Simultaneous use of adzuki beans (*Vigna angularis*) flour as meat extender and fat replacer in reduced-fat beef meatballs (*bebola daging*)

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Abstract Adzuki bean is high in protein and fiber with a potential to be used as meat extender and fat replacer in the meat product. Replacement of both the corn flour and fat with different percentages of adzuki beans flour (ABF) has successfully produced acceptable reduced fat meatballs. Meatballs with 100% (w/w) ABF replacement exhibited highest cooking yield and higher moisture content compared to meatballs without the flour, which indicates its ability to bind water. Increasing the ABF content also increased the hardness and chewiness of the meatballs, whilst decreasing their lightness and yellowness. Replacing the corn flour and fat contents with ABF has obviously decreased the fat and calorie contents of the meatballs, yet their protein and carbohydrate contents remained the same compared to control. The sensory test revealed that meatball samples with 25% (w/w) and 50% (w/w) ABF showed no significant difference compared to control but received highest overall acceptability among the panelists. This indicates that replacement of corn flour and fat with ABF especially at 50% (w/w) in the production of reduced fat meatballs resulted with better physicochemical properties and acceptable sensory compared to original meatballs.

Keywords Adzuki beans flour (ABF) · *Vigna angularis* · Fat replacer · Meat extender · Meatballs

Introduction

Meatballs are usually made from the emulsion of meat protein, fat and water with the addition of other ingredients such as salt, flour, and spices, and then molded into round shape (Colmenero 1996; Purnomo and Rahardiyana 2008). Usually, meatballs are boiled, baked or fried and served with pasta but also can be consumed on its own with or without dipping sauce (Huda et al. 2010). Meatballs are known differently worldwide such as *bakso* in Indonesia (Purnomo and Rahardiyana 2008), *kofta* in India (Modi et al. 2009a), *cig kofté* in Turkey (Bingol et al. 2012), *kung-wan* in China (Kang et al. 2014) and many other names based on its country of origin and culture. In Malaysia, meatballs made from beef meat are known as *bebola daging*. They can easily be found in Malaysian market and among the favorite snack foods (Huda et al. 2009).

Meatballs are known for the juiciness and flavourful taste due to the amount of fat used in the processing (Desmond et al. 1998; Huang et al. 2005). Fat is one of the major contributors to the organoleptic quality of meatballs such as flavor, texture and binding properties, which the reduction of this major component in meat products might affect its sensory characteristics (Colmenero 1996). However, fat is directly related to health problems such as obesity and coronary heart disease (Bray et al. 2004; Hu et al. 2001). The concern on the health issue encouraged studies on the replacement of fat in the production of meat products.

Various legume flours were tested as fat replacers in meat products. For example, pea flour, starch, and fiber were used as fat replacers to produce low-fat bologna (Pietrasik and Janz 2010). Meanwhile, Tabarestani and Tehrani (2012) managed to optimize the production of low-fat hamburger by using 8.52% soy flour, 1.48% split-pea

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flour and 5% starch. Legumes flours were also applied as meat binders or extenders. For examples, decorticated soya bean, Bengal gram, green gram and black gram flours were used as binders to produce buffalo meat burger (Modi et al. 2004). Blackeye bean flour, chickpea flour, lentil flour and rusk were used as meatballs extenders (Serdaroğlu et al. 2005). Meanwhile, cowpea flour and common bean flour experimented as the meat extender in meatloaves and sausages, respectively (Akwetey et al. 2014; Dzudie et al. 2002).

From the studies mentioned, none was conducted by using adzuki beans. Adzuki beans were reported to have 18–24% protein content (Yadav et al. 2018; Sai-Ut et al. 2009), which could be suitable to be used as a meat extender. Moreover, it also could be applied as the fat replacer in meat products, simultaneously. The hypothesis of this study is a significant difference ($P < 0.05$) in terms of cooking yield, textural properties, colour, proximate composition and sensory evaluation between the meatball samples with and without adzuki beans flour (ABF), regardless of its amount will be observed. In order to test this hypothesis, this study aims to produce reduced-fat meatballs by replacing the fat and corn flour contents with adzuki beans flour at certain percentages, and determine the physicochemical characteristics, nutritional compositions and sensory acceptance of the reduced-fat meatballs.

