

EFFECT OF EXTRUDED FLAXSEED ENRICHED DIET ON PHYSICO-CHEMICAL AND SENSORY CHARACTERISTICS OF BROILER MEAT

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Abstract: The aim of this experiment was to examine the effect of the addition of extruded flaxseed to chicken feed on physico-chemical and sensory characteristics of breast and leg-thigh meat. The basic chemical composition, pH value, instrumental colour and sensory characteristics of white (breast) and dark meat (leg-thigh) were examined by feeding two groups (both comprising males and females) of 500 Ross 308 hybrid line chickens by standard feed (control group) and with the addition of 6% of extruded flaxseed mixture (experimental group). Instrumental characteristics of colour were changed, especially in white meat. Both breast muscles of male broilers were significantly lighter, but a* values were significantly lower in *m. pectoralis profundus* and b* values higher in *m. pectoralis superficialis* of both genders. In dark meat, a* values were significantly lower in the meat of males, while b* values were higher in the meat of females. The addition of extruded flaxseed to chicken feed did not led to significant changes in the sensory characteristics of meat.

Key words: chicken meat, extruded flaxseed, instrumental colour, sensory evaluation

Introduction

Meat is an important source of high biological value proteins, minerals, vitamins and other nutrients. On the other hand, meat lipids do not have such beneficial characteristics, but rather properties such as high fat and cholesterol content, high energy and atherogenic value, bad ratio of saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA), low content of ω-3 PUFA, as well as a poor ratio of ω-6/ω-3 FA (Delgado-Pando *et al.*, 2010).

Fatty acid profile of meat lipids can be improved by a diet rich in ω -3 PUFA especially in monogastric animals (pigs, poultry and fish) since their organism absorbs fatty acids in their intact form (Bou *et al.*, 2009).

Poultry meat has become very important in the last several decades and nowadays accounts for about 33% of global meat production (FAO, 2010). Until recently, flaxseed oil was predominantly used in chicken feed, as the use of flaxseed is limited by antinutritional factors such as: cyanogenic glycosides, phytic acid, linatin dipeptide (vitamin B6 antagonist) (Anjum *et al.*, 2013). The extrusion process reduces the content of antinutritional factors by more than 93%, at the same time retaining useful components and rendering extruded flaxseed adequate for use in animal diet (Anjum *et al.*, 2013).

In the process of increasing the level of ω -3 PUFA in meat, it is important to achieve positive nutritional and functional effects on meat and at the same time not diminish the sensory quality. Meat with a higher content of unsaturated fatty acids has a higher nutritional value; however, the higher content of unsaturated fatty acids, especially in dark meats, results in their oxidative instability and poorer sensory characteristics of taste and odour. Poorer taste and odour can be ascribed to the presence of compounds from, for instance, marine products used in animal feed and the oxidation of unsaturated fatty acids (Bou *et al.*, 2009). More pronounced oxidative instability of meat means that sensory changes will also be more noticeable (Palmquist, 2009).

The goal of this experiment was to examine the effect of the addition of extruded flaxseed to chicken feed on physic-chemical and sensory characteristics of breast and leg-thigh meat as the most valuable parts in nutritional and economic terms.

Materials and methods

Experimental design and animal management

One thousand unsexed one-day chickens of the Ross-308 hybrid line had *ad libitum* access to water and to the diets (starter to 28 days, followed by 28–45 day finisher). The experiment was carried out at the chicken farm of meat company “Union MZ”, Svilajnac, Serbia. The chicks were reared under standard conditions of housing and management in floor pens with wooden shavings as litter material. