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Evaluation of Physico-Chemical Properties of Malaysian Commercial Beef Meatballs

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Abstract: The aim of the study was to evaluate the physico-chemical properties of commercial beef meatballs. A total of six samples of beef meatballs from different manufacturers were analyzed for proximate composition, mineral content (Ca and Na), color and textural analysis. The proximate analysis showed that there was a significant ($p<0.05$) difference among the samples. There was a large variation in the Ca and Na content in commercial beef meatballs. Significant differences among the samples' colors (L, a, b values) were also observed. All samples were significantly different in terms of the folding test, but not significantly different in terms of hardness, except for one sample that had a high hardness value. The study revealed showed that there were variations in the nutritional values as well as the textural properties in Malaysian beef meatballs produced by different manufacturers.

Key words: Beef meatballs, proximate composition, physico-chemical properties, textural properties, commercial products

INTRODUCTION

Protein is important for human beings and meat is known as the best source of animal protein. The meat that is usually used for sources of protein is poultry, beef, pork and mutton. In Malaysia, beef is the third largest source of meat after poultry and pork (Ministry of Agriculture, 2009). Besides being marketed in raw form, processed meat is also available in the Malaysian market. Some processed meats that are popular among Malaysian people are frankfurters, meatballs, nuggets and burgers. Beef meatballs, which in Malaysia are called Bebola, are also popular in other countries with different local names. They are called Bakso in Indonesia (Purnomo and Rahardiyan, 2008), Kung-Wan in Taiwan (Hsu and Chung, 2001), Koefte in Turkey (Serdaroglu and Degirmencioglu, 2004), Nem nuong in Vietnam (Legasse, 2009), Polpette in Italy (Porrini *et al*., 1995), Kofta in India (Sarkar, 2009) and Konigsberger klopse in Germany (McGavin, 2009).

Beef meatballs are produced using a combination of salt, sugar and starch; additives such as sodium polyphosphate and monosodium glutamate are also commonly added because they can increase the water-binding and fat-emulsifying capacities of the myofibrillar proteins and improve the taste of the products. Salt is added in the processing to extract salt-soluble proteins, thus increasing the binding, yield and juiciness of the product

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(Tseng *et al*., 2000). Asian-style meatballs are commonly produced by emulsifying fine ground meat with starch of some sort, mixing salt and certain herbs specific to ethnic cuisine and finally shaping the product into balls. They are then cooked in boiling water, steamed, or deep fried (Purnomo and Rahardiyan, 2008). Asian-style meatballs are different from Western-style meatballs, which are usually made from minced meat (Hsu and Chung, 1998).

Texture is the most important characteristic influencing the quality of meatballs, while color plays a minor role in product quality. Consumers prefer a hard texture and a brightly colored product (Hsu and Chung, 1998; Hsu and Yu, 1999). The texture or gel strength of chicken meatballs increases with the addition of crude transglutaminase (TGase) (Tseng *et al*., 2000). Early post-mortem meat used in beef meatball production results in a more desirable texture (Purnomo and Rahardiyan, 2008). Higher salt addition causes more salt-soluble protein to be extracted, which results in a harder final product (Hsu and Chung, 1998). Hsu and Yu (1999) reported that the addition of 2.4% salt and 0.5% phosphate produced maximum texture scores that approximately coincided with the maximal acceptance score. Decreasing the fat level resulted in lower texture and overall palatability scores (Serdaroglu and Degirmencioglu, 2004).

In terms of color, the increased addition of fat produced lighter products. Salt was found to significantly decrease the product's Hunter Lab value (Hsu and Chung, 1998). Tapioca starch is a common starch material for meatball production. The addition of lentil flour resulted in a lighter product when compared to blackeye bean flour, chickpea flour or rusk (Serdaroglu *et al*., 2005). The incorporation of soya flour is not recommended in meatball production because lypoxygenase enzymes that are released and activated after contact with water and oxygen form ethyl-phenyl-ketones that has an unpleasant odor. Hsu and Sun (2006) reported that pork meatballs made of soya bean products were adhesive, viscous and brittle, but were low in sensory acceptance in terms of odor and taste.

