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Chemical characteristics of traditional fish crackers (*kemplang*) heated using a microwave oven

[1]Guttifera, [2]Rahmawati, L., [3]Sari, S.R., [4]Pratama, F., [4]Widowati, T.W., [5]Dewi, S. and [6,*]Purwandoko, P.B.

[1]*Department of Fisheries Science, Faculty of Agriculture, Universitas Sumatera Selatan, Palembang, Indonesia*
[2]*Research Center for Food Technology and Processing, National Research and Innovation Agency, Yogyakarta, Indonesia*
[3]*Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Bengkulu, Indonesia*
[4]*Department of Agriculture Technology, Universitas Sriwijaya, Palembang, Indonesia*
[5]*Department of Agriculture, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang, Indonesia*
[6]*Research Center for Appropriate Technology, National Research and Innovation Agency, Subang, Indonesia*

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Abstract

Fish crackers (*kemplang*) are distinctive foods produced in Palembang, Indonesia, but their production process involves conventional frying using oil, which is very dangerous for health because it can cause heart disease and increase cholesterol levels. Therefore, this study aimed to examine the chemical characteristics of Palembang fish crackers heated using a microwave oven. A factorial randomized block design was used with two treatment factors, the addition of eggs (A) as well as the difference in water content (B). Factor A has 3 sublevels of A1 = without eggs, A2 = egg yolks, A3 = whites and yolks, while B has 2, including B1 = 7.5±1%, and B2 = 13.5±1%. The parameters observed include water, protein, fat and amino acid contents. The results showed that the water content of the crackers decreased significantly, while the protein and amino acid levels increased after heating. The reduced fat content was caused by increased oxidation due to the increased temperature. Palembang fish crackers (*kemplang*) with high protein and amino acids can be produced using a dough formulation with the addition of eggs and water content of 13.5±1%. Furthermore, the use of a microwave oven is a healthier alternative to conventional methods.

1. Introduction

Fish crackers (*kemplang*) are one of the traditional foods from the South Sumatra province, especially Palembang City. They are often consumed with rice and side dishes or used as a snack (Indriani *et al*., 2019). The crackers are produced from mashed fish meat, tapioca flour, salt, and water through dough mixing, molding, steaming, slicing, drying and frying. The common *kemplang* is a product prepared by frying with oil (Suryaningrum *et al*., 2016). This method is considered less effective and efficient due to complicated techniques in terms of size and composition. The oil used is heated to a high temperature of up to 200°C, and the process is performed in two pans (Prasetya, 2009). Oke *et al*. (2018) revealed that frying can change the nutritional and sensory characteristics of the product due to its interaction with oil. The process also increases the fat levels by 13% due to a large amount of oil trapped in the ingredients' pores. This is consistent with Neiva *et al*. (2012) that fried fish crackers have a high fat content of 26.11±0.5%.

During frying, the heating process affects the quality of cooking oil through hydrolysis and oxidation. Repeated heating increases the free fatty acids level, which causes damage to cooked food and an increase in the fat content of the final product (Nizori and Mishra, 2018). Furthermore, frying at high temperatures is very dangerous to health because the consumption of excess oil causes heart disease and increased cholesterol levels (Indriani *et al*., 2019). The microwave oven is an

*Corresponding author.
Email: *prad011@brin.go.id*

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efficient alternative to the conventional method, where food molecules are subjected to radiation, which causes rotation due to the absorption of electromagnetic energy (Kutlu *et al*., 2021). This method also helps to produce low-fat food as well as maintain product quality and acidity of n-3 polyunsaturated fatty acids (PUFAs) (Regulska-Ilow and Ilow, 2002). Microwave cooking protects the structure of fatty acids and prevents the isomerization of the unsaturated variants (Oke *et al*., 2018). It can save time, generate heat faster, use energy efficiently as well as produce a final product with better quality in terms of taste, color, and nutritional content (Kutlu *et al*., 2021).

