

Effect of Red Dragon Fruit (*Hylocereus Costaricensis*) Peel Flour Substitution on Mud Cake Characteristics

Marella Adhania Dewanto^{1*}, I Nengah Kencana Putra¹, Gusti Putu Ganda Putra¹,
Ayu Septi Anggraeni², Suratno²

¹Faculty of Agricultural Technology, Udayana University, Denpasar, Indonesia

²Research Centre for Food Technology and Processing (PRTTP), National Research and Innovation Agency (BRIN), Yogyakarta, Indonesia

*Email Correspondence: Dewanto.2382511002@student.unud.ac.id

ARTICLE INFO

Article History:

Received September 27, 2026

Accepted October 22, 2026

Published online October 22, 2026

Keywords:

Red dragon fruit peel flour;

Mud cake;

Dietary fiber;

Antioxidant activity;

Mineral composition.

ABSTRACT

Red dragon fruit (*Hylocereus costaricensis*) peel flour is a promising local food ingredient rich in dietary fiber, minerals, and bioactive compounds, making it suitable for functional food development. This study evaluated the effects of substituting wheat flour with red dragon fruit peel flour on the chemical, physical, and sensory characteristics of mud cake, identified the optimal formulation, and determined its mineral and dietary fiber contents. A Completely Randomized Design (CRD) was applied using five formulations: F0(100:0), F1(95:5), F2(90:10), F3(85:15), and F4(80:20) (wheat flour dragon fruit peel flour), with three replications. Data were analyzed using one-way ANOVA followed by Duncan's Multiple Range Test (95% confidence level), while the best formulation was selected using the De Garmo effectiveness index. Flour substitution significantly affected ash, fat, crude fiber, antioxidant activity, color, texture, and several sensory attributes but had no significant effect on moisture or protein content. Increasing substitution levels increased ash (0.65–1.41%), fat (5.09–6.40%), and crude fiber (2.76–4.88%) contents, whereas carbohydrate content decreased from 44.65% to 32.64%. The optimal formulation was F2 (90% wheat flour:10% red dragon fruit peel flour), with an effectiveness index of 0.68. Compared with the control (F0), the selected formulation (F2), containing 10% red dragon fruit peel flour, showed higher magnesium (from 26.105 to 36.914 mg/100 g), manganese (from 0.325 to 1.186 mg/100 g), potassium (from 283.276 to 438.674 mg/100 g), and total dietary fiber (from 3.81% to 5.32%). Total dietary fiber is distinct from crude fiber; therefore, these values refer specifically to total dietary fiber and should not be interpreted as crude fiber measurements. These findings suggest that substituting 10% of wheat flour with red dragon fruit peel flour may enhance the nutritional composition and functional food potential of mud cake while maintaining its overall quality.

INTRODUCTION

The increasing demand for functional foods has encouraged the utilization of agricultural by-products as sustainable sources of nutrients and bioactive compounds. Red dragon fruit (*Hylocereus costaricensis*) peel is a promising by-product because the peel may account for approximately 35% of the fruit's total weight and contains betalain pigments with potential applications as natural colouring agents.¹ The nutritional potential of dragon fruit peel is also supported by compositional analysis: Astuti et al. reported crude fiber contents of 50.58–50.62% in dragon fruit peel flour, together with moisture contents of 6.37–6.52% and protein contents of 9.24–9.43%.² These values demonstrate

the potential of peel flour as a fiber-rich ingredient, although crude fiber should not be interpreted as equivalent to total dietary fiber.

Mud cake (*kue lumpur*) is a traditional Indonesian cake whose nutritional composition depends on its ingredients and formulation. Hapsari reported a fiber content of 3.08% in a mud cake formulation containing red bean purée and sweet potato purée, illustrating the potential for formulation changes to influence the nutritional profile of this product.³ However, this value does not represent all conventional mud cakes. Incorporating red dragon fruit peel flour as a partial substitute for wheat flour may provide an opportunity to increase dietary fiber and modify the mineral and antioxidant profiles of mud cake while valorizing a food-processing by-product. Therefore, the effects of substitution on nutritional composition, antioxidant activity, physical characteristics, and consumer acceptance need to be evaluated to identify a formulation that balances nutritional improvement with product quality.

Red dragon fruit peel accounts for approximately 30–35% of the fruit's total weight and is commonly discarded during processing, making it a potential raw material for food-product development.¹ The peel contains dietary fiber, betalains, and phenolic compounds that may contribute to the nutritional and antioxidant properties of food products. However, the benefits observed in the final product depend on the substitution level, processing conditions, and food matrix. Previous studies have reported different optimal substitution levels across bakery products. For wheat-flour cookies, replacing 5%, 10%, and 15% of wheat flour with pitaya peel flour increased ash and fiber contents, while reducing crumb height; nevertheless, substitution up to 15% did not significantly impair overall sensory acceptability.⁴ In white bread, substitution levels of 3%, 6%, and 9% increased ash and crude fiber contents but also increased hardness and density while reducing loaf volume. The 6% formulation provided the most favourable balance of appearance and texture.⁵ A more recent biscuit study using 0–9% red dragon fruit peel powder similarly found that increasing substitution enhanced fiber content and antioxidant activity, whereas sensory acceptance declined at higher levels, with 6% identified as the preferred formulation.⁶ These findings suggest that greater incorporation does not necessarily produce better overall product quality.

The application of red dragon fruit peel flour in bakery and confectionery products has shown promising results. Previous studies reported improvements in antioxidant activity, dietary fiber content, and nutritional value when the flour was incorporated into chiffon cake, steamed sponge cake, cookies, and pancakes. Nevertheless, increasing substitution levels may alter product quality by affecting color, texture, flavor, and consumer acceptance because of the high fiber content and the presence of natural pigments. Therefore, determining an appropriate substitution level is essential to balance nutritional enhancement with desirable sensory characteristics.

Mud cake (kue lumpur) is a traditional Indonesian snack associated with local culinary culture and social occasions. It is typically prepared from wheat flour, potatoes, eggs, sugar, and coconut milk, producing a moist, soft-textured cake with a mildly sweet flavour.³ Although its ingredients contribute energy and other nutrients, the nutritional composition of mud cake varies with the recipe and ingredient proportions. For example, Hapsari reported a fiber content of 3.08% in a mud cake formulation containing red bean purée and sweet potato purée, illustrating how ingredient substitution can modify its nutritional profile.³ More directly, Cahyani et al. investigated red dragon fruit peel purée at substitution levels of 10%, 13%, 16%, 19%, and 22%. They reported crude fiber contents of 2.75–4.51% and antioxidant capacity values of 14.33–18.23 mg/L, while sensory characteristics differed significantly among treatments.⁷ These findings demonstrate the potential of incorporating red dragon fruit peel into mud cake, but also indicate that increasing the proportion of peel-derived ingredients may affect product acceptability. However, the previous study used peel purée rather than peel flour, and its substitution levels and analytical outcomes cannot be directly equated with those of a flour-based formulation. The present study therefore evaluates red dragon fruit peel flour as a partial substitute for wheat flour at levels of 5%, 10%, 15%, and 20%, assessing nutritional composition, antioxidant activity, physical characteristics, and sensory acceptance. This approach addresses whether the use of a dried, flour-based by-product can improve the nutritional profile of mud cake while maintaining acceptable product quality.

Although several studies have investigated the incorporation of red dragon fruit peel flour into bakery products, limited information is available regarding its application in mud cake. Furthermore, previous studies have primarily focused on proximate composition or antioxidant activity, whereas comprehensive evaluations integrating chemical composition, physical properties, sensory quality, mineral composition, and dietary fiber remain scarce. In addition, information on the optimum substitution level that maintains product acceptability while improving nutritional quality is still limited.

