Effect of packaging methods on salt-reduced smoked-steamed ham using herbal extracts

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ABSTRACT
The aim of the study was to analyze the use of herbal extracts on reduced-salt smoked-steamed ham and to choose the optimal method of packaging. The 36 muscles were allocated to three groups: standard (S) with a content of NaCl = 2.5% and two experimental groups. The first one with a reduced salt content to 1.5% by the use of basil extract (E1) and the second group with an addition of oregano (E2). Hams were storage for 10, 20 and 30 days after packaging in barrier bags, vacuum conditions and modified atmosphere condition. The results indicate that the addition of herbal extracts increases the polycyclic aromatic hydrocarbons content (P < 0.05) but does not cause exceeded the recommended standards. The most advantageous packaging technology for hams with reduced salt content is vacuum. These hams were characterized by the most advantageous color parameters and the lowest hardness.

1. Introduction
A significant increase in the total meat consumption has been observed over the last two decades. The most dynamic increase in consumption was recorded for poultry meat, then for pork, beef and meat of other species. Pork meat and its products are a good source of wholesome protein, iron and zinc (Gjerlang-Enger et al., 2015). The meat processing requires the use of salt due to its following functions: shaping the fixed flavor profile, maintaining the color, proper level of protein solubilization strongly associated with the maintenance of own and added water. In developed countries, sodium consumption significantly exceeds the recommended levels, hence different ways to limit the consumption of table salt are sought. One of the ways is the reduction of table salt from food products at the stage of their production. The excess of sodium in the diet determines the development of civilization diseases such as hypertension which is the cause of strokes (WHO, 2012), cancers, especially of stomach, large intestine (Webster, Trieu, Dunford, & Hawkes, 2014) and increases the risk of cardiovascular diseases occurrence. In response to consumer expectations, manufacturers of meat products search for technological solutions that allow to limit sodium content in them (Toldara & Barat, 2014). The observed trend is so strong that even manufacturers of traditional cold meats covered in the European Union by protection within Protected Designation of Origin (PDO) reduce the content of table salt from 7–6% to 3% of sodium chloride (Skrlep et al., 2016). Two basic methods for table salt reducing in meat products include limiting the addition of sodium chloride or substitution with KCl or CaCl₂ (Alino et al., 2010).

On the one hand, salt content reduction is desirable and necessary, on the other hand it causes many difficulties in the technological process and storage. Too low concentration of table salt causes a greenish-gray discoloration resulting from salt intake by muscle tissue and accompanying biochemical changes. Low salt content shortens the shelf life (Cutter, 2006). The key to reducing salt content in meat products is consumer acceptance related to the level of salt taste sensation as well as consumers′ habits for high salt content in this type of products. NaCl content reduced compared to the standard value in the meat raw material subjected to the processing increases the ability to maintain water, too high salt content causes the reduction of this parameter by the phenomenon of "protein

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salting out” (Nguyen, Arason, Thorarinssdottir, Thorkelsson, & Gudmundsdóttir, 2010). Complete elimination of table salt from meat products is not possible due to the technological functions it fulfills. The table salt primarily gives the desired textural profile due to the impact on the structure of meat proteins (hardness, elasticity, cohesion, gumminess, chewiness and adhesiveness) and facilitates the diffusion of flavors (Delgado-Pando et al., 2018; Zhang et al., 2018, 2019; Zhou et al., 2019).

Meat products with reduced sodium content require alternative methods of fixing. The use of high pressure technologies (Hygremea & Pandey, 2016), modified protective atmosphere, acidification, e.g. using natural lactic acid (Unulu, Nielsen, & Ionita, 2016), competitive microflora (Baka, Noriega, Martens, Van Derlinden, & Van Impe, 2014), application of natural plant extracts, have been studied so far as techniques for prolonging the meat products durability (Burt, 2004; Haugaard, Hansen, Jensen, & Grunert, 2014; Rojas & Brewer, 2008). The study conducted by De Candia, Quintieri, Caputo, and Baruzzi (2016) showed an effect of compounds naturally occurring in spices (cinnamon, garlic, sage, oregano, pepper, thyme and rosemary) on antibacterial activity, limiting the development of food pathogens and saprophytic microorganisms.

