

COMPARISON OF BOILING, STEAMING, AIR FRYING, DEEP-FRYING, MICROWAVING AND OVEN-COOKING ON QUALITY CHARACTERISTICS OF *keropok lekor* (MALAYSIAN FISH SAUSAGE)

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ABSTRACT

Keropok lekor (KL) (Malaysian fish sausage) is usually boiled and then deep-fried for consumption. The combination of these cooking methods could produce greasy and fatty products thus negatively affect health in a long term. Other cooking methods could be better alternatives to the common methods. Therefore, this study aimed to investigate the effect of six cooking methods namely boiling, steaming, air frying, deep-frying, microwaving and oven-cooking on the KL quality. The cooked samples were analysed for the moisture, fat, linear expansion, cooking yield, water holding capacity, colour, texture and sensory properties. Boiling showed the highest linear expansion (3.02%), cooking yield (104.10%) and water holding capacity (41.04%). Meanwhile, deep frying significantly reduced ($p < 0.05$) the moisture (39.83%) and increased the fat (6.58%) contents, exhibited harder texture (93.13N) and showed a higher yellowness value (8.23) compared to other cooking methods. No significant difference ($p > 0.05$) was found in other properties; however, panellists significantly ($p < 0.05$) preferred the crispiness and overall acceptability of the deep-fried followed by oven-cooked KL. Indeed, textures and colours had significant ($p < 0.05$) relationships with sensory properties. In conclusion, deep-frying and oven-cooking reduced the moisture content and increased the hardness of KL, which increased the panelists' preferences. However, deep-fried KL had a higher fat content due to the cooking with oil; therefore, the oven-cooked KL can be the healthier alternative.

Key words: Cooking methods, deep-fried, fish products, heat treatments, *keropok lekor*

INTRODUCTION

Manufacturing and production of formulated fish products have become progressively significant due to the varieties they can offer. It has been reported that world fish production for consumption increased tremendously from 67 per cent in the 1960s to 87 per cent in 2014. The figures are estimated to increase by 21 per cent in 2025 indicating the growing demand for fish products especially in developing countries (OECD-FAO, 2016). *Keropok lekor* is one example of the formulated fish product that resembles sausage in texture, hence known as Malaysian fish sausage. The *keropok lekor* is a very popular snack food in Malaysia and other Asian countries. It is made by

mixing fish flesh, starch, flour, and seasonings such as salt, sugar and monosodium glutamate (MSG). The homogenous dough is rolled into a cylindrical shape, similar to a sausage, and is typically boiled to gelatinize the starch before being served or further deep-fried to obtain a more preferable texture and taste (Nor-Khaizura *et al.*, 2009; Murad *et al.*, 2017).

The formulations of *keropok lekor* (fish sausage) may vary, but the starch composition can be as high as 60 percent, which permits the fish sausage to expand during cooking and contributes to the crispy characteristics of the product. Low-value pelagic fishes like round scad (*Decapterus maruadsi*), round hering (*Dussumieria haselitti*) and sardine (*Sardinella aurita*) are often used in the production of the fish sausage (Kaewmanee *et al.*, 2015). The fish species, the freshness of fish, the ratio

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of the primary substances and the cooking methods may influence the quality of the final product (Taewee, 2011).

Deep frying is a commonly used cooking method for fish sausage either after the rolling or boiling process (Nor-Khaizura *et al.*, 2009). The fish sausage becomes crispy and crunchy outside but the inside texture is soft. This cooking method is very convenient and produced exclusive sensorial properties of fried food that is highly accepted by consumers (Bordin *et al.*, 2013). During the deep frying process, the high temperature causes water to evaporate, oil is absorbed into the food and the aromatic compounds are released making the final product dominated by oil and the by-product of oil (Gertz *et al.*, 2014; Sadgrove *et al.*, 2015). As a result, deep-frying leads to an increase in fat content and a decrease in the shelf life of the product during storage due to the oxidation of fat (Kok *et al.*, 2004).