Recently, there has been a tendency for consuming convenience store food among consumers and beef meatballs have become one of the choices that fulfill consumers' protein needs. In general, beef meatballs are high in protein and carbohydrate content, which are important macronutrients required by the human body. The purpose of this study was to determine the range of qualities and characteristics of commercial Malaysian beef meatballs.

MATERIALS AND METHODS

Sample Collection and Preparation

Six frozen samples of beef meatballs (A, B, C, D, E and F) were collected from supermarkets located in the northern part of Malaysia and transported to the laboratory in ice boxes. Each type of beef meatball came from a different manufacturer. Two packets of each brand were picked randomly and analyzed. For sample preparation, the frozen beef meatballs were thawed overnight at 4°C, cooked in boiling water for 5 min and then cooled at room temperature.

Proximate and Mineral Composition

The proximate composition of the beef meatballs was determined according to the AOAC (2000). The crude protein and crude lipid contents were measured by Kjeldahl and Soxhlet methods, respectively. The ash content was determined by ashing the samples overnight at 550°C. The moisture content was determined by drying the samples overnight at 105°C and the carbohydrate content was calculated by computing the difference. For mineral determination, the samples were digested in 30% H_2O_2 and 65% HNO_3. Ca and Na were measured using a flame atomic absorption spectrophotometer (Perkin Elmer 3110, US).

Color Measurement

The color measurement was done based on the CIE (1978) system color profile of lightness (L), while redness (a) and yellowness (b) were measured by a reflectance colorimeter (Minolta Spectrophotometer CM-3500d, Japan). The colorimeter was calibrated throughout the study using a standard white ceramic tile.

Cooking Yield

Cooking yield was determined by measuring the difference in the sample weight before and after cooking and was calculated according to Serdaroglu (2006).

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked beef balls}}{\text{Weight of uncooked beef balls}} \times 100$$

Folding Test

The folding test was conducted to analyze the gel strength of the cooked beef meatballs and was determined according to Yu (1994). Cooked samples were cut into 3 mm thick portions. The slices were held between the thumb and the forefinger and folded to observe the way that they broke. The scale used was as: (1) breaks by finger pressure, (2) cracks immediately when folded in half, (3) cracks gradually when folded in half, (4) no cracks showing after folding in half and (5) no cracks showing after folding.

Textural Measurements

The texture measurement on the meatballs was conducted with a computer-assisted Stable Micro Systems TA-XT2i Texture Analyzer. The procedures for operating the Texture Analyzer were stated in the Standard Operating Procedure (SOP). The tests were carried out to compare the texture profile of meatballs obtained from different tests. First, we conducted the Texture Profile Analysis (TPA), which was used to determine hardness, cohesiveness, elasticity and chewiness (Bourne, 1978). This test was carried out by using a compression platen with a 75 mm diameter. The TA-XT2i setting for the TPA test was: load cell 25 kg, pre-test speed = 2.0 mm sec^{-1}, test speed = 2.0 mm sec^{-1}, post-test speed = 5.0 mm sec^{-1}, distance = 50% and trigger type = Auto - 30 g.

Statistics

An analysis of variance was used to evaluate the data and significant differences among the means were determined by the one-way ANOVA and Duncan's multiple test ($p = 0.05$) by using a computer based program of SPSS 11.5 for Windows. Each analysis was replicated three times for proximate and mineral composition and five times for color, cooking yield, folding test and textural measurement.

RESULTS

Labeling Information

Based on the products' labels (Table 1), the main ingredients used in Malaysian beef meatballs were quite similar. They include beef, starch, sugar, salt, flavor enhancers and permitted food conditioners. Information about the amount of meat that was used is not available. The types of flavor enhancers and food conditioners that were used in the beef meatballs usually were not clearly stated on the label. One of the meatball products (sample F) did not have any labeling information. This product was normally produced by small (home) manufacturers.

Proximate Composition

The proximate composition of a product mainly depends on the ingredients used in its formulation. Different manufacturers produce different formulations. Table 2 shows that there were significant differences ($p<0.05$) in the proximate composition among the samples. The significant differences ($p<0.05$) also show in the Na and Ca content of different brands of meatballs.