The study was carried out in order to examine an influence of storage time and packaging method on selected quality traits of smoked-steamed ham with reduced salt content. In addition, the aim of the study was to analyze the possibility of counteracting the effects of reduced salt content in ham by adding biologically active extracts of basil (Ocimum basilicum L.) and oregano (Oregano vulgare L.).

2. Material and methods

2.1. Raw meat

The study material consisted of pig muscles (musculus quadriceps femoris) obtained from the right half-carcasses of pigs produced in the quality system Pork Quality Standard (PQS) (Guzek, Głąbska, Wojtasik-Kalinowska, & Wierzbicka, 2013). Class E half-carcass weight according to the European post-mortem classification system SEUROP (Council Regulation (EC) No. 1234/2007, Commission Regulation (EC) No. 1249/2008) selected for the experiment was in the range of 43.6 ± 2.3 kg with slaughtering efficiency of 77.29 ± 2.25%. Pigs were obtained from the Polish Landrace × Duroc breeds crossbreeding. The slaughtered was carried out at the age of 180 d ± 6 d at body weight of 110 ± 14.5 kg. The animals were free from the homozygous form of the Ryanodine receptor 1 (RYR1) recessive stress sensitivity gene, the gene responsible for an increased incidence of meat quality defects of the PSE type (pale – soft – exudative).

2.2. Technological process

Quadriceps femoris muscles were divided into three groups: standard with NaCl (5) content of 2.5%, with NaCl content reduced to 1.5% and with the addition of 0.04% water-soluble basil extract (E1), with NaCl content reduced to 1.5%, and with the addition of 0.04% water-soluble oregano extract (E2). In each of the analyzed groups, 12 Quadriceps femoris muscles (36 muscles) were used. The plant extract used in the experiment was produced by Firmenich SA (Geneve, CHE) company, included into the register of food additives (EFSA, 2013). Table 1 shows the ingredients and nutritional value for the experimental extracts. The muscles were injected with saline solutions using an injection system with a three-needle beam (Universal Injector, Delitech Dagema, Willich, Germany) for 1 min at 3 bar pressure. The mean weight gain after injection was 300 g, which was 25% of the muscle mass before injection. Subsequently, the meat was subjected to the massaging (plastification) process using a tumbler (LPM-20, Glass, Paderborn, Germany) in the 50/50 interval work cycle for 45 min. The muscles were then placed in the cured meat net using a 150 mm diameter applicator. After draining, the ham was smoked in a smoking chamber using beech and alder wood chips at 40°C for 2.5 h. The hams were then subjected to a steaming process at 95°C in a convection-steam oven (CPE-

| Table 1. Ingredients and nutritional value of water-soluble basil and oregano extract. |
|-------------------------------|-----------------|------------------|
| **Ingredients**               | **Basil**       | **Oregano**      |
| Maize maltodextrin            | -               | Maize maltodextrin|
| Flavouring components¹       | -               | Flavouring components⁠ |
| Estragole                     | 0.03%           | Estragole        |
| Methylleugenol                | 0.003%          | Methylleugenol   |
| Thuyone                       | 0.0007%         | Thuyone          |
| Safrole                        | 0.0001%         | -                |
| E 1450 Modified corn stretch  | 1.6%            | E 414 Acacia gum Arabic |
| Nutritional value²            |                 | 7.6%             |
| Energy (kJ/100 g)             | 398             | 304              |
| Energy (kJ/100 g)             | 1665            | 1272             |
| Protein (g/100 g)             | 0.31            | 0.45             |
| Carbohydrates                 | 95.97           | 71.46            |
| (excluding fibre; g/100 g)    |                 | (excluding fibre; g/100 g) |
| Sugars                        | 4.00            | 4.97             |
| Saturated (g/100g)            | 0.12            | -                |
| Sodium (g/100 g)              | 0.12            | -                |

¹Quantities based on contribution from flavoring components and/or food ingredients with flavoring properties (as defined in Article 3 of Regulation (EC) No. 1334/2008)

