Color and texture analyses of meatballs made from beef, pork, rat, dog meats, and their mixtures

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Abstract. The aim of this study was to evaluate color and texture of meatballs made from beef, pork, rat, dog meats, and their mixtures. A total of 32 meatballs have been made and they were grouped into eight treatments containing four meatballs, respectively. Color intensity consisting of lightness ($L^*$), redness ($a^*$), and yellowness ($b^*$) has been tested using chromameter CR-400. Additionally, texture of meatballs consisting hardness, gumminess, springiness, chewiness was analyzed using AMETEX test and calibration instrument. The data obtained from this study was furthermore analyzed using one-way analysis of variance (ANOVA) and the pairwise differences among treatments were tested by Duncan’s multiple range test (DMRT). The results showed that $L^*$, $a^*$, $b^*$ were significantly different among treatments ($P<0.01$). The $L^*$ value of dog meat was different with beef, pork, and rat meat. Also, the $a^*$ value of beef was similar to pork and significant different with dog and rat meat, while $b^*$ value of dog meat was different with other meats. The $L^*$, $a^*$, $b^*$ scores in mixture samples consistently represented the average value of color scores of samples consisting various species. Moreover, texture analysis indicated highly significant effect of treatments on hardness, gumminess, springiness, and chewiness ($P<0.05$). Highest hardness, gumminess, and chewiness scores were found in meatballs made from beef and rat, respectively. In addition, springiness of meatballs was relatively similar among treatments. This study concluded that meatballs made from different species and mixtures had different color and texture. Further study should be conducted to test whether color and texture analysis could be utilized for checking meat-based food adulteration and halalness.

1. Introduction
Nowadays, there are many meat processed products derived from chopped meat, one of them is meatball. Meatball is one of popular meat processed products in the world [1]. According to SNI 1-3818-1995, meatball is round shaped food derived from meat mixture (not less than 50%) and starch or other cereals with/out allowed additional component. Meatball is widely spread and favored in Indonesia. Several factors affecting consumer preferences of meatball are appearance, juiciness, taste and texture [2]. Texture includes hardness, springiness, cohesiveness, gumminess and chewiness [3]. Hardness is the most important factor determining meatball quality [4]. Texture identification is performed by several ways [5]. The most common method is texture profile analysis (TPA) [3]. Numbers of texture assessment have previously been established [6].

Color of food product also determines consumer choice because it is one of freshness indicators which is able to be assessed by chromameter test. Differences of color intensity among species have
been previously reported due to different concentrations of myoglobin [7]. Beef contains highest myoglobin concentration followed by lamb, and pork [7]. Additionally, texture and meat color evaluations have been reported to describe transformation of meat color during storage [8]. Generally, species identification in meat and meat processed products is conducted by DNA analysis of mitochondrial genome using polymerase chain reaction (PCR) [9,10,11]. However, different color intensity among meats from different animal species may be useful to check species origin of meat based products, especially meat processed products such as meatball, sausage, and etc. Utilizations of texture and color analyses to distinguish and to trace meat origin in the processed products have not been reported elsewhere. Thus, the aim of this study was to evaluate color and texture of meatballs made from beef, pork, rat, dog meats, and their mixtures.

2. Materials and Methods
2.1. Meatball production
Meatballs were made by using meats from different animal species. They were beef (S), pork (B), and dog meats (A) bought from traditional market, whereas rat (T) meat was obtained from wild rat in the rice field. Right thigh muscles were selected to be used as main raw material to produce meatballs. A total of 32 meatballs were made that divided into eight kinds of meatball based on the origin of meat used, i.e. beef, dog, pork, rat, beef-dog, beef-pork, beef-rat, and beef-dog-pork-rat meatballs, respectively. The ingredients and method to produce meatballs were according previous study [10]. The proportion of meat in the meatball was set according to Table 1.

| Ingredients          | S(g) | A(g) | B(g) | T(g) | SA(g) | SB(g) | ST(g) | SABT(g) |
|----------------------|------|------|------|------|-------|-------|-------|---------|
| Beef (S)             | 100  | 0    | 0    | 0    | 50    | 50    | 50    | 25      |
| Dog meats (A)        | 0    | 100  | 0    | 0    | 50    | 0     | 0     | 25      |
| Pork (B)             | 0    | 0    | 100  | 0    | 0     | 50    | 0     | 25      |
| Rat (T)              | 0    | 0    | 0    | 100  | 0     | 0     | 50    | 25      |
| Garlic               | 2    | 2    | 2    | 2    | 2     | 2     | 2     | 2       |
| Tapioc flour         | 15   | 15   | 15   | 15   | 15    | 15    | 15    | 15      |
| Salt                 | 2    | 2    | 2    | 2    | 2     | 2     | 2     | 2       |
| Pepper               | 1    | 1    | 1    | 1    | 1     | 1     | 1     | 1       |
| Total                | 120  | 120  | 120  | 120  | 120   | 120   | 120   | 120     |

S is beef meatball; A is dog meatball; B is pork meatball; T is rat meatball; SA is meatball containing beef and dog meat; SB is meatball containing beef and pork; ST is meatball containing beef and rat meat; and SABT is meatball containing meat from four species.