Based on the fact that excessive consumption of fried products can lead to serious health risks such as obesity and hypertension (Qin *et al.*, 2021), the food industry has put efforts into developing alternative methods to cook food products with low oil content but produce similar features of flavour, colour and texture. Many types of cooking methods are available, however to the best of our knowledge, there is limited information regarding the effect of different cooking methods of the *keropok lekor* on the colour and cooking characteristics as well as its sensory attributes or consumer expectations. Hence, the objectives of this study are to investigate the effects of different cooking methods namely boiling, steaming, air frying, deep-frying, microwaving and oven-cooking on physicochemical and sensory properties of *keropok lekor*.

MATERIALS AND METHODS

Materials

Sardine (*Sardinella aurita*) and Mackerel (*Rastrelliger kanagurta*) were purchased from a local market located in Seri Kembangan, Selangor, Malaysia. Sago flour, tapioca starch, sugar, salt and MSG (Ajinomoto (Malaysia) Berhad, Malaysia) were obtained from a grocery store in Putrajaya, Malaysia.

Keropok lekor production

The fresh fish was cleaned, washed and the flesh was separated using deboner (Ding-Han Machinery Co., Ltd., DH811-200, Taiwan). The flesh was put into a plastic bag, sealed and kept in a freezer at -18°C before mixing with other ingredients to form the final dough. The dough was prepared with slight modifications according to Nur Liyana *et al.* (2019), which used fish flesh 50.2%; sago flour

17.5%; tapioca starch 17.5%; salt 1.3%; sugar 0.8%; MSG 0.2% and crushed ice 12.5%. After mixing, the dough was rolled into a sausage-like shape weighed approximately 30 g each. The samples were packed in an air-tight polyethylene plastic bag and stored at -18 °C for further cooking treatments and analyses.

Cooking methods

All samples were pre-boiled, which is a standard method in the processing of the *keropok lekor*. Water was heated in the pot until it reached the boiling point (100°C). Then, samples were placed in the pot and boiled for 10 min. Then, the boiled samples were divided into six groups, cooled down and dried at room temperature (25-28°C). The first group was re-boiled for 10 min at 100 °C. The second group was steamed at 100 °C for 1 h using a manual steamer. The third group was air-fried for 15 min at 150 °C using an air fryer (International Cooking Concepts Model ZM-AF400, Germany). The fourth group was deep fried in cooking oil using a domestic deep fryer (Stainless Steel Deep Fryer FDF 1035ss, Faber, Italy) for 6 min at 160 °C. The fifth group was cooked in the microwave (Model R-360J(S), Sharp, Japan) for 2 min at a low power level (10P) which is equal to 80W. The sixth group was cooked for 20 min in the oven at 150 °C.

Moisture and fat analyses

The moisture and fat contents of the samples were analyzed based on AOAC Method 934.01 and method 991.36, respectively (AOAC, 1990). Both analyses were conducted in triplicate.

Linear expansion

The length of the sample was measured before and after cooking using a vernier calliper and the linear expansion of the sample (%) was calculated using the following formula (Murad *et al.*, 2017):

$$\text{Linear expansion (\%)} = (LA - LB)/LB \times 100\%$$

in which, LA = length after cooked and LB = length before cooked.

Cooking yield

The percentage of cooking yield was determined by calculating the weight differences of the samples before and after cooking (Turp, 2016). The cooked samples were cooled to room temperature (25-28 °C) for 10 min and were reweighed to calculate the cooking yield using the following formula:

$$\text{Cooking yield (\%)} = (WA/WB) \times 100\%$$

in which WA = weight after cooked and WB = weight before cooking

Water holding capacity

The water holding capacity (WHC) was determined based on the method of Murad *et al.* (2017) with slight modifications. The samples (5 g) were blended and homogenized with 10 mL of distilled water. After centrifugation for 10 min at 2000 r.p.m., the supernatant was collected and calculated by using the formula below:

$$\text{Water Holding Capacity (\%)} = (\text{VB} - \text{VA}) / \text{WS} \times 100\%$$

where, VB = volume of water before centrifuged, VA = volume of water after centrifuged, and WS = weight of the sample

Colour analysis

The colour of the cooked samples was measured using Konica Minolta portable colourimeter (CR-400, Konica Minolta, Japan) for its lightness (0=black, 100=white), redness ($-a^*$ =greenness, $+a^*$ =redness) and yellowness ($-b^*$ =blueness, $+b^*$ =yellowness) (L^* , a^* , and b^* values, respectively).

