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Physicochemical and Nutritional Characteristics of Indonesian Buffalo Skin Crackers

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ABSTRACT

In the present study, two different samples of buffalo skin crackers were analyzed for their chemical composition, linear expansion, specific volume, color and amino acid content. The method of analysis is according to official method. The results indicated that both buffalo skin cracker samples had high protein content and that pre-fried skin crackers contained more protein than fried skin crackers. The expansion parameters of the buffalo skin crackers indicated that the sample that was lighter in weight, of smaller size and of lower moisture content expanded more during frying. According to amino acid data, the most common amino acid in the buffalo skin crackers was glycine. Chemical score, amino acid score and amino acid index were calculated from the amino acid data; these results indicated that the quality of protein in the buffalo skin crackers was lower than that of meat. Skin crackers have higher protein content but lower protein quality than common meat products in the market. The attendance of this cracker was diversifying the meat-based food products.

Key words: Buffalo byproduct, skin crackers, physicochemical properties, amino acid composition, protein quality

INTRODUCTION

Most Asian countries are agrarian, that is, 60 to 80% of the population is engaged in or related to farm operations in one way or another. Livestock has been an integral component of traditional agriculture. In Asia, buffalo (*Bubalus bubalis*) play a pivotal role in overall social development; they provide milk, meat, skins and draft power for agricultural operations. Buffalo form a vital part of the property, possessions and profession of rural farmers. They are also an easily convertible currency and a reliable 'living bank' to serve the immediate needs of rural populations in several communities. Buffalo are widely utilized for meat production; domestic and export markets are rapidly expanding in India and Southeast Asia as meat demand increases and the animals are assuming an important role in the socioeconomic development of rural Asia (Nanda and Nakao, 2003).

The animals are mainly slaughtered for meat, which forms the most important product; all other parts become byproducts. These byproducts are subdivided into edible and non-edible materials. Byproducts constitute nearly 60 to 70% of the slaughtered carcass; 40% of these

byproducts are edible and 20% are inedible (Ranganayaki and Srinivasan, 1999). Subba (2002) reported that meat byproducts constitute 50 to 60% of slaughtering yield, depending upon animal species. The utilization of such byproducts is important for the viability of the meat industry. These byproducts are used both as food and for non-food purposes, but there are some edible meat byproducts that have not been optimized for human consumption. Pearl (2004) noted that, based on value and volume, the largest component of animal byproducts is skin.

The chemical composition of a particular animal skin varies with the animal's age, its sex, its fat level and the treatment the skin has received after being removed from the carcass. In general, skin is low in fat and minerals and high in protein. The composition of steer skin is 61.2% moisture, 35.0% protein, 3.2% fat and 1.1% ash. The amino acid composition of collagen is essentially the same as that of gelatin (Idson and Braswell, 1957). Related to amino acid composition of skin, Li *et al.* (2004) found that glycine, proline, lysine are the higher amino acid composition both in calf and bullfrog skin collagen. Schrieber and Gareis (2007) noted that glycine alone constitutes approximately 33% of amino acid component, proline and hidroxiproline together about 22%. Poppe (1999) noted that all the amino acids that occur in proteins are present in gelatin with the probable exception of tryptophan and cysitine, although the latter is sometimes detected in trace amounts.

The thickness of the skin varies with species, age, sex and region of the body (thicker on the back and on the external surfaces of the limbs, thinner on the ventral and on the flexon surfaces (Ockerman and Hansen, 1999). Spanghero *et al.* (2004) reported that the skin fold thickness of buffalo (1.97 cm) is higher than the skin fold thickness of bovines (1.30 cm). Furthermore, that study measured the percentage of fifth quarter composition of buffalo and bovines, which includes skin, whole skin, fore- and hind legs, the entire digestive tract, lights (lungs, trachea, heart, spleen, diaphragm and liver) and tail. The data from that study indicated that buffalo skin percentage (11.5%) is higher than bovine skin percentage (9.0%) in regards to fifth quarter composition. Ockerman and Hansen (1999) observed that the range of skin yield (percentage of live weight) of cattle was 5.1 to 8.5%, whereas that of sheep and lamb was from 11.0 to 11.7%.

Most frequently, animal skin and bone is used for commercial gelatin production (Veis, 1964; Ward and Courts, 1977). Fish skin has also been utilized for commercial purposes; in recent years, it has been used to produce gelatin (from cod, for example (Gudmunsson and Hafsteinsson, 1997) and from black and red tilapia (Jamilah and Harfinder, 2002). Leather is another buffalo skin-based product that contributes to world markets (Nanda and Nakao, 2003). The use of skin for producing gelatin, leather and other products has proven commercially viable. However, the use of buffalo skin for direct consumption in the form of crackers also possesses significant commercial potential, particularly because of its skin fold thickness and the high percentage of buffalo byproduct it represents.

