Journal of Food Quality ISSN 1745-4557

POTENTIAL USES OF MECHANICALLY DEBONED BULLFROG (*RANA CATESBEIANA*) MEAT TO PARTIALLY REPLACE LEAN PORK TO PRODUCE EMULSIFIED MEATBALLS

KUO-CHIANG HSU,[1] DENG-CHENG LIU,[2] HERBERT W. OCKERMAN[3] and FA-JUI TAN[2,4]

[1]Department of Nutrition, China Medical University, Taichung, Taiwan
[2]Department of Animal Science, National Chung Hsing University, Taichung 402, Taiwan
[3]Department of Animal Sciences, The Ohio State University, Columbus, OH

[4]Corresponding author. TEL: +886-4-22870613 ext. 246; FAX: +886-4-22860265. EMAIL: tanfj@dragon.nchu.edu.tw

Received for Publication September 10, 2009
Accepted for Publication May 3, 2011

doi:10.1111/j.1745-4557.2011.00393.x

ABSTRACT

The objective of this study was to evaluate the qualities of emulsified meatballs where part of the lean pork was substituted with mechanically deboned bullfrog (*Rana catesbeiana*) meat (MDBM) during manufacturing and subsequently stored at 4C. Meatballs were manufactured by adding 0, 7.5, 15, 22.5 or 30% MDBM. The meatballs had higher moisture, lower protein and fat contents, darker color, lower water-holding capacity, higher cooking loss and softer texture as the MDBM usage level increased. The thiobarbituric acid and volatile basic nitrogen values of the products significantly ($P < 0.05$) increased, and the shear values, springiness and fracturability decreased as the MDBM usage level increased ($P < 0.05$). The products containing 7.5% MDBM had higher acceptable sensory characteristics than those samples containing more MDBM. In conclusion, emulsified meatballs that had 7.5% mechanically deboned bullfrog meat, substituted with equal quantities of the lean pork, were acceptable based on their physicochemical and sensory qualities.

PRACTICAL APPLICATIONS

Many animal by-products which are produced during processing are edible and valuable. How to utilize these by-products has become a great issue for the industry. In this study, high-quality proteins which were obtained from mechanically deboned bullfrog meat (MDBM) resulted in emulsified meatballs with acceptable qualities. More specifically, this information could make MDBM a possible material to substitute for part of the added lean meat in many emulsion-type meat products and increase products marketability because of lower raw ingredients' cost. This finding may be useful for both marine and domestic animal industries to make better use of this by-product. Lastly, this information can be used to enhance the potential reduction of animal wastes, which might pollute the environment.

INTRODUCTION

Mechanical deboning is a process for the removal of residual lean meat from animal or poultry bone frames, which are meat processing by-products, with low commercial value, but still contain many useful and nutritional materials. The mechanical deboner produces batter-type material which can be further utilized in food manufacturing, and increases the utilization and values of these by-products (Hedrick *et al.* 1994). Utilization of mechanically deboned meat in many products has been well documented (Raphaelides *et al.* 1998; Li and Wick 2001; Mielnik *et al.* 2002; Daros *et al.* 2005; Perlo *et al.* 2005).

Bullfrog (*Rana catesbeiana*) is a popular food material in Taiwan and many other countries. However, bullfrog legs are the only major consumed parts; the other parts are either dumped or used for animal feed. How to make good use of this animal by-product and produce high-quality meat products is of interest to the food industries. In addition, many studies have indicated that the characteristic texture of mechanically deboned meat makes it suitable for utilization in emulsified or restructured products, such as comminuted sausages, meatballs, restructured chicken nuggets and so on (Lai *et al.* 1991; Mielnik *et al.* 2002; Daros *et al.* 2005). The Chinese-style emulsified meatballs, also known as "kung-wan" in Taiwanese, is a very popular emulsified meat product in Taiwan and many other countries, and is commonly made with ham meat and pork backfat. Su *et al.* (1988) indicated that many factors, such as quantities of salt and polyphosphate, ratio of lean to fat, and portion of lean would affect the quality of emulsified meatballs. Utilization of mechanically deboned meat makes it a possible material to substitute for part of the added lean meat in emulsified meat products (Huang and Wang 1998; Yuste *et al.* 1999). To the best of our knowledge, fewer studies regarding the acceptability of meat products containing mechanically deboned frog meat have been reported.