2.2. Texture and color analyses
Hardness, cohesiveness, gumminess, resilience, springiness and chewiness of meatballs were analyzed using AMETEX Test and Calibration Instrument. Meatball with 2 cm of diameter were placed on the instrument and compressed with 10,000 mm/s of pressure. Also, meatball samples were analyzed using Chromameter CR-400 to determine L*, a*, and b* scores.

2.3. Experimental design and data analysis
This study applied completely randomized experimental design (CRD) with eight treatments and four replications. The data observed in this study was then analyzed using one-way analysis of variance (ANOVA) to evaluate significant effect of treatments to the parameters observed with 5% alpha and Duncan’s multiple range test was also performed to evaluate pairwise differences among meatballs.

3. Results and Discussion
3.1. Texture and color of meatball made from different meat sources
Both texture and color analysis of meatballs indicated inconsistent results. The ingredients used to produce meatballs were similar for each treatments. The only different thing in the ingredients was...
meat sources that used as differentiator among treatments, therefore ingredients and procedure to produce meatballs in this study should not be taken into account in discussions since they were exactly the same. Texture differences among meatballs from different species are presented in Table 2. Hardness is the maximum strength on the first bite [12]. Meatballs made from pork and dog meats were significantly different with meatballs made from beef and rat meat. In addition, meatballs containing more than one species were not consistently different. The highest hardness score went to beef and rat meatballs. Beef and rat meatballs showed no gumminess difference but they were highest score compared to other meatballs with different meat sources. Gumminess is product of hardness and cohesiveness [12]. Springiness represents recovery period between first and second bite [12]. Moreover, springiness of meatballs were relatively similar among meatball samples. Meatball originated from rat meat had highest chewiness score than other samples (P<0.01). Chewiness is product of gumminess and springiness [12]. Additionally, no significant difference among treatments was found for cohesiveness and resilience.

Color of meatball were objectively analyzed using Chromameter CR-400 for parameters of lightness (L*) or white within range 0 to 100, score of a* and b*, respectively. Score of a* and b* represent redness and yellowness that have positive and negative values. Score of a* is ranged from 0 to 60 for red and 0 to -60 for green. Furthermore, score of b* is ranged from 0 to 60 for yellow and 0 to -60 for blue [13]. Dog meatball had lowest L* score compared to meatball made from other species while meatballs made from meat mixtures were inconsistent (Table 2). No difference L* score between beef and pork and rat meat was detected in this study. This result suggested that it could not be used to differentiate species origin in meatball. Redness (a*) score of beef meatball was different with dog and rat meatballs, however it was not different with pork meatball. In addition, yellowness score (b*) of beef was significantly higher than dog meatball, on the other hand it was not different with pork and rat meatballs. These results suggested that meatballs could not differentiate based on L*, a*, b* scores due to inconsistent results. Flour and spices addition were able to be reason of this result [14]. Moreover, using DNA analysis of mitochondria ORF genome is much more accurate and effective to identify species origin in meat and meat products to date compared to physical analyses due to lack of consistent results [10, 11].

Table 2. Texture and color scores of meatballs made from different sources of meat

| Parameter        | S      | A     | B     | T     | SA    | SB    | ST    | SABT | P-Value |
|------------------|--------|-------|-------|-------|-------|-------|-------|------|---------|
| Lightness (L*)   | 44.25^cd | 38.60^a | 44.91^cd | 46.16^cd | 42.19^abc | 45.53^cd | 47.42^d | 41.17^ab | 0.000   |
| Redness (a*)     | 8.11^a  | 11.35^c | 7.98^a  | 9.29^b  | 9.26^b  | 8.56^ab  | 10.94^d | 9.53^b  | 0.000   |
| Yellowness (b*)  | 11.51^c | 10.02^a | 11.21^bc | 11.09^bc | 11.24^bc | 12.55^d  | 10.16^a | 10.51^ab | 0.000   |
| Hardness (N)     | 18.06^e | 10.41^ab | 7.67^a  | 17.99^e | 13.17^cd | 11.76^ab | 9.62^ab | 15.97^de | 0.000   |
| Cohesiveness     | 0.38    | 0.38    | 0.38    | 0.44    | 0.41    | 0.38    | 0.40   | 0.41    | 0.206   |
| Gumminess (N)    | 6.68^cd | 3.99^ab | 2.97^a  | 7.87^d  | 5.39^bc  | 4.44^ab  | 3.83^a  | 6.06^c  | 0.000   |
| Resilience       | 0.51    | 0.49    | 0.47    | 0.62    | 0.55    | 0.49    | 0.53   | 0.51    | 0.504   |
| Springiness      | 0.91^abc | 0.89^ab | 0.86^a  | 0.94^c  | 0.91^bc  | 0.91^bc  | 0.89^ab | 0.93^bc | 0.027   |
| Chewiness (N)    | 6.05^d  | 3.56^ab | 2.61^a  | 7.39^f  | 4.88^cd  | 4.05^bc  | 3.43^ab | 6.08^d  | 0.000   |

S is beef meatball; A is dog meatball; B is pork meatball; T is rat meatball; SA is meatball containing beef and dog meat; SB is meatball containing beef and pork; ST is meatball containing beef and rat meat; and SABT is meatball containing four species of meat. Different superscript in similar row shows significant differences.

4. Conclusions

Texture and color analyses on meatballs were conducted in this study, however, they could not be used to distinguish original material of meatballs due to inconsistent results. Further study should be taken into account to get more consistent result in order to be an alternative to check food adulteration and halalness of animal based foods.
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