Texture profile analysis

Texture profile analysis was carried out as described by Kaewmanee *et al.* (2015) with some modifications using a texture analyzer (TA-XTPlus, Micro Stable Systems, UK). The samples were compressed by a probe with a blade (HDP/BSK), using pre-test speed and post-test speed of 10 mm s⁻¹, test speed of 5 mm s⁻¹ and distance of 10 mm. The characteristics that had been analysed were hardness, cohesiveness, springiness, chewiness, and resilience.

Sensory evaluation

Sensory analysis was carried out based on Nur Liyana *et al.* (2019) with several modifications. Thirty consumer panellists received six random samples from the mid-section of fish sausages (2 cm × 2 cm × 2 cm) with questionnaires and instructions for the evaluation of samples using a hedonic scaling with a 9-point scale (1 = dislike extremely, 9 = like extremely). Sensorial analyses were conducted in a laboratory with individual booths located in the tasting room, which was air-conditioned and free of disturbing factors. The sensory attributes that had been tested include appearance, colour, texture, crispiness, taste, oiliness and overall acceptability.

Statistical analysis

Statistical analyses were conducted using Minitab statistical software (Minitab 19, Minitab Inc, Pennsylvania). The analysis of variance (ANOVA) was used to compare the data. Tukey's test was performed at confidence limits of 95% ($P < 0.05$). Pearson correlation was also carried out to determine

the correlation between selected parameters. All analyses were carried out in triplicate.

RESULTS AND DISCUSSION

Moisture content, fat content, linear expansion, cooking yield and WHC

Table 1 shows the moisture content, fat content, linear expansion, cooking yield and WHC of the *keropok lekor* obtained using different cooking methods. The moisture contents of air-fried, deep-fried and oven-cooked fish sausages were significantly reduced ($p < 0.05$) compared to other cooking methods. The deep-fried samples had the lowest moisture content (39.83%) while the steamed and boiled samples displayed the highest value (55.78% and 55.07%, respectively). Steaming and boiling processes allowed the absorption of water into fish sausages resulted in increased moisture content. These results reflect the finding of Choi *et al.* (2016) who found that steaming of chicken steak produced higher moisture content than other cooking treatments.

The deep-frying method resulted in a significantly higher ($p > 0.05$) fat content (6.58%) compared to other cooking methods (1.59% - 2.76%). Indeed, deep frying was the only method that used oil as a medium of cooking. Kassama and Ngadi (2016) showed a strong linear relationship between oil uptake and moisture loss during deep-frying of chicken breast indicated that deep-frying decreases the moisture content while increasing the fat content of the food. Similarly, García-Arias *et al.* (2003) suggested that the reduction of moisture content during frying contribute to an elevated level of fat in the cooked fish fillet. The result was likely caused by the penetration and absorption of oil into the sample during frying (Weber *et al.*, 2008) after water is partially lost by evaporation (Saguy & Dana, 2003). However, other factors such as the rate of change in food temperature and the temperature of the cooking method (higher in deep frying than in steaming) may influence the results (HassabAlla *et al.*, 2009).

The boiled sample showed a significant increase ($p < 0.05$) of linear expansion compared to the air-fried sample. The steamed sample also had a positive expansion although not significantly different ($p > 0.05$) compared to others. Meanwhile, other cooking methods reduced the linear expansion of the samples. The positive values obtained by boiled and steamed samples were probably affected by the involvement of water uptake during the cooking process. Water is absorbed into the fish sausage during boiling, while during steaming, water vapour is entrapped inside the fish sausage and expanded.