²Council Directive 90/496/EEC as amended. IOFI Information Letter no 1438: “Energy value of flavourings"
110, Kuppersbuch, Gelsenkirchen, Germany) to reach a temperature of 75°C in the geometric center of the muscle. After the completion of the process, the samples were cooled to 2°C and packaged using three packaging methods: C-control, VAC-vacuum, MAP-modified atmosphere packaging. In the C system, the hams were packed in PA/PE (polyamide/polyethylene) barrier bags without closing. Packaging under vacuum conditions consisted of placing hams in sealed PET/PE bags using a vacuum packaging machine (EDESSA VAC-20 SL 2A, Barcelona, Spain). When packaging under MAP conditions, a 70% N₂ and 30% CO₂ gas mixture was used. The Sealpac M3 packaging machine (Sealpac, UK) was used for packaging in the MAP system. The cover film for MAP packaging was made of polypropylene with permeability: O₂ = 10 cm³/m²·24 h (O) -0.1 MPa, moisture vapor <3 g/m²·24 h, and standard PP packaging (polypropylene) with dimensions 187/137/50 mm were used. The analyses of hams were carried out on four dates: on the day of packaging (d0) and after 10 (d10), 20 (d20) and 30 (d30) days of refrigerated storage at a temperature of 0 ± 1°C.

2.3. Analysis of ham quality

Technological efficiency of the production process for smoked-steamed hams with reduced salt content was calculated on the basis of the difference in mean raw weight of the muscles and the smoked meat obtained from them according to the following formula:

\[
CL = \left(1 - \frac{M_f}{M_i}\right) \cdot 100\% 
\]

where CL - cooking loss (%); \(M_i\) - initial weight (g); \(M_f\) - final weight (g).

Chemical composition. Raw and smoked pork ham composition (water, fat, protein, connective tissue and salt content) was determined using a near-infrared spectrometer NIRFlex N-500 (Buchi, Switzerland). Measurements were conducted using a NIRFlex solids module of spectral range 12,500–400 nm in reflectant mode. Subsequent samples, which were the slices of the cross-section in the muscle diameter were homogenized and placed on Petri dish covering the surface with a 0.5 cm layer. Three measurements of each sample were conducted at a 32 scanning rate (Wyrwisz et al., 2016).

The pH value of the low salt smoked pork ham was measured according to the PN-ISO 2917:2001/Ap1:2002 standard. pH-metric results were obtained using a Testo 205 series pH-meter equipped with a insertion glass electrode, which was placed directly into the samples (2 cm deep into samples). Each measurement was performed in five replications, taking the mean value as the assay result. The temperature of samples during measurements was 0 ± 1°C.

Color components were measured using MINOLTA CR-400 (Osaka, Japan) chromometer in the L* a*b system. Following settings were used: illuminate D65; a standard observation of 2°, the aperture 8 mm. The device was calibrated before measuring started to white standard plate (L* = 98.45; a* = −0.10; b* = −0.13). The values of color parameters L* (lightness), a* color axis ranged from greenness (-a*) to redness (+a*) and b* color axis ranged from blueness (-b*) to yellowness (+b*) were measured on the cross-section of the muscle, five measurements were taken for each sample (muscle) in the central part of the sample (Wyrwisz et al., 2016).

Shear force test was performed using INSTRON (Model 5965, MA, USA) with Warner-Bratzler shear force (WBSF) attachment consisting of a V-notch blade according to Wyrwisz et al. (2016). Warner-Bratzler shear force was determined for the samples that were complete rolls cut from samples cooled to a temperature of 2 ± 1°C in the direction of the muscle fiber course. Ten cylindrical samples, with the diameter of 1.27 cm and height of 2.5 ± 0.3 cm, were shear using a “V” shaped steel knife (60° into lower edge). Wide slit in a small table 4 mm. The direction of cutting force was perpendicular to the muscle fibers orientation. The test was conducted with constant head speed (cell capacity 500 N) – 200 mm/min, at standardized temperature of the samples (2 ± 1°C). The recorded parameter was the maximum cutting force. Each sample was assessed 6 times (Wyrwisz et al., 2016).

