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The impact of low salt level and addition of selected herb extracts on the quality of smoked pork*

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This study analyzed the possibility of producing pork meat products with reduced content of salt using oregano and basil extracts. Thirty-six porcine quadriceps muscles of the thigh were used in the study. The hams were cured in eight experimental brines containing 2.5, 2.0%, and 1.6% salt; 0.02, 0.04%, and 0.06% oregano extract; and .02, 0.04, and 0.06% basil extract. In addition, commercial hams produced using 2.5% salt brine were tested while brine containing 2.0% salt was prepared for control production. After curing and smoking, the obtained hams were analyzed for basic chemical composition (water, protein, fat, connective tissue, salt), physicochemical properties (pH, color, texture), and sensory indicators.The results obtained confirmed that basil extract is preferable for producing hams with reduced salt content, since the salty taste of the product was more intense at lower doses compared to hams prepared using oregano extract. On the other hand, the use of oregano extract had a positive effect as it maintained the saltiness of the product but at a high dose (i.e. 0.06%). Oregano extract also contributed to the dark color of the product. However, in order to maintain the desired product texture, oregano extract should not be used as an alternative to salt at a dose above 0.04%.Basil extract at a lower dose (0.02%) showed a positive effect on the salty taste, while at a higher dose (0.06%) it positively affected the chewiness and hardness of low-sodium hams.

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Traditional salt (sodium chloride – NaCl) is an indispensable element of the human diet. Sodium cation regulates the volume of extracellular fluid and plasma in the body, determines the membrane potential of cells, and takes part in transport through cell membranes. Its physiological effects are closely related to the activity of other cations such as potassium and calcium [Adrogu'e and Madias 2008]. In humans, the demand for food-grade salt varies based on age, gender, and general condition of the body, but it is assumed that an average adult should consume about 2.3 g NaCl per day [WHO 2016].

In recent years, there has been an increase in the global consumption of meat and meat products derived from monogastric animals (pork, poultry) – Cooper *et al*. [2004], Horbańczuk *et al*. [2008]. This is especially dynamic in China, Brazil, and Sub-Saharan Africa [Sansa and Combris 2015, Desierea *et al*. 2018]. Due to the increase in the consumption of various processed products having a high amount of salt,the consumption standards are exceeded two or even three times. Consumers are used to excessive salt levels in processed products [Sansa and Combris 2015], because salt acts as an inexpensive preservative [Desmond 2006, Pedro and Nunes 2007]. In addition, the salty taste suppresses or masks the bitter feeling [Kilcast and den Ridder 2007]. Salt also enhances the product texture by increasing the hydration of proteins and improving their binding to fat [Man 2007, Bess *et al*. 2013, Tomovič *et al*. 2013]. It has been estimated that up to 90% of the NaClconsumed every day is contributed by processed products and only 10% is supplemented individually [Andersen *et al.* 2009]. Products such as sauces (e.g. soya), salted vegetables, fish, sausages, cheese, and ready-made salty snacks (e.g. sticks, chips) contain the most amount of salt [Desmond 2006, Brown *et al*. 2009].Excessive intake of salt leads to many serious diet-related diseases. For instance, high salt intake is primarily considered as a direct cause of hypertension, which in a chronic state leads to obesity, diabetes, heart disease, stroke, and kidney disease [Hoffmann *et al.* 2008]. Moreover, increased levels of sodium in the diet may contribute to the development of gastric cancer and kidney stones [He and MacGregor 2009].

In view of the growing awareness about the harmful effects associated with excessive salt intake, the WHO agreed on a project in 2013, one of the objectives of which is to reduce salt consumption by 30% by the year 2025 ("Global Strategy on Diet, Physical Activity and Health") – WHO [2016]. Accordingly, the project worked toward reducing the amount of salt used in the production of finished products, including meat and cold cuts. At present, 100 g of ham contains about 1.25 g of salt [Greiff *et al*. 2015]. Several methods have been studied so far to reduce the amount of salt needed to produce cold cuts, such as the use of other metal salts (e.g. KCl) or flavor enhancers like monosodium glutamate or yeast extract. High-pressure processing and power ultrasound were also analyzed to promote the production of low-sodium meat products [Ruusunen *et al*. 2005, Desmond 2006, Inguglia *et al.* 2017]. Unfortunately, none of the analyzed methods showed satisfactory results, but instead reducedthe production efficiency or deteriorated the sensory properties of the product.