Color, Cooking Yield and Folding Test

Statistical analyses indicated that these values were significantly ($p<0.05$) different among the beef meatballs from different manufacturers. All of the beef meatballs did not show consistent changes after being subjected to cooking. Some increased, while some decreased, in L and a and b values after cooking (Table 3).

Table 1: Ingredient information for the Malaysian commercial beef meatballs

Samples	Ingredients
A	Beef, flour, sugar, salt, black pepper, contains permitted food conditioner
B	Beef meat, salt, vegetable oil, beef fat, sugar, spices, permitted food conditioner
C	Beef meat, edible starch, milk protein, salt, sugar, spices, M.S.G., sodium polyphosphate
D	Beef meat, food starch, salt, sugar, spices extract, permitted food conditioner and flavour
E	Beef meat, salt, sugar, monosodium glutamate, food starch, spices and permitted food conditioner
F	N/A

Table 2: Proximate composition and mineral content of Malaysian commercial beef meatballs

	Moisture	Protein	Crude fat	Ash	Carbohydrate	Ca content	Na content
Samples	-------------------------	----------	(%)	----------	-------------------------	(mg/100 g)	(mg/100 g)
A	65.17 ± 0.13^{d}	9.75 ± 0.36^{c}	7.05 ± 0.34^{c}	2.40 ± 0.01^{c}	15.64 ± 0.03^{c}	10.8 ± 0.01^{c}	827.6 ± 0.23^{ab}
B	71.67 ± 0.25^{b}	11.75 ± 0.27^{b}	2.04 ± 0.18^{d}	2.75 ± 0.27^{b}	11.87 ± 0.18^{d}	10.2 ± 0.01^{c}	709.0 ± 0.35^{c}
C	67.52 ± 0.15^{c}	9.22 ± 0.71^{c}	9.25 ± 0.47^{b}	1.76 ± 0.04^{d}	12.30 ± 0.35^{d}	8.7 ± 0.00^{d}	258.1 ± 0.04^{e}
D	63.26 ± 0.13^{e}	9.37 ± 0.19^{c}	11.09 ± 0.54^{a}	2.89 ± 0.01^{b}	13.37 ± 0.38^{b}	14.0 ± 0.01^{b}	366.1 ± 0.27^{d}
E	73.78 ± 0.15^{a}	12.51 ± 0.12^{a}	2.39 ± 0.76^{d}	3.40 ± 0.25^{a}	8.02 ± 0.48^{e}	5.7 ± 0.00^{e}	804.2 ± 0.58^{a}
F	63.25 ± 0.64^{e}	7.39 ± 0.09^{d}	1.69 ± 0.20^{d}	2.02 ± 0.03^{d}	25.86 ± 0.60^{a}	18.0 ± 0.00^{a}	242.6 ± 0.19^{e}

Data are Mean±SD (n = 6). Means with the same superscript within the same column are not significantly different ($p<0.05$)

Table 3: Colour measurements, cooking yield and folding test scores for Malaysian commercial beef meatballs

Samples	L	a	b	Cooking yield (%)	Folding test
A	50.27 ± 0.75^{c}	4.37 ± 0.46^{b}	16.51 ± 0.45^{d}	102.53 ± 0.74^{bc}	3.4 ± 0.55^{b}
B	54.47 ± 2.98^{b}	6.68 ± 0.48^{a}	15.67 ± 0.56^{e}	99.50 ± 0.39^{e}	3.8 ± 0.45^{ab}
C	55.70 ± 0.49^{b}	2.79 ± 0.11^{d}	18.73 ± 0.46^{c}	101.78 ± 0.61^{cd}	4.2 ± 0.84^{a}
D	47.73 ± 0.41^{d}	4.03 ± 0.27^{b}	15.83 ± 0.33^{de}	102.85 ± 1.27^{b}	3.2 ± 0.46^{c}
E	58.79 ± 0.62^{a}	3.27 ± 0.26^{c}	19.12 ± 0.63^{ab}	101.39 ± 0.43^{d}	4.0 ± 0.00^{a}
F	49.42 ± 1.94^{cd}	3.27 ± 0.35^{c}	19.68 ± 0.88^{a}	107.20 ± 0.33^{a}	4.2 ± 0.45^{a}