The objective of this study was to evaluate the physicochemical qualities of emulsified meatballs containing various amounts of mechanically deboned bullfrog meat (MDBM) including proximate composition, water-holding capacity (WHC), cooking loss, thiobarbituric acid (TBA), volatile basic nitrogen (VBN), instrumental color and sensory evaluation, after the processed products were stored under refrigeration.

MATERIALS AND METHODS

Emulsified Meatballs Preparation

Fresh delegged bullfrogs (*R. catesbeiana*) were obtained from a local frog-raising farm in Pingtung, Taiwan, and were mechanically deboned using a deboner (Type 696, Baader Food Processing Machinery, Lubeck, Germany) and stored at –20C prior to manufacturing emulsified meatballs. Fresh pork legs and frozen pork backfat were purchased from a local meat market in Pingtung, Taiwan. Pork legs were grounded, utilizing a 3-mm plate. Fat was partially thawed in a 4C cooler for approximately 6 to 8 h prior to grinding through the same-sized plate. Meatball samples in each group were formulated with 25% pork backfat. The samples containing 7.5, 15, 22.5 or 30% MDBM were first mixed with 67.5, 60, 52.5 or 45% ground pork. Salt (1.8%) and phosphate (0.2%) were combined in a mixer (JD-61, Jenn Dah Foods Machinery Co. Ltd., Chia-Yi, Taiwan) for 3 min, and then pork backfat (25%) and other nonmeat ingredients including 3.5% sugar, 2.0% potato flour, 1.0% monosodium glutamate, 0.3% white pepper powder and 0.05% sodium erythorbate were added (lean and backfat were considered as 100%), and mixed thoroughly for approximately another 4 min. The meat mixtures were manually formed into meatballs with an approximate weight of 20 g, cooked in a water bath in approximately 85C until the internal temperature of the meatballs reached and maintained 70C for 20 min, which was monitored by a thermometer (TS-2, Suntex Instruments Co., Ltd., Taipei, Taiwan), cooled in an ice bath for 10 min, dried at room temperature (approximately at 25C) for 10 min, packed in plastic bags (approximately 500 g per bag) and stored at 4C for 14 days. The meatballs were analyzed at day 0 for proximate composition, color values, WHC, cooking loss, rheological properties and sensory characteristics, and at day 0, 7 and 14 for TBA and VBN values.

Proximate Composition

Moisture and ash contents were measured according to the AOAC (1997a,b) methods. Crude fat was determined by using a Soxtec fat analyzer (Lin 2002; Soxtec System HT, 1043 Extraction Unit and 1046 Service Unit, Tecator Co., Hoganas, Sweden). Crude protein was determined by the Kjeldahl method (Lin 2002) using a digestion unit (Di-24, Seton Finite Co., Kaohsiung, Taiwan) and a distillation unit (UDK 126D, VELP Scientifica, Usmate, Italy).

Instrumental Color Measurement

Approximately 5 g ground cooked samples were placed in a measuring container, and L^* (lightness), a^* (redness) and b^* (yellowness) values of the cooked samples were measured with a color meter (Nippon Denshoku Ze 2000, Nippon Denshoku Industries Co. Ltd., Tokyo, Japan). Three measurements were made for each sample and averaged. A standard plate (number A-17863) with "Y" = 94.81, "X" = 92.83 and "Z" = 111.27 was used as a reference.

WHC and Cooking Loss

WHC was measured according to the Dagbjartsson and Solberg (1972), and Lin (2002) methods and modified as follows. Five grams of cooked sample was mixed with 10 mL water, placed in a 50-mL centrifuge tube, weighted, vortexed for 1 min and centrifuged for 10 min (2,000× g, 15C; Hitachi Centrifuge, Model SCR20B, Hitachi Koki Co. Ltd., Tokyo, Japan). After removing the supernatant, it was reweighed and calculated as WHC (expressed as g H_2O absorbed / g meat) = $[(\text{Weight}_{\text{meatballs after centrifuge}} - \text{Weight}_{\text{meatballs before centrifuge}})] / \text{Weight}_{\text{meatballs before centrifuge}}$. On the other hand, cooking loss (%) of meatballs was calculated as cooking loss = $[(\text{Weight}_{\text{meat batter used to form meatballs before cooking}} - \text{Weight}_{\text{meatballs after cooking, cool and drained}})] / \text{Weight}_{\text{meat batter used to form meatballs before cooking}} \times 100$.

TBA and VBN

TBA values of the samples were determined according to the method described by Salih *et al.* (1987). TBA value was

Table 1. PROXIMATE COMPOSITION AND COLOR VALUES OF EMULSIFIED MEATBALLS WITH VARIOUS AMOUNTS OF MECHANICALLY DEBONED BULLFROG MEAT (MDBM) ADDED

	Proximate composition (%)				Color values		
MDBM added (%)	Moisture	Protein	Fat	Ash	L^* value	a^* value	b^* value
0	59.95 ± 0.75^c	24.07 ± 0.46^a	17.22 ± 0.88^a	2.40 ± 0.45^a	63.66 ± 1.17^a	2.82 ± 0.78^a	11.54 ± 0.07^a
7.5	60.61 ± 0.74^{bc}	23.76 ± 0.35^{ab}	15.44 ± 0.29^b	2.03 ± 0.97^a	62.46 ± 2.08^{ab}	2.35 ± 0.14^a	11.62 ± 0.46^a
15.0	61.03 ± 0.80^{ab}	23.39 ± 0.69^b	15.04 ± 0.26^b	1.99 ± 0.46^a	62.23 ± 1.28^{ab}	2.51 ± 0.11^a	11.64 ± 0.31^a
22.5	61.43 ± 0.69^{ab}	22.56 ± 0.36^c	14.23 ± 0.14^c	1.93 ± 0.46^a	60.82 ± 0.76^b	2.50 ± 0.04^a	11.71 ± 0.48^a
30.0	62.43 ± 1.24^a	21.87 ± 0.20^d	14.16 ± 0.04^c	1.92 ± 0.27^a	59.14 ± 1.29^c	2.62 ± 0.05^a	11.79 ± 0.40^a

[a–d] Means within a column that have different superscripts are significantly different ($P < 0.05$).

expressed as mg malonaldehyde/kg meat. VBN was determined by the Conway micropipette diffusion method (Chinese National Standard 1995) and was expressed as mg VBN/100 g of sample.

Textural Properties Measurement

A cylinder (diameter 1 cm, height 1 cm) which was removed from the meatballs using a metal core was placed on the loading stage. Strength was recorded as springiness (kg) when the sample was compressed to 50% of the original height using a Rheometer (CR-200D, Sun Scientific Co. Ltd., Tokyo, Japan) with a # 1 circle-type probe having a diameter of 15 mm at 100 mm/min speed (Lin 2002). A shear value (kg) was measured by cutting completely through the circular cylinder meatballs (diameter 1 cm, height 1 cm) which were placed horizontally on the loading stage and sheared using a # 9 probe. A whole meatball was placed on the loading stage, and the strength was recorded as fracturability (kg) when the # 2 ball-type probe, having a diameter of 5 mm, started to penetrate the surface of the meatballs. Prior to analysis, samples were allowed to equilibrate to room temperature (approximately 20 to 25C, 0.5 to 1 h).

Sensory Evaluation

Meatballs in polyethylene bags were cooked in an 85C water bath for 20 min, cooled to room temperature (approximately 25C) and then served to the sensory panel which consisted of 12 meat science faculty members and students. Attributes of color, off-aroma, flavor, texture, springiness and overall acceptability were evaluated. The sensory evaluation was conducted using a 1- to 7-point scale. The scoring scale for color included: 7 = the darkest color, 6 = darker color, 5 = less dark color, 4 = neither darker nor lighter color, 3 = less light color, 2 = lighter color and 1 = the lightest color. Off-aroma and flavor scoring scales included: 7 = the highest intensity, 6 = higher intensity, 5 = less high intensity, 4 = neither higher nor lower intensity, 3 = less low intensity, 2 = lower intensity and 1 = the lowest intensity. Texture scoring scale included: 7 = the hardest texture, 6 = harder texture, 5 = less hard texture, 4 = neither harder nor softer texture, 3 = less soft texture, 2 = softer texture and 1 = the softest texture. Springiness scoring scale included: 7 = the highest springiness, 6 = higher springiness, 5 = less high springiness, 4 = neither less nor lower springiness, 3 = less low springiness, 2 = lower springiness and 1 = the least springiness. Overall acceptance scoring scale included: 7 = the highest acceptance, 6 = higher acceptance, 5 = less high acceptance, 4 = neither higher nor lower acceptance, 3 = less low acceptance, 2 = lower acceptance and 1 = the lowest acceptance.

