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Original research article

Effect of Fish Bone Powder on Dough Rheological and Physicochemical and Microstructural Properties of Dried Instant KGM-Wheat Noodle

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ABSTRACT

Convenience foods include dried instant noodles, which are made from wheat flour and lack nutrients, especially calcium. This study made noodles by replacing 3-9% fish bone powder (FBP) for wheat flour. Increasing FBP decreased dough rheological characteristics, while replacing wheat flour with 9% FBP fluctuated considerably. In noodles, substituting FBP led to higher L*, a*, and b* values ($p>0.05$) and decreased tensile strength ($p\leq0.05$), except in the 9% FBP sample. FBP lowered cooking times compared to wheat flour ($p>0.05$). All KGM-wheat noodles with FBP exhibited reduced water absorption ($p\leq0.05$) and increased cooking loss ($p\leq0.05$) compared to those without FBP. A sheet-like structure with local rupture and enlarged starch granules was found in the FBP substitution sample. KGM-wheat noodles replaced 3% FBP (calcium 754.42 mg), nearly meeting the 800 mg daily recommendation.

Keywords: Calcium fortification; Cooking properties; Noodle; Microstructure; Rheological properties

1. Introduction

Noodles are one of the many wheat-flour-based products found throughout the world. Traditionally, noodles are made from wheat flour, water, and salt, partially cooked by steaming followed dehydrated by drying or frying [1]. Based on nutritional properties, noodles are high in carbohydrate and fat and low in fiber, protein, and vitamins and minerals [2]. As a result, this common food lacks adequate essential nutrients to be consumed. It has been investigated how to

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improve the quality of noodles by fortifying or partially substituting traditional ingredients with various functional ingredients to obtain noodles with high nutrition, health benefits, and distinctive properties. Substitutes have included mushroom powder [3] and ginkgo biloba powder [4]. Very few studies have been conducted on substituting fish bone powder (FBP) for noodles.

The Thai recommended daily intake (TRDI) for calcium is 800 mg [5]. Insufficient calcium intake has been related to chronic diseases, specifically osteoporosis [6]. FBP is considered to be a calcium source in the form of hydroxyapatite [7]. In 2021, approximately 66 million tons of marine fish were captured worldwide [8]. Approximately 10-15% of the total fish weight is comprised of bone [9]. In addition to this, an estimated 10 million tons of fish bone were removed as a byproduct of processing. Utilizing this abundant calcium by-product to create enhanced noodles could be a means of optimizing profits from the fishing business while also offering health advantages to consumers [10].

The distinctive viscoelastic characteristics of wheat noodles serve as an indicator of noodle quality, mostly resulting from the presence of gluten protein in wheat flour [11, 12]. Konjac glucomannan (KGM) is a high-molecular-weight polysaccharide that is soluble in water and has a neutral pH. It has been demonstrated to be effective as a food additive and thickening agent, enhancing the quality of dough with low levels of gluten [13, 14]. In order to increase the textural qualities and gelling properties of the noodles, FBP and KGM were used for fortification or substitution [15]. The purpose of this study was to determine the effect of constituent modifications on the rheological properties of dough, and the physicochemical properties of noodles, while simultaneously enhancing calcium content.

2. Materials and Methods

2.1 Materials

Wheat flour and salt were purchased from a supermarket (Pathum Thani, Thailand). Konjac glucomannan (KGM > 75%, viscosity 20,000 Pa.s., 95% passed a sieve with pores of diameter < 125 µm) was purchased from Krunthepchemi Co. (Bangkok, Thailand). Modified starch (KREATION@NE) was obtained from Siam Modified Starch Co., Ltd. (Pathum Thani, Thailand). FBP was provided by P.C. Tuna Co., Ltd. (Samut Sakhon, Thailand). After the boiling of raw fish bones, any meat remaining to the bones was removed. Then, the dried matter is passed through a screen with holes smaller than 150 µm and stored at -20ºC before being incorporated into the formulation. Guar gum, sodium bicarbonate and sodium tripolyphosphate were purchased from Chemipan Corporation Co., Ltd. (Bangkok, Thailand).

2.2 Preparation of dried instant KGM-wheat noodles fortified with FBP

On the basis of our prior findings regarding KGM-wheat noodles, we determined that 3% KGM was the optimal level to use as a partial replacement for wheat flour in dried instant KGM-wheat noodles. The production of noodle dough was carried out according to the formula and method mentioned by Hosawangwong and Sakamut [16], with a slight modification. The control formula consisted of 57.87% wheat flour, 6.63% modified starch, 1.79% KGM, 0.73% salt, 0.22% guar gum, 0.15% sodium bicarbonate, 0.07% sodium tripolyphosphate (STPP), 0.5% flavor enhancer, and 32.54% drinking water. In order to produce dried instant KGM-wheat noodles fortified with FBP, concentrations of FBP replacing wheat flour were as follows: 0%, 1.74%, 3.47%, and 5.21% for each treatment name (corresponding to 3%, 6%, and 9% FBP of wheat flour dry basis (w/w), respectively); all other ingredients remained unchanged throughout all treatments. The resulting treatments were labeled as follows: K0FB0, which consisted of noodle without KGM and FBP (serving as the control); K3FB0, which contained 3% KGM but no FBP; K3FB3, which contained 3% KGM and 3% FBP; K3FB6, which contained 3% KGM and 6% FBP; and K3FB9, which contained 3% KGM and 9% FBP.

2.3 Dough rheology

The rheology of the dough was assessed utilizing a stress-controlled rheometer (Kinexus Ultra Plus, Malvern Instrument, Malvern, UK) in accordance with the modified procedure described by Cao et al. [17]. The measurement was conducted utilizing a parallel plate geometry measuring 40 mm in diameter, with a 3 mm spacing. The dough samples performed a temperature sweep program with the following parameters: a strain of less than 0.1%, a frequency of 1 Hz, a temperature range of 25 to 90ºC, and a heating rate of 5ºC min^{-}1. The rheological parameters determined were the storage modulus (G'), loss modulus (G"), tan δ (G"/G'), and complex modulus (G*), all as a function of temperature.

2.4 Determination of color

A colorimeter (ColorFlex CX2687, HunterLab, USA) was used to measure the L* (lightness), a* (redness), and b* (yellowness) values of the cooked noodles following the method given by Nawat et al. [18]. Nine samples were collected for each treatment. The total color difference (TCD) between the control and dried instant KGM-wheat noodles with FBP was determined using the methodology outlined by Liu et al. [19].

2.5 Determination of tensile strength

The tensile strength of cooked noodles was measured using a texture analyzer (TA-XTPlus, Stable Micro Systems, Godalming, Surrey, UK) following the method described by Cao et al. [17] with a slight adjustment. Nine measurements were taken on each sample in order.

2.6 Determination of cooking properties

The cooking parameters, such as cooking time, cooking loss, and water absorption, were evaluated following the AACC method, 66-50 [20], with minor adjustments. All measurements were performed in triplicate.

2.7 Determination of microstructure

The microstructure of the samples was investigated using field emission scanning electron microscopy (FE-SEM) (JSM7800F, JEOL, Japan) at an operating voltage of 2 kV, following the methodology outlined by Cao et al. [17]. The microstructure was examined under a magnification of 1000x.

2.8 Chemical analysis

The moisture, protein, fat, crude fiber, and ash contents were determined using the AOAC [21] method. The carbohydrate content was determined by deducting the combined amounts of fat, protein, ash, and moisture from 100%. The energy value was computed utilizing the formula outlined by the National Research Council [22]. The calcium concentration was measured using an inductively coupled plasma optical emission spectrometer (ICP-OES).

2.9 Statistical analysis

One-way analysis of variance and Duncan's new multiple range test at 5% level of significance were used to compare between all values. Each experiment was carried out in triplicate.