Other cooking methods such as air frying, deep-frying, microwaving, and oven-cooking showed negative values due to the shrinkage of the fish sausage. Taewee (2011) stated that starch is the key ingredient that causes the expansion and crispness of the snack. The finding is consistent with Huda *et al.* (2010) who reported that inadequate water during the baking process led to incomplete gelatinization of starch. It can thus be suggested that cooking fish sausage using air frying, deep-frying, microwaving, and oven-cooking methods reduced the starch gelatinization, hence decreased the expansion of the fish sausage.

The boiled and steamed samples resulted in significantly higher cooking yields ($p < 0.05$), while deep-fried and oven-cooked samples had the lowest significant ($p < 0.05$) cooking yield. This result can be reflected in the moisture content of the samples, in which water absorbed by the boiled and steamed samples increased the yield as compared to water removal for deep-fried and oven-cooked samples. A study by Trevisan *et al.* (2016) suggested that the moisture loss during frying, baking, and grilling decreased the cooking yield. Similarly, Das *et al.* (2013) proposed that the difference in cooking yield of food products is due to the variation in their moisture retention characteristics.

The highest WHC ($p < 0.05$) were shown in both boiled and steamed samples compared to other samples except for the microwaved samples. The WHC values obtained were significantly ($p < 0.05$) lower from deep-fried, oven-cooked and air fried samples. According to Suleman *et al.* (2020), the loss of water that occurs during frying leads to the aggregation of the protein. This aggregation causes the proteins to lose their three-dimensional structure, thus contribute to the loss of WHC. In addition, the contraction of collagen and denaturation of α -actin and myosin of the samples could reduce WHC (Trevisan *et al.*, 2016).

Colour and texture profiles

Colour and texture profiles of the *keropok lekor* treated with different cooking methods are shown in Table 2, while the appearances of the *keropok lekor* are displayed in Figure 1. Microwaved samples had significantly higher L^* values demonstrating lighter colour than air-fried samples ($p < 0.05$). In contrast, no significant differences ($p > 0.05$) in L^* values of the boiled, steamed, deep-fried and oven-cooked samples. The L^* values depend on the cooking temperature which resulted in the pigment degradation on the outer layer of foods (Huda *et al.*, 2011). Both deep frying and oven-cooking methods significantly increased ($p < 0.05$) the redness (a^*) of the samples compared to other cooking methods. There was no significant difference ($p > 0.05$) of a^*

values between boiling, steaming, air frying and microwaving methods. About the yellowness parameter (b^*), deep frying showed the highest value compared to the other cooking methods. Krokida *et al.* (2001) reported that during frying, heat and mass transfer phenomena take place, thus cause physicochemical changes, which affect the colour of the fried products.

The data obtained in the present study was consistent with the visual observation that the deep-fried *keropok lekor* appeared golden yellow, thus significantly increase the yellow hue of *keropok lekor*. This result was similar to a study reported by Huda *et al.* (2001) who found that fried products had desirable homogenous yellow colour with higher b^* values. In addition, several reactions occur during the heating of fish and meat including denaturation of protein and browning reaction that subsequently affect the colour and taste development of the food (HassabAlla *et al.*, 2009; Das *et al.*, 2013). A previous study indicated that Malaysian commercial fish sausages had variable colour characteristics range from 58.73–79.56 for L^* value, 0.58–17.43 for a^* value and 12.69–22.96 for b^* value (Huda *et al.*, 2012). The present study, however, showed each cooking method presented different colour. The technique, medium of cooking, the composition of ingredients and condition of frying oil can also influence the formation of colour in food (Kulp *et al.*, 2016).