According to Anderson *et al.* [2015], the use of spices and herbs can significantly reduce sodium intake, which was also reported by Fawolo *et al*. [2014]. However, to date, the effect of herbal extracts as an alternative in reducing the salt content in ham has not been studied. Wang *et al*. [2014] studied the possibility of reducing the amount of salt added to soups after using herbs and showed satisfactory results. Similarly, Ghawi *et al*. [2014] demonstrated that the use of herbs in tomato soups with reduced salt increasedthe sensory characteristics.

Therefore, it has been hypothesized that the use of appropriate herb extracts in the production of smoked ham with reduced salt content would allow maintaining the physicochemical and sensory properties of the product.

The aim of study was to check whether the use of herbal extracts in brine can compensate for the reduction in salt content by maintaining a standard flavor and textural profile of hams.

Material and methods

Preparation of samples

The study used 36 porcine quadriceps muscles of the thigh (*Musculus quadriceps femoris*) obtained from 18 (male) fattening pigs which resulted from the crossbreeding of Polish Landrace and Duroc conducted following the Pork Quality Standard (PQS). The animals were maintained as per the requirements of the PQS system.Feeding was based on three fattening phases; the use of maize and fishmeal in feed was excluded in the last phase. The animals weighing 105±5 kg were slaughtered at ZM Olewnik (Sierpc, Poland) in accordance with the EU legislation. Half-carcasses were subjected to blast chilling in counterflow to 2°C. After 24 hof slaughter, they were cut down. The quadriceps muscles of the thigh (QF) separated from the carcasses were transported to the laboratory under refrigeration conditions.

The commercial hams used in the experiment originated from the meat obtained from animals that were slaughtered in the same slaughterhouse on the same day and from the same batch. These hams were processed at ZM Olewnik-Bis [Świerczynek, Mazowieckie, Polska]. The muscles (QF, n=36) with external fat were subjected to wet curing by injectingbrine to 6% of the weight of the raw material (uninjected brine was added during the massaging process) and drummed massaging (≤5°C, 12 h).The 3% brine contained 2.5% curing salt (E 250), 0.05% ascorbic acid, 0.1% sugar, 1500 mg/kg of multiphosphorus mixture, 0.15% carrageenan, and 0.15% spice (bay leaf, allspice). Hams were placed in nonshrinking nets (30°C, 2h) and smoked with warm smoke at 40°C for 2.5 h. Each 1 kg of ham was steamed at 85°C,till 72°C was reached inside the element, for 50±10 min. Next, the hams were cooled by blowing air to the smoking-and-steaming chamber for evaporation and redirected to cooling below 10°C. Then, the cooled and vacuum-packed hams were sent to the laboratory under cooling conditions (≤4°C).

Experimental design

The experiment was carried out in duplicate. The muscles (QF, n=36) were standardized based on weight (0.9±0.1 kg) and divided into three groups:

– commercial (K): six pieces for commercial production with 2.5% salt content; these hams were produced in the conditions of a laboratory owned byMeat Plants Olewnik Bis, Świerczynek, Polska;

– control (C):six pieces for standard production with 2.0% salt content;

– production with oregano (EO) and basil (EB) extracts with 1.6% salt content: four pieces with 0.02% oregano extract (EO1) and four with 0.02% basil extract (EB1) in brine;four pieces with 0.04% oregano extract (EO2) and four with 0.04% basil extract (EB2) in brine;four pieces with 0.06% oregano extract (EO3) and four with 0.06% basil extract (EB3) in brine.

The decision to lower the salt level in brine to 1.6% is because it is limit value. Furthere reduction of the salt level in the brine causes the product quality to deteriorate below the level of consumer acceptance [Aliño *et al*. 2010]. As limited knowledge of the possible use of EO and EB extracts as an alternative to reduced salt content in brine is limited, 2.0% salt in brine was also used in the study.

