Effects of composition and storage duration of mechanically deboned poultry meat on sensory properties of frankfurters

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Abstract. This research aimed to study the influence of differences in the composition and storage length of mechanically deboned poultry meat (MDPM) on the sensory properties of frankfurters. Three variants of frankfurters were produced from three respective alternatives of MDPM that differed solely in proportions of meat from broiler backs and necks. Similarly, a commercially available and freshly produced MDPM of unknown composition was used as the control. All the four variants of MDPM were stored at -18 °C for 1, 45 and 90 days. Sensory profiling of the frankfurters was performed by 8 panellists using a quantitative-descriptive analysis (QDA). Two-factorial ANOVA and principal component analysis (PCA) of the sensory evaluation results revealed significant (p < 0.05) effects of the storage time of the MDPM variants on sensory characteristics of the frankfurters, regardless of their composition.

1. Introduction
Mechanically deboned poultry meat (MDPM) is produced by mechanical separation of soft tissues from bones after manual deboning. It is the main raw material for production of thermally processed poultry sausages, such as frankfurters. Due to a large number of consumers of frankfurters in Bosnia and Herzegovina (B&H), those sausages have a dominant place in the production portfolio of most of B&H meat processing companies. To meet the high expectations of the consumers and improve their own market competitiveness, it is essential for each of the companies to be devoted to continuously improve the sensory properties of its products.

Current B&H regulation on MDPM [1] requires, among other things, that it can be stored at a minimum of -18 °C for up to three months. Thus, it is implied that the storage duration of MDPM has a key impact on the overall quality of poultry sausages, in which their sensory quality attracts particular attention of the consumers. There are many approaches to sensory evaluation of sausages, among which the quantitative-descriptive analysis (QDA) is one of the most widely used and reliable sensory profiling methods [2].

The goal of the study was to evaluate the effects of the composition and the storage duration of MDPM on sensory characteristics of experimentally produced frankfurters.
2. Materials and methods
To assess the effects of composition and storage duration of MDPM on sensory properties of frankfurters, experimental production of frankfurters was performed as a two-factorial completely randomized design with a $4 \times 3$ factorial structure [3]. The first factor was the MDPM composition (variant) at four levels: MDPM1, MDPM2, MDPM3 and MDPMC, while the second factor was the MDPM storage duration (D) at three levels: D1, D2 and D3. All coded factors, levels and experimental treatments are displayed in Table 1.

**Table 1.** Two-factor completely randomized design for experimental production of frankfurters using MDPM$^a$ of different composition (variants) and storage time

| Frankfurters (F) | MDPM variant | MDPM storage duration (D) |  
|-----------------|-------------|---------------------------|
|                 |             | D1 (1 day)                | D2 (45 days) | D3 (90 days) |
| F1$^b$          | MDPM1       | MDPM1×D1                  | MDPM1×D2    | MDPM1×D3    |
| F2$^c$          | MDPM2       | MDPM2×D1                  | MDPM2×D2    | MDPM2×D3    |
| F3$^d$          | MDPM3       | MDPM3×D1                  | MDPM3×D2    | MDPM3×D3    |
| Fc$^e$          | MDPMC       | MDPMC×D1                  | MDPMC×D2    | MDPMC×D3    |

$^a$ MDPM, mechanically deboned poultry meat  
$^b$ F1, frankfurters produced from MDPM1 (50% of deboned back meat + 50% of deboned neck meat) after D1, D2 and D3 storage durations at -18 °C  
$^c$ F2, frankfurters produced from MDPM2 (70% of deboned back meat + 30% of deboned neck meat) after D1, D2 and D3 storage durations at -18 °C  
$^d$ F3, frankfurters produced from MDPM3 (30% of deboned back meat + 70% of deboned neck meat) after D1, D2 and D3 storage durations at -18 °C  
$^e$ Fc, frankfurters produced from MDPMC (commercially available MDPM with unknown composition) after D1, D2 and D3 storage durations at -18 °C

Four variants of MDPM were used for production of the frankfurters. Three of them (MDPM1, MDPM2 and MDPM3) were experimentally produced with different proportions of broiler back and neck meat, while commercially available MDPMC with unknown composition was used as the fourth variant (Table 1). The three experimental variants of MDPM were produced in a commercial processing plant in B&H. After the commercial cutting of the carcasses, broiler backs (pelvic and thoracic portions) and necks were stored overnight at 2 °C before deboning. The deboning was done by AM2C SM 210 separator (AM2C SAS, Quimper, France) adjusted to yield about 50% ± 5% MDPM, and connected to a Wolf AW 160 grinder (K+G Wetter GmbH, Germany). Every batch of the MDPM was vacuum packed in Cryovac BB405 bags (Cryovac A/S, Oslo, Norway) as 10-kg blocks, which were frozen at -30 °C and stored at -18 °C. The MDPM blocks were delivered next day under cold chain conditions to Menprom Meat Industry, where experimental production of frankfurters was carried out. In the same way, the MDPMC was freshly produced and delivered from another common supplier. All the four MDPM variants were stored at -18 °C until the formulation of the sausages. On the same day of delivery, the first third of each of the four MDPM variants was used to produce the frankfurters (D1 storage duration), the second and the third parts of the variants were used after 45 days (D2 storage duration) and 90 days (D3 storage duration), respectively.