Crackers are a food product produced by frying. Crackers are usually produced from a plant source, viz., cassava (Lertworasirikul, 2008), a mixture of sago and cassava starch (Tongdang *et al.*, 2008), rice (Maneerote *et al.*, 2009; Sirpatrawan, 2009), glutinous rice, rice, tapioca, corn, sago, wheat and mungbean (Mohamed *et al.*, 1988). Fish and its derivates have also been used as cracker ingredients, as in fish crackers or keropok (Yu *et al.*, 1981; Siau *et al.*, 1985; Jamilah *et al.*, 1998; Cheow *et al.*, 1999, 2004; Kyaw *et al.*, 2001), surimi powder crackers (Huda *et al.*, 2000), big-eye fish crackers (King, 2002), fish protein hydrolysate crackers (Yu and Tan, 1990) and keropok lekor (Nor-Khaizura *et al.*, 2009). In addition, prawn meat has been used to make crackers (Omobuwajo, 2003). Julianty *et al.* (1994) have also added egg white powder to make fish crackers. The use of offal in cracker production was studied by Subba (2002), who mixed

spleen, lung, liver and bone into the cracker formulation. The use of milk products for the production of cheese crackers has been studied by Pozo-Bayón *et al.* (2009).

In West Sumatra Province in Indonesia, there is one traditional cracker not found in other regions. It is made from buffalo skin and known locally as karupuak jangek. The term originates from the Western Sumatran Minangkabau language, in which karupuak means crackers and jangek means skin. However, when buffalo skin becomes scarce, cow skin is usually used as an alternative.

Processing the buffalo skin involves boiling it, scraping away the hair, cutting into the skin into a size suitable for commercialization, then salting, drying, pre-frying (latua) and frying it. The fried skin cracker can be consumed directly, but most people usually eat it with foods like satay, soto and cooked rice. The crackers are usually produced in home industries in two forms: pre-fried skin crackers (latua crackers or ready-to-cook skin crackers) and fried skin crackers (ready-to-eat skin crackers). The production of pre-fried skin crackers aims to provide early thermal processing to minimize the moisture still present in sun-dried crackers. Pre-frying gives the crackers a higher degree of expansion in the final frying process. The pre-fried crackers provide consumers with the option of ready-to-cook crackers so that they can cook freshly made crackers when they want them. Fried crackers cannot be stored for long, as they lose crispiness.

MATERIALS AND METHODS

Raw material: Two brands of pre-fried buffalo skin crackers were purchased from markets in Padang, West Sumatra, Indonesia at March 2008. The samples were brought to the Fish and Meat Processing Laboratory, Food Technology Programme, School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia, for further processing and analysis. All analysis was completed at June 2009. The proximate (moisture, protein, fat and ash) and color analysis was run six times, the physical properties analysis thirty-six times and the amino acid analysis twice.

Frying of buffalo skin crackers: Frying of the buffalo skin crackers was carried out using a Single Pan Deep Fat Fryer (ANVIL, South Africa) with palm oil at 180°C for 1 min.

Proximate composition: The macronutrient of buffalo skin crackers was determined according to AOAC (1998) procedures. Crude protein content was determined using the Kjehdahl method (AOAC, Method 955.04). Crude lipid content was determined by the Soxhlet method (AOAC, Method 920.39). Ash content was determined by drying the sample overnight at 550°C (AOAC, Method 932.03).

Volume of crackers: The volume of the crackers was measured using beads and a volumetric glass container, according to Zulviani (1992). Pieces of each samples were placed vertically in the glass container, which was filled to about a quarter of its volume with beads. More beads were then added to the glass until it was full and a flat surface was achieved. The volume of beads was then measured using the volumetric glass. The volume of crackers was determined to be V2-V1.