Pork processing

Brine solutions of 2.5, 2.0, and 1.6% concentration were prepared using nitrite curing salt (NaCl 98.4%, (E 250) $NaNO_2$ 0.5-0.6%, anticaking agent (E 536) $K_4[Fe(CN)_6]$ maximum 10mg/kg; CIECH, Janikowo, Poland). Then, 1.6% brine was added into six beakers in which the solutions of basil (0.02%, 0.04%, 0.06%) and oregano (0.02, 0.04, 0.06%) extracts were prepared. The basil extract (BASIL FLAVOUR 868668;Firmenich, Geneva, Switzerland) had the following composition of aromatic substances: estragole 0.3%, methylugenol 0.003%, thuyone 0.0007%, safrole 0.0001%, methyl chavicol 0.6% phenol 0.5-1.0%, and benzene 0.1-0.5% on the carrier of maltodextrin and modified corn starch 1.6% (E1450).In the oregano extract (OREGANO FLAVOUR 572831 TP0454;Firmenich, Geneva, Switzerland), the carrier was gum arabic and the main taste as well as smell agent was carvacrol.

The QF was injected with the above-mentioned brine solutions with or without herbal extracts, depending on the technological variant. A three-needle bar injector (Injector Universal; DelitechDagema, Willich, Germany) was used forthis purpose. The solutions wereinjected up to 20% of the initial muscle mass. The injected QF were then subjected to plasticization with a vacuum tumbler (LPM 20; Glass, Paderborn, Germany) for 40 minutes,in aprograminvolving 50% working time and 50% relaxation time. Each production group (K=commercial; EO=oregano extract; EB=basil extract) was separately smoked in a smoking chamber (UW-150; Borniak, Borne Sulinowo, Poland) using an electric smokegenerator and beech chips with granulation of 4.0–12.0 mm, for 2.5 h at a temperature of 40°C inside the chamber. Immediately after smoking, the hams were subjected to steaming in a convection-steam oven (CPE 110;Küppersbuch, Gelsenkirchen, Germany) at the full steaming temperature of the chamber until 75°C was reached in the geometric center of the hams. The finished products were chilled to 2°C.

Physical analysis of ham

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

Color. Four-centimeter-thick slices were cut out of cooled hams, and the color on the freshly cut surface was examined. Ten color measurements were performed with an illuminant performer D65 2° standard observer. The results were presented on the CIE-L*a*b* scale, where parameter L indicates the brightness level (0 white and 100 black), while a* and b* are color coordinates (+a*: red, a*: green, +b*: yellow, b*: blue) (ComisionInternationale de l'Eclairege). Ten measurements were taken each time in different areas of the sample surface.

Warner-Bratzler Shear Force (WBSF). Thick rolls of 2.5 inches were cut out from the slices of ham based on the direction of the muscle fibers. These rolls were used to determine the cutting force(WBSF; N) using the INSTRON universal testing machine (model 5965; MA, USA) with a Warner-Bratzler attachment. Six scores were made for each sample. Then, the rolls were cut across the fibers in the middle using a V-shaped knife. A 500-N head operating at a rate of 200 mm/min was used to cut the samples.

Texture Profile Analysis (TPA). Cubes with sidesmeasuring 1 cm were cut from a slice of 1-cm-thick ham and subjected to TPA double compression test using the INSTRON universal testing machine (model 5965; MA, USA). Six scores were made for each sample. Based on the parallel orientation of the muscle fibers, the samples were placed under the piston of a 500-N head operating at 200 mm/min and doubly compressed to the point of 50% reduction of their initial height, with a relaxation time of 5 s.

Basic chemical composition

For analyzing the basic composition of the hams,the content of moisture, fat, protein, salt, and connective tissue was examined using near-infrared spectrometry (NIR Flex Solids N-500; BÜCHILabortechnik, Falwil, Switzerland). A 1-cm-thick slice was initially ground and homogenized in a homogenizer (N-500; BÜCHI, Switzerland). Measurements were conducted using a NIRFlex solids module in a spectral range of 12.500–400 cm^1 in reflectant mode. Subsequently, the slices of the cross-section in the muscle diameter were homogenized and placed on a Petri dish covering the surface with a 0.5-cm layer. Three measurements were taken for each sample at a 32 scanning rate [Wyrwisz *et al*. 2016].