Data are Mean±SD (n = 10). Means with the same superscript within the same column are not significantly different ($p<0.05$)

Table 4: Textural properties of Malaysian commercial beef meatballs

Samples	Hardness (N)	Cohesiveness (ratio)	Springiness (mm)	Chewiness (N mm)
A	60.50 ± 0.81^{b}	0.54 ± 0.09^{b}	12.70 ± 1.03^{a}	41.07 ± 6.74^{b}
B	57.45 ± 0.30^{b}	0.65 ± 0.07^{a}	12.83 ± 0.89^{a}	48.52 ± 9.57^{b}
C	60.90 ± 0.27^{b}	0.65 ± 0.01^{a}	10.91 ± 0.26^{b}	43.20 ± 1.04^{b}
D	56.66 ± 0.66^{b}	0.55 ± 0.04^{b}	13.08 ± 0.41^{a}	40.49 ± 7.16^{b}
E	57.60 ± 1.33^{b}	0.62 ± 0.05^{a}	12.53 ± 1.95^{a}	44.48 ± 8.71^{b}
F	82.20 ± 0.94^{a}	0.66 ± 0.01^{a}	13.05 ± 0.25^{a}	68.41 ± 6.45^{a}

Data are mean±standard deviation (n = 10). Means with the same superscript within the same column are not significantly different ($p<0.05$)

Textural Properties

The analysis revealed that there were significant differences ($p<0.05$) in the textural properties of the samples (Table 4). For example, Sample F had a high hardness value, cohesiveness ratio and chewiness value. Samples A, B, C, D and E showed similar textural properties, especially in chewiness (no significant difference at $p<0.05$).

DISCUSSION

Labeling Information

As for the main ingredients in the meatballs, the percentage of meat content in the samples were not identified because such information was unavailable. According to the Malaysian Food Regulation of 1985, Article 147 (Law of Malaysia, 1996) states that manufactured meat that is prepared should not contain less than 65% meat content. In addition, the regulation stated that it should contain more than 1.7% nitrogen in organic combination. That regulation also stated that manufactured meat is allowed to contain permitted preservatives, coloring substances, flavoring substances, flavor enhancers and food conditioners. The food conditioners that may be added to Malaysian manufactured meat products are phosphate, ascorbic acid, sodium ascorbate, isoascorbic acid and sodium isoascorbate. Most of the meatballs sample contains monosodium glutamate (MSG) which is one of the permitted flavour enhancer.

Proximate Composition

The processing condition and the meatball formulation include cooking temperature and ingredients such as salt, fat, sugar, polyphosphates and water that can have significant effects on product qualities (Hsu and Chung, 1998; Hsu and Yu, 1999). Commercial beef meatballs have a moisture content ranging from 63.25 to 73.78%. Similar results were reported for Indonesian traditional meatballs with a moisture content that ranged from 69.52 to 71.17% (Purnomo and Rahardiyan, 2008). However, the moisture content in the present samples was found high compared to Turkish-style meatballs (koefte) that contained rice bran, which ranged from 58.13 to 66.82% (Yilmaz, 2005), or with koefte that contained whey powder, which ranged from 56.10 to 64.70% (Serdaroglu, 2006).

The protein content of commercial beef meatballs ranged from 7.39 to 12.51%. This result was lower compared to the protein content of Indonesian meatballs, which ranged from 13.38 to14.44% (Purnomo and Rahardiyan, 2008). Traditional koefte meatballs showed a higher protein content (25.51%) (Ulu, 2004). Koefte meatballs prepared with different levels of fat and flour also showed a higher protein content, ranging from 16.1 to 19.85% (Serdaroglu and Degirmencioglu, 2004). Pork meatballs were also reported to have a higher protein content, ranging from 17.30 to 19.26% (Huang *et al*., 2005) and 25.51 to 29.85% (Ulu, 2004). Traditional Taiwan meatballs, called Kung-Wang, showed a broad range of protein content ranging from 12 to 22% (Hsu and Yu, 1999).