V1 = Beads volume without sample
V2 = Beads volume filled with sample

Specific volume of crackers: Specific volume was defined as the volume of the crackers divided by the weight of the crackers as described by Zulviani (1992). The weight of the sample was measured using a digital balance (MA150 C Sartorius moisture balance).

$$\text{Specific volume} = \frac{V2 - V1}{W}$$

Where:
V1 = Bead volume without sample
V2 = Bead volume filled with sample
W = Sample weight

Expansion volume of crackers: Expansion volume was determined according to Rosmawaty *et al.* (1996) by calculating the specific volume of fried skin crackers and the specific volume of pre-fried skin crackers as follows:

$$\text{Expansion volume} = \frac{Vf - Vp}{Vp} \times 100$$

Where:
Vf = Specific volume of fried skin crackers
Vp = Specific volume of pre-fried skin crackers

Linear expansion of crackers: Linear expansion was determined using the modified method of Cheow *et al.* (2004). The skin crackers were ruled with three lines using a fine oil pen. Each line was measured for pre-fried and fried crackers. The percentage linear expansion was calculated as follows:

$$\text{Percentage linear expansion} = \frac{Lp - Lf}{Vp} \times 100$$

Where:
Lp = Length fried skin crackers
Lf = Length pre-fried skin crackers

Colorimetric of crackers: Color measurement was based on a CIE (1978) system color profile. L*, a*, b*, c* and H° values were measured by a reflectance colorimeter (Minolta Spectrophotometer CM-3500d, Japan). Throughout the study, the colorimeter was calibrated using a standard white ceramic tile.

Amino acid of crackers: The test samples were hydrolyzed in duplicate with 6 N HCl at 110° C for 24 h and derivatized with AccQ reagent (6-aminoquinolyl-N-hydroxysuccinimdyl carbamite) before chromatographic separation using an AccQ Tag™ reversed phase (3.9×150 mm) analytical

column (Waters®). The amino acid analysis was performed on a HPLC system comprised of a Waters 1525 Binary HPLC Pump, a 717 Plus autosampler (Waters®) and a Waters 2475 Multi λ Fluorescence detector (wavelength excitation 250 nm, emission 395 nm). Chromatographic peaks were integrated, identified and quantified with Breeze™ software version 3.20 by comparing them to known standards (amino acid standard H, Pierce, Rockford, Illinois). Methionine and cysteine were determined by the same method (acid hydrolysis after treatment with performic acid oxidation). Tryptophan was not analyzed in this study since the primary content of the skin is collagen. Heinz and Hautzinger (2007) noted that collagen is digestible, but is devoid of the essential amino acid tryptophan.

Chemical score of crackers: The chemical score was determined by comparing the essential amino acid content of the crackers and the amino acid content of egg as a standard (Acton and Rudd, 1987). The essential amino acid (EAA) content of egg, according to the FAO (1970) report is: lysine 6.98, methionine + cysteine 5.79, isoleucine 6.29, leucine 8.82, valine 6.85, phenylalanine + tyrosine 9.89 and tryptophan 1.49/100 g protein.

Amino acid score of crackers: The amino acid score was determined by comparing the essential amino acid content of the samples with the amount of amino acid content suggested for human nutritional needs (Sawar and Mcdonough, 1990) the amount suggested for humans aged 2-5 years old was used in the present study (FAO/WHO/UNU, 1985). The amounts of essential amino acid content recommended for human needs were histidine 1.9, lysine 5.8, methionine + cysteine 2.5, threonine 3.4, isoleucine 2.8, leucine 6.6, valine 3.5, phenylalanine + tyrosine 6.3 and tryptophan 1.1 g/100 g.

Amino acid index of crackers: Amino acid index determination was obtained from the chemical score data. The score obtained for every amino acid was then converted to $\log_{10}$. The average of the scores was converted to antilog to determine the amino acid index score (Acton and Rudd, 1987).

Statistical analysis: The data collected were analyzed using Statistic Package for Social Science (SPSS), version 11.5. Means of the treatment showing significant differences ($p<0.05$) were subjected to a t-test.

RESULTS

The proximate compositions of buffalo skin crackers: Proximate analysis showed that there were significant differences between pre-fried and fried skin crackers, especially in terms of moisture, protein and fat content. As shown in Table 1, the moisture content decreased after frying from 6.53 to 3.27% (sample A) and 5.78 to 3.00% (sample B) and the protein content of the samples decreased from 81.09 to 77.23% (sample A) and 79.22 to 75.59%. On the other hand, the fat content increased after frying from 8.14 to 14.94% (sample A) and 10.66 to 16.22% (sample B).

Physical properties of buffalo skin crackers: As shown in Table 2, the pre-fried skin crackers and fried skin crackers were analyzed to determine weight, volume, length and specific volume.