Therefore, this study evaluated the effects of substituting wheat flour with red dragon fruit (*Hylocereus costaricensis*) peel flour on the chemical, physical, and sensory characteristics of mud cake. The study also identified the optimum formulation using the De Garmo effectiveness index and compared the mineral and total dietary fiber contents of the selected formulation with those of the control. It was hypothesized that increasing the proportion of red dragon fruit peel flour would significantly affect the nutritional composition of mud cake, including its mineral content, dietary fiber content, and antioxidant activity. It was further hypothesized that substitution would alter the colour and texture profile of the product because of differences in pigment content, water-binding capacity, and the proportion of wheat flour in the formulation. Regarding sensory acceptance, it was hypothesized that the level of substitution would significantly influence panelists' ratings of colour,

aroma, taste, texture, and overall acceptance, and that an intermediate substitution level might provide a more favourable balance between nutritional improvement and sensory quality than the highest substitution level. Finally, the selected formulation was expected to differ from the control in mineral and total dietary fiber contents. The findings are expected to provide scientific evidence supporting the development of nutritionally enhanced traditional foods through the sustainable utilization of fruit-processing by-products.

Therefore, this study aimed to evaluate the effects of replacing wheat flour with red dragon fruit (*Hylocereus costaricensis*) peel flour at substitution levels of 0%, 5%, 10%, 15%, and 20% on the chemical composition, antioxidant activity, colour, texture profile, and sensory acceptance of mud cake (kue lumpur). The study also aimed to identify the optimum formulation using the De Garmo effectiveness index and compare its mineral and total dietary fiber contents with those of the control.

It was hypothesized that increasing the proportion of red dragon fruit peel flour would significantly affect the chemical composition and antioxidant activity of mud cake. Substitution was also expected to alter colour and texture because of differences in pigment content, water-binding capacity, and the proportion of wheat flour in the formulation. Furthermore, substitution level was hypothesized to influence sensory ratings for colour, aroma, taste, texture, and overall acceptance. An intermediate substitution level was expected to provide a more favourable balance between nutritional improvement and sensory quality than the highest substitution level. Finally, the selected formulation was expected to differ from the control in mineral and total dietary fiber contents.

MATERIALS AND METHODS

Materials

Fresh red dragon fruits (*Hylocereus costaricensis*) at commercial maturity were obtained from a local farm in Banyuwangi, East Java, Indonesia. The fruits were selected based on uniform size, bright red peel color, and the absence of physical damage. Wheat flour, eggs, granulated sugar, coconut milk, margarine, vanilla, and salt used for mud cake preparation were purchased from a local supermarket. Analytical-grade reagents including 96% ethanol, DPPH (2,2-diphenyl-1-picrylhydrazyl), and other analytical chemicals were used for antioxidant analysis.

Preparation of Red Dragon Fruit Peel Flour

Red dragon fruit peels were separated from the pulp, washed thoroughly with running water, and cut into small pieces. The peels were dried in a hot-air oven at 60°C for 10 h until a constant weight was achieved. The dried peels were ground using a laboratory blender and sieved through a 40-mesh sieve to obtain fine peel flour. The flour was stored in airtight polyethylene containers at room temperature until further use.

Preparation of Mud Cake

The preparation of mud cake followed the method described by Putri and Lastariwati, with modifications to accommodate the substitution treatments used in this study.⁸ Five formulations were prepared based on the ratio of wheat flour to red dragon fruit peel flour (*Hylocereus costaricensis*): F0 (100:0), F1 (95:5), F2 (90:10), F3 (85:15), and F4 (80:20), respectively. Thus, F0 served as the control, containing 100% wheat flour and no red dragon fruit peel flour.

First, margarine and sugar were mixed using a mixer for 1 min. Eggs, vanilla, and mashed potatoes were then added and mixed until homogeneous. The flour mixture corresponding to each treatment was subsequently incorporated, followed by the addition of coconut milk. The batter was mixed for a further 5 min until a homogeneous consistency was achieved.

The batter was then cooked on a stovetop using a mud cake mould until the product was fully cooked. The cooking procedure followed the conditions established for this study, with a reported cooking time of 15 min and a target temperature of 100°C with pan dimensions into a 12-hole mud cake mould with a diameter of 30 cm. After cooking, the mud cakes were removed from the moulds and used for subsequent chemical, physical, and sensory analyses.

Experimental Design

The experiment employed a Completely Randomized Design (CRD) consisting of five formulations with different substitution levels of red dragon fruit (*Hylocereus costaricensis*) peel flour: F0 (100:0), F1 (95:5), F2 (90:10), F3 (85:15), and F4 (80:20), expressed as wheat flour-to-red dragon fruit peel flour ratios. For each formulation, one batch of batter was prepared and divided into three portions for replication. Thus, the three replications were obtained from the same batch of batter rather than from independently prepared production batches. Analytical measurements were conducted on samples from each replication according to the procedures specified for each parameter.

Chemical Analysis

Moisture, ash, protein, fat, and crude fiber contents were determined using standard AOAC (2005) analytical procedures. Carbohydrate content was calculated by difference. Antioxidant activity was determined using the DPPH radical scavenging assay and expressed as percentage inhibition. The optimum formulation obtained from the effectiveness index analysis was further analyzed for mineral composition, including potassium, magnesium, manganese, calcium, phosphorus, iron, zinc, copper, cobalt, and selenium using Inductively Coupled Plasma–Mass Spectrometry (ICP-MS). Total dietary fiber content was also determined using the AOAC enzymatic–gravimetric method.

Physical Analysis

Color characteristics were measured using a chromameter and expressed as CIE L* (lightness), a* (redness), and b* (yellowness). Texture Profile Analysis (TPA) was carried out using a texture analyzer to determine hardness, adhesiveness, resilience, cohesiveness, springiness, gumminess, and chewiness.

Sensory Evaluation

Sensory acceptance was evaluated using a 25-member untrained adult consumers, comprising male and female participants aged 20–45 years. Participants were required to be non-smokers, in good general health and free from symptoms of respiratory illness, such as influenza or the common cold, at the time of evaluation. They were also required to have normal colour vision and to be in a comfortable psychological state, without undue stress or emotional distress, and in a positive mood during the evaluation. Before participating in the sensory evaluation, all participants were informed about the purpose and procedures of the study, and written informed consent was obtained from each participant. Participation was voluntary, and participants were informed of their right to withdraw from the evaluation at any time without penalty. Five mud cake formulations were evaluated using three-digit sample codes to minimise bias associated with product identification. The sample codes were assigned as follows: F0 (100% wheat flour:0% red dragon fruit peel flour) was coded 376; F1 (95%:5%) was coded 932; F2 (90%:10%) was coded 418; F3 (85%:15%) was coded 794; and F4 (80%:20%) was coded 130. Samples were evaluated for colour, aroma, taste, texture, and overall acceptance using a seven-point hedonic scale ranging from 1 (dislike extremely) to 7 (like extremely). Drinking water was provided between sample evaluations to minimise carry-over effects.

Statistical Analysis

All experimental data were analyzed using IBM SPSS Statistics version 25. One-way analysis of variance (ANOVA) was performed to determine significant differences among treatments. When significant differences ($p < 0.05$) were detected, means were separated using Duncan's Multiple Range Test (DMRT). The optimum treatment was selected using the De Garmo effectiveness index, considering chemical, physical, and sensory characteristics simultaneously.

RESULTS

Chemical Characteristics

The chemical properties of mud cake were assessed through proximate analysis (moisture, ash, protein, fat, and carbohydrate), crude fiber, and antioxidant activity. Standard AOAC (2005) methods were used for proximate analyses.