3. Results and Discussion

3.1 Rheological properties of dough

Figs. 1a-d illustrates the variation in rheological parameters of KGM-wheat dough, comprising the storage modulus (G'), loss modulus (G"), tan δ (G"/G'), and complex modulus (G*), in response to temperature changes. With increasing temperature, the dynamic moduli (G', G", and G*) exhibited an increase. The dough samples exhibited viscoelastic behavior predominated over solidlike behavior, as evidenced by the G'>G" values [23]. The complex modulus (G*) is defined as the measure of dough intensity [24]. Dough exhibiting a higher G* value indicate a higher dough intensity . The dough samples supplemented with 3% KGM demonstrated the highest values of G', G", and G*, suggesting that the incorporation of KGM enhanced the viscoelastic characteristics of the dough. The water, typically distributed as tiny drops inside the protein network matrix and enveloped by starch granules, has the ability to serve as a plasticizer [17, 25]. The molecular structure, when strongly bonded with substantial quantities of water, has the potential to alter the moisture distribution of the dough [26]. The reduction of the plasticizing influence of water resulted in an enhancement of the mechanical characteristics of wheat gluten, thus enhancing the viscoelasticity of the dough [25]. Consequently, the viscosity and elasticity of the dough underwent an increase. Nevertheless, the KGM-wheat dough containing FBP (K3FB3, K3FB6, and K3FB9) exhibited lower values in comparison to the dough sample without FBP (K0FB0 and K3FB0). The observed phenomenon can be explained by the specific properties of FBP, such as its composition and solubility, as well as the concentration of wheat starch in the system. The study involved incorporating FBP by replacing wheat flour, leading to a reduction in the amount of wheat starch. The quality attributes of noodles produced from combinations of wheat flour and starch obtained from African breadfruit (*Artocarpus altilis*) were shown to be inferior to those of noodles produced simply from wheat (control) [27]. The moisture distribution of the dough may be more significantly influenced by starch, which contains a hydroxyl group, than by FBP, which contains a substantial quantity of ash (approximately 65-77%) [10, 28]. The viscoelastic properties of the dough may be reduced by the plasticizing impact of water molecules, which could be enhanced by the replacement of FBP at low content (3-6%). Nevertheless, the dynamic modulus was higher in the KGM-wheat dough with FBP at 3% and 6% when FBP was replaced with high content at 9%. This may be due to the fact that the FBP has high protein content next to ash (21.75% protein) [29]. It is possible that the viscosity and elasticity of the system may be influenced by the protein concentration in fish bone powder. The physicochemical properties of dough can be influenced by the status and distribution of water, as well as its interaction with other components during processing [17].

The tangent delta (tanδ) was also employed to assess the rheological behavior of the sample, distinguishing between its elastic and viscous properties [30]. A sample exhibiting a tanδ value of less than 1 indicated a predominance of elasticity rather than viscosity. During the initial heating stage, the tanδ values for all samples remained around 0.30-0.35, indicating a tendency towards elastic behavior. The inclusion of FBP resulted in an elevation of the tanδ, indicating a correlation between FBP and the reduction of elastic behavior.

The G', G", and G* values, which were measured as a function of temperature, are presented in Figs. 1a-d. All samples demonstrated a consistent pattern as temperatures increased, which can be divided into two distinguishable phases. During the initial phase, the values of all doughs remained consistent. During the subsequent phase, the gelatinization temperature was attained, leading to an observed increase in the values of G', G", and G*. The temperature range at which wheat flour undergoes gelatinization is between 58 and 64ºC [31]. Upon gelatinization, the heating of the starch granules resulted in the continual breaking of intramolecular hydrogen bonds and the subsequent reformation of intermolecular hydrogen bonds [32]. Consequently, an elastic network structure was formed, which trapped water molecules within the structure through hydrogen bonds. As a result, the amount of free water reduced, leading to an increase in the G', G", and G* values of all samples.

3.2 Colour of noodles

Table 1 illustrates the effect of different levels of FBP on the color of dried instant KGM-wheat noodles. Color is often a crucial characteristic that influences consumer approval [33]. The majority of consumers prefer a bright and light-yellow instant noodle [34]. Replacing KGM led to a significant reduction in the L*, a*, and b* values ($p \leq 0.05$), but substituting wheat flour with FBP resulted in an increase in all values. The control sample, K0FB0, had the greatest L* value of 47.24, but there was no significant difference ($p > 0.05$) compared to the samples K3FB6 and K3FB9. On the other hand, the sample K3FB0 had the lowest L* value of 44.56 ($p \leq 0.05$), and there was no significant difference ($p > 0.05$) compared to the sample K3FB3. The K0FB0 had the highest a* value of 1.98, while the K3FB0 had the lowest a* value of 0.32 ($p \leq 0.05$) and was not statistically different ($p > 0.05$) from the K3FB3 and K3FB6. The b* value exhibited a comparable pattern to that of the a* value. The K0FB0 had the highest b* value of 11.88, while the K3FB0 had the lowest b* value of 6.87 ($p \leq 0.05$). The b* value of K3FB0 was not statistically different ($p > 0.05$) from the K3FB3. The KGM was identified as a sugar source that promotes the Maillard browning reaction [35]. Although the substantial decrease in L*, a*, and b* values achieved by substituting KGM, the FBP values remain greater than those of wheat flour. Comparatively, the natural L*, a*, and b* values of FBP are 58.96, 1.34, and 9.13 respectively, while those of wheat flour are 52.35, 0.37, and 4.62, respectively. Consequently, the color value of K3FB0 closely resembles that of K0FB0. According to Liu et al. [19], the total color difference (TCD) for all dried instant KGM-wheat noodles was found to be greater than 1.5, as shown in Table 1. This finding suggests that human vision can distinguish all dried instant KGM-wheat noodles from the control sample.

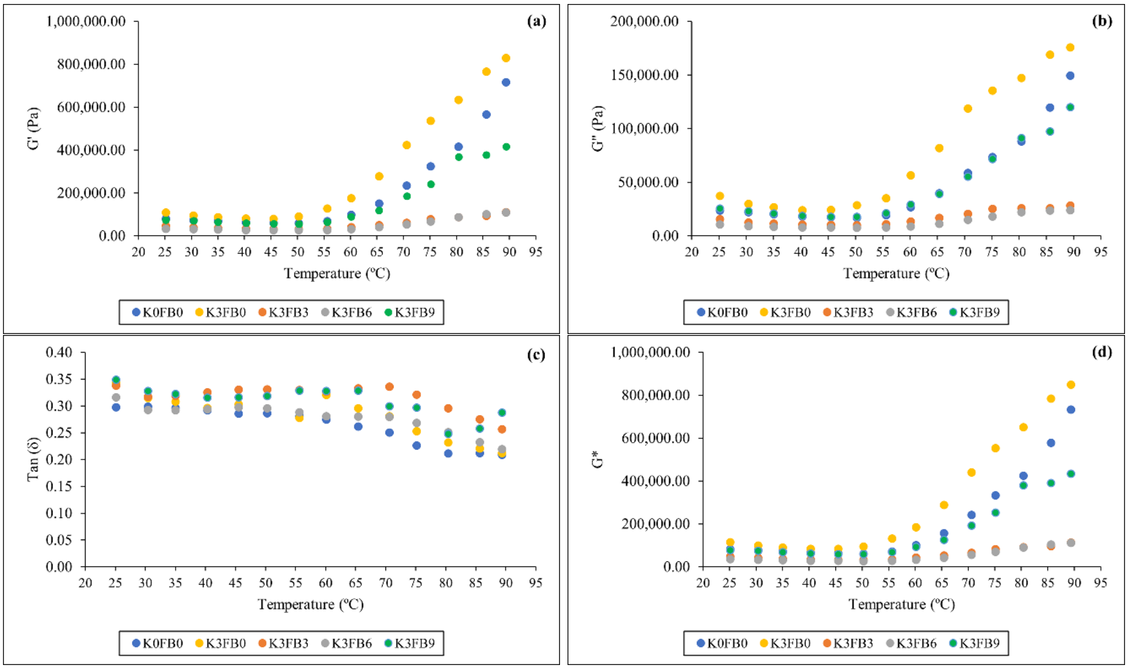

Fig. 1. Rheological properties of dough in the presence of different percentages of FBP: (A) loss modulus (G'), (B) storage modulus (G"), (C) tan δ, and (D) complex modulus.

3.3 Tensile strength of noodle

Tensile strength was measured to assess the fundamental rheological characteristics. Table 1 illustrates the effect of various quantities of FBP on the tensile strength of cooked KGM-wheat noodles. Strong noodles had a greater tensile strength, indicating that they have a higher degree of crosslinking between gluten subunits, which enhances the structural integrity of the noodles. The K3FB6 had the lowest tensile strength of 8.93 ($p \leq 0.05$) and did not differ significantly ($p > 0.05$) from the K0FB0 and K3FB3. On the other hand, the K3FB0 had the greatest value of 10.52 and did not differ significantly ($p > 0.05$) from the K3FB9. The observation of an increase in tensile strength subsequent to the incorporation of KGM suggests that KGM enhanced the strength of the noodles. The inclusion of KGM resulted in alterations in the aggregation behavior of gluten in dough through noncovalent interaction or physical entanglement, thus promoting the formation of cross-links in gluten [13, 14, 36].

The incorporation of FBP resulted in a considerable decrease in the tensile strength of cooked noodles, as seen in Table 1. When FBP was added at concentrations of 3%, 6%, and 9%, the tensile strength dropped by approximately 15.05%, 17.88%, and 4.34%, respectively, compared to the K3FB0 sample without FBP. A decrease in the proportion of wheat flour in cooked noodles fortified with FBP could account for the decreasing texture parameter. In fact, when the concentration of FBP increased, the proportion of gluten in the system decreased. As a result of this incorporation, the mechanical properties of gluten in the dough decreased [25], resulting in a weak gluten network in the noodles. Nevertheless, according to the data presented in Table 1, the tensile strength of K3FB9 was observed to be higher than that of K3FB3 and K3FB6. This result was consistent with the flow characteristics of dough, as depicted in Figure 1. The elasticity and viscosity of the system could be influenced by the high protein content of FBP, which is next to ash (21.75% protein) [29]. This could lead to an increase in the tensile strength of noodles.

3.4 Cooking properties of noodle

Table 1 presents the cooking characteristics of noodles, which include cooking time, water absorption, and cooking loss. The K0FB0 (control sample) had the shortest cooking time of 4.00 min, which increased when the amounts of KGM and/or FBP increased, reaching 4.50-4.58 min ($p \leq 0.05$). There is the suggestion that an extended cooking time for KGM-wheat noodles could potentially signify the formation of a compacted structure in the noodles that contain KGM. Xie et al. [30] observed similar results and suggested that the maximal cooking time of pasta containing 5% semolina flour and egg white protein could potentially indicate the development of pasta with a uniform structure. No statistically significant variation was observed as the quantity of bone powder increased.

The consideration of water absorption is employed to the quantity of water that is absorbed under specific conditions [3]. According to the data in Table 1, it was seen that the inclusion of 3% KGM led to a slight increase in water absorption of the noodles, but this increase was not statistically significant ($p > 0.05$) when compared to the control group (K0FB0). On the other hand, all KGM-wheat noodles replaced with FBP showed a substantial decrease in water absorption ($p \leq 0.05$). The water absorption was reduced by approximately 16.48%, 18.77%, and 12.47% when FBP was substituted at 3%, 6%, and 9%, respectively, in comparison to K3FB0. The substitution of KGM in noodles resulted in a greater water absorption index. This is attributed to the ability of KGM to interact with water molecules and its stereoscopic conformation [17, 37]. The decreased water absorption index of the noodles resulting from the addition of FBP may be attributed to the reduced wheat gluten content in the sample, which caused the gluten protein network to become weakened. Due to the high ash content (approximately 65-77%) of fish bone, replacing it with FBP reduced the amount of wheat starch and weakened the gluten network's ability to retain water in the structure, resulting in a lower water absorption index. Nawaz et al. [18] found that the addition of fish had an impact on the water absorption index of vermicelli, which is consistent with the findings presented here. In contrast to the control noodle, the noodle fortified with fish meat exhibited a reduced starch content, which subsequently led to a lowered water absorption index [18].

Cooking loss is an indicator utilized to estimate the total cooking performance and is considered an indicator of disintegration phenomenon [38]. The addition of 3% KGM resulted in a slight decrease in cooking loss, approximately 0.18% lower than the control (K0FB0), although this difference was not statistically significant ($p>0.05$). On the other hand, substituting FBP at 3%, 6%, and 9% led to a noticeable increase in cooking loss, which was statistically significant ($p\leq0.05$) compared to the K3FB0. However, there was no significant difference ($p>0.05$) in cooking loss between the K3FB6 and K3FB9 and the control. This finding indicates that the inclusion of KGM diminished the mobility of water-soluble constituents in hot water, whereas the incorporation of FBP facilitated the release of water-soluble constituents from starch granules into hot water. Amylose begins to diffuse from the swollen starch granules subsequent to their rupture and swelling, which occurs as a result of the disruption of amylopectin double helices during gelatinization [39]. When KGM is added, the gluten-starch network becomes more compact. This compact network, along with the presence of KGM, can prevent the starch granules from swelling during cooking. As a result, the cooking loss is reduced [36]. Conversely, there was a greater rate of cooking loss observed in KGM-wheat noodles that were combined with FBP. This could be attributed to the replacement of wheat flour with FBP. As the concentration of FBP increased, the gluten content decreased. Consequently, the decrease in the strength of the gluten-starch structure was insufficient to retain an adequate amount of water-soluble components within the system, leading to an increase in the loss of water during cooking.

Table 1. Color (L*, a*b*), total color difference (TCD), textural properties and cooking properties of KGM-wheat noodles.

Measurement	Treatments				
	K0FB0	K3FB0	K3FB3	K3FB6	K3FB9
Color characteristics (cooked noodle)					
L*	47.24±0.83^{a}	44.56±0.45^{b}	45.32±0.36^{b}	46.95±1.19^{a}	46.91±0.60^{a}
a*	1.98±0.33^{a}	0.32±0.16^{c}	0.38±0.17^{c}	0.40±0.09^{c}	0.81±0.09^{b}
b*	11.88±1.00^{a}	6.87±0.21^{d}	7.24±0.25^{d}	7.94±0.54^{c}	8.99±0.44^{b}
TCD	0	5.92	5.27	4.25	3.13
Textural properties (cooked noodle)					
Tensile strength (g)	9.27±0.47^{b}	10.52±0.28^{a}	9.14±0.34^{b}	8.93±0.18^{b}	10.08±0.63^{a}
Cooking properties (cooked noodle)					
Cooking time (min)	4.00±0.00^{b}	4.58±0.20^{a}	4.50±0.00^{a}	4.50±0.00^{a}	4.50±0.00^{a}
Water absorption (%)	246.11±14.29^{a}	251.56±9.66^{a}	215.97±25.13^{b}	211.80±14.03^{b}	223.67±11.41^{b}
Cooking loss (%)	7.26±0.43^{bc}	7.08±0.79^{c}	7.88±0.23^{a}	7.74±0.42^{ab}	7.56±0.37^{ab}

K0FB0, dried instant noodle; K3FB0, dried instant noodle with 3% KGM without FBP; K3FB3, dried instant noodle with 3% KGM and 3% FBP; K3FB6, dried instant noodle with 3% KGM and 6% FBP; K3FB9, dried instant noodle with 3% KGM and 9% FBP. Mean and standard deviation with different superscript letters within the same experiment indicate significant differences ($p\leq0.05$).

3.5 Microstructure of noodle

Fig. 2 displays the microstructure of KGM-wheat noodles with and without FBP. The images are magnified by a scanning electron microscope at 1000x. The control sample exhibited the starch granule being fully immersed within the gluten network structure. The matrix produced by the KGM substitution (K3FB0) was comparable to that of the control; however, the network connecting the starch and protein matrix was more effectively maintained in comparison to the control. Despite the gluten protein content being diminished due to the incorporation of KGM, the gluten network structure remained unaffected. There may have been an increased interaction between carbohydrates and proteins. KGM could alter gluten conformation through physical involvement and non-covalent interactions in the starch-protein-KGM complex, as well as influence glutenin subunit association [17, 38], thereby inducing the formation of the protein network.

As depicted in Fig. 2, a sheet-like structure exhibiting local rupture was identified in the FBP substitution sample. With higher concentration of fish bone powder, the remarkable sheet-like structure with local rupture became more pronounced. The noodles with a higher amount of FBP clearly exhibited a greater level of starch swelling. The gluten content was diminished, a less strong gluten network was produced, and starch gelatinization could potentially happen at an accelerated rate due to the FBP substitution. This may have occurred because the starch granule was incapable of being encased in the weakened protein matrix, and might be allowed into water during the heating process [33]. The findings align with the cooking loss qualities and tensile strength (Table 1, Fig. 3) of the noodles, as these parameters are manifested in the structure of the noodles.

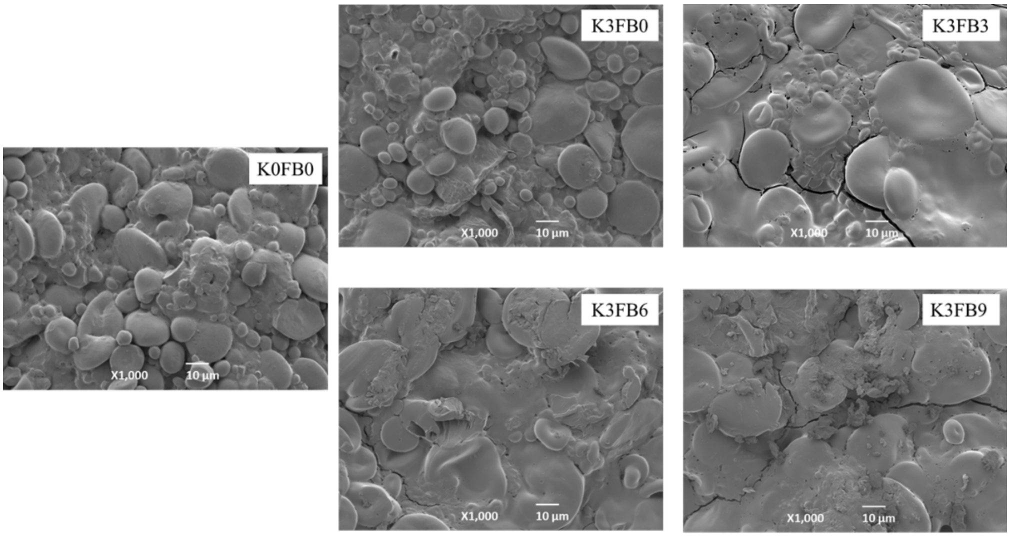

Fig. 2. Microstructure of KGM-wheat noodles incorporated with and without FBP. (K0FB0) control noodle with 0% KGM and 0%FBP, (K3FB0) noodle with 3%KGM and 0%FBP, (K3FB3) noodle with 3%KGM and 3%FBP, (K3FB6) noodle with 3%KGM and 6%FBP, and (K3FB9) noodle with 3%KGM and 9%FBP.