Several studies have demonstrated the use of microwave energy for food processing. Devraj *et al*. (2020) examined the effect of heating on the physicochemical and microstructural properties of two varieties of brown rice. Meanwhile, Noor *et al*. (2021) assessed the effects of conventional and microwave frying on oil absorption, texture, and physical and chemical properties of beef patties. The heating of vegetables and fruits with the method led to the irreversible degradation of polysaccharides, which caused a decrease in intercellular adhesion and softening of the food (Sila *et al*., 2006; Kamali and Farahnaky, 2015; Nguyen *et al*., 2019). Oztop *et al*. (2007) optimized the frying of potato chips using a microwave oven at 550 W for 2.5 mins to produce products with optimal texture and color. Bai-Ngew *et al*. (2011) reported that the application of a microwave vacuum led to good color retention and 90% oil reduction in durian chips. Guttifera *et al*. (2022) evaluated the physical and microstructural properties of Palembang fish crackers using the microwave oven method. There are currently no studies analyzing the chemical characteristics of Palembang fish crackers. Therefore, this study aims to determine the protein, fat, and amino acid levels of Palembang fish crackers (*kemplang*) cooked in a microwave. The results are expected to provide information about the product's nutritional content, often consumed as an alternative healthy snack by the public.

2. Materials and methods

2.1 Materials

The main ingredients used in this study were snakehead fish (*Channa striata*), tapioca flour, chicken eggs, and salt to produce fish crackers (*kemplang*). The chemicals used for protein analysis are selenium catalyst, sulfuric acid (H_2SO_4), aquadest, methylene blue and sodium hydroxide (NaOH). Fat content analysis using N-Hexane for fat solvent, then amino acid analysis using aspartic acid, glutamic acid, serine, histidine, glycine, threonine, alanine, tyrosine, methionine, phenylalanine, isoleucine, lysine, lysine, chloride acid, N_2 gas, potassium pH 10.4 OPA 10.4, and H.P air (pure high).

2.2 Sample preparation

Kemplang sample preparation consisted of mixing, molding into cylinders, steaming, slicing, drying, and heating with a microwave oven. The *Kemplang* formulation in this study is shown in Table 1. A 600 g of dough was weighed with an analytical balance (Mettler Toledo AL-204) and then divided into 8 parts. Each piece was shaped into a cylinder with a diameter of 2 cm and a length of 20 cm. They were then steamed for 30 mins at 100-110°C and cooled for 36 hrs. Subsequently, the slicing stage was carried out by cutting the dough into a thickness of 4 mm, followed by drying at 55°C until the water content was suitable for treatment B1 (7.5±1%, for 18 hrs) and B2 (13.5±1%, for 24 hrs). Subsequently, five samples were heated with a microwave oven (LG MS2042D) at the automatic energy level for 50 s.

2.3 Water content

The water content was measured using the SNI (Indonesian National Standard) method 01-2354-2-2006. Approximately 2 g of the sample was ground and weighed using an analytical balance, after which it was dried in a non-vacuum oven at 105°C for 16-24 hrs. It was transferred from the cup to a desiccator for 30 mins and weighed again until constant. The water content is measured by the equation below (thermogravimetric):

$$\text{Water content (\%)} = \frac{m1-m2}{m2} \times 100\%$$

Table 1. Palembang fish crackers (*kemplang*) formulation heated using a microwave oven.

Materials	Sample Code					
	A1B1	A2B1	A3B1	A1B2	A2B2	A3B2
Water (mL)	600	570	540	600	570	540
Fish Meat (*Channa striata)* (g)	600	600	600	600	600	600
Tapioca (g)	1500	1500	1500	1500	1500	1500
Salt (g)	42	42	42	42	42	42
Egg Yolk (mL)	-	30	-	-	30	-
Whole Egg (mL)	-	-	60	-	-	60

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Where m1 = initial mass (g) and m2 = dried mass sample after drying (g)

2.4 Protein content

Protein content was measured using the Association of the Official Analytical Collaboration (AOAC) International method 01-2354.4-2006. Protein analysis was carried out by the Kjeldahl method which consists of destruction, distillation, and titration. A total of 0.3 g sample was weighed and put into a 50 mL Kjeldahl flask then 20 mL H_2SO_4 and Se catalyst were added and heated until the solution color changed to clear green. After the solution was cool, then add 500 mL of distilled water into the distilled and homogenized. The results were titrated using NaOH until the color changed to green. The solution was dripped with H_2SO_4 until the color returned to its original blue color to find out the excess of titration. The crude protein was calculated using the following formula.