Table 1. Chemical characteristics of mud cake substituted with red dragon fruit peel flour

	F0	F1	F2	F3	F4
Moisture Content (%)	42,89 ± 1,11 ^a	43,79 ± 8,27 ^a	45,74 ± 4,10 ^a	47,68 ± 1,74 ^a	50,41 ± 3,68 ^a
Ash Content (%)	0,65 ± 0,05 ^a	0,77 ± 0,21 ^a	1,09 ± 0,28 ^{ab}	1,23 ± 0,33 ^b	1,41 ± 0,24 ^b
Protein Content (%)	3,97 ± 0,07 ^a	4,28 ± 0,14 ^a	4,11 ± 0,01 ^a	4,08 ± 0,37 ^a	4,26 ± 0,05 ^a
Fat Content (%)	5,09 ± 0,06 ^a	5,39 ± 0,22 ^{ab}	5,62 ± 0,59 ^{ab}	6,05 ± 0,59 ^{bc}	6,40 ± 0,20 ^c
Carbohydrate Content (%)	44,65 ± 1,01 ^b	42,17 ± 8,37 ^b	38,93 ± 3,73 ^{ab}	36,25 ± 1,18 ^{ab}	32,64 ± 3,81 ^a
Crude fiber content (%)	2,76 ± 0,09 ^a	3,60 ± 0,07 ^b	4,51 ± 0,08 ^c	4,71 ± 0,01 ^d	4,88 ± 0,04 ^e
Antioxidant Activity	18,78 ± 0,39 ^a	22,54 ± 0,94 ^b	25,65 ± 1,05 ^{bc}	25,35 ± 2,94 ^c	28,67 ± 1,46 ^d

Note: The same notation within the same parameter row indicates no significant difference according to the Duncan test ($p > 0.05$).

As shown in Table 1, the substitution of wheat flour with red dragon fruit peel flour significantly affected the ash ($p = 0.017$), fat ($p = 0.016$), carbohydrate ($p < 0.05$), crude fiber ($p < 0.001$), and antioxidant activity ($p = 0.001$) of mud cake. In contrast, no significant effects were observed on moisture ($p = 0.321$), and protein ($p = 0.252$).

Physical Characteristics

Color characteristics

Color is one of the most important quality attributes influencing consumer acceptance of bakery products because it is the first characteristic perceived before aroma, texture, or taste.

Table 2. Color test of mud cake substituted with red dragon fruit peel flour

Treatment (Wheat Flour : Red Dragon Fruit Peel Flour)	L*	a*	b*
F0 (100% : 0%)	49,69 ± 2,47 ^c	4,15 ± 0,09 ^a	24,78 ± 0,81 ^d
F1 (95% : 5%)	34,16 ± 2,28 ^a	24,05 ± 0,91 ^b	7,40 ± 0,43 ^c
F2 (90% : 10%)	42,57 ± 0,65 ^b	26,01 ± 0,35 ^{bc}	3,66 ± 0,16 ^a
F3 (85% : 15%)	40,65 ± 0,49 ^b	30,21 ± 0,35 ^d	3,29 ± 0,43 ^a
F4 (80% : 20%)	34,33 ± 3,85 ^a	26,75 ± 2,56 ^c	5,63 ± 0,71 ^b

Note: The same notation in the same column indicates no significant difference according to the Duncan test ($p > 0.05$).

In Table 2, The substitution of wheat flour with red dragon fruit peel flour significantly affected the lightness (L*), redness (a*), and yellowness (b*) of mud cake ($p < 0.05$).

Texture characteristics

Texture is a crucial factor that can influence the flavor profile of an ingredient, whether in fresh or processed foods.

Table 3. Textural characteristics of mud cake substituted with red dragon fruit peel flour

Parameter	Treatment (Wheat Flour : Red Dragon Fruit Peel Flour)				
	F0 (100% :	F1 (95% : 5%)	F2 (90% :	F3 (85% : 15%)	F4 (80% : 20%)

	0%)		10%)		
Hardness	178,56 ± 7,75 ^d	143,91 ± 15,09 ^c	138,31 ± 17,60 ^{bc}	116,92 ± 7,83 ^{ab}	106,65 ± 14,09 ^a
Adhesiveness	-215,19 ± 66,16 ^a	-182,48 ± 46,46 ^{ab}	-150,93 ± 10,19 ^c	-132,43 ± 52,29 ^{cd}	-107,69 ± 15,48 ^d
Resilience	4,98 ± 0,08 ^b	3,43 ± 0,35 ^a	3,14 ± 0,45 ^a	3,17 ± 0,69 ^a	3,35 ± 0,18 ^a
Cohesion	0,65 ± 0,03 ^b	0,65 ± 0,20 ^b	0,60 ± 0,31 ^{ab}	0,57 ± 0,03 ^a	0,60 ± 0,04 ^{ab}
Springiness	96,87 ± 2,84 ^a	109,52 ± 20,70 ^a	157,86 ± 39,81 ^a	99,37 ± 0,53 ^a	134,56 ± 60,29 ^a
Gumminess	115,68 ± 3,20 ^d	93,89 ± 7,70 ^c	83,25 ± 11,54 ^{bc}	66,77 ± 8,40 ^{ab}	64,08 ± 11,90 ^a
Chewiness	112,19 ± 6,22 ^{ab}	102,97 ± 22,15 ^b	130,09 ± 28,49 ^b	66,34 ± 8,27 ^a	90,53 ± 57,01 ^{ab}

Note: The same notation within the same parameter row indicates no significant difference according to the Duncan test ($p > 0.05$).

As shown in Table 3, the substitution of wheat flour with red dragon fruit peel flour significantly affected the hardness ($p < 0.001$), resilience ($p = 0.001$), cohesion ($p = 0.031$), and gumminess ($p < 0.001$) of mud cake. In contrast, the substitution had no significant effect on adhesiveness ($p = 0.087$) or chewiness ($p = 0.198$). These results indicate that incorporating red dragon fruit peel flour primarily altered the structural and mechanical properties of the mud cake, while its adhesive characteristics and chewiness remained relatively unchanged.