3.6 Chemical composition

The chemical composition of noodles is detailed in Table 2. The degree of FBP replacement implemented in noodle formulations had an impact on their chemical composition. There was no statistically significant variation ($p>0.05$) found in moisture, protein, or fat. However, a notable increase in ash content was observed with the increase in FBP level ($p\leq0.05$). This may be the result of the higher ash content (65-77%) in FBP. In this investigation, it was observed that KGM-wheat noodles exhibited a relatively low fat content (0.26-0.31%), in contrast to the findings of other researchers (1.5-2.5%) [40]. The findings of this study were consistent with those of another study [3], which examined the lipid content of dried noodles fortified with mushrooms (ranging from 0.98 to 2.10%). This is due to the processing differences between frying and drying. The energy content varied between 325.88 and 360.11 Kcal/100 g. The energy value of KGM-wheat noodle fortified FBP was notably lower ($p \leq 0.05$) in comparison to the control group, but did not differ significantly ($p > 0.05$) from that of K3FB3. A possible cause for the decrease in energy value observed in the sample substituted with FBP: a reduction in carbohydrate content. As a result of incorporating FBP, the calcium content of KGM-wheat noodle increased. In comparison to K3FB0 (34.11 mg/100 g), the calcium content of KGM-wheat noodles fortified with 3% and 6% FBP was 754.42 and 1607.02 mg/100 g, respectively. According to the Royal Thai Government Gazette [5], the Thai Recommended Daily Intake (Thai RDI) of calcium is 800 mg. Based on the results, we determined that the 3% FBP substitution of KGM-wheat noodles was slightly lower than the recommended calcium intake, whereas the 6% FBP substitution achieved the recommended intake. In a serving size of 100 g of noodles, the KGM-wheat noodles substituted with 3% FBP had 10.53 g of protein, 0.31 g of fat, 3.65 g of ash, 78.97 g of carbohydrate, and an energy value of 360.11 kcal.

Table 2. Chemical composition of KGM-wheat noodles incorporated with FBP.

Chemical composition (%)	Treatments			
	K3FB0	K3FB3	K3FB6	K3FB9
Moisture^{NS}	7.64±3.48	5.22±2.03	9.01±1.20	7.10±0.54
Protein^{NS}	10.76±0.31	10.53±0.23	10.44±0.33	10.78±0.64
Fat^{NS}	0.26±0.06	0.31±0.06	0.30±0.04	0.31±0.09
Ash	1.96±0.02^{d}	3.65±0.48^{c}	5.29±0.31^{b}	7.49±0.35^{a}
Carbohydrate	78.35±3.41^{a}	78.97±1.47^{a}	73.69±1.95^{b}	69.25±2.52^{c}
Energy (Kcal/ 100g)	354.84±14.00^{a}	360.11±7.26^{a}	337.99±5.79^{b}	325.88±12.13^{b}

K3FB0, dried instant noodle with 3% KGM without FBP; K3FB3, dried instant noodle with 3% KGM and 3% FBP; K3FB6, dried instant noodle with 3% KGM and 6% FBP; K3FB9, dried instant noodle with 3% KGM and 9% FBP. Mean and standard deviation with different superscript letters within the same experiment indicate significant differences ($p \leq 0.05$).

^{NS} Non-significantly different ($p > 0.05$).

4. Conclusion

In many Asian countries, noodles are among the most consumed foods during both adolescence and adulthood. However, the nutritional value of noodles produced solely from wheat flour is an issue of argument, particularly with regard to the presence of minerals such as calcium. In order to produce instant KGM-wheat noodles, wheat flour was substituted with FBP. The rheological parameters of dough exhibited a decrease in substituted noodles containing FBP as compared to noodles made with KGM-wheat without FBP. The cooking time of KGM-wheat noodles containing FBP was 4.50 minutes, which was not significantly different from the cooking time of noodles without FBP. Substituting FBP not only resulted in an increase in L*a*b* values, but also led to an increase in cooking loss of noodles. The incorporation of FBP in KGM-wheat noodles resulted in a decrease in both tensile strength and water absorption, as compared to the KGM-wheat noodles without FBP. The microstructure observed by SEM revealed the presence of a sheet-like structure exhibiting local rupture subsequent to the replacement of FBP. FBP enhanced the calcium and ash contents of noodles while maintaining the same levels of moisture, fat, and protein as noodles made without FBP. For adolescents and adults, dried instant KGM-wheat noodles may serve as an alternative calcium source with health benefits.

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