Statistical Analyses

In this study, four trials and four samples for each treatment were conducted for the proximate composition, instrumental color measurement, WHC, cooking loss, TBA and textural properties measurement. Two trials were conducted for the sensory evaluation. Data were analyzed using the general linear model of Statistical Analysis System Procedures (Version 8.02 for Windows, 2001, SAS Institute Inc., Cary, NC) with a 5% level of significance. Means were separated using Duncan's new multiple range test.

RESULTS AND DISCUSSION

Proximate Composition and Instrumental Color Measurement

Meatballs formulated with 15 to 30% MDBM had higher ($P < 0.05$) moisture and lower protein and fat ($P < 0.05$) than the control meatballs and meatballs formulated with 7.5% MDBM (Table 1). The increase of moisture was because of the incorporation of MDBM to the meatballs, and was highest ($P < 0.05$) when 30% MDBM was incorporated into the meatballs. This change of proximate composition can be ascribed to the fact that MDBM had comparatively higher moisture and lower fat contents (82.64 and 2.80%, respectively) when compared with the lean pork (75.40 and 3.99%, respectively) in the emulsified meatballs. Similarly, when making frankfurter sausages, adding 30 to 40% mechanically deboned chicken meat, which had comparatively higher

TABLE 2. CHANGES IN WATER-HOLDING CAPACITY (WHC) AND COOKING LOSS OF EMULSIFIED MEATBALLS WITH VARIOUS AMOUNTS OF MECHANICALLY DEBONED BULLFROG MEAT (MDBM) ADDED

MDBM added (%)	WHC*	Cooking loss (%)†
0	0.37 ± 0.05^{a}	4.27 ± 0.71^{b}
7.5	0.30 ± 0.03^{b}	4.33 ± 0.96^{b}
15.0	0.28 ± 0.06^{bc}	4.70 ± 1.20^{b}
22.5	0.24 ± 0.04^{cd}	6.14 ± 2.35^{ab}
30.0	0.22 ± 0.04^{d}	7.11 ± 2.11^{a}

* WHC = [(Weight$_{after\ centrifuge}$ – Weight$_{before\ centrifuge}$)] / Weight$_{before\ centrifuge}$.

† Cooking loss = [(Weight$_{before\ cooking}$ – Weight$_{after\ cooking,\ cool\ and\ drained}$)] / Weight$_{before\ cooking}$ × 100.

a–d Means within a column that have different superscripts are significantly different ($P < 0.05$).

moisture contents, resulted in a final product with significantly higher moisture contents (Huang and Wang 1998). No significant difference in ash contents was observed between treatments ($P > 0.05$).

The incorporation of 22.5 and 30.0% MDBM into the meatballs resulted in a significantly ($P < 0.05$) lower L^* color value, which indicated a darker color. No significant ($P > 0.05$) differences in the a^* and b^* color values were observed among the samples. This change in color of meatballs because of the incorporation of MDBM was because MDBM had comparatively lower L^* color value (55.28) than the ground lean pork (64.05). Similarly, Huang and Wang (1998) reported that adding more mechanically deboned chicken meat resulted in frankfurter sausages which had significantly lower L-values. The heme pigments, which are released from bone marrows during mechanical processing, might explain the darker color of MDBM that incorporated into the meatballs, thus the product became darker.