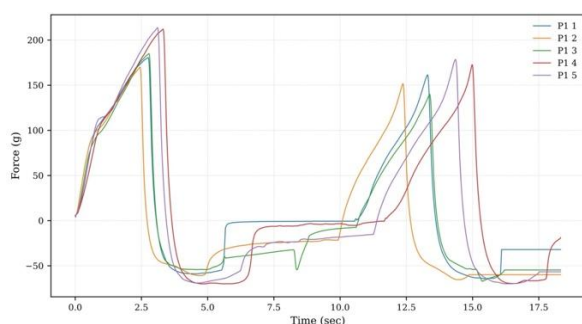


Figure 1. Texture profile analysis graph of treatment 0

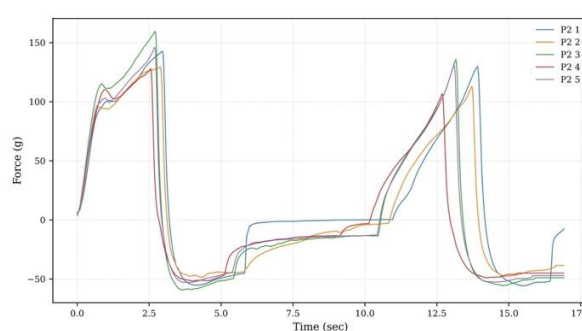


Figure 2. Texture profile analysis graph of treatment 1

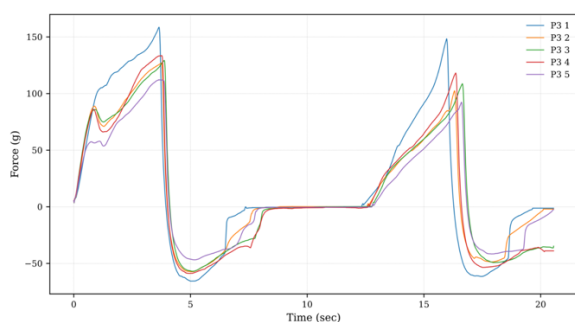


Figure 3. Texture profile analysis graph of treatment 2

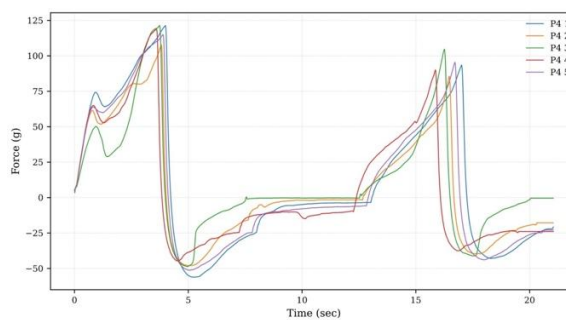


Figure 4. Texture profile analysis graph of treatment 3

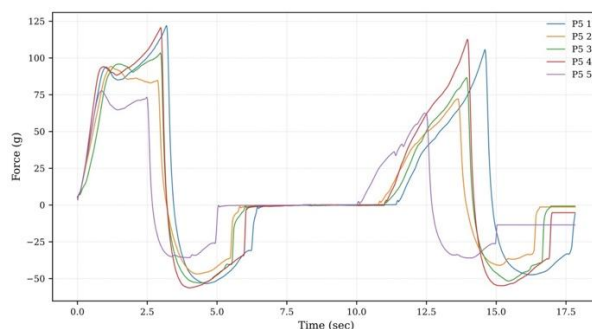


Figure 5. Texture profile analysis graph of treatment 4

Sensory Characteristics

Organoleptic testing regarding the level of preference for color, taste, aroma, texture, and overall quality of the mud cake product was conducted using a hedonic test ⁶.

Table 4. Sensory characteristics of mud cake substituted with red dragon fruit peel flour

Product Code	Color	Odor	Texture	Taste	Overall
F0	4,72 ± 1,02 ^a	5,40 ± 0,71 ^a	5,44 ± 0,96 ^b	5,28 ± 0,89 ^a	5,16 ± 0,80 ^a
F1	5,24 ± 0,97 ^b	5,32 ± 0,95 ^a	5,48 ± 0,92 ^b	5,56 ± 0,58 ^{ab}	5,48 ± 0,59 ^a
F2	6,12 ± 0,93 ^c	6,08 ± 0,81 ^b	5,56 ± 0,87 ^b	6,08 ± 0,95 ^b	6,20 ± 0,76 ^b
F3	5,88 ± 0,88 ^c	5,28 ± 0,94 ^a	4,48 ± 0,82 ^a	5,24 ± 0,83 ^a	5,40 ± 0,65 ^a
F4	6,16 ± 0,85 ^c	5,08 ± 1,08 ^a	4,04 ± 1,49 ^a	5,48 ± 1,33 ^a	5,36 ± 1,04 ^a

Note: The same notation in the same column indicates no significant difference. Hedonic scale 1–7 (dislike extremely – like extremely).

Best Formulation Selection Using the De Garmo Effectiveness Index

The determination of the best treatment in this study was conducted using the De Garmo effectiveness index method.

Table 5. Values for Determining the Best Treatment for mud cake

Treatment (Wheat Flour : Red Dragon Fruit Peel Flour)	Amount of Nh
F0 (100% : 0%)	0,35
F1 (95% : 5%)	0,44
F2 (90% : 10%)	0,68
F3 (85% : 15%)	0,39
F4 (80% : 20%)	0,52

In this method, each parameter is assigned a weight based on its level of importance and then normalized to obtain a normalized weight. The value of each treatment is subsequently normalized into an effectiveness value (Ne) and multiplied by the normalized weight (Nh). The sum of these products constitutes the effectiveness index value for each treatment. The best results were obtained with treatment F2.

Mineral Content of Selected Product Treatments

The results of the independent sample t-test indicate the effect of substituting red dragon fruit peel flour on the mineral content of the selected mud cake product.

Table 6. Mineral content of mud cake substituted with red dragon fruit peel flour

Treatment	Mineral Content	Value
F0	Mg (mg/100g)	26,106 ± 1,131
F2		36,914 ± 0,724
F0	Mn (mg/100g)	0,325 ± 0,013
F2		1,186 ± 0,037
F0	Zn (mg/100g)	1,497 ± 0,205
F2		1,260 ± 0,086
F0	K (mg/100g)	283,276 ± 5,668
F2		438,674 ± 18,483
F0	Fe (mg/100g)	2,558 ± 0,180
F2		2,656 ± 0,078
F0	Se (µg/kg)	ND (Not Detected)
F2		3,602 ± 2,561
F0	Ca (mg/100g)	2,574 ± 0,777
F2		3,547 ± 0,401
F0	Cu (mg/100g)	0,178 ± 0,015
F2		0,176 ± 0,019
F0	Co (µg/kg)	10,524 ± 0,944
F2		21,784 ± 2,707
F0	P (mg/100g)	91,273 ± 2,981
F2		82,817 ± 1,883

Dietary Fiber of Selected Product Treatments

The results of the independent sample t-test indicate the effect of substituting red dragon fruit peel flour on the dietary fiber content of the selected mud cake product.

Table 7. Dietary fiber of mud cake substituted with red dragon fruit peel flour

Treatment	Fiber Content	Value (%)
F0	Insoluble Dietary Fiber	3,22 ± 0,07
F2		4,88 ± 0,05
F0	Soluble Dietary Fiber	0,25 ± 0,02
F2		0,44 ± 0,01
F0	Total Dietary Fiber	3,47 ± 0,05
F2		5,32 ± 0,07

DISCUSSION

Moisture Content

The moisture content of mud cake showed a numerical increase from 42.89 ± 1.11% in the control to 50.41 ± 3.68% in the formulation containing 20% red dragon fruit peel flour. However, the

differences among treatments were not statistically significant ($p = 0.321$), indicating that the observed trend does not provide sufficient evidence of a treatment effect. Dietary fiber may contribute to water retention because of its water-binding properties, although this effect depends on the characteristics of the fiber and the food matrix.⁹ Studies on fruit peel flours have also demonstrated that their hydration properties can vary according to their composition and physical characteristics. Nevertheless, water-holding capacity was not directly measured in the present study; therefore, the proposed mechanism should be interpreted as a possible explanation rather than a confirmed cause of the observed moisture trend.

Ash Content

Ash content reflects the total mineral content of a food product and is commonly used as an indicator of its inorganic composition. The ash content increased from $0.65 \pm 0.05\%$ in the control (F0) to $1.41 \pm 0.24\%$ in F4 (80% wheat flour : 20% red dragon fruit peel flour). The increase in ash content was attributed to the naturally high mineral content of red dragon fruit peel flour, which contributed more inorganic components to the formulation as the substitution level increased. Similar findings were reported by ¹⁰, who observed increased ash content in crackers fortified with red dragon fruit peel flour, and by ¹¹, who reported that red dragon fruit peel flour contains a relatively high ash content, reflecting its rich mineral composition.

Protein Content

Protein content is an important nutritional parameter that contributes to the nutritional quality of bakery products. Protein content ranged from $3.97 \pm 0.07\%$ in the control (F0) to $4.28 \pm 0.14\%$ in F1, while the remaining treatments showed comparable values between 4.08% and 4.26%. These results suggest that substituting wheat flour with up to 20% red dragon fruit peel flour did not substantially alter the protein content of the product. The absence of significant differences is attributed to the relatively low protein content of red dragon fruit peel flour, which is mainly composed of dietary fiber and bioactive compounds rather than protein. Consequently, partial substitution of wheat flour had little effect on the overall protein composition of mud cake. Similar findings were reported by ¹² and ¹³, who observed that the incorporation of red dragon fruit peel flour did not significantly increase the protein content of bakery products.

