terms of appearance, colour, taste, texture and overall acceptance of waffle from each formulation using a 9-point Hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) was used for each attribute. Samples were served with 3-digit codes on white plastic plates under white light at room temperature to prevent bias [24, 25].

2.5 Statistical analysis

Data were processed in SPSS Statistics v.26. The physicochemical results of date seed flour and wheat flour was statistically analyzed using an independent sample t-test to determine the differences between these two types of flour at 5% significance level. ANOVA was used to analyse physicochemical and sensory parameter values, and for results shown significant differences, a post-hoc Tukeys's test was conducted at a significance level of 5%.

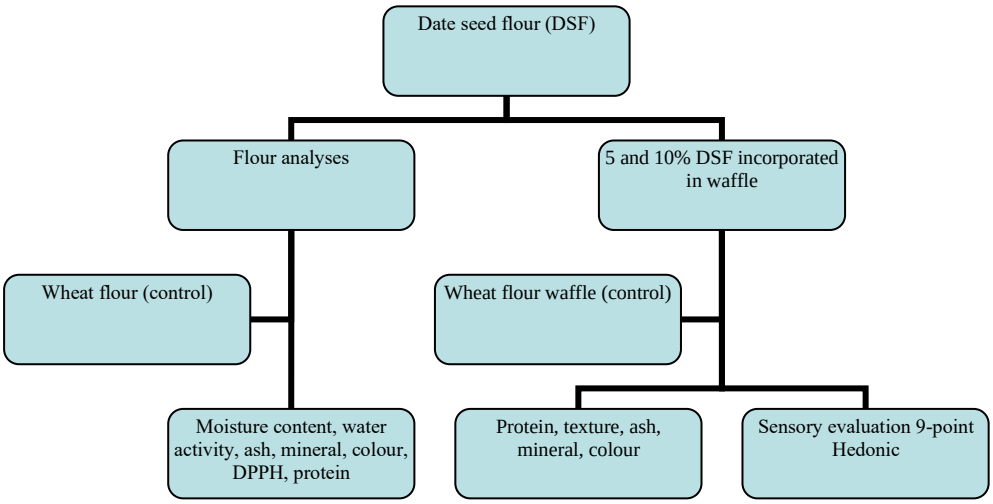

Fig. 1. Experimental design

3 Results and Discussion

3.1 Analyses on date seed flour (DSF)

3.1.1 Moisture content and water activity

Date seed flour (DSF) recorded significantly ($p<0.05$) lower moisture content and water activity compared to wheat flour (WF) as in **Table 1**. The moisture content in the DSF in this study is comparable to study done by Jahan *et al*. (2023) [15] even though different sample treatment was applied on the date seed. In terms of water activity, there is no comparable result for DSF due to the limited research available.

Moisture content for DSF and WF met the standard stated in Food Regulation 1985, which limits wheat flour moisture to 14% [26]. Moisture content affects flour quality, including texture, flavour, and shelf life. For example, wheat flour with 13% to 15% moisture can last for one year [27]. Shtëmbari (2023) [28] highlights that moisture content and water activity are crucial for flour quality where low moisture and water activity levels enhance storage stability and help in preventing spoilage and maintain overall quality. Carter *et al*. (2015) [29] suggest a water activity range of 0.62 to 0.68 for wheat flour to prevent mould and reduce rancidity.

Table 1. Moisture content and water activity of date seed flour and wheat flour

	Moisture content (%)	Water activity (aw)
Date seed flour (DSF)	10.21±0.17[b]	0.56±0.03[b]
Wheat flour (WF)	13.73±0.22[a]	0.67±0.00[a]

Data are presented as mean ± standard deviation. Different letters present vertically indicates a significant ($p<0.05$) difference between means.

3.1.2 Ash and mineral

In **Table 2**, ash content in DSF is significantly higher ($p<0.05$) than in WF due to the milling process removes bran from wheat, which lowers its ash content [30]. However, the ash in DSF is lower than ash reported in earlier studies by Jahan *et al* (2023) [15], El-Shahat and Marwa (2022) [31] (4.98%), Elgindy (2020) [19] (1.09%), and Hassan (2021) [16] (1.16%). It might be contributed to different methods of processing the DSF. The highest ash content was reported by El-Shahat and Marwa (2022) [31], who used air drying method. According to Food Regulation 1985 (26), wheat flour should not have more than 1% ash. Ash in food is a measure of its mineral content, meaning higher ash content indicates more minerals like magnesium, calcium, and phosphorus [32].