The four variants of frankfurters (F1, F2, F3 and FC; Table 1) were produced according to the same recipe and technological procedure, which was routinely used at Menprom Meat Industry, i.e. they differed only in respective MDPM variants. Mechanically deboned poultry meat was thawed for 24 h at 4 °C before use. Each batch of the frankfurter variants was prepared with 25.7 kg of MDPM, 10.9 kg of chicken skin fat emulsion, 3.4 kg of water (ice), 0.58 kg of nitrite salt, 0.85 kg of corn starch, 0.55 kg of soya proteins and other ingredients (commercial spice and additive mixtures). The frankfurters were initially heated at 55 °C for 20 min, then smoked at 65 °C for 10 min, and finally processed at 80 °C for
25 min to reach a core-temperature of 79 °C. Immediately after the heating process, the sausages were rinsed in cool water (7 °C) for approximately 1 h and cooled at 4 °C for 2 h. After the cooling step, cellulose casings were automatically peeled off, the frankfurters were vacuum packed in pouches (4 sausages each) and stored at 4 °C (±1 °C) for 2 weeks until sensory analysis.

To evaluate the compliance of chemical composition of the four MDPM variants (Table 1) with legal norms [1], a 300 g sample of each of the variants was taken in triplicate before commencement of the sausage formulation. The samples were immediately transported under cold chain conditions to the Department of Food Hygiene and Technology, Veterinary Faculty, University of Sarajevo, where the contents of moisture [4], total fat [5], total proteins [6] and calcium [7] were analysed.

To perform sensory evaluation, the sausages were transported under cold chain conditions to the Faculty of Agriculture and Food Sciences, University of Sarajevo and stored at 4 °C (±1 °C) until the evaluation. Spatial conditions for the evaluation were arranged according to the international standard [8], and the sensory profiling method was inspired by the previously described QDA methods [2, 9, 10]. The sensory panellists were selected after four sessions of group discussions and individual rating. To avoid bias, the training sessions were performed by a passive panel coordinator, who was informed of the objective of the sensory analysis. Since the panellists had already been trained in the evaluation of meat products, the training primarily focused on the definition and respective intensity of sensory characteristics of the frankfurters, as well as on the application of the evaluation method. During the training, commercially available frankfurters from different producers were used, as well as samples of the experimental sausages. However, the assessors were not aware of the content and the origin of the sausages. Finally, the set of 10 sensory characteristics of the frankfurters included appearance, colour, palpation consistency, oral (first bite) consistency, chewiness, juiciness, surface odour, taste, flavour and overall acceptability (Table 3). Selection of the panellists was done based on calculation of the coefficient of variation (CV) of their testing results, and the panellists who showed CV > 30% were excluded. In this way, the sensory profiling panel was selected among 20 invited assessors, which finally consisted of eight (three female and five male) trained assessors aged between 32 and 64 and with from 5 to 20 years of experience in the sensory profiling of sausages and other meat products.

Prior to the final evaluation, the vacuum pouches were unpacked, the frankfurters were boiled in water for 5 min and each assessor was served with a hot sausage sliced into 4-5 cm long pieces on a warm plastic plate marked with a 3-digit random number and covered by foil. Samples of the each treatment (Table 1) were served in triplicates to the assessors in their own time, and the serving order was randomised with regard to sample, replicate and assessor, with short breaks through the assessment to reduce the sensory fatigue effect. The panellists were served with water and flat bread between samples for cleansing the palate. Sensory evaluation of the sausages was carried out on a scorecard using a 70 mm unstructured line scale for each of the 10 sensory characteristics, with an anchor of 10 mm from each side marked as “low” and “high” intensity of the sensory characteristic. The panellists scored each of the 10 sensory characteristics by placing a vertical mark across the interval line at the point which best reflected the magnitude of his or her perceived intensity of the sensory property. The evaluation results were converted into numerical scores by measuring the distance from the left end of the scale to the point marked by the panellists. The evaluation score of each panellist was calculated as an average grade of the three replicates of the each treatment (Table 1).