Materials and methods

Adzuki beans were purchased from 99 Speedmart shop in Serdang, Selangor, Malaysia. The beans were rinsed and soaked in distilled water for 30 min followed by oven drying at 100 °C for an hour. The dried beans were milled into flour by using Retsch ultra centrifugal mill (ZM200, Germany) with a 12-tooth rotor and sieve size of 0.5 mm. This adzuki beans flour (ABF) was packed in HDPE 6 × 7 cm plastic bags and kept at room temperature until further usage.

Frozen topside beef and beef fat were purchased from Seri Kembangan wet market, Selangor, Malaysia. The meat was cut into cubes and rinsed before being further processed (Fig. 1). Salt, sodium tripolyphosphate (STPP), sugar, monosodium glutamate (MSG), corn flour, and onion powder were purchased from Harmoni shop, Serdang, Selangor, Malaysia.

Meatballs processing

Tables 1, 2 display the formulation used in preparing meatballs before addition of the ABF and the amount of ABF as the fat and corn flour replacer, respectively. The total combined percentage of fat and corn flour from the

Fig. 1 Processing steps in the production of meatball samples

Table 1 Formulations used in meatball preparation was referred to a manual by Haron (2005) before replacing both the fat and corn flour with adzuki beans flour (ABF)

Ingredients	Amount (% g/100 g)
Meat	74.0
Fat	10.0
Iced water	8.7
Corn flour	4.2
Salt	1.2
Onion powder	0.7
Sugar	0.6
STPP	0.5
Monosodium glutamate	0.1
Adzuki beans flour	0.0
Total	100.0

meatball formulation was replaced with 0, 25, 50, 75 and 100% (w/w) ABF for the production of the reduced-fat meatballs. The processing steps involved are shown in Fig. 1.

Analysis methods performed on the meatballs

Each meatball produced was weighed to approximately 10 g. Eighteen meatball samples were prepared for each formulation, and each analysis was carried out in triplicate.

Table 2 Amount of adzuki beans flour (ABF) added into the meatball formulations as replacement of both the fat and corn flour

Meatball formulation	Total amount of fat and corn flour		Adzuki bean flour	
	Weight (g/100 g)	Percentage (% g/14.20 g)	Weight (g/100 g)	Percentage (% g/14.20 g)
A	14.20	100.00	0.00	0.00
B	10.65	75.00	3.55	25.00
C	7.10	50.00	7.10	50.00
D	3.55	25.00	10.65	75.00
E	0.00	0.00	14.20	100.00

Cooking yield

The cooking yield was determined in order to observe the effect of type and amount of fat replaced (i.e. the ABF) on the amount of water take-up in the meatball samples. This value was calculated based on the weight of the meatball before and after cooking as shown below (Murphy et al. 1975).

$$\text{Cooking yield} = \frac{(\text{weight of cooked meatball})}{(\text{weight of uncooked meatball})} \times 100\%$$

Texture profile analysis

Texture profile analysis (TPA) was performed on the meatball samples by using a texture analyzer (TA-XT2i, Stable Micro System, United Kingdom). The attributes reported were the samples' hardness, cohesiveness, springiness, and chewiness, while the type of probe used was P/O 2.0 with the diameter of the probe's ball of 2.0 mm. The pre-test speed, test-speed, and post-test speed were 2.0, 2.0, and 5.0 mm/s, respectively, with 5.0 mm distance, time of 5.0 s, and depth strip of 10 mm.

Determination of the meatballs' color

The color of the meatball samples was determined by using HunterLab Ultrascan Spectrocolorimeter (Hunter Associate Laboratory Inc., Reston, USA), where their L , a , b , values expressed as L (lightness; 0 = black, 100 = white), a ($-a$ = greenness, $+a$ = redness), and b ($-b$ = blueness, $+b$ = yellowness) values were recorded.

Proximate analysis of the meatballs

The proximate composition of the meatball samples was determined according to the AOAC methods (2012) for the sample's moisture, ash, crude protein, and crude fat content, while the calorie and carbohydrate contents were calculated afterwards by the difference.

Sensory evaluation of the meatballs

Preference test using 7-point hedonic scale was carried out in order to analyze the sensory properties of the meatballs—color, odor, texture, taste, and overall acceptability. The scale for each sensory attribute ranged from 7 (extremely like), 4 (neither like nor dislike), and 1 (extremely dislike), and a total of 30 untrained panelists were involved in this evaluation.