The determination of benzo(a)pyrene content was carried out according to the methodology: PB-258/LF issue 1 of 04/2014 and the sum of four PAHs (benzo(b)fluoranthene, benzo(a)pyrene, chrysene, benzo(a)anthracene according to the methodology (from calculations) PB-258/LF issue 1 of 04/2014) was carried out with the use of high-performance liquid chromatography with fluorescence detection. This method involves the extraction of PAHs from the organic phase sample with an organic solvent, followed by purification of the obtained extract and its concentration. Then, separation and quantification of PAHs is carried out using the high-performance liquid chromatography method. Chromatographic conditions were: HPLC PAH (4.6 × 150 mm, 3.5 µm) column, mobile phase acetonitrile/water (0 min 50/50, 2 min 50/50, 22 min 0/100), flow rate of mobile phase 1.5 ml min⁻¹, volume of injection was 100 µl, temperature of column 30°C, maximum analysis time +25 min.

Microbiological tests were carried out in the study. At 0 d and after 20 (D20) and 30 (D30) days of storage from each experimental group (S, E1 and E2) and within each packaging system (C, VAC and MAP), 3 hams of 450 ± 30 g were taken for microbiological analyses. The samples were transferred to the JARIS SA laboratory (Łajski, PL) in original packaging without opening. The number of yeast and mold in 1 g of material was examined by PN-ISO 7954:1999. The plate method was used, where the incubation was carried out at 25°C by 5 days with the selective medium with tenfold dilution of the sample ACH with chloramphenicol, deep seeding and oxygen conditions. The count of Pseudomonas aeruginosa was determined according to PN-EN 12780 and PN-EN ISO 16266 was used: microbiological substrate for surface culture CN, conditions of incubation: 37°C, 2 days, oxygen conditions.

Presence of anaerobic sporulating bacteria was determined according to “Wrzosik” medium by conditions of incubation: 37°C, 3 days, anaerobic conditions. Confirmatory tests: Gram staining, growth on WB Wilson medium-Blair, growth on WH Willis-Hobbs.

In addition, the presence of Listeria monocytogenes was determined by the horizontal method (detection of the presence and number of bacteria PN-EN ISO 11290 + A1: 2005: Ap1: 2006 + Ap2: 2007), conditions of incubation: 37°C, 2 days, oxygen conditions, surface culture, medium ALOA. Confirmatory tests: hemolysis, CAMP test, Gram stain, catalase, carbohydrate distribution (xylose, rhamnose).

The presence of Salmonella spp. in 25 g was investigated using the horizontal Salmonella spp. detection method PN-EN ISO 6579:2003+AC:2014-11 according with substrates: (buffered peptone water −37°C 18 h); (RVS −41.5°C 24 h);
The chemical composition of ham analyzed on one-way ANOVA. The physicochemical properties of hams in the study were calculated according to 3 x 3 x 4 factorial arrangement for 3 processed methods, 3 packaging methods (C, VAC, MAP) and 4 dates of determination (0 d, 10 d, 20 d, 30 d) with interaction. All analyses were performed using the SPSS 21.0 statistical package (SPSS, 2012). The distribution of all variables was in accordance with the normal distribution, which was verified by the Kolmogorov–Smirnov test. The results are presented as mean and pooled SEM values. Differences were considered significant at P < 0.05 and P < 0.01.

3. Results and discussion
The technological efficiency of the production process for smoked-steamed hams with reduced salt content was 62.76%.

3.1. Effect of ham process
The production process including recipe variants in which the salt content was reduced and the extracts of basil and oregano were used affected (P < 0.001) pH, L*, a*, b* values. There was no influence of the production process taking into account the modification of the recipe on the value of the cutting force parameter (P > 0.05). The storage time affected (P < 0.001) the pH of packaged smoked pork products (Table 3). Hams from group S were characterized by a pH level from D0 6.22 ± 0.07 to 6.33 ± 0.08 on the 30th day of refrigerated storage (D30) for C, similarly for C in groups E1 and E2. These transformations indicate a progressive process of protein degradation towards a pH close to 7.0. Both in the case of the E1 and E2 groups, non-directional changes in the pH parameter were observed for MAP as opposed to VAC, where the trend of significant acidification of samples to 6.05 ± 0.19 for S VAC D30 was observed. The obtained pH results for VAC are opposite to the pH results of packing C. The observed changes occurred regardless of the technological variant used. In general, the refrigeration storage period had no effect on the L* coordinate value but significantly affected a* (P < 0.001) and b* parameter changes (P < 0.001). The cutting force parameter values were dependent on the storage period (P < 0.001). The packaging system with the same level of probability affects the examined qualitative characteristics of the products for pH, L*, a*, b*, WBSF. Table 3 shows the interaction between the recipe and the packaging system that influenced the a*, b* and WBSF parameters (P < 0.001).