The deep-fried sample showed the highest significant hardness ($p < 0.05$) among all the samples, followed by the oven-cooked samples ($p < 0.05$). The air-fried and microwaved samples had the medium significant ($p < 0.05$) hardness level, while the steamed and boiled samples were the least significant hard ($p < 0.05$) compared to other samples. The observed increase in hardness for the deep-fried and oven-cooked samples could be attributed to crust formation that hardens the food surface as the frying temperature and the rate of heat transfer increases (Das *et al.*, 2013). The hardness of muscle foods product is strongly influenced by the structural changes of their protein fractions due to the thermal, mechanical and ingredients used (Acosta *et al.*, 2021). Besides, the lowest hardness in steamed and boiled samples could be due to weakened muscle structure and the leaching out of soluble protein as both cooking methods involved water (Li *et al.*, 2017). Interestingly, the air fried sample had the highest significant ($p < 0.05$) chewiness level. This was followed by the boiled, steamed, oven-cooked, microwaved and deep-fried samples, although all these samples had no significant different changes ($p > 0.05$). No significant changes ($p > 0.05$) for the samples' cohesiveness, springiness, and resilience were observed among all the cooking methods.

Table 1. Effect of different cooking methods on moisture content, fat content, linear expansion, cooking yield and water holding capacity of the *keropok lekor*

Cooking Methods	Moisture Content (%)	Fat Content (%)	Linear Expansion (%)	Cooking Yield (%)	Water Holding Capacity (%)
Boiling	55.07 ± 0.51 ^a	2.75 ± 1.68 ^b	3.02 ± 2.38 ^a	104.40 ± 1.22 ^a	41.04 ± 0.82 ^a
Steaming	55.78 ± 1.32 ^a	1.59 ± 1.85 ^b	0.38 ± 0.66 ^{ab}	102.72 ± 1.21 ^a	40.65 ± 0.66 ^a
Air Frying	46.13 ± 2.22 ^b	2.18 ± 0.04 ^b	-1.88 ± 2.37 ^b	89.60 ± 0.34 ^c	38.63 ± 0.77 ^{bc}
Deep Frying	39.83 ± 4.19 ^b	6.58 ± 0.79 ^a	-1.12 ± 1.13 ^{ab}	80.61 ± 2.17 ^d	35.66 ± 1.21 ^c
Microwaving	53.70 ± 1.75 ^a	2.76 ± 2.70 ^b	-0.76 ± 0.66 ^{ab}	98.52 ± 0.96 ^b	39.19 ± 2.00 ^{ab}
Oven-Cooking	44.23 ± 2.46 ^b	1.80 ± 1.16 ^b	-0.71 ± 0.61 ^{ab}	82.24 ± 1.14 ^d	35.94 ± 1.17 ^{bc}

Different small letters in the same column indicate a significant difference between cooking methods ($p < 0.05$).

Table 2. Effect of different cooking methods on the colour and texture of the *keropok lekor*

Cooking Methods	Colour			Texture				
	L*	a*	b*	Hardness (N)	Cohesiveness	Springiness (mm)	Chewiness (N.mm)	Resilience
Boiling	48.88 ± 0.77 ^{ab}	2.37 ± 0.14 ^b	6.36 ± 0.45 ^{ab}	29.03 ± 0.75 ^d	0.33 ± 0.10 ^a	0.96 ± 0.05 ^a	11.05 ± 1.27 ^{ab}	0.05 ± 0.01 ^a
Steaming	48.74 ± 1.04 ^{ab}	2.68 ± 0.16 ^b	6.51 ± 1.26 ^{ab}	27.33 ± 1.87 ^d	0.27 ± 0.01 ^a	0.89 ± 0.11 ^a	6.63 ± 1.00 ^b	0.05 ± 0.02 ^a
Air Frying	45.31 ± 0.81 ^b	2.44 ± 0.20 ^b	4.82 ± 1.14 ^b	59.23 ± 0.26 ^c	0.31 ± 0.03 ^a	0.91 ± 0.06 ^a	16.29 ± 3.14 ^a	0.08 ± 0.04 ^a
Deep Frying	48.09 ± 1.26 ^{ab}	4.40 ± 0.16 ^a	8.23 ± 0.77 ^a	93.13 ± 1.76 ^a	0.10 ± 0.13 ^a	0.58 ± 0.33 ^a	2.40 ± 3.39 ^b	0.10 ± 0.03 ^a
Microwaving	49.84 ± 2.51 ^a	2.13 ± 0.10 ^b	6.22 ± 0.66 ^{ab}	50.02 ± 3.56 ^c	0.33 ± 0.30 ^a	0.73 ± 0.32 ^a	3.32 ± 0.84 ^b	0.15 ± 0.10 ^a
Oven-Cooking	46.63 ± 1.01 ^{ab}	4.57 ± 0.37 ^a	6.33 ± 0.12 ^{ab}	74.48 ± 6.42 ^b	0.11 ± 0.09 ^a	0.88 ± 0.16 ^a	3.59 ± 2.73 ^b	0.07 ± 0.07 ^a