Statistical analysis

Statistical analysis in this study was carried out by using MINITAB® software (Minitab package version 16.0 Inc., USA) statistical package. Significant differences between the data obtained were determined statistically using one-way analysis of variance (ANOVA) with Tukey's multiple comparison tests at 95% confidence level. The values were expressed as a mean $\pm$ standard deviation.

Results and discussion

Cooking yield, texture, and color properties of the meatballs

Cooking yield

The cooking yield indicates the amount of water take-up upon cooking the meatballs where higher cooking yield indicates greater water take-up, which leads to heavier cooked meatballs. Meatball E with 100% ABF replacing the fat and corn flour exhibited highest ($P < 0.05$) cooking yield ($108.55 \pm 0.61\%$) as compared to other meatball samples (Table 3). The cooking yield of meatball E was also significantly higher ($P < 0.05$) than that of meatball A (i.e. control sample) which consists of 4.20% (w/w) corn flour. Additionally, the cooking yield resulted from the addition of ABF was also higher than that of legume flours including rusk, chickpea, black bean, and lentils with cooking yield ranged from 82.37 to 93.20% (Dzudie et al.

Table 3 Cooking yield, texture, and color properties of meatball samples with different amount of adzuki beans flour (ABF)

Meatball formulation	Adzuki beans flour (% g/14.20 g)	Cooking yield	Texture properties			Colour properties			
			Hardness (g)	Springiness (mm)	Cohesiveness	Chewiness (mm)	L*	a*	b*
A	0.00	103.08 ± 1.33 ^b	137.24 ± 23.60 ^b	1.19 ± 0.3 ^a	0.574 ± 0.06 ^a	92.49 ± 22.75 ^b	57.80 ± 0.19 ^a	2.45 ± 0.03 ^a	11.45 ± 0.17 ^a
B	25.00	99.21 ± 0.71 ^c	157.22 ± 20.82 ^b	1.13 ± 0.31 ^a	0.580 ± 0.04 ^a	103.21 ± 33.95 ^b	53.32 ± 0.25 ^b	1.97 ± 0.01 ^c	9.36 ± 0.11 ^b
C	50.00	104.81 ± 0.20 ^b	188.63 ± 38.62 ^{ab}	1.12 ± 0.26 ^a	0.576 ± 0.06 ^a	121.81 ± 37.35 ^b	51.42 ± 0.31 ^c	2.02 ± 0.04 ^{bc}	8.20 ± 0.12 ^c
D	75.00	105.14 ± 0.65 ^b	229.11 ± 75.83 ^a	1.13 ± 0.33 ^a	0.56 ± 0.06 ^a	143.64 ± 60.07 ^{ab}	49.20 ± 0.54 ^d	2.03 ± 0.04 ^{bc}	7.31 ± 0.27 ^d
E	100.00	108.55 ± 0.61 ^a	217.75 ± 12.11 ^a	1.53 ± 0.54 ^a	0.630 ± 0.09 ^a	206.27 ± 70.14 ^a	47.32 ± 0.16 ^e	2.10 ± 0.06 ^b	6.58 ± 0.09 ^e

Mean values with different letters in the same column are significantly different ($P < 0.05$). L*, lightness; a*, redness; b*, yellowness

2002; Serdaroğlu et al. 2005). These findings indicated stronger water-binding properties of the ABF in the meatballs as compared to corn flour and the reported legume flours. In relation to hydration properties, low hydration capacity of 13 adzuki beans accessions was reported by Yadav et al. (2018). Water absorption capacity of seeds depends on the cell wall structure, the seed's composition, and the cells' compactness in the seed (Kaur et al. 2005). Additionally, hydration rate is related to the size of adzuki beans used (Yousif and Deeth 2003). Therefore in this study, it is assumed that changes took place in the seeds' properties during the meatball processing, particularly the meatball soaking (45 °C, 20 min) and cooking (90 °C, 20 min) stages. According to Sefa-Dedah and Stanley (1979), seed coat of adzuki beans accessions possesses good hydration properties which allowed rapid softening of the seed during soaking. Furthermore, during cooking, the intercellular matrix of the middle lamellae loosens, resulted in cell separation (Ghribi et al. 2015) which subsequently softened a bean's texture and decreased the compactness of a bean's cells. Yadav et al. (2018) also reported an increase in a bean's tenderness upon cooking. These changes in adzuki bean properties must have allowed greater water absorption and enhanced the water binding capacity of ABF-based meatballs.

Texture profile analysis

Meatballs D and E containing 75% (w/w) and 100% (w/w) ABF, respectively, exhibited significantly ($P < 0.05$) greater hardness and chewiness as compared to other meatballs (Table 3). Textural properties of meat products depend on the extracted protein, stromal protein content, the degree of comminuting, and the type of non-meat ingredient. In the case of meatball, the extenders, binders, and starch also play important roles in affecting the product's hardness (Serdaroğlu et al. 2005). Therefore in this study, higher amount of ABF may contribute to higher protein content and starch properties which therefore resulted in meatballs with greater hardness and chewiness, particularly in meatballs D and E. This was supported by Huda et al. (2010) which stated that higher carbohydrate content in legume flour may increase both the hardness and chewiness of the meatball.

On the other hand, there was no significant difference ($P > 0.05$) between the meatball samples in terms of their springiness and cohesiveness. These results were supported by Modi et al. (2009c), where the meat kofta replaced with oat flour and carrageenan showed no significant different ($P > 0.05$) of springiness and cohesiveness compared to control. According to Huda et al. (2010), the meatball's cohesiveness may increase with the increase in its salt

content, while higher springiness may be obtained with the use of salt in combination with water and phosphates. A similar amount of salt was used in all meatball formulations in this study (Table 1), therefore justified their similar cohesiveness and springiness properties. These findings also showed that the amount of fat, corn flour, and ABF did not significantly ($P > 0.05$) affect these properties in the meatball samples.

Color characteristics of meatballs'

Colour of meatballs is highly dependent on the amount of fat, types of flour, and the additives used (Huda et al. 2010; Serdaroğlu et al. 2005). In this study, Table 3 shows a significant decrease ($P < 0.05$) in the lightness and yellowness of the meatball samples with decrease in the amount of fat (i.e. increase in the amount of ABF). It is suggested that the higher fat content in meatball A has diluted the myoglobin which resulted in the lighter color (Serdaroğlu 2006). A similar finding was reported by Huda et al. (2010) on the color attributes of commercial meatballs containing wheat flour, whey protein, and soy protein isolates. Serdaroğlu (2006) also reported lower redness and yellowness in meatballs added with the highest amount of whey protein (4% w/w) and fat (20% w/w) contents.

Meatball samples in earlier studies exhibited readings of 38.90–69.10 (Dzudie et al. 2002; Serdaroğlu 2006; Ikhlas et al. 2011). Furthermore, Huda et al. (2010) reported readings of 49.42–50.27 for commercial beef meatballs which were approximately similar to that of meatball samples containing 50–100% ABF in this study; 47.32–51.42. The similar lightness property, therefore, suggested greater consumer acceptability for the meatball samples containing ABF.

Proximate analysis

Moisture content

Table 4 shows that the moisture content of the meatball samples significantly increased ($P < 0.05$) with the increase in the amount of ABF up to 75% w/w (meatball D). Dzudie et al. (2002) also reported increased in moisture content in beef sausage with the increased amount of common beans flour added. Similarly, increased in the moisture content was observed in meatball samples with an increase in the amount of wheat bran added (5–20%) (Yilmaz 2005). In the presence of 4% (w/w) corn flour, meatball samples with a lower amount of fat exhibited higher moisture content as compared to samples with a higher amount of fat (Serdaroğlu and Değirmencioglu 2004).

The moisture content in the meatballs however significantly decreased ($P < 0.05$) when 100% ABF (i.e.

meatball E) was used. This outcome indicated the ability of the flour as water binder up to a certain amount only and is highly dependent on the amount of fat present. Total replacement of fat and corn flour contents with ABF in meatball E did not result in better water binding property as compared to meatball D. Despite these findings, the moisture content in meatballs B–E were higher as compared to meatball samples with addition of rusk, black bean flour, chick pea flour, and lentil flour which exhibited 63.0% (w/w), 63.1% (w/w), 64.1% (w/w), and 65.0% (w/w) moisture content, respectively (Serdaroğlu et al. 2005). Additionally, meatball E was able to retain up to 73.30% (w/w) moisture despite the 0% (w/w) fat and corn flour contents. Therefore, it can be concluded that the ABF possessed better water binding property and is a suitable meat extender or fat replacer.