Fat Content

Fat content is an important component of bakery products because it contributes to flavour, texture, mouthfeel, and overall product quality.¹⁴ In the present study, fat content increased from $5.09 \pm 0.06\%$ in the control (F0) to $6.40 \pm 0.20\%$ in F4 (80% wheat flour:20% red dragon fruit peel flour). Although this increase may reflect differences in the composition of the formulations, the specific mechanism responsible for the observed change cannot be established from the present

data. Dietary fiber, including pectin, can influence water binding and structural interactions within food matrices; however, these properties do not necessarily result in increased fat retention in the final product.¹⁵ Therefore, the increase in measured fat content should not be attributed solely to interactions between dietary fiber and lipids.

The increase in fat content should also be interpreted in relation to the carbohydrate content, which was determined by difference. This method calculates carbohydrate content by subtracting moisture, ash, protein, and fat from 100%. Consequently, an increase in measured fat content contributes mathematically to a decrease in calculated carbohydrate content when the other components remain constant.¹⁶ Although moisture content increased numerically from $42.89 \pm 1.11\%$ in F0 to $50.41 \pm 3.68\%$ in F4, the difference was not statistically significant ($p = 0.321$). Thus, the moisture trend should not be interpreted as a significant treatment effect or as an established explanation for the changes in fat and carbohydrate contents. These results should be interpreted in the context of the overall proximate composition and the limitations of the carbohydrate-by-difference method.

Carbohydrate Content

Carbohydrate content is a major nutritional component in bakery products and was determined by the difference method. Carbohydrate content decreased from $44.65 \pm 1.20\%$ in the control (F0) to $32.64 \pm 3.07\%$ in F4 (80% wheat flour : 20% red dragon fruit peel flour), indicating that increasing the proportion of red dragon fruit peel flour significantly reduced the carbohydrate content of the product. The reduction in carbohydrate content was mainly attributed to the replacement of wheat flour, which is rich in starch, with red dragon fruit peel flour containing higher levels of dietary fiber and minerals. Because carbohydrate was calculated by difference, the increases in moisture, ash, fat, and crude fiber contributed to the decrease in the calculated carbohydrate content. Similar findings were reported by ⁵ and ¹², who found that the incorporation of red dragon fruit peel flour reduced the carbohydrate content of bakery products due to the replacement of starch-rich flour with fiber-rich ingredients.

Crude Fiber Content

Crude fiber content is an important nutritional parameter associated with the functional properties of food products. Crude fiber increased progressively from $2.76 \pm 0.09\%$ in the control (F0) to $4.88 \pm 0.04\%$ in F4 (80% wheat flour : 20% red dragon fruit peel flour). The increase in crude fiber content was attributed to the high insoluble fiber content of red dragon fruit peel flour, particularly cellulose and lignin, which directly enriched the fiber composition of mud cake. Similar findings were reported by ¹⁷, who observed increased crude fiber content in biscuits fortified with dragon fruit peel,

and ⁵, who reported that dragon fruit peel flour contains approximately 25.48% crude fiber, contributing to a significant increase in the fiber content of bread.

Antioxidant Activity

Antioxidant activity, determined using the DPPH radical-scavenging assay, increased from $18.78 \pm 0.39\%$ inhibition in the control (F0) to $28.67 \pm 1.46\%$ inhibition in F4 (80% wheat flour:20% red dragon fruit peel flour). This numerical increase suggests that the incorporation of red dragon fruit peel flour may enhance the in vitro radical-scavenging capacity of mud cake extracts. Dragon fruit peel contains bioactive compounds, including phenolic compounds, flavonoids, and betalains, which may contribute to antioxidant activity.¹⁸

In this study, the samples were extracted using 96% ethanol, and DPPH absorbance was measured at 517 nm. Ethanol can extract certain phenolic compounds and other antioxidant constituents, although the extraction efficiency depends on solvent polarity, extraction conditions, and the characteristics of the compounds present. Because 96% ethanol contains relatively little water, the resulting extract may differ in composition from extracts obtained using aqueous ethanol or other solvents. Therefore, the measured DPPH inhibition represents the radical-scavenging activity of compounds recovered under the specific extraction conditions rather than the total antioxidant potential of the mud cake.

The measured activity may also be influenced by thermal processing. Betalains and some phenolic compounds can undergo degradation or chemical transformation during heating, potentially affecting their subsequent extraction and radical-scavenging activity. However, the stability of these compounds was not directly evaluated in this study, so thermal degradation cannot be established as the cause of any observed changes. Furthermore, because red dragon fruit peel contains naturally coloured pigments, appropriate sample blank correction is important to minimize potential interference with absorbance measurements at 517 nm.

The DPPH assay is an in vitro chemical method that measures the ability of extract constituents to reduce a stable synthetic radical under specified analytical conditions.¹⁹ It does not account for digestion, absorption, metabolism, or physiological antioxidant mechanisms in humans. Accordingly, the observed increase in DPPH inhibition indicates a change in the in vitro radical-scavenging activity of the extracts but does not establish antioxidant efficacy or health benefits in humans.

Physical characteristics

Color characteristics

Color parameters—specifically lightness (L^*), redness (a^*), and yellowness (b^*)—are crucial for determining the color quality of food products, as they relate to sensory acceptance and the precision of processing operations.²⁰

Lightness (L^)*

Lightness (L^*) indicates the brightness of the product, with higher values representing a lighter color and lower values indicating a darker appearance. The L^* value decreased from F0 ($49,69 \pm 2,47$) to F4 ($34,33 \pm 3,85$), indicating that increasing the proportion of red dragon fruit peel flour produced a darker product. The reduction in L^* value was attributed to the increasing concentration of betalain pigments, particularly betacyanins, naturally present in red dragon fruit peel, which imparted a red-purple color and reduced product brightness. In addition, thermal processing may have contributed to pigment degradation and Maillard browning, further decreasing lightness. Similar findings were reported by ⁶ and ⁵, who observed that increasing the proportion of red dragon fruit peel flour significantly decreased the L^* value of bakery products.

Redness (a^)*

Redness (a^*) represents the intensity of red color in the product, with higher positive values indicating greater redness. The a^* value increased markedly from 4.15 ± 0.09 in the control (F0) to 30.21 ± 0.35 in F3 (85% wheat flour : 15% red dragon fruit peel flour), while F4 showed a slightly lower value (26.75 ± 2.56) but remained significantly higher than the control. The increase in redness was attributed to the high content of betalain pigments, particularly betacyanins, in red dragon fruit peel, which impart a characteristic red-purple color to the cake matrix. The slight decrease in a^* value at the highest substitution level (F4) may be associated with partial thermal degradation of betalains during baking. Similar findings were reported ⁶, who observed that the incorporation of red dragon fruit peel significantly increased the redness of bakery products due to the presence of betacyanin pigments.

Yellowness (b^)*

Yellowness (b^*) indicates the intensity of yellow color in the product, with higher positive values representing greater yellowness. The b^* value decreased markedly from 24.78 ± 0.81 in the control (F0) to 3.29 ± 0.43 in F3 (85% wheat flour : 15% red dragon fruit peel flour), while F4 showed a slightly higher value (5.63 ± 0.71). The reduction in b^* value was attributed to the dominance of betalain pigments, particularly betacyanins, which masked the natural yellow color of wheat flour and egg yolk, causing the product color to shift from yellow toward red-purple. Similar results were reported by (Biswas et al., 2025), who found that the incorporation of red dragon fruit peel significantly decreased

the b^* value of bakery products. A comparable trend was also observed by ²¹, who reported that increasing beetroot flour substitution reduced the yellowness of cupcakes because the red betalain pigments became more dominant.

Texture characteristics

Texture is a crucial factor that can influence the flavor profile of an ingredient, whether in fresh or processed foods. The flavor of a food product can be affected by its texture and consistency. A texture analyzer is the instrument typically used to analyze texture profiles.