The carbohydrate content showed an increase with a decrease in the protein content. Commercial beef meatballs had carbohydrate contents that ranged from 8.02 to 25.86%. The addition of up to 25% of tapioca starch in meatball production is still acceptable. This is because the incorporation of up to 50% of tapioca starch still has acceptable sensory properties (Purnomo and Rahardiyan, 2008).

The Malaysian Food Regulation of 1985 stated that manufactured meat should not contain more than 30% fat. Malaysian beef meatballs can be classified as low-fat meatballs since the fat content ranges from 1.69 to 11.09%. Low-fat traditional Turkey koefte beef meatballs reported a similar fat content that ranged from 7.9 to 8.8% (Serdaroglu *et al.*, 2005), which was lower than the normal traditional koefte with a fat content of 14.70% (Ulu, 2004). Low-fat traditional Taiwan Kung-wan pork meatballs also showed a similar fat content ranging from 6.69 to 8.63%, which was lower than normal Kung-wans having a fat content of 17.51% (Hsu and Sun, 2006). The lower fat content of commercial beef meatballs illustrates the trend in the perception of Malaysian consumers on the negative effects of high fat content and high cholesterol on health.

The ash content of Malaysian commercial beef meatballs ranged from 1.76 to 3.40%. Similar results were also reported by Serdaroglu *et al.* (2005) on the ash content of koefte beef meatballs, which ranged from 2.6 to 2.8%. However, an earlier report by Serdaroglu and Degirmencioglu (2004) showed a slightly lower ash content in koefte beef meatballs, ranging from 1.7 to 2.2%. The main source of ash, which is bone and salt, is also added during meatball production. Salt is one of the processing factors that has an influence on the quality of the meatballs (Hsu and Chung, 1998). Normally, salt is added in amounts of 1.5 to 2.0% to extract salt-soluble proteins and thus increase the binding, yield and juiciness of the product (Tseng *et al.*, 2000).

Meat and meat products are important for the human diet in many parts of the world because they provide well- some of the essential elements (Demirezen and Uruc, 2006). Calcium (Ca), an element useful for bone development and growth and sodium (Na), part of the common formula for salt, are added during meatball processing. There were significant differences in the Ca and Na contents among the samples. There was also a large variation in the nutritional values of commercial beef meatballs; the range of values for Na content included 585 mg/100 g, while the range of values for Ca content included 12.3 mg/100 g. Based on these results, the Ca content of sample C and the Na content of sample B were similar to the results obtained in the Turkey meatballs reported by Ferreira *et al.* (2000), which were 7.57±0.70 and 688.34±23.78 mg/100 g, respectively. Turkey frankfurters showed higher Ca and Na contents of 7.57±0.05 and 1327.11±33.09 mg/100 g, respectively. Since consumer markets are demanding low-Na meat products, the partial replacement or the substitution of salt with other binding agents to maintain or improve the quality of meat products is desirable.

Color, Cooking Yield and the Folding Test

The color attributes of cooked meat products arise mainly from the pigmentation of the meat from which they were made and the additives that were used in their formulation (Serdaroglu, 2006). The lightness values for samples A and F were similar to the results in meatballs containing wheat flour, whey protein concentrate and soy protein isolate reported by Ulu (2004), which ranged from 50.60-51.70. Other samples were slightly lighter than pork meatballs (Huang *et al.*, 2005), except sample D. The values for the a (redness) in all the samples were similar to the results reported by Yilmaz (2005). The yellowness values of commercial beef meatballs were higher than those reported by Huang *et al.* (2005), or with treated rice bran meatballs and wheat flour of cooked meatballs reported by Ulu (2004).

Cooking yield is an important data that are used by the meat industry to predict the behavior of their products during processing (Ulu, 2006). The values of the cooking yield were similar to the results in high-fat Kung-Wan meatballs reported by Huang *et al.* (2005), which ranged from 101.57 to 103.84%, or in low-fat Kung-Wan meatballs reported by Hsu and Sun (2006), which ranged from 98.04 to 102.19%. The cooking yield of the Kung-wan significantly increased with higher salt levels (Hsu and Sun, 2006). The meat also tended to shrink during the cooking process due to the denaturation of meat protein; the loss of water and fat also contributed to the shrinking process (Serdaroglu *et al.*, 2005).

The folding test was slightly different due to the different ingredients used for each sample. A higher folding test can be reached with a washing treatment. Yu (1994) reported that the double washing treatment on fish meat enabled an increase in the folding score of the fish balls to 5.0 compared to 3.0 in the sample without the washing treatment. The washing treatment will increase the ratio of myofibrillar protein to sarcoplasmic protein and the higher degree of myofibrillar protein is essential for the formation of protein networks during the cooking of meatball products.

Textural Properties

The hardness for all of the samples was higher compared to the veal meatballs containing wheat flour, whey protein and soy protein isolate reported by Ulu (2004), which ranged from 19.2 to 28.3 N. Kung-Wan meatballs containing rice bran also showed a lower hardness value, which ranged from 17.18 to 26.88 N (Huang *et al.*, 2005). According to Serdaroglu *et al.* (2005), the factors responsible for the textural properties in comminuted meat proteins are the degree of the extraction of myofibrillar protein, stromal protein content, the degree of comminuting and the types and levels of non-meat ingredients such as fat and starch. Increasing the fat content of meatballs will lower their hardness values. Meatballs with a higher fat content showed a lower hardness value (Ulu, 2004; Huang *et al.*, 2005). Starch or carbohydrate content also had an effect on the hardness of beef meatballs. For example, Sample F showed higher hardness values due to its high carbohydrate content (25.86%). The increase of the hardness value is due to the increase of the carbohydrate content, which is also reported by Huang *et al.* (2005).

The cohesiveness value of Malaysian beef meatballs was higher than the cohesiveness value of veal meatballs reported by Ulu (2004), which ranged from 0.38-0.43. However, this cohesiveness value was lower as compared to the Kung-wan meatballs, which ranged from 0.78-0.81 (Huang *et al.*, 2005). Hsu and Chung (2001) reported salt significantly increased product cohesiveness. Meatballs prepared by Ulu (2004) had no salt, while meatballs prepared by Huang *et al.* (2005) contained two percent salt. Salt is one of the ingredients that is normally added during the production of meatballs in Malaysia and this clearly explains the higher cohesiveness value compared to the reported by Ulu (2004).

Malaysian beef meatballs showed a slightly higher springiness value compared to veal meatballs, which ranged from 6.7-6.9 mm (Ulu, 2004) or to the Kung-wan meatballs, which ranged from 9.4 to 9.5 mm (Huang *et al.*, 2005). According to Hsu and Yu (1999), some processing factors that influenced the springiness or elasticity value in low-fat Kung-Wan meatballs were salt and water; the springiness is also significantly influenced by phosphates that are added during processing. Higher phosphate levels significantly increased the cohesiveness, springiness and viscosity of low-fat Kung-Wan meatballs.

A similar trend as for hardness value was also observed in the chewiness value. Huang ***et al.*** (2005) stated a connection among hardness, gumminess and chewiness, but springiness, adhesiveness and cohesiveness showed no relation with hardness, gumminess or chewiness. The chewiness value in Malaysian beef meatballs ranged from 40.48 N mm to 68.42 N mm. This value is similar to the chewiness value of veal meatballs reported by Ulu (2004), which ranged from 40.3 to 76.1 N mm.

CONCLUSION

In summary, the proximate composition, color and textural properties were generally different among the different brands of beef meatballs. The moisture and protein content of commercial beef meatballs ranged from 63.25 to 73.78% and 7.39 to 12.51%, respectively. The lightness and hardness value ranged from 47.73 to 58.79 and 56.66 to 82.20 N, respectively. The differences in the quality characteristics of beef meatballs were mainly due to the difference in the formulation.

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