Table 1: Proximate composition of different buffalo skin crackers

Processing stage	Sample	Moisture	Protein	Fat	Ash
Pre-fried	A	6.53 ± 0.06^{Aa}	81.09 ± 0.89^{Aa}	8.14 ± 0.18^{Bb}	3.35 ± 0.24^{B}
	B	5.78 ± 0.16^{Ba}	79.22 ± 0.50^{Ba}	10.66 ± 0.69^{Ab}	3.65 ± 0.19^{Ab}
Fried	A	3.27 ± 0.09^{Ab}	77.23 ± 0.58^{Ab}	14.94 ± 0.51^{Ba}	3.65 ± 0.28^{B}
	B	3.00 ± 0.09^{Bb}	75.59 ± 0.34^{Bb}	16.22 ± 0.63^{Aa}	4.23 ± 0.22^{Aa}

^{AB}Means with different letter(s) of samples A and B in the same processing stage are significantly different ($p<0.05$). ^{ab}Means with different letter(s) of pre-fried and fried samples in the same branch are significantly different ($p<0.05$)

Table 2: The weight, volume, length, specific volume, expansion volume and linear expansion of different buffalo skin crackers

Processing stage	Sample	Weight	Volume	Length	Specific volume	Expansion volume	Linear expansion
Pre-fried	A	2.30 ± 0.50^{A}	9.06 ± 2.14^{A}	2.30 ± 0.31^{A}	4.01 ± 0.93^{A}	-	-
	B	1.62 ± 0.60^{Bb}	3.75 ± 1.12^{Bb}	1.83 ± 0.25^{Bb}	2.45 ± 0.67^{Bb}	-	-
Fried	A	2.46 ± 0.50^{A}	18.03 ± 3.28^{A}	3.62 ± 0.42^{A}	7.46 ± 1.29	91.35 ± 37.85^{B}	58.07 ± 13.25^{B}
	B	1.93 ± 0.59^{Ba}	14.50 ± 2.80^{Ba}	3.06 ± 0.39^{Ba}	7.97 ± 2.12^{a}	233.55 ± 68.70^{A}	68.23 ± 14.74^{A}

^{AB}Means with different letter(s) of samples A and B in the same processing stage are significantly different ($p<0.05$). ^{ab}Means with different letter(s) of pre-fried and fried samples in the same branch are significantly different ($p<0.05$)

Table 3: The color of different buffalo skin crackers

Processing stage	Sample	L*	a*	b*	C*	H°
Pre-fried	A	52.63 ± 0.89^{a}	4.70 ± 0.45^{a}	23.55 ± 0.26^{Ba}	24.00 ± 0.30^{Ba}	78.73 ± 0.98^{a}
	B	53.46 ± 0.80^{a}	4.96 ± 0.40	24.51 ± 0.30^{Aa}	24.98 ± 0.30^{Aa}	78.51 ± 0.95^{a}
Fried	A	63.90 ± 0.52^{b}	5.31 ± 0.20^{b}	30.99 ± 0.50^{Ab}	31.56 ± 0.53^{Ab}	80.34 ± 0.37^{b}
	B	64.11 ± 0.37^{b}	4.98 ± 0.31	29.63 ± 0.30^{Bb}	30.02 ± 0.37^{Bb}	80.47 ± 0.64^{b}

^{AB}Means with different letter(s) of samples A and B in the same processing stage are significantly different ($p<0.05$). ^{ab}Means with different letter(s) of pre-fried and fried samples in the same branch are significantly different ($p<0.05$)

Those results were used to determine expansion volume and linear expansion of buffalo skin crackers. The score of expansion volume had a range of 91.35 to 233.55% and the linear expansion had a range of 58.07 to 68.23%.

Color (L*, a*, b*, c* and H°) of buffalo skin crackers: In general, the buffalo skin crackers' color showed increases in all color parameters for both sample A and sample B after frying. The increase in color I ntensity ($p<0.05$) can be seen in Table 3 in which L* value increased after frying from 52.63 to 62.90 (sample A) and 53.46 to 64.11 (sample B),a* value increased after frying from 4.70 to 5.31 (sample A), b* value increased after frying from 23.55 to 30.99 (sample A) and 24.51 to 29.63, c* value increased after frying from 24.00 to 31.56 (sample A) and 24.98 to 30.02 and H° value increased after frying from 78.73 to 80.34 (sample A) and 78.51to 80.47.

Amino acid composition, chemical score, amino acid score and EAA index of buffalo skin crackers: The amino acid contents of the skin crackers were obtained after frying. Table 4 shows that glycine was the most prevalent among the 17 amino acids, while the others were low in concentration. As described in Table 5, those parameters for protein quality were obtained from the amino acid composition of fried skin crackers.