3.2. Effects of packaging methods and storage times
The basic composition of the examined meat is shown in Table 2. An application of herbal extracts and reduction of salt content to 1.5% in injection resulted in an increase of water content in the product (P > 0.05). The content of fat and protein in hams was not dependent on the technological modification applied. Significant differences in fat and protein were observed between raw meat and meat after processing in all three groups of hams. Increasing the level of protein and fat due to the technological process (smoking, steaming) results from technological losses and biochemical changes in the structure of the tissue under the influence of temperature (water loss) (Aaslyng, Vestergaard, & Koch, 2014).

The pH (Table 3) for the S group samples was stable and was within 6.05–6.30. Similar results were obtained previously by Pietrask and Gaudentte (2014), which proves the proper values of this parameter. Similarly stable pH was observed for smoked meats from all packaging systems: C, MAP, VAC. The exception were the hams from VAC D30 groups, for which the lowest pH value was observed (P < 0.05). Damaziak et al. (2016) also observed the lowest pH of smoked goose filets stored in VAC, compared to other types of packaging. With reference to samples of smoked pork from E1 production packaged under C, MAP, VAC conditions, stable equalized pH values were also found except for C D10 where the lowest (P < 0.05) pH value was observed. For samples of smoked pork from E2 production packaged in C, MAP, VAC, also stable pH values were noted except for VAC D 30 6.47 ± 0.18, which was the lowest of all analyzed samples (P < 0.05).

The L* values (Table 3) for smoked pork samples from S production were characterized by similar values for all packing systems except VAC D30 (L* = 63.53 ± 3.53), where the values of this parameter were the lowest (P < 0.05). VAC D30 smoked products were darker with respect to other samples with the same salt content and the same storage periods as the C and MAP hams. The smoked pork samples from the E1 group were characterized by aligned L* values (P < 0.05) in all packaging systems and storage periods. The smoked products from the E2 group had the lowest (P < 0.05) L* values for D0. This may be due to the antioxidant properties of the oregano extract (Rodriguez-Meizoso et al., 2006). The C samples in the

### Table 2
| Treatment group | Moisture a | Fat b | Protein c | Salt | Ash | Connective tissue |
|-----------------|------------|-------|-----------|------|-----|------------------|
| Raw meat        | 73.9 ± 1.61 a | 4.1 ± 1.29 b | 21.6 ± 0.69 c | nd   | 1.4 ± 0.16 | 1.3 ± 0.21 a |
| Standard ham    | 66.7 ± 3.56 a | 4.5 ± 2.01 b | 24.3 ± 0.64 c | 1.2 ± 0.04 c | nd   | 0.7 ± 0.02 b |
| E1 ham          | 67.2 ± 4.64 a | 4.5 ± 0.22 b | 25.6 ± 1.66 c | 1.0 ± 0.19 c | nd   | 0.5 ± 0.28 a |

a–c: Means within a row without a common superscript differ significantly (P < 0.05).

E1 ham = brine 1.5% NaCl and 0.04% oregano extract; E2 ham = brine 1.5% NaCl and 0.04% basil extract; nd = not detected.

Medias (± DE) para la composición básica de los músculos cuádriceps femoral en bruto y procesados.