$$\text{Protein content (\%)} = \frac{(\text{NaOH Volume} - \text{Titration Volume}) \times \text{N NaOH} \times 6.25 \times 14}{\text{Weight of Sample (g)}} \times 100\%$$

2.5 Fat content

Fat content was measured using the SNI (Indonesian National Standard) 01-2354.3-2006 method by weighing the empty round bottom flask, and 2 g of the sample was placed in a fat sleeve. Approximately 150 mL of chloroform was put in a round bottom flask, and the fat shell was arranged into a Soxhlet extractor. Subsequently, the extraction process was conducted at 60°C for 8 hrs. Evaporation of the mixture of fat and chloroform was performed until the sample was dry. The round bottom flask containing fat was then placed in an oven at 105°C for 2 hrs to remove the residual chloroform and water vapor. The flask was cooled in a desiccator for 30 mins and then weighed.

$$\text{Fat Content (\%)} = \frac{W_3 - W_2}{W_1} \times 100\%$$

Where W_1 = Weight of sample (g), W_2 = Weight of flask without fat content (g) and W_3 = Weight of flask with fat content (g).

2.6 Amino acid content

The amino acid content was determined using the IK.LP-04.7-LT-1.0 HPLC (High Performance Liquid Chromatography) method. The sample was hydrolyzed in 5 mL of 0.01 N HCl, and it was filtered through a 0.45 -micron Millipore filter paper. Subsequently, potassium borate buffer (pH 10.4) was added in a ratio of 1: 1.5, and the mixture was placed in a clean empty vial. Then, 25 µL of OPA reagent was added, and it was allowed to stand for 1 min to complete the derivatization process. 5 µL of the sample was injected into an HPLC column (Water Corporation, USA) for 35 mins. The amino acid standard has 15 components: aspartic acid, glutamate, serine, histidine, glycine, threonine, arginine, alanine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine and lysine.

2.7 Statistical analysis

The data were analyzed using the Analysis of Variance (ANOVA) and then continued with the 5% BNJ test (Honest Significant Difference) for treatments with a significant effect. A confidence level above 95% ($p<0.05$) was considered statistically significant. Furthermore, a factorial randomized block design was used, and the factors include the addition of chicken eggs (A1= control without adding eggs; A2= adding egg yolk; A3= adding egg white and yolk) as well as the difference in water content (B1= 7.5±1% of water content; B2= 13.5±1% of water content). This research has 6 different treatments which consist of (A1B1= without adding egg with 7.5±1% of water content; A2B1= adding egg yolk with 7.5±1% of water content; A3B1= adding egg white and yolk with 7.5±1% of water content; A1B2= without adding eggs with 13.5±1% of water content; A2B2= adding egg yolk with 13.5±1% of water content; A3B2= adding egg white and yolk with 13.5±1% water content). Furthermore, the research results were compared with the Indonesian National Standard (SNI) number 01-2713 -1999 (Table 2).

Table 2. Chemical content comparisons of Palembang fish crackers (*kemplang*) and conventional fish crackers based on SNI (Indonesian National Standard) number 01-2713-1999.

Chemical Content	Conventional Crackers (% Based on SNI)	Palembang Fish Crackers (% Based on Research)
Water Content	Maximum 11	7.33
Protein Content	Minimum 6	33.78
Fat Content	Maximum 0.5	0.46

3. Results and discussion

3.1 Moisture content

Figure 1 shows the results of the average water content test in *kemplang* before and after heating. The highest and lowest water content was found in the A1B2 and A3B1 treatments at 14.20% and 7.33%, respectively. However, the average water content of this fish type cooked in a microwave oven is from 3.55% to 7.05%, indicating the lowest and highest in treatment A1B1 and A1B2, respectively.