Calcium in DSF in this study is higher than calcium found by Elgindy (2020) [19] which is 26.4 mg/100g in Khalas varieties but lower than the calcium reported by El-Shahat and Marwa (2022) [31] (98.3 mg/100g) for unknown varieties. Magnesium in DSF is significantly higher ($p<0.05$) than in WF because milling removes the mineral-rich bran and germ from wheat [30]. However, the magnesium content recorded in DSF is lower than magnesium reported by Hassan (2021) [16] for Mazafati varieties (77 mg/100g) and Elgindy (2020) [19] for Khalas varieties (89.3 mg/100g). These differences might be due to the different methods used to prepare the DSF.

Table 2. Ash and water activity of date seed flour and wheat flour

	Ash (%)	Calcium (mg/100g)	Magnesium (mg/100g)
Date seed flour (DSF)	0.66±0.03[a]	39.13±4.21[a]	18.35±0.25[a]
Wheat flour (WF)	0.36±0.07[b]	39.97±0.51[a]	7.29±0.75[b]

Data are presented as mean ± standard deviation. Different letters present vertically indicates a significant ($p<0.05$) difference between means.

3.1.3 Colour

DSF is significantly ($p<0.05$) darker than WF as can be observed from the L,a,b values in **Table 3** and picture in **Figure 2.** The L value for date seed flour in this study is lower than the L values reported by Najjar *et al*. (2022) [13] (L:38-45), indicating that the DSF in this study is darker than the previous study. The CIE colour of flour is mainly influenced by brightness and yellowness. Brightness depends on the amount of bran, while yellowness is affected by the carotenoid content in the endosperm [33]. High temperatures during processing can also make DSF darker.

Table 3. Colour of date seed flour and wheat flour

	L	a	b
Date seed flour (DSF)	20.38±0.52[b]	6.93±0.09[a]	11.28±0.25[a]
Wheat flour (WF)	38.86±0.6[a]	-0.27±0.01[b]	5.14±0.03[b]

Data are presented as mean ± standard deviation. Different letters present vertically indicates a significant ($p<0.05$) difference between means.

Fig. 2. Colour of date seed flour (a) and wheat flour (b)

3.1.4 Protein

The protein content in DSF is significantly lower ($p<0.05$) than in WF as stated in **Table 4**. DSF's protein levels are comparable to protein of DSF in Sriharsha *et al* (2021) [21] and Jahan *et al* (2023) [15] (5.25-5.92%), but higher than Elgindy (2020) [19] results for Khalas variety (4.69%), and lower than protein value reported by El-Shahat and Marwa (2022) [31] and Hassan (2021) [16] (7.41-7.9%) for Mazafati variety. High-protein flour is essential for baking because it forms gluten, which provides structure and elasticity to baked goods [34]. Both DSF and WF meet the requirement of flour which shall contain at least 7% protein [26].

Table 4. Protein of date seed flour and wheat flour

	Protein (%)
Date seed flour (DSF)	5.52±0.02[b]
Wheat flour (WF)	10.30±0.07[a]

Data are presented as mean ± standard deviation. Different letters present vertically indicates a significant ($p<0.05$) difference between means.

3.1.5 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity (RSA)

Table 5 shows the result of the radical scavenging activity (RSA) of DSF and WF. DSF has significantly higher ($p<0.05$) RSA than WF due to its rich content of antioxidants and phenolic compounds like epicatechin, catechin, tocopherol, and phytosterols ((35):(1)). The RSA of DSF in this study is similar to RSA found by Salar *et al* (2022) [36] in DSF from Mazafati variety (up to 70%) and higher than RSA reported by El-Shahat and Marwa (2022) [31] which is 62.24%. However, it is lower than the 83.90% RSA found by Darwish *et al* (2020) [37] in DSF from Siwi variety and 79.12% reported by Elgindy (2020) [19] for

DSF from Khalas variety. Overall, the RSA of DSF in this study is within the range with previous studies.

Table 5. RSA of date seed flour and wheat flour

	RSA (%)
Date seed flour (DSF)	70.03±2.92[a]
Wheat flour (WF)	2.65±0.12[b]

Data are presented as mean ± standard deviation. Different letters present vertically indicates a significant ($p<0.05$) difference between means.