WHC and Cooking Loss

The data showed that incorporating more MDBM into the meatballs resulted in a significant ($P < 0.05$) reduction in WHC of the samples (Table 2). The meatballs that did not contain MDBM had a WHC of 0.37; meatballs containing 7.5% MDBM had a WHC of 0.30, while meatballs containing 22.5% MDBM had a WHC of 0.22. Huang and Wang (1998) reported that incorporating more mechanically deboned chicken meat tended to result in frankfurter sausages with reduced WHC. This reduction of WHC of the product was probably because the MDBM texture was partially destroyed during mechanical separation and processing, thus resulting in less functionality of the raw materials. Therefore, the more MDBM added to the meatballs resulted in lower WHC. It was reported that processing during mechanical deboning might lead to changes in physical, chemical, sensory and functional properties of the meat materials, thus finally influencing the final quality characteristics and consumer acceptance of products (Yuste *et al.* 1999; Abdullah and Al-Najdawi 2005). In the present study, samples that contained 30% MDBM had significantly ($P < 0.05$) higher cooking loss of 7.11% when compared with meatballs that contained 0 to 15% MDBM, which had cooking losses ranging from 4.27 to 4.70% (Table 2). However, incorporating MDBM up to 15% did not significantly ($P > 0.05$) affect the cooking loss of the meatballs. A study done by Huang and Wang (1998) showed that incorporation of mechanically deboned chicken meat up to 40% did not significantly influence the cooking losses of frankfurter sausages. In this study, higher cooking loss of meatballs containing 30% MDBM was probably because of the lower WHC of the MDBM.

TBA and VBN

TBA values, which are indicators of lipid oxidation, are shown in Table 3. As expected, the TBA values of the samples tended to increase numerically with storage time even though without significant differences. Such an increase in TBA values of the emulsified products during storage has also been reported by other researchers (Thomas *et al.* 2006; Estévez *et al.* 2007). In the current study, the data also indicated that the meatballs containing no MDBM had significantly ($P < 0.05$) lower TBA values than the meatballs with added MDBM. In addition, samples containing 7.5 or 15% MDBM had lower TBA values during the refrigerated storage, and were less than the samples containing 22.5 or 30% MDBM. This result indicated that adding MDBM to meatballs up to 22.5 and 30% resulted in a higher lipid oxidation, which was undesirable for consumers. Incorporation of oxygen from air and heme iron from bone marrow during mechanical processing might have caused mechanically deboned meat to produce a higher incidence of lipid rancidity (Dawson and Gartner 1983; Love 1983; Hedrick *et al.* 1994).

Increased amounts of VBN, which is the result of decomposition of protein during storage by microorganisms, can be an index of meat product freshness. Except for 30.0% MDBM meatballs, the VBN values increased significantly ($P < 0.05$) with storage time (Table 3). Huang and Wang (1998) reported that VBN values of the frankfurter sausages containing mechanically deboned chicken meat increased after 14 days of refrigerated storage. In the current study, incorporating more MDBM to the meatballs tended to increase VBN values of the products. For example, meatballs that contained 30% MDBM had significantly ($P < 0.05$) higher VBN values during refrigerated storage, when compared with the meatballs that contained 0 to 15% MDBM, except for some minor exception. This increase of VBN values was more obvious when more than 22.5% of MDBM was incorporated into the meatballs after 7 days of refrigerated storage. It was probably because of the higher moisture contents of the products because of the addition of more mechanically deboned meat,

TABLE 3. CHANGES IN TBA AND VBN VALUES OF EMULSIFIED MEATBALLS WITH VARIOUS AMOUNTS OF MECHANICALLY DEBONED BULLFROG MEAT (MDBM) ADDED AND EVALUATED DURING REFRIGERATED STORAGE AT 4C

	Storage time (day)		
MDBM added (%)	0	7	14
TBA values (mg malonaldehyde/kg sample)			
0	1.59 ± 0.64^{dx}	1.70 ± 0.14^{dx}	1.89 ± 0.18^{dx}
7.5	3.85 ± 0.65^{cx}	3.93 ± 0.14^{cx}	4.17 ± 0.11^{cx}
15.0	4.09 ± 0.73^{cx}	4.19 ± 0.12^{cx}	4.38 ± 0.06^{cx}
22.5	5.20 ± 0.87^{bx}	5.40 ± 0.37^{bx}	5.60 ± 0.46^{bx}
30.0	6.50 ± 1.22^{ax}	6.58 ± 0.80^{ax}	6.77 ± 1.01^{ax}
VBN values (mg/100 g of sample)			
0	6.00 ± 1.13^{cy}	6.93 ± 1.52^{cy}	8.77 ± 1.43^{cx}
7.5	6.92 ± 1.25^{cby}	9.93 ± 3.55^{by}	12.47 ± 2.32^{bx}
15.0	8.77 ± 1.31^{by}	10.62 ± 2.26^{abx}	12.47 ± 1.23^{bx}
22.5	8.77 ± 1.31^{by}	11.31 ± 1.6^{abx}	13.16 ± 2.28^{bx}
30.0	13.39 ± 4.08^{ax}	13.39 ± 2.58^{ax}	15.47 ± 2.04^{ax}