Table 3 presents the diversity analysis in the treatment of *kemplang* before heating. It showed that factors A (addition of eggs) and B (water content) had a significant effect on water content, while the interaction between them had no significant effect. Furthermore, after heating the fish crackers in a microwave oven, the

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Table 3. Statistical results of the eggs addition, water, and their interaction with the chemical content of *kemplang* heated in a microwave oven.

Factor	Sample Code	Chemical Analysis					
		Water Content		Protein		Fat	
		SB	ST	SB	ST	SB	ST
A	A1	11.35[c]	tn	17.39[a]	29.71[a]	0.80[a]	0.63[a]
	A2	10.60[b]	tn	18.24[b]	31.19[b]	2.48[b]	2.20[b]
	A3	10.01[a]	tn	19.02[c]	33.11[c]	3.24[c]	3.09[c]
B	B1	7.92[a]	4.46[a]	tn	32.09[b]	2.02[a]	1.79[a]
	B2	13.38[b]	6.50[b]	tn	30.58[a]	2.33[b]	2.17[b]
AB	A1B1	tn	3.55[a]	17.05[a]	tn	tn	0.46[a]
	A2B1	tn	5.18[bc]	18.40[ab]	tn	tn	1.88[b]
	A3B1	tn	4.64[b]	19.31[b]	tn	tn	3.01[d]
	A1B2	tn	7.05[d]	17.73[ab]	tn	tn	0.80[a]
	A2B2	tn	5.74[c]	18.07[ab]	tn	tn	2.52[c]
	A3B2	tn	6.71[d]	18.73[d]	tn	tn	3.18[d]

Values with different superscripts within the same column are statistically significantly different. tn: not significant, sb: sample before being heated in the microwave oven, st: sample after being heated in a microwave oven.

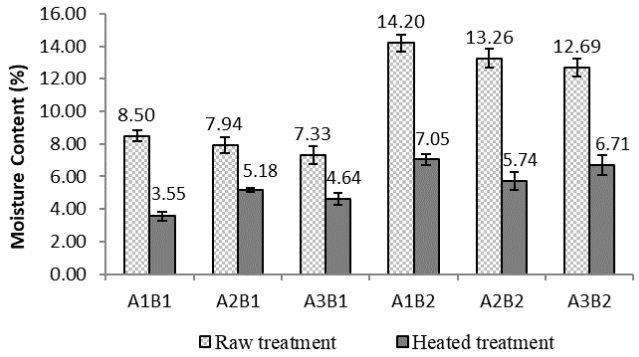

Figure 1. Water content of Palembang fish crackers (*kemplang*).

results showed that factor A had no significant effect on the water content in contrast to B and their interaction.

The B2 treatment of *kemplang*, heated in a microwave oven, had a higher water content than B1, hence, it absorbs more microwaves. As a result, the sample produces more heat more quicker since water is rapidly converted to vapor pressure while interacting with microwaves (Nguyen *et al*., 2013). The puffing process is enhanced by very hot steam, producing pressure (Moraru and Kokini, 2003). The rotation of the two poles (dipolar) of a microwave, when it interacts with water, generates heat and causes *kemplang* to expand quickly and evenly. However, a high moisture content does not always result in the good expansion of semi-dried products. According to Nguyen *et al*. (2013), for a semi-dried product to expand properly, it requires an appropriate moisture content. This statement is in agreement with Lee *et al*. (2000), who reported that puffing starch pellets expanded optimally at a 13% water content in contrast to 20%.

Figure 1 shows that treatment A1 (without the addition of eggs) had the highest water content compared to A2 and A3. The addition of eggs is thought to form a more porous structure for the easy access of water away from the material. In addition, egg whites could form a hollower structure to transfer water mass from the material to the surface quickly.

3.2 Protein content

The average protein content in *kemplang* before being heated in a microwave oven was 17.05% to 19.31%. The highest and lowest protein content was in treatments A3B1 and A1B2, respectively. After heating the values range from 29.16% to 33.78%. Figure 2 presents the analysis of the protein content of *kemplang* before and after treatment.