Different small letters in the same column indicate a significant difference between cooking methods ($p < 0.05$).



Fig. 1. *Keropok lekor* (Malaysian fish sausage) cooked using different methods.

Sensory evaluation

The result of the sensory evaluation of *keropok lekor* is presented in Table 3. Deep-fried *keropok lekor* consistently showed the highest value for all attributes. However, there were no significant differences in appearance, texture, and oiliness amongst all samples ($p > 0.05$). On the other hand, the crispiness and taste scores of deep-fried and oven-cooked *keropok lekor* were significantly higher compared to other cooking methods ($p < 0.05$). These results are likely to be related to higher retention of natural juice and enhanced release of flavour compounds during deep frying and oven-cooking (Das *et al.*, 2013). Furthermore, the *keropok lekor* will be immediately deep fry after rolling resulted in better taste than of the other cooking methods. The highest colour score of the deep-fried sample indicated that the panellists liked its colour. This could be due to caramelizing effect during deep-frying that produced uniform golden yellow colour. For overall acceptability, the panellists rated deep-frying as the cooking method that they like the most. The usage of oil during the deep-frying process increases the fat content of food products and people generally prefer the taste and texture of the fried foods due to the presence of fat that enhances the mouthfeel sensation (Kupiroviè *et al.*, 2017). The results of the texture profile analysis were following those found by Giovanelli (2017) who observed better taste and texture of fish sausage, with softly cooked inside and crunchy outside when the deep-frying method was used.

Relationship between the measured parameters

Table 4 shows the relationship between the parameters with significant differences resulted from

Table 1, 2 and 3. The purpose was to determine the parameters and cooking methods that influenced most of the *keropok lekor* quality. Positive significant correlations ($p < 0.05$) were determined between the cooking yield and WHC against the moisture, and between the WHC against the cooking yield, indicating the final weight of cooked *keropok lekor* was influenced by the capability of retaining the water during the heat treatments. The hardness, crispiness, taste and overall acceptability had a negative significant correlation ($p < 0.05$) against the moisture, cooking yield and WHC. These results showed that cooking methods reduced the water content in *keropok lekor*, thus, created harder and crispier textures, which improved the preference among panellists. Interestingly, the colour, crispiness, texture, and overall acceptability were positively significant correlated ($p < 0.05$) against the redness (a^*) values. The colour was a major factor for panellists especially the redness, which influenced their preference over other parameters. The crispiness, texture, and overall acceptability had positive significant correlations ($p < 0.05$) against the hardness and crispiness, indicating preference of the panellists towards crispier compared to soft *keropok lekor*. Panellists were also considered taste as the factor that influenced their overall acceptability, which was shown with positive significant correlations ($p < 0.05$) between these two parameters. To conclude, although the moisture content is important in determining the final weight of *keropok lekor*, the crispier and harder texture of *keropok lekor* with less water and redder colour was more preferred.