Fat content

Table 4 shows significantly lower ($P < 0.05$) fat content in the meatball samples added with ABF which was obviously influenced by the reduced fat portions. This is in agreement with the study by Prasad et al. (2011), where the fat when replaced with 8% oat flour and 2.5% casein in chicken kofta showed a significant reduction from 14.2 to 8.5%. Additionally, according to Serdaroğlu (2006), the fat was excessively separated in meat protein matrix when no binder was added to the meatballs. This statement is in agreement with Serdaroğlu and Değirmencioglu (2004) which reported that the increased in fat content leads to decrease in the free distance between the fat droplets, thus the fat droplets tend to join together and leach out during the cooking process. Similar observation occurred in meatball B, where the lower amount of ABF (25% w/w) as a binder was unable to retain the excessive fat. This situation led to fat leaching out from the meat protein matrix during cooking and therefore reduced the fat content of the meatball sample. Significantly higher ($P < 0.05$) fat content in meatball A (10.94% w/w) was due to addition of 2–5% (w/w) corn flour which hold the fat firmly in the meat protein matrix (Serdaroğlu and Değirmencioglu 2004) and subsequently contributed to higher cooking yield as compared to meatball B (refer Table 3).

Total (100% w/w) replacement of fat and corn flour contents in meatball samples with ABF complies with the Malaysian Food Regulations 1985 which stated that in order to have a meat product to be classified as low-fat, the product must contain no more than 3% (w/w) fat content. However, results on the meatballs' sensory acceptance must also be taken into consideration as consumers nowadays prefer to buy the not only product which is good for their health, but it also needs to be palatable and acceptable in terms of its taste.

Table 4 Proximate analysis of meatball samples with different amount of adzuki beans flour (ABF)

Meatball sample	Adzuki beans flour (% g/14.20 g)	Moisture content (% w/w)	Fat content (% w/w)	Protein content (% w/w)	Ash content (% w/w)	Carbohydrate (% w/w)	Calorie (kcal)
A	0.00	69.11 ± 0.17 ^c	10.94 ± 2.38 ^a	12.19 ± 0.93 ^a	1.93 ± 0.06 ^{ab}	5.87 ± 3.06 ^a	170.71 ± 11.50 ^a
B	25.00	70.91 ± 0.16 ^d	4.54 ± 1.93 ^b	15.5 ± 2.98 ^a	1.77 ± 0.08 ^{bc}	7.28 ± 1.21 ^a	131.99 ± 10.25 ^b
C	50.00	71.99 ± 0.07 ^c	4.24 ± 1.11 ^b	16.29 ± 0.79 ^a	1.82 ± 0.08 ^{abc}	5.66 ± 1.88 ^a	125.97 ± 5.53 ^{bc}
D	75.00	73.85 ± 0.17 ^a	3.11 ± 0.21 ^b	14.36 ± 1.92 ^a	1.71 ± 0.02 ^c	6.97 ± 2.00 ^a	113.29 ± 1.66 ^{bc}
E	100.00	73.30 ± 0.11 ^b	2.11 ± 0.37 ^b	15.88 ± 2.22 ^a	2.00 ± 0.09 ^a	6.77 ± 2.42 ^a	109.35 ± 2.16 ^c

Mean values with different letters in the same column are significantly different ($P < 0.05$)

Protein content

Table 4 shows that meatballs B-E exhibited higher yet insignificantly different ($P > 0.05$) protein content than that of meatball A, which was obviously due to the addition of the ABF. This result was in line with low-fat mutton kofta produced by replacing the hydrogenated fat with oat flour with the addition of 0.5% carrageenan (Modi et al. 2009b). These values of meatballs B-E were also higher as compared to the protein content in quail meatballs added with flour made of cassava, corn, wheat, sago, and potato which ranged from 13.12 to 13.32% (w/w) (Ikhlas et al. 2011). Furthermore, the values were higher than the protein content in commercial beef meatball samples added with selected flour and starches which ranged from 9.22 to 12.51% (w/w) (Huda et al. 2010). In a different study done by Purnomo and Rahardiyana (2008), the protein content in traditional Indonesian meatballs added with tapioca, 13.55% (w/w); and potato starch, 14.44% (w/w), were approximately similar with the protein content in meatballs B-E in this study. On the other hand, meatballs B-E exhibited lower protein content as compared to beef sausage added with common bean flour, 18.49–19.78% (w/w) (Dzudie et al. 2002); and meatballs added with wheat bran, 16.21–19.60% (w/w) (Yilmaz 2005).