Preparation of samples for sensory evaluation

Ham samples were cut into 2-mm-thick slices on a semiautomatic food slicer (Ma-Ga S712a; Bydgoszcz, Poland).Then, representative 30-g rectangles were cut from three parts of the anterior middle and posterior muscle region. The samples were coded with three-digit codes, in which the third digit indicated the group number.They were wrapped in a food film and stored for evaluation in the same conditions at 4°C. To avoid fatigue as well as to reduce the sensitivity and concentration of the evaluators (“carry-over effect”), taste neutralizers were provided between successive samples during the evaluation: white wheat roll and unsweetened black tea infusion (PN-ISO 5497-1998). Individual samples were served on disposable white paper trays.

Sensory evaluation

The semiconsumer evaluation involved 30 persons, including 15 women and 15 men, who were aged 25-35 years. An unstructured scale was used, with limit values for evaluatingthe intensity of a given sensory trait (salinity, juiciness, tenderness, and extract aroma) and a linear 9-point scale (1 – lowest and 9 – highest feeling of a given attribute (cm) for the evaluation of sample desire (salinity, juiciness, tenderness, overall evaluation).The boundary values were presented cumulatively depending on the intensity of the discriminant (e.g. 1 – not salty, 9 – very salty). The evaluators were trained to mark the answers in the questionnaire and proceed with the sample during the evaluation as well as neutralize the taste sensations between subsequent samples. Positions were allotted for the evaluatorsto prevent contact between them during the evaluation process. Comfortable conditions of light (300 lx), temperature (22°C), and air humidity (54%) were also ensured.

Statistical analysis

The results were presented as means and standard deviations. Comparison of means wasperformed using one-way analysis of variance (ANOVA) and Duncan’s procedure of multiple comparisons or two-way ANOVA only for the differences between type and level of extracts used. The two-way ANOVA was performed according to the linear model:

$$Y_{ijk}=\mu+\alpha_i+\beta_j+(\alpha\beta)_{ij}+\varepsilon_{ijk}$$

where:

Y_{ijk} – the observed value of the trait, αis the effect of i-th type of extract;

β_j – the effect of j-th level of extract;

$(\alpha\beta)_{ij}$ – the interaction of type and level, and εis the error term.

For all the analyses,the significance level was set at 0.05. Calculations were conducted using Statsoft, INC (2014).

Results and discussion

Physical quality of hams

The physical and chemical properties of the hams made with reduced salt content and using herbal extracts are described in Table 1. No difference was foundin the pH of hams after the use of oregano and basil extract (P=0.285). The pH value was affected by the level of extract used (P=0.024) and the interaction between the type and level of extract applied (P<0.001). It was demonstrated that with the increase in the level of extract in the EO group the ham pH increased, while for the EB group the pHdecreased. For both extract types, after the application at the level of 0.04%, the pH value of hamswas found to be comparable with that of K group hams, for which 2.5% salt was used. Application of extracts at the level of 0.02 and 0.06% resulted in a considerable increase in the pH of experimental ham (P<0.05). In contrast to the C group hams, for which brine with 2.0% salt content was used, the pH of experimental hams was always lower, regardless of the type and level of extract (P<0.05).

The highest brightness was noted in C group hams, which were also characterized by the lowest saturation of red and yellow color in comparison to the remaining study groups (Tab. 1). The type of extract seemed to significantly affect the brightness level (P=0.001). A substantial reduction in brightness was observed after the use of oregano extract, which at the same time affected the increase of red color and reduction of yellow color saturation. On the other hand, no influence of the level of extract (EO and EB) could be found on the ham brightness (P=0.099) and yellow color saturation (P=0.229). With extract levels of 0.02 and 0.04%, higher red color saturation was noticed in hams (P<0.001). The effect of the interaction between the type and level of extract addition (EO and EB) on ham brightness (P=0.041) and red color saturation was significant (P<0.001).