[a–d] Means within a column in the same test that have different superscripts are significantly different ($P < 0.05$).
[x–y] Means within a row in the same test that have different superscripts are significantly different ($P < 0.05$).
TBA, thiobarbituric acid; VBN, volatile basic nitrogen.

which could be further utilized by microorganisms, thus resulting in higher VBN values. A higher pH value (pH 6.82) of the MDBM, which was in the range of 6.6 to 7.5, was normally considered to encourage more microorganism growth and might explain a higher possibility of microbial activity in mechanically deboned meat (Jay 1996). In addition, higher levels of microorganisms might be incorporated during mechanical processing and product manufacturing if without proper handling, and Luiz *et al.* (2004) suggested that good microbiological quality control at every stage during processing should be followed. In the current study, during the 14-day refrigerated storage, the VBN values for all the meatballs in each group did not exceed 20 mg/100 g, which is the value that is often described as the level necessary to detect meat spoilage (Su and Lin 1988).

Textural Properties

Meatballs that contained more MDBM had significantly ($P < 0.05$) lower shear values, springiness and fracturability when compared with the control meatballs that did not contain any MDBM (Table 4). Daros *et al.* (2005) indicated that the addition of 60% or more of mechanically deboned poultry meat in the formulation of sausages caused significant changes in rheological properties. Huang and Wang (1998) reported that adding 20% or more mechanically deboned chicken meat significantly decreased springiness, chewiness, fracturability and hardness of frankfurter sausages. This decrease in textural properties because of the incorporation of MDBM to the meatballs during manufacturing was probably because the muscle proteins, especially myofibrillar proteins, were partially disrupted, thus resulting in adverse functionalities of products, including a decrease in textural property. Therefore, in this study, the more MDBM was incorporated into the meatballs, the less shear values they possess, the meatballs were less springy and fracturable, and they also had softer textures.

Sensory Evaluation

Incorporating more MDBM in the formula of meatballs resulted in darker sensory colors of samples, and this also agreed with the decrease in L^* color values (Tables 1 and 5). When evaluating comminuted sausages formulated from mechanically deboned poultry meat, Mielnik *et al.* (2002) pointed out that there was a strong correlation between color parameters measured by the sensory panel and measured using an instrument. Except for the samples that

TABLE 4. CHANGES IN RHEOLOGICAL PROPERTY OF EMULSIFIED MEATBALLS WITH VARIOUS AMOUNTS OF MECHANICALLY DEBONED BULLFROG MEAT (MDBM) ADDED

MDBM added (%)	Shear force (kg)	Springiness (kg)	Fracturability (kg)
0	0.44 ± 0.07^{a}	0.71 ± 0.08^{a}	0.30 ± 0.02^{a}
7.5	0.35 ± 0.05^{b}	0.64 ± 0.05^{b}	0.26 ± 0.01^{b}
15.0	0.26 ± 0.01^{c}	0.56 ± 0.04^{c}	0.24 ± 0.01^{b}
22.5	0.23 ± 0.06^{cd}	0.52 ± 0.03^{cd}	0.21 ± 0.01^{c}
30.0	0.18 ± 0.02^{d}	0.46 ± 0.04^{d}	0.20 ± 0.03^{c}

[a–d] Means within a column that have different superscripts are significantly different ($P < 0.05$).