Ash content

According to Moongngarm (2013), adzuki beans contain 4.09% (w/w) ash content, yet this value varies with the agricultural practices, soil, and fertilizers used during cultivation. Additionally, the amount of salt present also plays a significant role in determining the ash content of a particular product due to its high mineral content. The ash content in all meatball samples in this study was lower than that of low-fat meatballs added with black bean flour, chickpea flour, lentil flour, and rusk, 2.7–2.8% (w/w) (Serdaroğlu et al. 2005); low-fat meatballs added with wheat bran, 3.06–3.34% (w/w) (Yilmaz 2005); and low-fat meatballs added with other legume flours such as soy flour, Bengal gram flour, and green gram flour, 2.0–2.7% (w/w)

(Modi et al. 2004). Despite these differences, the ash content in commercial beef meatballs was 1.76–3.40% (w/w) (Huda et al. 2010) which was approximately similar with the ash content in meatball samples in this study. According to Ikhlas et al. (2011), besides the meat itself, the addition of starch, spices, and milk protein was reported to contribute to increasing the ash content in commercial beef meatball samples.

Carbohydrates and energy

Most legumes contain a high amount of carbohydrates which is partly beneficial for improving cooking yield, enhance water-holding capacity, reduce production cost, influence texture of end product, and surpass freezing thaw stability (Colmenero 1996; Huda et al. 2009). Table 4 shows that ABF did not give any significant effect ($P > 0.05$) on the carbohydrate content of the meatballs, but there was still an increment observed particularly in meatballs B, D, and E, as compared to meatball A. This finding may be due to the lower carbohydrate content in corn flour than that of ABF (Moongngarm 2013).

There was a significant decrease ($P < 0.05$) calories in meatballs B-E against meatball A. With reference to Table 4, it can be suggested that the higher calories in meatballs A and B was contributed by their higher amount of fat as compared to other meatballs. Chizzolini et al. (1999) stated that almost 10–15% or up to 80% of total calories in 100 g of meat products is contributed by the fat content.

Sensory evaluation of the meatballs

According to Table 5, meatball B was lighter in color due to its higher fat content as discussed earlier, thus this sample received the highest color acceptability score. Other meatballs received lower scores due to their darker color imparted by the higher amount of ABF, especially in meatball E with 100% (w/w) replacement. In terms of the taste and odor, the ABF did not impart any odd flavor to the meatballs. This suggestion was based on the higher yet

Table 5 Sensory analysis of meatball samples with different amount of adzuki beans flour (ABF)

Meatball formulation	Adzuki beans flour (% g/14.20 g)	Colour	Odor	Texture	Taste	Overall acceptability
A	0.00	4.17 ± 1.76 ^{bc}	4.43 ± 1.46 ^a	4.80 ± 1.65 ^{ab}	4.67 ± 1.47 ^{ab}	4.77 ± 1.52 ^{ab}
B	25.00	5.57 ± 0.86 ^a	4.73 ± .29 ^a	5.57 ± 1.14 ^a	5.50 ± 0.97 ^a	5.60 ± 0.97 ^a
C	50.00	4.47 ± 1.61 ^b	4.60 ± 1.57 ^a	5.47 ± 1.01 ^a	5.13 ± 1.28 ^{ab}	5.20 ± 1.22 ^{ab}
D	75.00	3.97 ± 1.40 ^{bc}	4.83 ± 1.32 ^a	4.77 ± 1.19 ^{ab}	4.50 ± 1.31 ^b	4.67 ± 1.30 ^b
E	100.00	3.20 ± 1.49 ^c	4.13 ± 1.43 ^a	3.97 ± 1.54 ^b	3.40 ± 1.55 ^c	3.53 ± 1.33 ^c

Mean values with different letters in the same column are significantly different ($P < 0.05$)

insignificant ($P > 0.05$) scores for the sample's odor in meatballs B-D as compared to meatball A. Similarly, there was no significant difference ($P > 0.05$) in the taste scores between meatball A and meatballs B-D. Despite these findings, similar to the scores for the color, meatball E with 100% (w/w) ABF replacement received lowest acceptability score for both its odor and taste. Thus it can be concluded that in terms of their appearance and flavor properties, reduced-fat meatballs are more acceptable with ABF replacement up to 75% (w/w) only. The outcomes, however, was in contrast with the sensory study done by Yilmaz (2005) which stated that the reduced-fat meatballs in the study exhibited distinctly unfavorable flavor and less juiciness, thus were rejected by the panelists.