The type of extract used had a significant impact on the WBSF of hams (P<0.001). The use of oregano extract in ham production resulted in higher values of the index than basil extract. It was further confirmed that withthe increase in the extract level (EO and EB) the WBSF value decreased significantly (P<0.001) but the value was always higher in the EO group than in the EB group (Tab. 1). The use of brine with extracts at levels of 0.02% and 0.04% was associated with considerably higher WBSF of the produced hams, in comparison with K and C hams. In contrast, the use of extracts at a level of 0.06% significantly decreased the WBSF of hamsas compared with K and C groups (Tab. 1).

The use of a specific type of extract had a significant influence on the water content in hams (P<0.001). The application of basil extract in low-sodium ham production had a greater impact on water retention in the product (Tab. 1). It was observed that with the increase in the level of extracts used, the level of water retained in the hams decreased (P<0.001). The use of brine with the lowest extract level of 0.02% had the most pronounced effect on water retention in hams in comparison with 0.04 and 0.06% levels, for which water retention was similar to thatachieved in K and C groups.

Higher protein level was confirmed for K vs C hams (P=0.025) and at the extracts level of 0.02 and 0.04% vs 0.06% (Tab. 1.). Protein level in hams was similar with the application of both extract types (Tab. 1). Consequently, the protein level in the hams was dependent on the type of ham, the level of the extracts, and the interaction between the type and level (P<0.001; Tab. 1).

The extract type used (EO and EB) had no influence on fat level (P=0.332). With the increase of extract content in the brine, better fat retention was observed in hams (P<0.001). The highest final fat content was observed in hams for 0.06% extract. A significant impact of the interaction between the type and level of extract on fat retention was also observed (P=0.001), which was considerably more pronounced for the oregano extract.

Salt content in K and C hams was highest among the studied groups (Tab. 1). The use of oregano extract had a markedly stronger effect on meat absorption of salt and its retention in ham (P=0.035). No influence was determined for the level of extract addition (EO and EB) on salt retention in hams (P=0.070). Considerably higher salt values were observed in EO hams at low (0.02%) and medium dose of the extract (0.04%; P<0.001).

The type of extract used had a considerable influence on the level of connective tissue in hams (P<0.001). The application of basil extract in ham production resulted in higher values of the index than oregano extract. It was

Table 1. Effects (means and standard deviations) of the use of oregano and basil extracts on the physical and chemical quality of hams produced with lower salt in brine

Parameter	pH	L*	a*	b*	WBSF	Moisture	Protein	Fat	Salt	Connective tissue
Commercial	6.12^{a}±0.1	68.7^{a}±2.3	13.4^{b}±1.3	8.62^{b}±0.5	13.7^{a}±0.9	67.1^{a}±2.5	24.4^{b}±1.7	4.36^{a}±1.0	1.36^{b}±1.7	0.55^{b}±0.2
Control	6.36^{b}±0.2	73.0^{b}±3.6	11.0^{a}±2.2	7.21^{a}±0.8	13.1^{a}±2.4	67.8^{a}±1.7	23.1^{a}±1.3	6.22^{b}±1.7	1.00^{a}±0.3	0.40^{a}±0.1
EO	6.33^{a}±0.13	66.21^{a}±4.06	13.11^{b}±1.55	8.64^{a}±0.86	15.67^{b}±5.00	67.06^{a}±1.52	24.16^{a}±1.38	6.38^{b}±1.39	0.82^{b}±0.08	0.40^{a}±0.14
EB	6.29^{a}±0.23	67.33^{b}±4.60	12.51^{a}±1.59	8.82^{a}±6.06	13.14^{a}±3.68	68.26^{b}±2.22	24.02^{a}±0.98	5.73^{a}±1.93	0.78^{a}±0.21	0.65^{b}±0.29
Extract content of brine										
0.02%	6.35^{b}±0.19	67.14^{a}±3.75	12.95^{b}±1.27	9.19^{a}±7.31	16.96^{c}±3.47	68.88^{c}±2.21	24.15^{b}±1.03	4.5^{a}±1.00	0.79^{ab}±0.08	0.61^{b}±0.15
0.04%	6.24^{a}±0.17	67.09^{a}±4.26	13.10^{b}±1.68	8.23^{a}±0.97	15.57^{b}±4.35	66.70^{a}±1.81	24.74^{b}±0.81	6.08^{b}±1.53	0.83^{b}±0.21	0.61^{b}±0.32
0.06%	6.34^{b}±0.19	66.08^{a}±4.97	12.37^{a}±1.71	8.76^{a}±1.22	10.82^{a}±3.08	67.40^{b}±1.18	22.98^{a}±0.85	7.59^{c}±0.80	0.77^{a}±0.15	0.36^{a}±0.19
Maineffects of extracts					*P*-values					
type	0.285	0.013	<0.001	0.702	<0.001	<0.001	<0.001	0.332	0.035	<0.001
level	0.024	0.099	<0.001	0.229	<0.001	<0.001	<0.001	<0.001	0.070	<0.001
type × level	<0.001	0.041	<0.001	0.033	<0.001	<0.001	<0.001	0.001	<0.001	0.946