3.2 Analyses on DSF substituted waffles

3.2.1 Protein

Waffle substituted with 5% DSF (F1) shown significantly ($p<0.05$) higher protein content compared to waffle substituted with 10% DSF (F2) and waffle made from 100% wheat flour (control) as can be observed in **Table 6**. The result is opposite with protein content in DSF and WF in **Table 4** which shown DSF had lower protein content than WF. The increased protein in the waffles substituted with DSF may be due to the interaction of DSF with other ingredient such as WF [35]. The protein content in this study was higher than in baked goods from previous studies such as Hassan (2021) (16) (10-40% DSF substitution), who found 7.88% to 8.54% protein in cake substituted with DSF, and Sriharsha *et al* (2021) [21], who reported 5.78% protein in cookies substituted with 12% DSF. The protein content in the F1 was similar to the protein found by Jahan *et al* (2023) [15] which is 10.48% to 12.4% in baked item substituted with 1-10% DSF. Overall, the waffle with DSF had higher protein content compared to waffle made with only wheat flour.

Table 6. Protein of date seed flour and wheat flour waffles

	Protein (%)
5% DSF waffle (F1)	10.85±0.21[a]
10% DSF waffle (F2)	10.30±0.42[b]
Wheat flour waffle (C)	9.92±0.06[c]

Data are presented as mean ± standard deviation. Different letters present vertically indicates a significant ($p<0.05$) difference between means.

3.2.2 Texture

Table 7 shows texture attributes of the waffles, including hardness, springiness, cohesiveness, gumminess, and chewiness which shows no significant differences ($p>0.05$) across all formulations and control. The control waffle had the highest hardness, gumminess, cohesiveness and chewiness. The addition of date seed flour typically increases

the hardness of baked products, making them harder and crisper due to the fibrous nature of date seeds [13]. This fiber content can interfere with gluten development, reducing dough cohesiveness and leading to a less cohesive final product [38]. Date seed flour can also increase gumminess and chewiness, contributing to a denser texture, although this effect varies depending on the amount DSF used [13]. Additionally, the springiness of baked goods tends to decrease with date seed flour, as the fibers and lower gluten content reduce the dough's elasticity, resulting in a denser product [17]. The addition of DSF which is rich in fiber [35], insignificantly reduced all the texture attributes but did not significantly impact the overall texture. This suggests that DSF can be added to waffles without affecting their texture.

Table 7. Texture of date seed flour and wheat flour waffles

	5% DSF waffle (F1)	**10% DSF waffle (F2)**	**Wheat flour waffle (C)**
Chewiness (g)	1645.54±265.51[a]	1950.13±129.74[a]	2255.84±349.74[a]
Gumminess (g)	1786.66±246.78[a]	2095.37±173.08[a]	2444.23±426.01[a]
Cohesiveness	0.77±0.01[a]	0.74±0.00[a]	0.79±0.04[a]
Springiness (mm)	0.92±0.02[a]	0.92±0.02[a]	0.93±0.02[a]
Hardness (g)	2329.32±321.25[a]	2817.88±245.07[a]	3079.33±540.37[a]

Data are presented as mean ± standard deviation. Different letters present horizontally indicates a significant ($p<0.05$) difference between means.

3.2.3 Ash and mineral

In **Table 8**, addition of DSF did not significantly ($p>0.05$) affected ash value in waffle substituted with DSF due to low substitution value [13] . Ash content in food indicates the presence of minerals such as magnesium, calcium, and phosphorus. Therefore, higher ash content reflects a greater concentration of these minerals [32]. Hence, the addition of DSF significantly ($p<0.05$) increased magnesium content in F1. This is because date seeds are found to be significant source of minerals [13]. Same pattern is observed for F2 that had no different ($p>0.05$) with control in terms of ash and minerals.

Table 8. Ash and minerals of date seed flour and wheat flour waffles

	5% DSF waffle (F1)	**10% DSF waffle (F2)**	**Wheat flour waffle ©**
Ash (%)	2.26±0.09[a]	2.25±0.11[a]	2.43±0.08[a]
Calcium (mg/100g)	178.80±4.21[a]	175.80±0.60[b]	177.02±1.16[ab]
Magnesium (mg/100g)	9.56±0.35[a]	7.62±0.06[b]	7.63±0.06[b]

Data are presented as mean ± standard deviation. Different letters present horizontally indicates a significant ($p<0.05$) difference between means.

3.2.4 Colour

F2 had significant ($p<0.05$) darker colour as can be seen from L and a value in **Table 9** and waffle picture **Figure 9**. The result is parallel to DSF colour in **Table 3** that shows DSF colour is darker than WF. Increasing the amount of date seed flour (DSF) in the waffle reduces its lightness. This darker colour can also be attributed to the Maillard reaction and sugar caramelization during baking, which generate brown pigments (melanoidins) [39].