In terms of the texture attribute, meatball E with 100% (w/w) ABF replacement received lowest acceptability score which was insignificantly different ($P > 0.05$) with meatballs A and D. There was also no significant difference ($P > 0.05$) in the texture acceptability scores between meatballs A-D. These findings indicated the consumers' acceptability on meatball samples with ABF replacement up to 75% (w/w) only, which was similar with the consumers' acceptance on color, odor, and taste of the meatballs as discussed earlier.

In sensory evaluation, overall acceptance of panelists towards a food product represents the potential of the product to be accepted by the consumers. The sensory scores in Table 5 revealed that meatball B with 25% (w/w) ABF replacement received the highest scores (5.20 ± 1.22) in terms of overall acceptability. This value was insignificantly different ($P > 0.05$) with the scores of meatballs A and C. The aim of this study was to produce reduced-fat meatballs, thus meatball C with 50% (w/w) ABF replacement was considered as the most acceptable meatball sample in terms of its sensory properties.

Conclusion

In comparison with the control sample, meatball with 100% (w/w) ABF replacing its fat and corn flour content resulted in significantly higher cooking yield and moisture

content which is beneficial in the meat industry. Moreover, a higher amount of ABF significantly increased the hardness and chewiness, whilst significantly decreased the lightness, redness, yellowness, fat, and calorie contents of the meatball samples as compared to the control sample. These findings were in agreement with the hypothesis of this study, except in the case of protein, ash, and carbohydrate contents of the meatballs, besides their springiness and cohesiveness which were insignificantly different than that of the control sample. In terms of the sensory properties, there was no significant difference between the meatballs, particularly in meatballs with 25% (w/w) and 50% (w/w) ABF replacement, as compared to the control sample, which did not agree with the hypothesis of this study. This conclusion indicates similar consumers' acceptability in both the control sample and the reduced-fat meatballs with up to 50% (w/w) ABF replacement thus proclaims the potential of ABF as the fat replacer and meat extender simultaneously.

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References

- Akwetey WY, Oduro IN, Ellis WO (2014) Whole cowpea (*Vigna unguiculata*) flour (WCPF) as non-conventional extender in meatloaf. *Food Biosci* 5:42–46
- AOAC International (2012) Official methods of analysis of AOAC International, 19th edn. AOAC International, Gaithersburg
- Bingol EB, Colak H, Cetin O, Hampikyan H (2012) Effects of sodium lactate on the shelf life and sensory characteristics of cig kofte—a Turkish traditional raw meatball. *J Food Process Pres* 38(3):1024–1036
- Bray GA, Paeratakul S, Popkin BM (2004) Dietary fat and obesity: a review of animal, clinical and epidemiological studies. *Physiol Behav* 83(4):549–555
- Chizzolini R, Zanardi E, Dorigoni V, Ghidini S (1999) Calorific value and cholesterol content of normal and low-fat meat and meat products. *Trends Food Sci Tech* 10:119–128
- Colmenero FJ (1996) Technologies for developing low-fat meat products. *Trends Food Sci Technol* 7:41–48