[a-c]Means within a column with like letters are similar (P<0.05). Comparisons used one-way ANOVA were made for selected groups: Commercial vs Control; EO vs EB and extracts levels.
EO – oregano extracts; EB – basil extracts; WBSF – Warner-Bratzler shear force.

also observed that with the increase in the level of basil extract, the content of connective tissue reduced (*P*<0.001), particularly at the highest dose (0.06%) – Table 1. The influence of the interaction between extract type and content in the brine on the content of connective tissue in hams could not be confirmed (*P*>0.05). The values of gumminess were found to be higher in C and K groups than the remaining study groups (Tab. 2). Considerably higher gumminess values were recorded for hams produced with basil extract (*P*<0.01). Higher levels of the extract (0.04 and 0.06%) resulted in reduced values of this texture (*P*<0.01) –Table 2.

Similarly to gumminess, the highest hardness values were obtained for K and C hams (Tab. 2). The hardness values were higher in EB hams than EO hams (*P*=0.05). With the increase in the level of extract (EO and EB) in brine, the values of hardness reduced in hams (*P*=0.006).

The values of chewiness for K hams were considerably higher than the remaining groups (Tab. 2). EB hams were characterized by a higher level of chewiness than the EO hams (*P*<0.001). Similar chewiness values were obtained for hams with low (0.02%) and medium (0.04%) dose of extract, but the values of this parameter for hams with the highest level of extract (0.06%) were found to be increased significantly (*P*<0.001).

Table 2. Effects (means and standard deviations) of use of oregano and basil extracts on the TPA test and sensory quality of hams produced with lower salt in brine