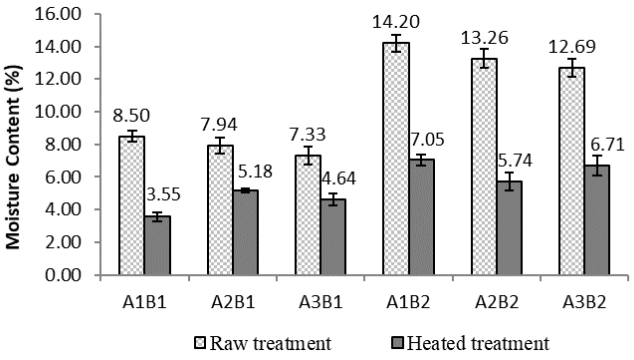

Figure 2. The protein content of Palembang fish crackers (*kemplang*).

Table 3 presents the statistical results through an analysis of diversity. It shows that factor A (addition of eggs) and its interaction with B have a significant effect. Meanwhile, factor B (water content) has no significant effect on the protein content of *kemplang* before being heated in a microwave oven. The diversity analysis of

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this fish type after being heated showed that factors A and B significantly affected the protein content compared to the interaction between them.

The statistical analysis results for the 5% BNJ test in Table 3 demonstrate the effect of adding eggs to *kemplang's* protein content before and after microwave heating. The high protein content in the A3 treatment was caused by snakehead fish (*Channa striata*) and additional components used in manufacturing *kemplang*. This fish type has a relatively high protein content of 22.1% w/w (Prasetya, 2009). According to the Indonesian Health Ministry (1981), eggs contain significant protein, with the egg white and yolk taking 10.8 and 16.3%, respectively.

The protein content in crackers is determined by the composition of the raw materials used. Snakehead fish meat is used as a protein source and starch flour is used to give the cracker viscosity and texture. The ratio of fish and starch plays a role in product volume expansion, crispness and consumer acceptance (Zzaman *et al*., 2017). Suryaningrum *et al*. (2016) explained that the ratio of starch and fish affects the water migration pattern in the dough during gelatinization which affects the product volume expansion. Some types of protein can increase the volume expansion because it can increase the viscosity of the extrudate due to cross-linking of proteins. In addition, proteins also play a role in volume expansion through their ability to influence the water distribution in the matrix and through their conformation and micromolecular structure (Moraru and Kokini, 2003).

Some of the protein components in eggs have non-polar properties, while those capable of interacting with microwaves are polar. The components that cannot interact with microwaves include globulins in snakehead fish (*Channa striata*) and egg yolks, which inhibit the absorption of heat into the material, preventing the *kemplang* from expanding ideally (Winarno, 1991). The expansion volume in treatment A3 was greater than A2 due to the addition of egg white. This is in agreement with Hartomo (1993), who reported that egg whites containing much albumin proteins are applied to develop food ingredients. Egg white albumin is a polar component interacting with microwaves to produce more heat than *kemplang* with the addition of only yolk. The results of this study are in agreement with Alavi *et al*. (1999), who reported that egg white protein increases the expansion ratio from 140 to 341%.

3.3 Fat content

The results showed that all treatments decreased fat content before and after heating with a microwave oven. The increase in fat oxidation was fastened by raising the temperature. Meanwhile, according to Rianingsih (2006), the decrease in fat is influenced by high temperature and long heating time. Figure 3 shows the fat content of *kemplang* before and after being heated in a microwave oven. The average fat content in this fish type was between 0.68 to 3.38% and 0.46 to 3.18%, respectively. The highest and lowest value was discovered in the A3B2 and A1B1 treatments, respectively. The analysis of diversity in fat content showed that factors A (addition of eggs) and B (water content) significantly influenced *kemplang* before and after heating using a microwave oven, while the interaction between them only had a significant effect after heating.