- Desmond E, Troy D, Buckley D (1998) The effects of tapioca starch, oat fibre and whey protein on the physical and sensory properties of low-fat beef burgers. *LWT Food Sci Technol* 31(7–8):653–657
- Dzudie T, Scher J, Hardy J (2002) Common bean flour as an extender in beef sausages. *J Food Eng* 52:143–147
- Ghribi AM, Maklouf I, Blecker C, Attia H, Besbes S (2015) Nutritional and compositional study of desi and kabuli chickpea (*Cicer arietinum*) flours from Tunisian cultivars. *Adv Food Technol Nutr Sci* 1(2):38–47
- Haron MY (2005) Manual teknologi pemprosesan produk daging, 1st edn. MARDI, Selangor
- Hu FB, Manson JAE, Willett WC (2001) Types of dietary fat and risk of coronary heart disease: a critical review. *J Am Coll Nutr* 20(1):5–19
- Huang SC, Shiau CY, Liu TE, Chu CL, Hwang DF (2005) Effects of rice bran on sensory and physico-chemical properties of emulsified pork meatballs. *Meat Sci* 70(4):613–619
- Huda N, Shen YH, Huey YL (2009) Proximate composition, color and texture profile of Malaysian chicken balls. *Pak J Nutr* 8:1555–1558
- Huda N, Shen YH, Huey YL, Ahmad R, Mardiah A (2010) Evaluation of physico-chemical properties of Malaysian commercial beef meatballs. *Am J Food Technol* 5(1):13–21
- Ikhlas B, Huda N, Noryati I (2011) Chemical composition and physicochemical properties of meatballs prepared from mechanically deboned quail meat using various types of flour. *Int J Poult Sci* 10(1):30–37
- Kang ZL, Zou YF, Xu XL, Zhu CZ, Wang P, Zhou GH (2014) Effect of a beating process, as a means of reducing salt content in Chinese-style meatballs (kung-wan): a physico-chemical and textural study. *Meat Sci* 96(1):147–152
- Kaur M, Singh N, Sodhi NS (2005) Physicochemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum* L.) cultivars. *J Food Eng* 69(4):511–517
- Modi VK, Mahendrakar NS, Rao DN, Sachindra NM (2004) Quality of buffalo meat burger containing legume flours as binders. *Meat Sci* 66:143–149
- Modi VK, Yashoda KP, Bhaskar N, Mahendrakar NS (2009a) Effect of carrageenan and oat flour on storage characteristics of fried mutton kofta. *J Food Process Pres* 33:763–776
- Modi VK, Yashoda KP, Mahendrakar NS (2009b) Low-fat mutton kofta prepared by using carrageenan as fat replacer: quality changes in cooked product during storage. *J Food Sci Technol* 46(4):316–319
- Modi VK, Yashoda KP, Naveen SK (2009c) Effect of carrageenan and oat flour on quality characteristics of meat kofta. *Int J Food Prop* 12:228–242
- Moongngarm A (2013) Chemical compositions and resistant starch content in starchy foods. *Am J Agric Biol Sci* 8(2):107–113
- Murphy EW, Criner PE, Grey BC (1975) Comparison of methods for calculating retentions of nutrients in cooked foods. *J Agric Food Chem* 23:1153–1157
- Pietrasik Z, Janz JAM (2010) Utilization of pea flour, starch-rich and fiber-rich fractions in low fat bologna. *Food Res Int* 43(2):602–608
- Prasad B, Rashmi MD, Yashoda KP, Modi VK (2011) Effect of casein and oat flour on physicochemical and oxidative processes of cooked chicken kofta. *J Food Process Pres* 35:359–368
- Purnomo H, Rahardyan D (2008) Indonesian traditional meatball. *Int Food Res J* 15(2):101–108
- Sai-Ut S, Ketnawa S, Chaiwut P, Rawdkuen S (2009) Biochemical and functional properties of proteins from red kidney, navy and adzuki beans. *Asian J Food Ag-Ind* 2(4):493–504
- Sefa-Dedeh S, Stanley DW (1979) Textural implications of the microstructure of legumes. *Food Technol* 33:77–83
- Serdaroğlu M (2006) Improving low fat meatball characteristics by adding whey powder. *Meat Sci* 72(1):155–163
- Serdaroğlu M, Degirmencioglu Ö (2004) Effects of fat level (5%, 10%, 20%) and corn flour (0%, 2%, 4%) on some properties of Turkish type meatballs (koefte). *Meat Sci* 68(2):291–296
- Serdaroğlu M, Yildiz-Turp G, Abrodímov K (2005) Quality of low-fat meatballs containing legume flours as extenders. *Meat Sci* 70:99–105
- Tabarestani HS, Tehrani MM (2012) Optimization of physicochemical properties of low-fat hamburger formulation using blend of soy flour, split-pea flour and wheat starch as part of fat replacer system. *J Food Process Pres* 38:278–288
- Yadav U, Singh N, Kaur A, Thakur S (2018) Physico-chemical, hydration, cooking, textural and pasting properties of different adzuki bean (*Vigna angularis*) accessions. *J Food Sci Technol* 55(2):802–810
- Yılmaz I (2005) Physicochemical and sensory characteristics of low fat meatballs with added wheat bran. *J Food Eng* 69(3):369–373
- Yousif AM, Deeth HC (2003) Effect of storage time and conditions on the cotyledon cell wall of the adzuki bean (*Vigna angularis*). *Food Chem* 81(2):169–174