Table 4: Amino acids of different fried buffalo skin crackers and comparison with other skin-based material

	Buffalo skin crackers					
Amino acid	Sample A	Sample B	Ox-skin collagen[a]	Ox-skin gelatine[b]	Calf skin collagen[c]	Fish (carp) skin[d]
Essential amino acid						
Cystine	2.47±0.15	2.29±0.26	-	-	-	-
Histidine	3.30±0.00	3.55±0.49	0.70	0.78	0.50	0.50
Isoleucine	2.05±0.05	2.02±0.09	1.88	1.72	1.10	1.00
Leucine	4.03±0.09	3.94±0.13	3.73	3.33	2.30	2.20
Lysine	3.61±0.05	3.40±0.24	3.96	4.50	2.60	2.80
Methionine	2.03±0.53	1.75±0.24	0.97	0.89	0.60	1.40
Phenylalanine	2.67±0.07	2.72±0.35	2.35	2.23	0.30	1.30
Threonine	3.68±0.00	4.04±0.55	2.26	2.22	1.80	2.40
Tyrosine	0.94±0.01	1.03±0.17	0.99	0.29	0.30	0.30
Valine	2.73±0.05	2.65±0.06	2.46	2.59	2.10	1.90
Non essential amino acid						
Arginine	7.89±0.22	7.98±0.64	8.22	8.80	5.00	5.50
Alanine	11.02±0.24	10.50±0.42	10.32	11.00	11.90	11.80
Aspartic acid	5.61±0.33	5.32±0.40	6.95	6.70	4.50	4.90
Glutamic acid	9.94±0.31	10.74±0.88	11.16	11.40	7.50	7.60
Glycine	22.29±0.41	23.08±1.73	26.57	27.50	33.00	33.20
Proline	11.37±0.20	11.19±0.31	14.42	16.35	12.10	11.40
Serine	4.01±0.04	3.81±0.11	4.27	4.21	3.30	3.50

[a]Bowes *et al.* (1955), [b]Eastoe (1955), [c]Giraud-Guille *et al.* (2000) and [d]Duan *et al.* (2009)

Table 5: Chemical score, amino acid score and EAA index of different fried buffalo skin crackers and comparison with other skin-based material

	Chemical score					
	Buffalo skin crackers					
Amino acid	Sample A	Sample B	Ox-skin collagen[a]	Ox-skin gelatin[b]	Calf skin Collagen[c]	Fish skin[d]
Histidine						
Lisine	51.68	48.74	56.73	64.47	37.25	40.12
Metionine+sistine	77.80	69.77	16.75	15.37	10.36	24.18
Treonina	71.81	78.92	44.14	43.36	35.16	46.88
Isoleusina	32.64	32.10	29.89	27.35	17.49	15.90
Leusina	45.69	44.62	42.29	37.76	26.08	24.94
Valina	39.85	38.68	35.91	37.81	30.66	27.74
Fenilalanina+tirosina	36.46	37.92	33.77	25.48	6.07	16.18
Triptophan						
Result	32.64	32.1	16.75	15.37	6.07	15.90
	Amino acid score					
	Buffalo skin crackers					
Amino acid	Sample A	Sample B	Ox-skin collagen[a]	Ox-skin gelatin[b]	Calf skin Collagen[c]	Fish skin[d]
Histidine	173.80 (100)	187.05 (100)	36.84	41.05	26.32	26.32
Lisine	62.19	58.66	68.28	77.59	44.83	48.28
Metionine+sistine	180.17 (100)	161.58 (100)	38.80	35.60	24.00	56.00
Treonina	108.14 (100)	118.84 (100)	66.47	65.29	52.94	70.59

Table 5: Continued

	Amino acid score					
	Buffalo skin crackers					
Amino acid	Sample A	Sample B	Ox-skin collagen[a]	Ox-skin gelatin[b]	Calf skin Collagen[c]	Fish skin[d]
Isoleusina	73.31	72.10	67.14	61.43	39.29	35.71
Leusina	61.05	59.62	56.52	50.46	34.85	33.33
Valina	77.99	75.69	70.29	74.00	60.00	54.29
Fenilalanina+tirosina	57.24	59.53	53.02	40.00	9.52	25.40
Triptophan	NA	NA	NA	NA	NA	NA
Result	57.24	58.66	36.84	35.60	9.52	25.40
	EAA index					
	Buffalo skin crackers					
Amino acid	Sample A	Sample B	Ox-skin collagen[a]	Ox-skin gelatin[b]	Calf skin Collagen[c]	Fish skin[d]
Histidine						
Lisine	1.71	1.69	1.75	1.81	1.57	1.60
Metionine + sistine	1.89	1.84	1.22	1.19	1.02	1.38
Treonina	1.86	1.90	1.65	1.64	1.55	1.67
Isoleusina	1.51	1.51	1.48	1.44	1.24	1.20
Leusina	1.66	1.65	1.63	1.58	1.42	1.40
Valina	1.60	1.59	1.56	1.58	1.49	1.44
Fenilalanina + tirosina	1.569	1.58	1.53	1.41	0.78	1.21
Triptophan						
Result	48.39	51.76	35.00	33.01	19.70	26.03