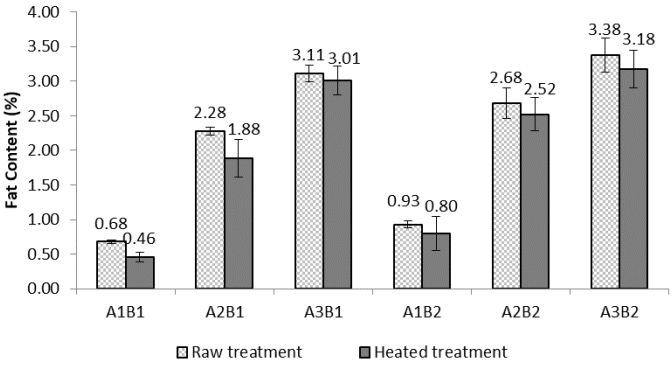

Figure 3. Fat content of Palembang fish crackers (*kemplang*).

Table 3 presents the BNJ test at a 5% level, showing the effect of adding eggs to the fat content of *kemplang* before and after microwave cooking. The high fat content in treatment A3 was thought to be due to the addition of eggs. The egg yolks contain about 31.9% fat (Indonesian Health Ministry, 1981), it was assumed that the high-fat content in A3 compared to A2 was due to differences in the percentage of egg composition added.

Fat reduces the conversion of starch during the gelatinization process by preventing mechanical damage to the granules, water absorption, reducing the conversion of starch (gelatinization), and subsequently reducing the volume expansion when heated in a microwave oven. Lecithin is a component of fat contained in eggs, inhibiting heat absorption. Furthermore, its content in yolk functions as an emulsifier, which causes the formation of bonds between fat and water fractions, making it difficult for water to interact with microwaves (Nguyen *et al*., 2013). When food is microwaved for a short time, the bound water inside becomes difficult to evaporate (Nguyen *et al*., 2013). As a result, with the addition of the egg, the fifty-second puffing time will not be enough to expand the *kemplang*, resulting in a hard texture.

3.4 Amino acid content

The amino acid analysis results were based on the

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best volume development in a previous study in Table 4, such as *kemplang* ripened in a microwave oven in the A1B2 treatment (Guttifera *et al*., 2020). In the amino-acids analysis of *kemplang* before and after being heated using a microwave oven, fifteen of its types were discovered. The highest and lowest value was found in glutamic acid and histidine at 0.89 and 1.15%, as well as 0.09% and 0.13% before and after heating, respectively. This implies that its value increases when *kemplang* is heated using a microwave oven. The results are in agreement with Liuhartana *et al*. (2013), which reported that the cooking process increases the amino acids in the ingredients.

Table 4. Amino acid composition of *kemplang* in A1B2 treatment (before and after heating using microwave oven).

Amino Acid Parameter	Results	
	Kemplang Before heating in the microwave (% w/w)	*Kemplang* After heating in the microwave (% w/w)
Aspartic acid	0.56	0.74
Glutamic acid	0.89	1.15
serine	0.25	0.38
histidine	0.09	0.13
glycine	0.19	0.25
threonine	0.18	0.25
arginine	0.25	0.34
Alanine	0.32	0.42
Tyrosine	0.13	0.17
methionine	0.13	0.15
Valin	0.25	0.32
Phenylalanine	0.23	0.30
I-leucine	0.27	0.34
leucine	0.44	0.57
lysine	0.44	0.55
Total Amino Acid	4.61	6.07

Amino acid is formed due to protein denaturation. The radiation from microwave breaks peptide bonds through local interactions with each polarized amide group (Liuhartana *et al.,* 2013). Furthermore, microwave heating increases the amino acid content compared to the conventional oven. Microwave-oven can break down complex structures (Xiang *et al*., 2020).

4. Conclusion

The characteristics of *kemplang* crackers, which are processed using the microwave-oven method, produced the highest and lowest water content in A1B2 and A3B1 at 14.20% and 7.33%, respectively. The highest and lowest protein content was discovered in A3B1 and A1B2 at 33.78% and 29.16%, while fat was in A3B2 and A1B1 at 3.18% and 0.46%, respectively. Therefore, *kemplang* crackers with an egg-based dough formulation and a moisture content of 13.5±1% produced the appropriate characteristics and can be recommended for healthy food based on Indonesian National Standard (SNI) number 01-2713-1999.

Conflict of interest

The authors declare no conflict of interest.

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