Parameter	Guminess	Hardnes	Chewiness	Cohesiveness	Salinity	Juiciness	Tenderness	Extractaroma
Commercial	$13.5^{b}\pm3.5$	$47.1^{b}\pm16.2$	$13.5^{b}\pm3.5$	$0.30^{b}\pm0.1$	$6.76^{a}\pm1.1$	$6.26^{b}\pm1.1$	$4.90^{a}\pm2.0$	$0.17^{a}\pm0.3$
Control	$9.06^{a}\pm3.8$	$35.9^{a}\pm11.8$	$2.17^{a}\pm1.1$	$0.20^{a}\pm0.1$	$6.55^{a}\pm2.4$	$4.38^{a}\pm3.3$	$5.92^{a}\pm2.6$	$1.83^{b}\pm1.5$
EO	$4.62^{a}\pm2.30$	$23.87^{a}\pm6.38$	$1.31^{a}\pm0.50$	$0.24^{a}\pm0.03$	$3.04^{a}\pm1.52$	$4.93^{a}\pm2.39$	$5.57^{a}\pm2.36$	$4.92^{a}\pm2.44$
EB	$7.28^{b}\pm3.75$	$26.16^{b}\pm9.81$	$3.01^{b}\pm3.68$	$0.24^{a}\pm0.06$	$4.91^{b}\pm2.08$	$5.65^{b}\pm2.06$	$5.60^{a}\pm2.46$	$5.23^{a}\pm2.71$
Extract content of brine								
0.02%	$6.94^{b}\pm1.94$	$27.01^{b}\pm3.57$	$1.85^{a}\pm0.86$	$0.23^{a}\pm0.03$	$4.02^{a}\pm2.05$	$4.72^{a}\pm2.17$	$5.32^{a}\pm2.27$	$4.76^{a}\pm2.77$
0.04%	$5.33^{a}\pm2.68$	$23.43^{a}\pm9.42$	$1.25^{a}\pm0.83$	$0.22^{a}\pm0.04$	$3.95^{a}\pm1.95$	$5.07^{a}\pm2.12$	$5.35^{a}\pm2.42$	$5.18^{a}\pm2.50$
0.06%	$5.49^{a}\pm4.97$	$24.46^{ab}\pm10.59$	$3.67^{b}\pm4.64$	$0.27^{b}\pm0.06$	$3.95^{a}\pm2.15$	$6.08^{b}\pm2.28$	$6.07^{b}\pm2.47$	$5.30^{a}\pm2.44$
				P-values				
Main effects								
type	<0.001	0.005	<0.001	0.760	<0.001	0.001	0.904	0.245
level	<0.001	0.006	<0.001	<0.001	0.944	<0.001	0.022	0.229
type×level	<0.001	<0.001	<0.001	0.121	0.001	<0.001	0.001	0.033

[a-b]Means within a column with like letters are similar (*P*<0.05). Comparisons used one-way ANOVA were made for selected groups: Commercial vs Control; EO vs EB and extracts levels.
EO – oregano extracts; EB – basil extracts.

No influence of the extract type (EO and EB) on ham cohesion was noted (*P*=0.760), butthe influence of extract level on the cohesion of low-sodium hams was confirmed at the dose of 0.06% (*P*<0.001). The significance of the interaction between the type and level of extract in the cohesion of the tested hams was not confirmed (*P*=0.121).

The values of the taste parameter for saltiness were similar for K and C hams (Tab. 2). The influence of the type of extract used in brine (EO and EB) on ham saltiness was confirmed (*P*<0.001). The perception of salty flavor in hams was affected to a greater degree with the use of basil extract than oregano extract. The influence of the level of extract on the perception of salty flavor in hams was not confirmed (*P*=0.944).

Hams from group K and those prepared with 0.06% extract (EO and EB) were characterized by higher juiciness. A considerably greater influence of basil extract on ham juiciness was observed in comparison with oregano extract (*P*=0.001). With the increase in the level of basil extract, juiciness increased particularly in the group of hams prepared with 0.06% extract (*P*<0.001) – Table 2. The influence of the type and level of extract on low-sodium ham juiciness was noted (*P*<0.001). Hams from group C and with 0.06% extract were characterized by the highest tenderness (Tab. 2). The influence of extract type on the salty ham tenderness was not confirmed (*P*=0.904). In addition, the influence of the level of extract on tenderness was not observed (*P*=0.022).

The obtained results did not confirm the influence of the type of extract on its aroma(*P*=0.245). Furthermore, the influence of the extract level (0.02, 0.04, and 0.06%) on the intensity of its perception (*P*=0.229) was also not confirmed. However, the influence of the interaction between the type and level of extract on the perception of its aroma intensity was confirmed (*P*=0.033).

The most important result of this study was that the use of basil extract in the production of low-sodium hams (1.6% NaCl) at a level of 0.02% resulted in a high sensation of saltiness. Theperceived sensation was closest to that observed for the control hams prepared with much more than 2.5% salt. This is due to the presence of astringents(e.g. succinic acid, lysine) in the basil extract, which cause the salty taste receptors (epithelial sodium channels) to be exposed on the tongue [Desmond 2006, Roper 2015]. Depending on the particle size of the salt, the salty taste will be more pronounced, or the taste turns bitter as in the case of $MgCl_2$. Previously, similar results were obtained by Wang *et al*. [2014] in a study on a model tomato soup, in which the authors examined the level of intensity of the salty taste based on the level of salt addition and the type of spice herbs used, including oregano and basil.