Table 9. Colour of date seed flour and wheat flour waffles

	5% DSF waffle (F1)	10% DSF waffle (F2)	Wheat flour waffle (C)
L	48.15 ± 0.23^{b}	41.47 ± 0.32^{c}	51.81 ± 0.16^{a}
a	4.62 ± 0.02^{b}	6.21 ± 0.13^{a}	6.32 ± 0.10^{a}
b	14.84 ± 0.11^{b}	10.76 ± 0.29^{c}	20.20 ± 0.11^{a}

Data are presented as mean ± standard deviation. Different letters present horizontally indicates a significant ($p<0.05$) difference between means.

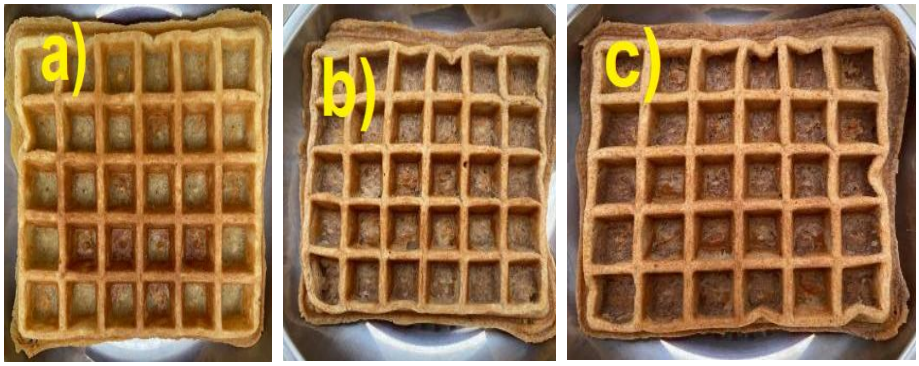

Fig. 3. a) Colour of wheat flour waffle (control) b) Colour of 5% DSF incorporated waffle and c) Colour of 10% DSF incorporated waffle

3.2.5 Sensory evaluation

Figure 4 shows panellists' evaluation on F1, F2 and control waffles for colour, taste, texture and overall acceptability by using 9-point hedonic scale. It is visible that panellist rated 7 (like moderately) for all attributes of waffle substituted with DSF. In term of colour, panellists least preferred waffle incorporated with 5% DSF due to darker colour compared to control (as can be seen from **Figure** 3). Addition of DSF significantly did not ($p>0.05$) influence the panellist's perception on colour (for waffle substituted with 10% DSF only), taste, texture and overall acceptability of waffle substituted with DSF compared to WF. The dark colour of the waffle, perceived by the panellists as an indicator of a well-cooked and caramelized product, may result from the Maillard reaction and sugar caramelization, which produce brown pigments (melanoidins) during baking [39]. This shows that incorporation of DSF in baked item such as waffle can be accepted by panellists.

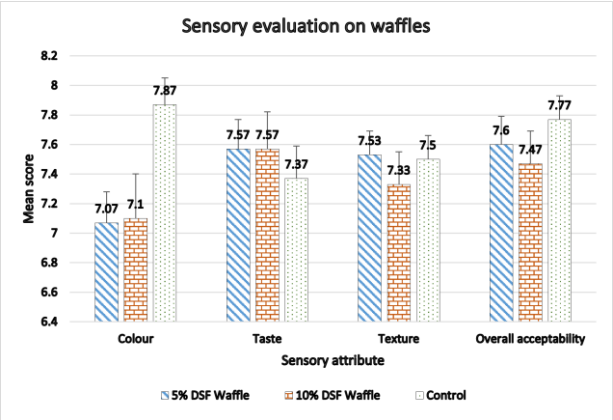

Fig. 4. Sensory evaluation of date seed flour and wheat flour waffles

4 Conclusion

This study confirms the potential of date seed flour (DSF) as a sustainable and nutritionally advantageous alternative to wheat flour (WF) in waffle production. Substituting WF with up to 10% DSF resulted in waffles with enhanced protein, calcium, and magnesium content, as well as increased antioxidant activity, without compromising textural characteristics or overall sensory acceptability. Despite the darker color of DSF, the sensory attributes of the waffles remained comparable to those made with WF. These findings underscore the feasibility of utilizing DSF in food formulations, offering a promising approach to reducing food waste and responding to consumer demands for more sustainable and nutritious products.

Authors contribution. Formal analysis, investigations, writing original draft preparation and data curation contributed to Nur Ain Humaira Amran. Conceptualization, methodology, writing, editing, visualization, supervision, project administration, and reviewing contributed to Naemaa Mohamad.

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Conflicts of interests. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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