Normality of the sensory evaluation data was checked by Kolmogorov-Smirnoff test. Two-factorial ANOVA was used to test simultaneous effects between the two factors and their levels (the MDPM composition with four levels/variants and the MDPM storage time with 3 levels; Table 1). When the effect of each of the analysed factors and their interactions was significant, the means were separated using Tukey’s test. Similarly, one-way ANOVA with Tukey’s test was used to analyse the data of chemical analyses. All of the analyses were performed by using the IBM SPSS Statistics v. 20 software (IBM Inc., USA). P-values less than 0.05 were considered statistically significant. Principal component analysis (PCA) was applied to identify clusters of mutually independent variables and to visualise effects of the two factors on the sensory characteristics of sausages. PCA was done by using the statistical package StatBoX 6.7 (Grimmersoft, Paris, France).
3. Results and discussion

Results of chemical analyses of the four MDPM variants are shown in Table 2. All of the MDPM variants showed desirable protein contents, since they had more than the legally required minimum of 12% of proteins [1]. In addition, all the MDPM variants displayed a higher protein content than those used in studies of Trinidad et al [11] (9.3%-14.5%) and Botka-Petrak et al [12] (13.46%-15.57%). Similarly, Trinidad et al [11] reported lower moisture contents (63.4-66.6%) than those of MDPM1, MDPM2 and MDPM3, but higher than the moisture content in the MDPMC. In contrast, Botka-Petrak et al [12] estimated moisture content in MDPM made of whole carcasses at 69.14%, which is in agreement with the moisture content in MDPM1, MDPM2 and MDPM3. The range of the total fat content reported by Trinidad et al [11] for MDPM made from chicken backs and necks (14.45%-27.7%) includes the average fat content of the MDPM2, while the MDPM1 and the MDPM3 had lower average fat contents. The MDPMC variant displayed significantly higher (p < 0.001) fat content than the other experimental MDPM variants, which should be considered when designing the recipes for poultry products. None of the MDPM variants met the compulsory maximum of 0.1% for the content of calcium [1]. Similar findings on the calcium content were reported [12], where only the MDPM made of whole broiler carcasses displayed the desirable content of 0.06% of calcium, while the MDMP variants made of the deboned meat of backs, wings and necks displayed an average calcium contents of 19.50%, 29.36% and 21.60%, respectively, being much higher than those found in this study. Such findings surely indicate the need to check and modify the deboning process, as it is known that the mechanical deboning leads to extraction and oxidation of the lipids from the bone marrow, and, consequently, to undesirable taste and odour of the final products [13].

Table 2. Chemical content of MDPMa variants (mean±standard deviation of three measurements)

| Parameter (%)       | MDPM1          | MDPM2          | MDPM3          | MDPMC         | p     |
|---------------------|----------------|----------------|----------------|---------------|-------|
| Moisture            | 69.60±0.46a    | 68.92±0.14a    | 69.93±0.71a    | 62.72±0.86b   | < 0.001|
| Total proteins      | 17.04±0.47ab   | 16.86±0.59ab   | 17.57±0.37a    | 16.07±0.23b   | 0.018 |
| Total fat           | 13.64±0.79a    | 14.70±0.51a    | 11.55±0.27b    | 20.21±0.43c   | < 0.001|
| Calcium             | 0.20±0.02a     | 0.19±0.04a     | 0.23±0.02a     | 0.32±0.05b    | < 0.001|

aMDPM, mechanically deboned poultry meat

bMDPM variants differed in content of deboned back meat and deboned neck meat (see Table 1 for details)

Different letters (a-c) in the same row denote significant differences (p < 0.05) (ANOVA with Tukey’s test)

Results of the sensory evaluation of the experimentally produced frankfurters showed that differences in the sensory attributes primarily occurred due to the effect of the MDPM storage duration. The two-factorial ANOVA (Table 3) resulted in highly significant (p < 0.001) effects of the MDPM storage duration (factor D) on all the 10 assessed sensorial characteristics, as well as a significant (p < 0.05) impact of the variants of frankfurters (factor F) on six of the sensory properties (oral consistency, juiciness, surface odour, taste, flavour and overall acceptability). Additionally, the interactions of the factors (D*F) also triggered a significant (p < 0.05) impact on chewiness of the sausages.