The color of hams is one of the most important attributes determining consumers' willingness to purchase. Earlier studies have demonstrated that consumers generally prefer pork with a dark red color [Fortomaris *et al.* 2005]. This is due to the fact that such an appearance is considered as associated with a better taste and at the same time a lower fat content [Ngapo *et al*. 2002, 2004]. In this study, a similar result was observed with the use of oregano extract in the production of hams. This is probably due to the antioxidant effect of the bioactive compounds [Pogorzelska-Nowicka *et al.* 2018, Yeung *et al*. 2018, 2019, 2020, Wang *et al.* 2018, Horbańczuk *et al*. 2019], such as phenols, especially carvacrol and thymol, present in the extract [Jayasena and Jo 2014, Stelmasiak *et al*. 2019]. The use of basil extract was also associated with a similar effect, but only at a high dose of application, because the plant contains only a lower concentration of bioactive compounds with antioxidant effects.

Salt reduction >2% is not possible in the case of homogenized meat products because it results in an unacceptable taste and texture profile and the products become too soft [Sofos 1983]. However, it is possible to reduce the salt by 1.6% after the application of alternative herbal extracts at doses of 0.02 and 0.04% without causing significant deterioration in the meat texture indices. If the extracts are used in an appropriate way, the concise structure preferred by the consumers can be maintained in the hams. Reduction of the salt content and useof higher doses of oregano and basil extracts are beneficial as they contribute to improving the product hardness and firmness.

The pH values obtained were consistent with those obtained for smoked pork hams by other researchers [Tomović *et al.* 2013. Their studies proved the high antioxidant properties of polyphenolic compounds, the concentration of which was found to be higher in EO hams. These results correspond to that ofFernandes *et al.* [2016]. They found that the antioxidant power of natural oregano extract was comparable to that of synthetic antioxidants (e.g. butylated hydroxytoluene). The application of oregano and basil extract in lower and medium concentrations increased the value of the cutting force, which contributes to improving the texture of the finished product in consumer's perception. The results obtained in this study correspond to those ofSchivazappand Virgili [2020] in terms of the level of acceptance of texture and sensory profile of low-sodium ham of Parma type.

The basic chemical composition of the hams used in the experiment was characteristic of this type of meat product.Changes in macroelements are difficult to achieve because they may result from the individual variability of fattening pigs or from their location in the smoking or steaming chamber depending on the heat flow caused by convection. The hams that were present in the outside of the batch accumulated a higher dose of heat, as a result of which protein denaturation occurred faster and stronger, which in turn resulted in more significant moisture loss. Water loss, in turn, led to the concentration of the remaining components.Special attention should be paid to the protective influence of oregano extract on the reduction of protein and fat loss during the production of low-sodium ham. The results of this study correspond with that of Garcia-Galicia *et al*. [2020], who revealed the protective influence of the substances present in natural extracts of both basil and oregano (thymol, carvacrol) on the myosin chains during the denaturation of lamb meat. The exception is salt, which migrated with water dripping down the bar;therefore, the salt content of the bar was different and varied in parts despite the uniform injection and massaging. This phenomenon was described much earlier by Krause *et al.* [1978]. The results obtained for the salt content in the hams correspond to those obtained by Pretorius and Schöfeldt [2018] for smoked low-sodium hams produced according to the dietary sodium reduction policy.

Conclusions

The application of basil extract in the production of low-sodium hams increases the salty taste in the product to a higher degree than oregano extract. The addition of basil extract for reducing salt in smoked hams can be freely limited to minimum dose values of 0.02-0.03% while maintaining a fixed sensory profile. On the other hand, water-soluble oregano extract should be added at higher levels than basil extract for achieving comparable results.The use of oregano extract is associated with stronger saturation of the red color in low-sodium hams at low brightness, which enables obtaining products with a dark-red color. Furthermore, the extract exhibits a protective effect onthe loss of proteins and fats during the production of low-sodium hams.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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