Hardness

Hardness represents the maximum force required to compress a food product during the first compression cycle and reflects its firmness. Hardness decreased from 178.56 ± 7.75 N in the control (F0) to 106.65 ± 14.09 N in F4 (80% wheat flour : 20% red dragon fruit peel flour). These results indicate that increasing the substitution level of red dragon fruit peel flour produced a softer cake. The reduction in hardness was attributed to the high dietary fiber and pectin content of red dragon fruit peel flour, which increased water retention and weakened the gluten network, resulting in a softer crumb structure. Similar findings were reported by ²², who observed reduced hardness in sponge cake with olive seed flour substitution, and ⁵, who reported that increasing red dragon fruit peel flour significantly softened bread because of gluten dilution and higher fiber content.

Adhesiveness

Adhesiveness represents the work required to overcome the attractive forces between the food surface and the probe during the first compression cycle. Adhesiveness values increased from -215.19 ± 66.11 in the control (F0) to -107.69 ± 15.48 in F4 (80% wheat flour : 20% red dragon fruit peel flour), indicating that the product became less adhesive as the substitution level increased. The decreasing adhesiveness was attributed to the high dietary fiber content of red dragon fruit peel flour, which reduced the stickiness of the crumb by binding water within the food matrix and limiting the amount of free surface moisture. Similar findings were reported by ⁵, who observed that increasing red dragon fruit peel flour modified the textural properties of bakery products, including adhesiveness, through changes in moisture distribution and crumb structure.

Resilience

Resilience reflects the ability of a food product to recover its original shape immediately after the first compression. The highest resilience value was observed in the control (F0) at 4.98 ± 0.08 , whereas the lowest value was obtained in F2 (90% wheat flour : 10% red dragon fruit peel flour) at 3.14 ± 0.45 . These results indicate that the incorporation of red dragon fruit peel flour reduced the resilience of mud cake. The reduction in resilience was attributed to the high dietary fiber and pectin contents of red dragon fruit peel flour, which interfered with the formation of the starch–gluten matrix

and produced a softer, less elastic crumb. Similar findings were reported by ²³ and ²⁴, who found that the incorporation of fiber-rich ingredients reduced the elasticity and recovery capacity of bakery products after compression.

Cohesion

Cohesion reflects the internal bonding strength of a food product and its ability to withstand repeated deformation without breaking. Cohesion values ranged from 0.57 ± 0.03 to 0.65 ± 0.03 , with the highest values observed in F0 (100% wheat flour : 0% red dragon fruit peel flour) and F1 (95% wheat flour : 5% red dragon fruit peel flour) (both 0.65), while the lowest value was obtained in F3 (85% wheat flour : 15% red dragon fruit peel flour) (0.57 ± 0.03). The reduction in cohesion was attributed to the replacement of gluten-containing wheat flour with fiber-rich red dragon fruit peel flour. The high dietary fiber and pectin contents competed for water during batter formation, weakening the gluten–starch matrix and reducing the internal bonding strength of the product. Similar findings were reported by ⁵, who observed reduced cohesion in bread fortified with red dragon fruit peel flour, and ²⁵, who explained that cohesion is closely related to the integrity of the internal food structure

Springiness

Springiness reflects the ability of a food product to recover its original shape after compression. Springiness values ranged from 96.87 ± 2.84 in the control (F0) to 157.86 ± 39.81 in F2 (90% wheat flour : 10% red dragon fruit peel flour). The comparable springiness values among treatments suggest that the remaining gluten network, together with the water-binding capacity of dietary fiber, was sufficient to maintain the elasticity of the cake despite partial wheat flour substitution. Similar findings were reported by ²⁶ and ²⁷, who found that moderate incorporation of fiber-rich ingredients maintained the springiness of bakery products by preserving the structural integrity of the starch–protein matrix.

Gumminess

Gumminess represents the energy required to disintegrate a semi-solid food until it is ready for swallowing and is calculated as the product of hardness and cohesiveness. Gumminess decreased from 115.68 ± 3.20 in the control (F0) to 64.08 ± 11.90 in F4 (80% wheat flour : 20% red dragon fruit peel flour). The reduction in gumminess was attributed to the weakening of the gluten network caused by the replacement of wheat flour with fiber-rich red dragon fruit peel flour. The higher dietary fiber content disrupted the starch–gluten matrix, resulting in lower hardness and cohesiveness, which consequently reduced gumminess. Similar findings were reported by ⁵, who observed that dragon fruit peel flour significantly reduced the gumminess of bread, and ²⁸, who explained that gumminess is directly influenced by hardness and cohesiveness.

Chewiness

Chewiness represents the energy required to chew a food product until it is ready for swallowing and is determined by the combined effects of hardness, cohesiveness, and springiness. Chewiness values ranged from 66.34 ± 8.27 in F3 (85% wheat flour : 15% red dragon fruit peel flour) to 130.09 ± 28.49 in F2 (90% wheat flour : 10% red dragon fruit peel flour). The similar chewiness values among treatments suggest that the interaction between hardness, cohesiveness, and springiness remained relatively stable despite the incorporation of red dragon fruit peel flour. At moderate substitution levels, the remaining gluten network was sufficient to maintain the structural integrity of the cake, whereas higher fiber levels tended to reduce chewiness by weakening the internal matrix. Similar findings were reported by ⁵, who observed changes in bread chewiness following dragon fruit peel flour substitution, and ²⁷, who reported that chewiness is strongly influenced by the combined effects of hardness, cohesiveness, and springiness.

Sensory Characteristics

Panelists generally preferred products containing 10% red dragon fruit peel flour (F2), which achieved the highest scores for aroma (6.08 ± 0.81), texture (5.56 ± 0.87), taste (6.08 ± 0.95), and overall acceptance (6.20 ± 0.76). In contrast, the highest color acceptance was observed in F4 (80% wheat flour : 20% red dragon fruit peel flour) with a score of 6.16 ± 0.85 . These findings indicate that moderate substitution improved overall sensory quality while maintaining desirable product characteristics. The improved sensory acceptance at the 10% substitution level was attributed to the balanced contribution of red dragon fruit peel flour, which enhanced product appearance without adversely affecting aroma, texture, or taste. However, higher substitution levels tended to reduce the acceptability of some attributes because the increased dietary fiber modified the texture and flavor profile of the product. Similar findings were reported by ⁵ and ⁶, who found that moderate incorporation of red dragon fruit peel flour improved the sensory quality of bakery products, whereas excessive substitution reduced consumer preference.

Best Formulation Selection Using the De Garmo Effectiveness Index

The optimum formulation was determined using the De Garmo effectiveness index, a multi-criteria decision-making approach that integrates all quality attributes according to their relative importance. As presented in Table 6, the effectiveness index values were 0.35 (F0), 0.44 (F1), 0.68 (F2), 0.39 (F3), and 0.52 (F4). Among all formulations, F2 (90% wheat flour and 10% red dragon fruit peel flour) achieved the highest effectiveness index (0.68), indicating the best overall product quality. This formulation exhibited the most balanced performance across chemical composition, antioxidant activity, color, texture profile, and sensory acceptance, although it did not always produce the highest value for every individual parameter.

The superior performance of F2 demonstrates that moderate substitution of wheat flour with red dragon fruit peel flour improved the nutritional characteristics without substantially compromising technological and sensory quality. At substitution levels above 10%, the increasing fiber concentration likely interfered with gluten network formation and starch gelatinization, resulting in less desirable texture and sensory properties. Conversely, lower substitution levels (5%) provided insufficient bioactive compounds and dietary fiber to maximize the functional value of the product. Therefore, a 10% substitution represented an optimal balance between nutritional enhancement and consumer acceptability.

The application of the De Garmo method is particularly suitable for functional food development because product quality depends on multiple attributes rather than a single analytical parameter. Consequently, selecting the optimum formulation based on an integrated effectiveness index provides a more comprehensive evaluation than relying solely on proximate composition or sensory acceptance. The selected formulation (F2) was subsequently subjected to mineral and dietary fiber analyses to further evaluate its nutritional advantages over the control formulation.