Table 3. Analysis of variance of effects of the MDPMa storage duration and the variants of frankfurters on sensory characteristics of the frankfurters (F-values for independent variables and interactions)
The dependence of the sensory properties of frankfurters on the MDPM storage duration is also displayed by the corresponding results of their PCA analysis (Figure 1), which explained 98.10% of variability of all results of the sensory evaluation of frankfurters. The PCA analysis determined that all frankfurters produced from all the four variants of MDPM after 1 day of storage (D1, blue coloured cluster), regardless of their composition, showed significantly better (p < 0.05; Table 3) colour, appearance, surface odour, taste, palpation consistency, juiciness and overall acceptability when compared to the frankfurters produced from the MDPM variants stored for 45 days (D2, red coloured cluster). On the other hand, D2 frankfurters displayed significantly higher (p < 0.05; Table 3) sensory scores for oral consistency, chewiness and flavour than all the other frankfurters, which indicates their favourable sensory properties. In contrary, the frankfurters produced from MDPM variants stored for 90 days (D3, green coloured cluster) exhibited significantly inferior (p < 0.05; Table 3) sensory characteristics than the sausages from MDPMs stored for 1 and 45 days. In support of this result, Froning et al [14] described a substantial decrease of sensory properties of frankfurters produced from frozen MDPM stored for 90 days. Also, it is notable that the poorest sensory properties in all the three clusters were obtained by frankfurters prepared from commercially available MDPMC (FCD1, FCD2 and FCD3). Such finding may be explained by significantly higher (p<0.001) content of total fat in MDPMC (20.06%; Table 2) compared to the other MDPM variants. A similar finding was described by Biswas et al [14], who reported significant differences (p<0.05) in some sensory properties of chicken sausages with increase of the fat content due to higher proportion of chicken skin and fat in the composition of the sausages.

| Characteristics               | MDPM storage duration (D) | Variants of frankfurters (F) | Sources of variations |
|-------------------------------|---------------------------|------------------------------|----------------------|
|                               | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D*F |
| Appearance                    | 4.51a | 3.77b | 3.12c | 3.73 | 3.82 | 3.86 | 3.80 | 371.09*** | 1.83 NS | 1.53 NS |
| Colour                        | 4.56a | 3.86b | 3.17c | 3.82 | 3.85 | 3.88 | 3.90 | 479.65*** | 0.98 NS | 0.69 NS |
| Consistency (palpation)       | 4.50a | 4.14b | 3.27c | 3.89 | 3.96 | 4.05 | 3.98 | 283.80*** | 2.25 NS | 0.65 NS |
| Consistency (oral)            | 3.70b | 3.99a | 3.31c | 3.66ab | 3.66ab | 3.75a | 3.61b | 278.60*** | 5.94** | 7.40*** |
| Chewiness                     | 3.77b | 4.01a | 3.32c | 3.74 | 3.70 | 3.72 | 3.65 | 169.31*** | 1.61 NS | 2.88* |
| Juiciness                     | 4.21a | 4.03b | 3.29c | 3.79 | 3.88 | 3.91 | 3.78 | 278.78*** | 3.62* | 3.01* |
| Surface odour                 | 4.32a | 3.89b | 3.13c | 3.75ab | 3.85a | 3.86a | 3.67b | 528.42*** | 8.80*** | 5.38*** |
| Taste                         | 4.31a | 3.85b | 3.14c | 3.75ab | 3.82a | 3.83a | 3.67b | 417.47*** | 4.51* | 3.81** |
| Flavour                       | 3.57b | 3.71a | 2.96c | 3.49a | 3.46a | 3.46a | 3.24b | 161.30*** | 9.99*** | 5.77*** |
| Overall acceptability         | 4.26a | 3.96b | 3.19c | 3.80a | 3.88a | 3.87a | 3.67b | 428.95*** | 9.68*** | 2.93* |

a MDPM, mechanically deboned poultry meat
b D1, D2 and D3 – mean intensity panel (n=8) scores of the sensory characteristics (using an unstructured line scale from 0 to 70 mm) of the frankfurters produced from the MDPM variants (see Table 1 for details) stored at -18 °C for 1, 45 and 90 days , respectively.
c F1, F2, F3 and FC – mean intensity panel (n=8) scores of the sensory characteristics (using an unstructured line scale from 0 to 70 mm) of the frankfurters produced from MDPM1, MDPM2, MDPM3 and MDPM, respectively (see Table 1 for details). Different letters (a-c) in the same row denote significant differences (p < 0.05) (Two-factorial ANOVA with Tukey’s test); NS, non-significant; * - significant at p < 0.05; ** - significant at p < 0.01; *** - significant at p < 0.001.
Figure 1. Principal component analysis (PCA) bi-plot of distribution of samples of the variants of frankfurters (F1, F2, F3 and FC – see Table 1 for details) and the different storage durations of mechanically deboned poultry meat (MDPM) at -18 °C (D1, D2 and D3 for 1, 45 and 90 days, respectively) with regard to sensory attributes of the frankfurters.

4. Conclusions
The findings of the study clearly indicate that the composition and storage duration of MDPM significantly affect sensory quality of frankfurters, where the intensity of the sensory properties of frankfurters significantly deteriorates with increasing the duration MDPM is stored at -18 °C.

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