[a]Calculations result from amino acid composition as reported by Bowes *et al*. (1955). [b]Calculations result from amino acid composition as reported by Eastoe (1955). [c]Calculations result from amino acid composition as reported by Giraud-Guille *et al*. (2000). [d]Calculations result from amino acid composition as reported by Duan *et al*. (2009)

DISCUSSION

The proximate compositions of buffalo skin crackers: The moisture content decreased after frying because the frying process caused moisture to evaporate from the samples. This phenomenon was supported by Moreira (2006), who reported that during the frying process, heat is transferred from the hot oil to the product surface by convection, then from the surface to the center of the chip by conduction. Liquid water moves from the inside of the chip to the evaporation zone, leaving the surface as vapor.

The decrease in the percentage of protein content after frying was relative, perhaps due to the increase in fat content after frying from the absorption of fat. This occurrence is similar to crackers made from the big-eye fish (*Brachydeuterus auritus*) as reported by King (2002), who stated that the protein content of fried crackers was lower than that of dried crackers because of the absorption of oil during frying. The protein percentage in the present study was higher than other ordinary crackers because they were produced without adding starch. As a result, the high protein content of the skin contributed to the protein content of the final product, although a slight decrease of protein occurred after processing because of oil absorption during frying. The protein content was very high compared to fish crackers with added starch, whose protein content was either 13.5 to 19.5% (Yu *et al*., 1994) or 8.3 to 16.9% (King, 2002).

Oil was absorbed as a result of expansion during frying, causing fat content after frying to increase. Some researchers have noted that high temperatures (around 160 and 180°C) cause water evaporation; the water is then transferred from the food to the surrounding oil, while oil absorbed by the food replaces part of the released water (Mellema, 2003). Oil uptake can be described by two mechanisms: (1) continuous fat absorption as part of a replacement between oil and the evaporated water and (2) an absorption process that usually occurs once frying has been completed (Saguy and Dana, 2003).

In general, the more water that is removed from the surface during deep-fat frying, the more oil that is absorbed (Ziaiifar *et al*., 2008). However, other aspects, viz. thickness and drying method before frying, can cause oil uptake to be different than the theoretical value.

In cracker production, the processing method will affect the fat content result, especially the draining time after frying. Prolonging the draining process after frying will improve the removal of oil from skin crackers. Moreira (2006) remarked that several factors affect oil absorption in fried foods, including process conditions (temperature and residence time), the initial moisture content of the product, raw material composition, slice thickness, pre-frying treatment, degree of starch gelatinization prior to frying and oil quality.

Physical properties of buffalo skin crackers: Physical properties results showed that there were differences in weight, volume and length between partially fried and fried skin crackers; however, those results affected the specific volume of both pre-fried and fried skin crackers. As shown in Table 2, sample A was heavier in weight and greater in volume and length than sample B, but exhibited a lower specific volume after it was fried. This result may be related to the interaction between the weight, volume and length of the crackers and the heat transfer of oil during the frying process. Because the pre-fried crackers were of a lower weight and smaller in volume and length in sample B, heat transfer from the oil to the crackers could have been accelerated, which would have made it easier for the oil to enter them. The specific volume thus became higher in sample B.

The fried buffalo skin crackers in sample A exhibited a linear expansion and specific volume lower than that of sample B. Table 1 shows that the moisture content of pre-fried skin crackers in sample A (6.53%) was higher than in sample B (5.78%); in the fried skin crackers in sample A, the moisture content (3.27%) was also higher than in sample B (3.00%). This expansion result was related to the total moisture of thermal treatment during drying and pre-frying. Drying and pre-frying treatments affect the total moisture in crackers. The higher the moisture loss during drying and pre-frying, the higher the linear expansion and specific volume. The greater the crackers' expansion, the less the moisture. During drying, the skins shrink and during frying, the temperature increases and the moisture still inside the skin evaporates. The process causes the skin to return to its previous (pre-drying) shape and then keep expanding to exceed normal skin dimensions, i.e., those in existence before drying created porosity in the skin via moisture loss.