Mineral Composition of the Selected Formulation

Mineral analysis was performed to determine whether substituting wheat flour with red dragon fruit peel flour improved the micronutrient composition of mud cake. The selected formulation (F2) was compared with the control (F0), and the results demonstrated that the incorporation of 10% red dragon fruit peel flour increased the concentrations of several nutritionally important minerals, particularly magnesium, manganese, potassium, calcium, cobalt, and selenium, while zinc, iron, copper, and phosphorus showed relatively small changes.

Mineral concentrations in F0 and F2 were compared. The results are reported as concentrations per 100 g or per kg depending on the element; units and uncertainty must be standardised. Because serving size and mineral bioavailability were not assessed, the results indicate composition only and do not establish the amount absorbed by consumers or health outcomes.

Magnesium

Magnesium content increased significantly from 26.11 to 36.91 mg/100 g following the substitution of 10% red dragon fruit peel flour. This increase can be attributed to the naturally high mineral concentration found in fruit peels, which frequently contain greater levels of macro-minerals than edible pulp because minerals accumulate within structural tissues. Magnesium is an essential macromineral involved in more than 300 enzymatic reactions, including ATP metabolism, protein synthesis, neuromuscular function, and bone development. Therefore, increasing magnesium concentration enhances the nutritional quality of mud cake and may contribute to improved dietary magnesium intake. The present findings agree with previous studies reporting increased magnesium

contents after incorporating fruit peel flours into bakery products, indicating that fruit processing by-products represent valuable mineral sources for functional food applications.

Manganese

Manganese concentration increased from 0.325 to 1.186 mg/100 g, representing one of the largest proportional increases among all minerals analyzed. Manganese functions as an essential cofactor for numerous enzymes associated with carbohydrate metabolism, antioxidant defense through manganese superoxide dismutase (Mn-SOD), and bone formation. The substantial increase observed in F2 indicates that red dragon fruit peel flour effectively enriched the product with this trace element. Because fruit peels naturally contain higher concentrations of trace minerals than refined cereal flour, partial substitution of wheat flour provides an effective strategy for increasing manganese intake while simultaneously supporting sustainable utilization of agricultural by-products.

Potassium

Potassium content increased markedly from 283.28 to 438.67 mg/100 g following substitution with red dragon fruit peel flour. Potassium is the predominant intracellular cation responsible for maintaining electrolyte balance, nerve impulse transmission, muscle contraction, and blood pressure regulation. The considerable increase observed in this study indicates that red dragon fruit peel flour is an excellent natural source of potassium and substantially improves the mineral profile of mud cake. The high potassium concentration is particularly advantageous because increasing dietary potassium intake has been associated with cardiovascular health and reduced hypertension risk. Therefore, the selected formulation may provide additional nutritional benefits beyond its improved antioxidant and dietary fiber contents.

Zinc, Iron, Copper, and Calcium

Although calcium showed an increasing trend, while zinc and copper exhibited slight decreases and iron increased only marginally, these differences were either statistically insignificant or biologically small. The limited response likely reflects the relatively similar mineral contributions from wheat flour and other ingredients such as eggs, milk, and margarine. Furthermore, mineral retention during baking is influenced by ingredient interactions and processing conditions, which may reduce measurable differences between formulations.

Selenium, Cobalt, and Phosphorus

Selenium and cobalt concentrations increased after substitution, whereas phosphorus decreased slightly. Selenium was detected only in the substituted formulation, suggesting that red dragon fruit peel flour contributed additional selenium to the product. Although selenium concentration remained relatively low, this result demonstrates the potential of fruit peel flour to enrich bakery products with trace minerals. Cobalt also increased significantly, whereas phosphorus decreased

moderately, possibly because of differences in the mineral composition of wheat flour and dragon fruit peel as well as processing-related mineral redistribution.

Overall, the mineral profile indicates that incorporating 10% red dragon fruit peel flour substantially enhanced several nutritionally important minerals, particularly magnesium, manganese, and potassium, while maintaining acceptable concentrations of the remaining essential minerals. These findings support the use of red dragon fruit peel flour as a sustainable functional ingredient capable of improving the micronutrient quality of traditional bakery products.

Dietary Fiber Content of the Selected Formulation

Dietary fiber analysis was conducted to evaluate the nutritional contribution of red dragon fruit peel flour in the selected formulation (F2) compared with the control (F0). The results demonstrated that substitution with 10% red dragon fruit peel flour significantly increased insoluble dietary fiber (IDF), soluble dietary fiber (SDF), and total dietary fiber (TDF). The IDF content increased from 3.22% in the control to 4.88% in F2, while SDF increased from 0.25% to 0.44%. Consequently, total dietary fiber increased from 3.81% to 5.32%, confirming that red dragon fruit peel flour is an effective source of dietary fiber for traditional bakery products.

The marked increase in insoluble dietary fiber is primarily attributed to the structural composition of red dragon fruit peel, which contains abundant cellulose, hemicellulose, and lignin. These polysaccharides constitute the major fraction of plant cell walls and remain relatively stable during thermal processing. Consequently, incorporating peel flour substantially increased the insoluble fiber fraction of kue lumpur. Previous studies have similarly reported that fruit peels generally contain a higher proportion of insoluble fiber than edible pulp, making them valuable ingredients for enriching bakery products with dietary fiber. Although soluble dietary fiber also increased, the magnitude of improvement was considerably smaller than that observed for insoluble fiber. This result may be explained by the relatively low proportion of soluble polysaccharides naturally present in dragon fruit peel compared with insoluble structural carbohydrates. In addition, thermal processing during batter preparation and baking may partially degrade soluble polysaccharides or alter their extractability, thereby limiting the measurable increase in soluble dietary fiber.

The increase in total dietary fiber demonstrates the nutritional advantages of incorporating red dragon fruit peel flour into kue lumpur. Total dietary fiber is widely recognized as an important dietary component associated with gastrointestinal health, improved glycemic regulation, reduced serum cholesterol, and lower risks of obesity and cardiovascular disease. Therefore, increasing dietary fiber without substantially reducing consumer acceptability represents an important strategy for developing healthier traditional foods. The present findings are consistent with previous studies demonstrating that fruit peel flours effectively increase dietary fiber content in bread, cookies, muffins, biscuits, and

other bakery products. These studies indicate that agricultural by-products can be successfully utilized as functional food ingredients while simultaneously supporting waste valorization and sustainable food production.

CONCLUSION

Replacing wheat flour with red dragon fruit peel flour affected ash, fat, carbohydrate, crude fibre, DPPH inhibition, instrumental colour, and selected texture and sensory attributes. Moisture and protein did not differ significantly. F2 (90% wheat flour:10% peel flour) had the highest reported De Garmo index (0.68) and overall sensory score (6.20 ± 0.76). Compared with F0, F2 had higher reported magnesium (26.11 to 36.91 mg/100 g), manganese (0.325 to 1.186 mg/100 g), potassium (283.28 to 438.67 mg/100 g), and total dietary fibre (3.81% to 5.32%), subject to verification of the underlying analytical records. The results identify F2 as the preferred formulation among those tested but should be interpreted cautiously because the three measurements were obtained from the same batter batch rather than independent production batches. Future work should use independently prepared batches, report complete analytical and sensory procedures, and verify the mineral and fibre data before making broader nutritional claims.