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E1 ham = brine 1.5% NaCl and 0.04% basil extract; E2 ham = brine 1.5% NaCl and 0.04% oregano extract; Standard ham = brine 2.5%; NaCl; E2 ham = brine 1.5% NaCl and 0.04% oregano extract; E1 ham = brine 1.5% NaCl and 0.04% basil extract; nd = not detected.
Table 3. Effect of packaging system and storage time in low salt (m. quadriceps femoris) quality.

| Process | Packaging system | Day of storage | L* | a* | b* | WBSF |
|---------|------------------|----------------|----|----|----|------|
| D0      |                  | 6.22±0.07      | 69.69±5.40 | 13.06±2.81 | 7.17±0.87 | 15.89±6.32 |
| D10     |                  | 6.19±0.01      | 72.80±6.20 | 2.62±2.33 | 11.88±2.14 | 15.72±2.04 |
| C       |                  | 6.33±0.16      | 68.55±5.42 | 7.32±2.30 | 11.09±0.77 | 13.75±1.39 |
| D30     |                  | 6.31±0.08      | 71.09±4.92 | 7.84±1.09 | 11.42±0.85 | 11.98±4.38 |
| MAP     |                  | 6.29±0.06      | 70.89±4.99 | 10.56±1.18 | 9.52±1.37 | 12.87±5.34 |
| VAC     |                  | 6.05±0.19      | 63.53±3.53 | 11.59±2.32 | 9.82±1.36 | 21.32±9.86 |
| D0      |                  | 6.20±0.11      | 69.04±5.58 | 13.47±2.34 | 7.46±0.88 | 16.93±4.01 |
| D10     |                  | 6.32±0.18      | 69.62±2.80 | 7.42±3.01 | 12.12±1.28 | 13.58±3.54 |
| E1      |                  | 6.06±0.12      | 67.36±4.47 | 8.59±2.86 | 10.23±1.06 | 16.07±5.96 |
| MAP     |                  | 6.20±0.12      | 66.39±5.25 | 10.27±1.89 | 9.51±1.65 | 13.96±5.45 |
| VAC     |                  | 6.07±0.08      | 67.09±4.86 | 8.70±1.71 | 9.40±1.40 | 15.79±2.44 |
| D30     |                  | 6.16±0.12      | 67.14±4.48 | 12.81±1.45 | 8.28±0.99 | 16.08±2.46 |
| D0      |                  | 6.24±0.18      | 69.07±5.81 | 13.19±2.15 | 8.15±0.85 | 13.08±4.91 |
| D10     |                  | 6.52±0.21      | 67.85±5.42 | 7.23±2.30 | 11.09±0.77 | 13.75±1.39 |
| C       |                  | 6.45±0.17      | 67.54±4.91 | 7.84±1.09 | 11.42±0.85 | 11.98±4.38 |
| D20     |                  | 6.62±0.07      | 69.32±6.75 | 11.59±1.28 | 8.98±0.84 | 10.74±1.83 |
| E1      |                  | 6.36±0.15      | 68.65±4.42 | 10.19±2.25 | 9.18±1.23 | 15.81±1.97 |
| MAP     |                  | 6.23±0.06      | 71.50±4.97 | 7.98±2.06 | 10.24±1.20 | 16.64±5.89 |
| VAC     |                  | 6.30±0.14      | 68.48±5.04 | 12.73±1.19 | 9.41±0.80 | 14.66±3.48 |
| D30     |                  | 6.01±0.11      | 67.00±3.78 | 12.33±2.01 | 9.17±1.05 | 17.69±2.61 |

Effect of

- process (R) SEM 0.016
- packaging system (PS) ***
- day of storage (DS) ***
- R × PS ***
- R × DS ***
- PS × DS ***

*a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z* Indicates within a row without a common superscript differ significantly (P < 0.05).
The mean values of the L* parameter. Regarding the samples from group C packed in MAP, no statistical differences were found for the obtained L* values in samples stored in D10, D20, D30 (P > 0.05).

The analogous situation concerned the analysis of results obtained for samples E2 VAC D10, D20, D30. Samples E2 C in D0 were characterized by the highest saturation level of red color (a* = 15.19 ± 2.15) (P < 0.05). A reduction of the a* parameter value (P < 0.05) was observed in subsequent cooling storage periods in the C packaging system. The red color saturation was significantly reduced compared to D0. In the case of smoked pork from the E1 production system packaged using C, MAP, VAC for D0, D10, D20, D30, unstable changes of red color saturation were observed, the changes of which took place in different directions.