The score for linear expansion and specific volume for buffalo skin crackers is in the same range as other crackers. The linear expansion range obtained for these crackers is in the range of linear expansion of commercial fish crackers, which was 45.68-125.78% (Huda *et al*., 2007) and dori fish crackers, which was 37.18-107.69% (Nurul *et al*., 2009). However, in these studies, greater linear expansion in fish crackers was related to the amount of starch used during the formulation of the fish crackers. Nurul *et al*. (2009) found that higher starch in cracker formulation showed higher linear expansion in the crackers, where the fish:flour percentages at 1.0:1.0, 1.5:1.0, 2.0:1.0 and 2.5:1.0 resulted in the following linear expansion: 107.69, 71.09, 56.28 and 37.18%, respectively.

Generally, the linear expansion and specific volume of crackers was caused by a domino effect beginning at the stage of obtaining fresh skin. Perfecting the aspects of drying, pre-frying (as an initial stage of frying) and frying affects the expansion of crackers. The difference in thickness due to the non-uniformity of the drying process will affect the results of the score of linear expansion, specific volume and expansion volume. Perfecting the drying and frying process will produce higher-quality crackers because a dry product produces better expansion. The expansion of the crackers can create internal hollows and will determine the final score for linear expansion, specific volume and expansion volume. Moreira (2006) reported that product thickness increases as a result of puffing. Fried products will shrink during frying, becoming more porous and crispy after frying. This phenomenon also occurs in tortilla chips, as shown in a study conducted by Kawas and Morreira (2001), where the product became more porous by the end of frying because of a decrease in bulk density caused by the water loss during the process. As frying time increases, the number of large pores increases, filling out the entire chip's structure in a regular distribution.

Crackers have been found to have higher expansion coefficients than most other food materials (Kim and Okos, 1999). During frying, it is obvious that a porous medium develops because of structural changes at the product's surface (Ziaiifar *et al*., 2009). An expansion in volume associated with the creation of a porous structure usually takes place. In addition, a crust at the product surface usually forms (Bhat and Bhattacharya, 2001).

Specifically, porosity increases during frying because of forceful water evaporation and pore formation and reaches a maximum at the end of the frying period. However, during the cooling period, porosity starts to decrease as a result of the absorbed oil implanted in the pore spaces and collapse phenomenon (Ziaiifar *et al*., 2009). Rahman (2001) also described pore formation as the result of the transport mechanisms of free water, bound water and water vapor. Pinthus *et al*. (1995) studied the mechanism of porosity development. They stated that during frying, water moves from inside the product to the evaporation zone before leaving the product through the surface as vapor. Some of this vapor may, however, remain trapped within the pores. This vapor expands and becomes superheated, distorting the pore walls and contributing to the development of porosity.

The color results for buffalo skin crackers was the opposite of other crackers, whose results usually showed a decrease in L* value after frying. Several researchers noted that the color degradation kinetics of food products involve complex phenomena and dependable models to predict experimental color change, which can be used in engineering calculations, are limited (Ahmed *et al*., 2002). Heat and mass transfer phenomena take place during frying and cause physicochemical changes, which affect the color of the fried products (Krokida *et al*., 2001).

The result of this research is related to the study of potato deep fat frying as reported by Krokida *et al*. (2001). They noted that the lightness of potato strips increases during the early stages of frying, though it remains almost constant afterwards. Similar to the change in lightness, the a* parameter increases significantly during frying. All the process variables affect the b* parameter in the same manner that they affect the a* parameter. In general, higher b parameter values yield more yellow products, which is desirable for fried products.

Basically, the interaction between carbohydrates and amino acids in foodstuffs causes a non-enzymatic browning color after heat treatment. Hutchings (1999) noted that Maillard reactions include those involving reducing sugars, aldehydes and ketones with amines, amino acids, peptides and protein. In a related study, Conforti and Lupano (2004) found that the use of honey as a source of sugar in biscuit production caused the parameter L* (lightness) to decrease with the

honey content (i.e., the biscuits became darker in appearance). The decrease in L* could be because of Maillard and caramelization reactions. Baixauli *et al.* (2002) found that, visually, squid rings became more reddish (a relatively lightly saturated brown or red) as corn flour concentration increased. The a* value increased as the concentration of corn flour (from 0 to 42 % of flour) increased, both for non-frozen and frozen squid rings.

In this study, however, there was no addition of flour as a carbohydrate source in skin cracker manufacturing and no browning effect in skin crackers resulted. Indeed, the color of skin crackers after frying was lighter than after pre-frying. Expansion of the crackers during frying caused the total pigment that existed in the partially fried crackers to be distributed to other parts of the expanding crackers. As the result, the pigment thus distributed caused a decrease in the final L* values of the fried crackers. High temperatures during processing also caused pigment degradation in the skin, furnishing the other probable reason for a decrease in L* values.