BIBLIOGRAPHY

1. Roriz CL, Heleno SA, Alves MJ, et al. Red pitaya (*Hylocereus costaricensis*) peel as a source of valuable molecules: Extraction optimization to recover natural colouring agents. *Food Chem.* 2022;372. doi:10.1016/j.foodchem.2021.131344
2. Susanti D, Puji Astuti E. Proximate Analysis: Content of Red Dragon Fruit Peel. *Public Health Journal.* 2025;19(2):60-68. doi:10.12928/dpphj.v19i2.12512
3. Putri Hapsari A, Program Studi S- D, Boga Jurusan Pendidikan Kesejahteraan Keluarga T. *Pengaruh Proporsi Bahan Utama (Puree Kacang Merah Dan Tepung Terigu), Dengan Puree Ubi Madu Terhadap Sifat Organoleptik Kue Lumpur Influence Of Main Materials Proportion (Red Bean Puree And Wheat Flour), With Honey Sweet Potato Puree On Organoleptical Characteristics Of Mudcake Niken Purwidiani.*
4. Ho LH, Abdul Latif NW binti. Nutritional composition, physical properties, and sensory evaluation of cookies prepared from wheat flour and pitaya (*Hylocereus undatus*) peel flour blends. *Cogent Food Agric.* 2016;2(1). doi:10.1080/23311932.2015.1136369
5. Razip NH binti M, FMNA A, Manikam RVS, Gandaseca S. Physicochemical and Sensory Characteristics of Bread Substituted with Dragon Fruit Peels. *Indonesian Food Science and Technology Journal.* 2025;9(1):1-12. doi:10.22437/iftj.v9i1.36626

6. Biswas M, Alam M, Akhtaruzzaman M, et al. Valorization of red dragon fruit peel (*Hylocereus polyrhizus*) as a functional ingredient for fortified biscuits: physicochemical, nutritional, and sensory implications. *Future Foods*. 2025;12. doi:10.1016/j.fufo.2025.100768
7. Cahyani NPDAM, Antarini AAN, Tamam B. *Karakteristik Organoleptik, Kapasitas Antioksidan Dan Kadar Serat Pada Kue Lumpur Dengan Penambahan Pure Kulit Buah Naga Merah (Hylocereus Polyrhizus)*. Vol 14. 2025.
8. Putri RMAS, Lastariwati B. Kue Lumpur Dengan Substitusi Ikan Patin Sebagai Makanan Kaya Nutrisi Untuk Generasi Z. Published online October 2023.
9. Chumroenvidhayakul S, Thilavech T, Abeywardena M, Adisakwattana S. Investigating the Impact of Dragon Fruit Peel Waste on Starch Digestibility, Pasting, and Thermal Properties of Flours Used in Asia. *Foods*. 2022;11(14). doi:10.3390/foods11142031
10. Salsabillah II, Purwani E, Sofyan A. Pengaruh Substitusi Tepung Kulit Buah Naga Merah Terhadap Kadar Air, Kadar Abu, dan Tekstur Crackers. *Nutriology: Jurnal Pangan, Gizi, Kesehatan*. 2025;6(1):41-52. doi:10.30812/nutriology.v6i1
11. Qalbi R, Giovani S, Guo Q, Adelina NM. Effect of Drying Time on Physicochemical Characteristics of Dragon Fruit Peels Powder (*Hylocereus polyrhizus*). *Journal of Agri-Food Science and Technology*. 2024;4(2):81-96. doi:10.12928/jafost.v4i2.9294
12. Chumroenvidhayakul S, Thilavech T, Abeywardena M, Adisakwattana S. Dragon Fruit Peel Waste (*Hylocereus undatus*) as a Potential Ingredient for Reducing Lipid Peroxidation, Dietary Advanced Glycation End Products, and Starch Digestibility in Cookies. *Antioxidants*. 2023;12(5). doi:10.3390/antiox12051002
13. Nirmalawaty A, Mahayani AAPs. *Stigma 13 (1): 15-23; Analisa Kimia Bakpia Kering Substitusi Tepung Kulit Buah Naga Chemical Analysis of Dry Bakpia With Dragon Fruit Peels Flour Substitution*. 2020.
14. Lin S. Dietary fiber in bakery products: Source, processing, and function. In: *Advances in Food and Nutrition Research*. Vol 99. 2022:37-100. doi:10.1016/bs.afnr.2021.12.001
15. Sempio R, Sahin AW, Walter J, Arendt EK, Zannini E. Impact of isolated and chemically modified dietary fiber on bakery products: Current knowledge and future directions. *Cereal Chem. John Wiley and Sons Inc*. 2024;101(1):7-37. doi:10.1002/cche.10722
16. McCleary B V, McLoughlin C. Measurement of Available Carbohydrates in Cereal and Cereal Products, Dairy Products, Vegetables, Fruit, and Related Food Products and Animal Feeds: First Action 2020.07. *J AOAC Int*. 2021;104(6):1465-1478. doi:10.1093/jaoacint/qsab019

17. Bhise S, Dharmendrakumar P, Shukla P, Sangeeta S. Nutritional and Organoleptic Evaluation of Fiber-Rich Biscuit Fortified with Dragon Fruit peel. *Archives of Current Research International*. 2025;25(9):269-275. doi:10.9734/acri/2025/v25i91494
18. Le NL. Functional compounds in dragon fruit peels and their potential health benefits: a review. *Int J Food Sci Technol. John Wiley and Sons Inc.* 2022;57(5):2571-2580. doi:10.1111/ijfs.15111
19. Nwachukwu ID, Sarteshnizi RA, Udenigwe CC, Aluko RE. A concise review of current in vitro chemical and cell-based antioxidant assay methods. *Molecules*. 2021;26(16):4865. doi:10.3390/molecules26164865
20. Adiyatmoko F, Pujimulyani D, Ainul Fitri I, Studi Teknologi Hasil Pertanian P, Agroindustri F, Mercu Buana Yogyakarta U. *Sifat Fisiko-Kimia Dan Organoleptik Bolu Terigu-Mocaf Dengan Penambahan Temulawak Dan Baking Powder*. 2023.
21. Agyei-Poku B, Amponsah SA, Adi DD, Mohammed B. Comparative Assessment of Matrix Integration Dynamics Between Beetroot Powder and Paste in Wheat-Based Cupcake Formulations. *Food Sci Nutr*. 2025;13(9). doi:10.1002/fsn3.70863
22. Jahanbakhshi R, Ansari S. Physicochemical Properties of Sponge Cake Fortified by Olive Stone Powder. *J Food Qual*. 2020;2020. doi:10.1155/2020/1493638
23. Guiné RPF. Textural Properties of Bakery Products: A Review of Instrumental and Sensory Evaluation Studies. *Applied Sciences (Switzerland)*. MDPI. 2022;12(17). doi:10.3390/app12178628
24. Pasukamonset P, Pumalee T, Sanguansuk N, et al. Physicochemical, antioxidant and sensory characteristics of sponge cakes fortified with Clitoria ternatea extract. *J Food Sci Technol*. 2018;55(8):2881-2889. doi:10.1007/s13197-018-3204-0
25. Rosenthal AJ, Thompson P. *What Is Cohesiveness?-A Linguistic Exploration of the Food Texture Testing Literature*. 2021.
26. Jati IRAP, Setijawaty E, Purwestri RC. Effects of Red Dragon Fruit Puree Application on Physicochemical Properties of Selected Bakery Products. *Applied Sciences (Switzerland)*. 2024;14(23). doi:10.3390/app142311023
27. Khoirunnisah FM, Aji AS, Saloko S, Aprilia V, Sailendra NV. Pengaruh Teknik Penanakan terhadap Sifat Fisik (Tekstur dan Warna) Nasi dari Beras Analog Berbahan Baku Tepung Sorgum, Mocaf, Glukomanan, dan Kelor. *Amerta Nutrition*. 2024;Vol. 8 Issue 4:506-512.
28. Rathnayake HA, Navaratne SB, Navaratne CM. Porous Crumb Structure of Leavened Baked Products. *Int J Food Sci. Hindawi Limited*. 2018;2018. doi:10.1155/2018/8187318