Table 3. Effect of different cooking methods on sensory of the *keropok lekor*

Cooking Methods	Sensory Attributes								Overall Acceptability
	Appearance	Color	Texture	Crispiness	Taste	Oiliness			
Boiling	5.20 ± 1.78 ^a	5.23 ± 1.76 ^{ab}	5.03 ± 1.73 ^a	3.60 ± 1.55 ^b	4.57 ± 1.76 ^b	5.70 ± 1.75 ^a			4.70 ± 1.66 ^{bc}
Steaming	5.47 ± 1.66 ^a	5.47 ± 1.59 ^{ab}	5.43 ± 1.85 ^a	3.93 ± 1.60 ^b	4.93 ± 2.02 ^b	5.67 ± 1.83 ^a			4.93 ± 2.05 ^{bc}
Air Frying	5.53 ± 1.61 ^a	5.10 ± 1.49 ^b	4.67 ± 1.65 ^a	4.17 ± 1.66 ^b	5.07 ± 1.72 ^b	5.40 ± 1.96 ^a			4.83 ± 1.60 ^{bc}
Deep Frying	6.17 ± 1.90 ^a	6.33 ± 1.52 ^a	5.83 ± 2.04 ^a	5.87 ± 2.06 ^a	6.90 ± 1.45 ^a	6.40 ± 1.28 ^a			6.57 ± 1.46 ^a
Microwaving	5.13 ± 1.76 ^a	5.00 ± 1.72 ^b	4.83 ± 1.60 ^a	4.20 ± 1.61 ^b	4.57 ± 2.00 ^b	5.30 ± 1.80 ^a			4.67 ± 1.77 ^c
Oven-Cooking	5.93 ± 1.93 ^a	5.83 ± 1.80 ^{ab}	5.63 ± 1.88 ^a	5.53 ± 1.57 ^a	5.83 ± 1.76 ^{ab}	5.73 ± 1.89 ^a			5.97 ± 1.71 ^{ab}

Different small letters in the same column indicate a significant difference between cooking methods ($p < 0.05$) based on a 9-point of scale (1= dislike extremely, 9= like extremely)

Table 4. Pearson Correlations of selected parameters measured on the *keropok lekor*

	Moisture	Fat	LE	CY	WHC	L*	a*	b*	Hardness	Chewiness	Colour	Crispiness	Taste
Fat	-0.603												
LE	0.637	-0.175											
CY	0.978*	-0.487	0.691										
WHC	0.937*	-0.522	0.644	0.979*									
L*	0.590	0.159	0.514	0.584	0.421								
a*	-0.799	0.442	-0.307	-0.841	-0.880*	-0.316							
b*	-0.341	0.782	0.111	-0.301	-0.420	0.469	0.588						
Hardness	-0.965*	0.659	-0.670	-0.967*	-0.973*	-0.406	0.790	0.433					
Chewiness	-0.116	0.047	-0.009	0.041	0.229	-0.564	-0.321	-0.433	-0.088				
Colour	-0.728	0.670	-0.198	-0.710	-0.751	-0.115	0.915*	0.810	0.717	-0.233			
Crispiness	-0.892*	0.594	-0.539	-0.930*	-0.975*	-0.279	0.935*	0.595	0.938*	-0.326	0.865*		
Taste	-0.897*	0.738	-0.449	-0.869*	-0.877*	-0.295	0.894*	0.687	0.885*	-0.089	0.947*	0.933*	
Overall Acceptability	-0.855*	0.673	-0.365	-0.855*	-0.892*	-0.228	0.956*	0.721	0.863*	-0.242	0.967*	0.961*	0.980*

Value with (*) showing significant correlation ($p < 0.05$). A value near 1 showing a positive correlation while a value near -1 showing a negative correlation. LE= linear expansion; CY= cooking yield; WHC= water holding capacity.

CONCLUSION

The different cooking methods (boiling, steaming, air frying, deep-frying, microwaving, and oven-cooking) had different effects on the physicochemical and sensory properties of the *keropok lekor*. Higher moisture content, cooking yield and water holding capacity were obtained by the boiled and steamed *keropok lekor*. In contrast, despite the highest fat content and hardest texture, deep-fried *keropok lekor* was the most preferred by the panellists influenced by the crispiness level. Oven-cooked *keropok lekor* had almost similar characteristics as the deep-fried *keropok lekor* but with lower fat content. Therefore, oven cooking can be used as an alternative to deep-frying to cook *keropok lekor* for a healthier option.

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