The transfer of protein to the frying oil during frying is another probable cause for the decrease in lightness of the skin crackers. Koga *et al.* (1997) reported that glycine, alanine and leucine from foodstuffs were the browning substances in frying oil. In a study performed by Totani *et al.* (2006), 50% of the browning of frying oil in food manufacturing was due to the thermal deterioration of the oil itself and the remainder was likely due to a reaction involving amino acid in juice exuded from the frying foodstuffs.

Amino acid composition, chemical score, amino acid score and EAA index of buffalo skin crackers: The concentration of amino acids was relatively similar compared to other skin-based material. Skin is an organ rich in collagen, which is known to contain high amounts of glycine; thus skin crackers contain glycine in higher amounts compared to other amino acids. Nakamura *et al.* (2003) reported that collagen can be found in all animal parts but is especially concentrated in skin-associated tissues and bones. McCain *et al.* (1971) identified glycine as the highest amino acid, amounting to 33.6 g/100 g in cow collagen. High glycine content was also found in fishery products. Yamaguchi *et al.* (1976) determined amino acid content in cod collagen; glycine, the most prevalent amino acid identified, had a score of 31.4 g/100 g. This is very similar to results obtained by Kimura *et al.* (1969), who determined a glycine score of 30.8 g/100 g. Compared to buffalo meat, the skin crackers in this study were lower in some essential amino acids as reported by Ziauddin *et al.* (1994). The lysine (9.7), leucine (7.24), methionine (4.51), phenylalanine (4.23) and valine (4.51) from Ziauddin *et al.* (1994) were higher than from the skin crackers, while the content of other essential amino acids identified was relatively similar.

The quality of protein in foods is determined by the types of amino acid and total essential amino acids present. Protein quality will be higher if amino acid types in food are similar to the amino acid types required by the human body. Chemical score, amino acid score and EAA index were used to determine protein quality.

Chemical score is a long-accepted standard for protein quality. A chemical score is obtained by comparing the amino acid content of a sample with egg protein as a standard; results range from 0 to 100. The chemical score of skin crackers is higher than other materials based on skin. Compared to beef meat, a primary animal product, the chemical score result of fried skin crackers is lower; the chemical score of beef as calculated from amino acid data as reported by Paul and Southgate (1978) was 69.09. The chemical score of skin crackers is lower than fishery product. Acton and Rudd (1987) reported that the chemical score of various types of seafood was around 67.

Amino acid score is important if we want to know more about the role of essential amino acids in protein sources for human needs. In the present study, all amino acid scores were scaled between 0 and 100. An amino acid score of above 100 was counted as 100. Amino acid score data showed lower scores compared to buffalo after calculating from the amino acid data from reported by Ziauddin *et al.* (1994) is 46.79 and beef after calculated from the amino acid data as reported by Paul *et al.* (1978) which showed a higher amino acid score (116.36) and should be counted as 100.00. In comparison, for fishery products, the result reported by Acton and Rudd (1987)was found high amino acid scores, at around 98 on various types of seafood.

The Essential Amino Acid (EAA) index is a standard used to determine the chemical quality of protein. It was developed to overcome the shortcomings of chemical and amino acid scores. In this study, the EAA index was lower than the EAA index obtained from buffalo and beef meat. After calculation from amino acids as reported by Ziauddin *et al.* (1994) and Paul and Southgate (1978), an index of 72.84 for buffalo meat and 87.47 for beef was determined. The result obtained in the present study was still lower than the results obtained from fishery products. Acton and Rudd. (1987) reported that, in general, the essential amino acid index of fish is about 79-90, while for other seafoods, the average EAA index was around 85.

In general, the skin crackers were slightly higher in protein quality than other animal skin materials, but were of a lower protein quality than meat. Dominated by connective tissues, animal skin contains mainly collagen, which has a low biological value (Heinz and Hautzinger, 2007) and a lower essential amino acid content compared to muscle (Henckel *et al.*, 2004). However, the skin used in these crackers represents a diversification of the use of animal byproducts and could be utilized in the food industry.

CONCLUSIONS

The results showed that both fried and partially fried skin crackers have a high protein content. The specific volume, expansion volume and linear expansion of skin crackers were related to the weight, volume and length of the samples. There was color deterioration during frying because of cracker expansion, as indicated by increases in final L*, a*, b*, c* and H° values. Glycine was the most prevalent amino acid in buffalo skin crackers, an outcome that corresponded with amino acid content in other skin-based products. The chemical score, amino acid index and EAA index showed that the skin crackers were of lower protein quality than meat, which is the main animal protein source in everyday foodstuffs.

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