Yellowness (b) in the standard production samples was unstable and generally increased with the storage time for individual storage periods in the C packaging system and was reduced in MAP and VAC packaging systems. In the smoked samples from the E1 group, no direction of yellow saturation changes was found, this parameter in the E1 group was unstable. While in the case of smoked samples from S and E1 groups, there was no correctness of the direction of changes in the yellow saturation parameter, similar values for parameter b* were observed in the case of E2 VAC D10 (b* = 11.09 ± 0.77), D20 (b* = 11.42 ± 0.85) and D30 (b* = 14.07 ± 1.60), (P > 0.05).

In the S group, significant changes in WBSF values for S C D0 (15.89 ± 6.32) and S C D30 (20.68 ± 4.05) were observed (P < 0.05). With regard to the S VAC and S MAP groups, no stable direction of changes was observed. For the samples from the S MAP (15.78 ± 1.67) and VAC (21.32 ± 1.86 group), a significant increase in the WBSF parameter value (P < 0.05) was observed in the last storage period D30. The study conducted by Jung et al. (2012) showed an increase in the hardness parameter of pork sausages in the first 7 d of refrigerated storage. Over the next 2 weeks, the authors observed further increase in the sausage hardness parameter. These changes may be caused by a number of factors, among which the most common ones are: pre-slaughter factors, post-slaughter treatment, packaging, muscle type as well as intramuscular fat content IMF, water loss, concentration of dry matter (Desmond & Kenny, 2005).

The analysis of the content of benzo(a)pyrene (Table 4) showed that the smoked pork produced within the framework of the experiment contained within 50% of upper limits of b(a)
content in smoked meat products regulated by EU Regulation No. 1327/2014. Similarly produced smoked pork contained within one-third of the allowable levels for a total of four PAHs. The lowest content of B (a) P was found (P < 0.05) in the case of hams without the addition of extract additives (S). In hams with the addition of basil extract, B (a) P content was the highest within all analyzed groups (Table 4). With regard to the results for the sum of PAHs, the lowest content of these compounds was noted for the samples from the S group, the average for smoked meats from the E1 group and the highest for the smoked pork from the E2 group.

Microbiological analysis showed the development of yeasts and fungi only on the surface of hams in the last 30 d of refrigerated storage (Table 5). The most dynamic development of microorganisms was observed for smoked pork from the group S VAC 1.3 × 10³ CFU, then on smoked pork from the E2 group (9.1 × 10² CFU) and SC (8.7 × 10² CFU). These results are in line with previous results presented by Andrew, Falowo, Fayemi, and Mucheunje (2014), who found a documented antibacterial effect of oregano extract in relation to Pseudomonas species, Escherichia coli, Campylobacter jejuni, Salmonella species. In the case of smoked pork from the E1 group, a slight development of yeast and mold at a level of 1 × 10² CFU was observed. It can be assumed that this was caused by aseptic action of basil (Riyazi, Ebrahimnezad, Hosseini, Meimandipour, & Ghorbani, 2015).

### 3.3. Effect of interaction

A strong (P < 0.001) interaction of R × DS was observed in all tested quality parameters of smoked pork: pH, L*, a*, b*, WBSF. Similarly, PS × DS interaction had an influence (P < 0.001) on parameters such as pH, a*, b*, WBSF, but had no effect (P > 0.001) on the value of L* coordinate. The interaction of R × PS × DS was significant (P < 0.001) for the parameters a*, b*, WBSF (P < 0.001) and L* (P < 0.05).

### 4. Conclusion

Hams with reduced salt content, in which spice herb extracts were used, should be packed in a vacuum system, indicating the possibility of refrigeration storage up to 20 d, better maintenance of color parameters and maintenance of the desired hardness of these products. An application of technological modifications presented in this study would allow...
to obtain a microbiologically safe product which quality parameters not change during packaging and storage up to 20 d in refrigeration conditions. The use of water-soluble basil and oregano extracts and the reduction of NaCl content affect reduction in the accumulation of polycyclic aromatic hydrocarbons in smoked pork products with reduced salt content. The use of the VAC, MAP packaging system and basil and oregano extracts is of an application nature to maximize the storage period of refrigerated meat products with reduced salt content.

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