TABLE 5. CHANGES IN SENSORY* VALUES OF EMULSIFIED MEATBALLS WITH VARIOUS AMOUNTS OF MECHANICALLY DEBONED BULLFROG MEAT (MDBM) ADDED

MDBM added (%)	Color	Off-aroma	Flavor	Texture	Springiness	Overall acceptance
0	2.46 ± 1.14^{c}	2.40 ± 0.96^{a}	4.96 ± 1.25^{a}	5.46 ± 1.07^{a}	4.88 ± 1.00^{a}	5.50 ± 1.45^{a}
7.5	2.77 ± 1.21^{bc}	2.52 ± 1.08^{a}	5.04 ± 1.00^{a}	5.00 ± 1.20^{ab}	4.46 ± 1.14^{ab}	5.31 ± 1.29^{ab}
15.0	2.85 ± 1.01^{abc}	2.50 ± 1.14^{a}	4.73 ± 0.78^{ab}	4.65 ± 1.09^{bc}	4.00 ± 0.98^{bc}	4.92 ± 1.00^{abc}
22.5	3.36 ± 1.25^{ab}	3.00 ± 1.55^{a}	4.96 ± 0.84^{ab}	4.65 ± 1.32^{bc}	3.50 ± 1.17^{cd}	4.65 ± 0.94^{bc}
30.0	3.48 ± 1.26^{a}	2.69 ± 1.41^{a}	4.15 ± 1.19^{b}	4.04 ± 1.04^{bc}	3.15 ± 0.97^{d}	4.27 ± 1.48^{c}

* The sensory evaluation conducted using a 1 to 7 scale, with 1 representing the lowest intensity, lightest color, softest texture and least springiness.
[a–c] Means within a column that have different superscripts are significantly different ($P < 0.05$).

contained 30% MDBM, the other meatballs had similar flavor evaluation results ($P > 0.05$). No significant ($P > 0.05$) difference of off-aroma in the meatballs was observed. As mentioned previously, in the current study, meatballs containing more MDBM had significantly ($P < 0.05$) lower rheological properties when compared with the control that did not contain any MDBM (Table 5). This decrease of textural properties measured by a rheometer could also be detected by a sensory evaluation. Meatballs containing more MDBM, especially when 15% and more of MDBM were incorporated into the formula, had lower sensory texture and springiness scores, which suggested a softer texture and less springiness of these meatballs. Such loss of texture and springiness characteristics of meatballs because of the incorporation of higher quantities of MDBM to the meatballs was because MDBM lacks integral texture when compared with normal muscle tissue. Incorporation of more MDBM in the formula tended to decrease the overall acceptability of the products, especially incorporating 15% or more MDBM during manufacturing of the meatballs. Changes of texture and springiness because of the addition of MDBM could be the major factor that resulted in the less total overall acceptability of the samples.

CONCLUSIONS

MDBM has potential for utilization in the manufacture of emulsified meatballs. Up to 7.5% could be incorporated into emulsified meatballs formulation as a substitute for lean pork when making emulsified meatballs without seriously affecting the physicochemical, textural and sensory properties.

ACKNOWLEDGMENTS

We thank Dr. Yun-Chu Wu for the kind provision of deboner. The assistance of Mr. J.M. Su, Miss P.J. Shiu and Miss Y.C. Chen is gratefully acknowledged.

REFERENCES

ABDULLAH, B. and AL-NAJDAWI, R. 2005. Functional and sensory properties of chicken meat from spent-hen carcasses deboned manually or mechanically in Jordan. Int. J. Food Sci. Technol. *40*, 537–543.

AOAC. 1997a. *Moisture in Meat. 950.46. Official Methods of Analysis*, 16th Ed., Association of Official Analytical Chemists, Washington, DC.

AOAC. 1997b. *Ash of Meat. 920.153. Official Methods of Analysis*, 16th Ed., Association of Official Analytical Chemists, Washington, DC.

CHINESE NATIONAL STANDARD. 1995. Method of volatile basic nitrogen determination for frozen fishes. Manual of Chinese National Standard, Code 1451-N6029. Taiwan: Bureau of Central Standard.

DAGBJARTSSON, B. and SOLBERG, M. 1972. A simple method to determine the water-holding capacity of muscle foods. J. Food Sci. *37*, 499–500.

DAROS, F.G., MASSON, M.L. and AMICO, S.C. 2005. The influence of the addition of mechanically deboned poultry meat on the rheological properties of sausage. J. Food Eng. *68*, 185–189.

DAWSON, L.E. and GARTNER, R. 1983. Lipid oxidation in mechanically deboned poultry. Food Technol. *37*, 112–116.

ESTÉVEZ, M., VENTANAS, S. and CAVA, R. 2007. Oxidation of lipids and proteins in frankfurters with different fatty acid compositions and tocopherol and phenolic contents. Food Chem. *100*, 55–63.

HEDRICK, H.B., ABERLE, E.D., FORREST, J.C., JUDGE, M.D. and MERKEL, R.A. 1994. Principles of meat science. In *Principles of Meat Science*, 3rd Ed. (H.B. Hedrick, E.D. Aberle, J.C. Forrest, M.D. Judge and R.A. Merkel, eds.) pp. 153–154, Kendall/Hunt Publishing Company, Dubuque, IA.

HUANG, C.C. and WANG, T.Y. 1998. Quality characteristics of Frankfurter sausages made from mechanically deboned chicken meat. J. Chin. Soc. Anim. Sci. *27*, 567–577.

JAY, M.J. 1996. Intrinsic and extrinsic parameters of foods that affect microbial growth. In *Modern Food Microbiology*, 5th Ed., (M.J. Jay, ed.) pp. 38–44, Chapman & Hall, New York, NY.

LAI, S.M., GRAY, J.I., SMITH, D.M., BOOREN, A.M., CRACKEL, R.L. and BUCKLEY, D.J. 1991. Effects of oleoresin rosemary, tertiary butylhydroxyquinone and sodium tripolyphosphate on the development of oxidative rancidity in restructured chicken nuggets. J. Food Sci. *56*, 616–620.

LI, C.T. and WICK, M. 2001. Improvement of the physicochemical properties of pale soft and exudative (PSE) pork meat products with an extract from mechanically deboned turkey meat (MDTM). Meat Sci. *58*, 189–195.

LIN, H.Y. 2002. *Investigation of the application of nata (bacterial cellulose) to Chinese-style meatball*. Master Thesis, Providence University, Taichung, Taiwan.

LOVE, J.D. 1983. The role of heme iron in the oxidation of lipids in read meats. Food Technol. *37*, 117–120.

LUIZ, A.D.F., MOREIRA, F.C., CORREA, E.D.F. and FALCAO, D.P. 2004. Monitoring of the dissemination of Salmonella in the chicken Frankfurt-sausage production line of a sausage factory in the state of São Paulo, Brazil. Memórias Instituto Oswaldo Cruz *99*, 477–480.

MIELNIK, M.B., AABY, K., ROLFSEN, K., ELLEKJR, M.R. and NILSSON, A. 2002. Quality of comminuted sausages formulated form mechanically deboned poultry meat. Meat Sci. *61*, 73–84.

PERLO, F., BONATO, P., TEIRA, G., FABRE, R. and KUEIDER, S. 2005. Physicochemical and sensory properties of chicken nuggets with washed mechanically deboned chicken meat: Research note. Meat Sci. *72*, 785–788.

RAPHAELIDES, S.N., GRIGOROPOULOU, S. and PETRIDIS, D. 1998. Quality attributes of pariza salami as influenced by the addition of mechanically deboned chicken meat. Food Qual. Pref. *9*, 237–242.

SALIH, A.M., SMITH, D.M., PRICE, J.F. and DAWSON, E. 1987. Modified extract action 2-thiobarbituric acid method for measuring lipid oxidation in poultry. Poult. Sci. *66*, 1483–1488.

SU, H.P., LEE, T.G., CHI, S.P. and LIN, C.W. 1988. Effect of material composition on meat ball quality. Food Sci. (Taiwan) *15*, 154–159.

SU, H.P. and LIN, C.W. 1988. A survey of the storage characteristics of dried sliced pork. J. Chin. Soc. Anim. Sci. *17*, 83–90.

THOMAS, R., ANJANEYULU, A.S.R. and KONDAIAH, N. 2006. Quality and shelf life evaluation of emulsion and restructured buffalo meat nuggets at cold storage (4 ± 1C). Meat Sci. *72*, 373–379.

YUSTE, J., MOR-MUR, M., CAPELLAS, M., GUAMIS, B. and PLA, R. 1999. Mechanically recovered poultry meat sausages manufactured with high hydrostatic pressure. Poult. Sci. *78*, 914–921.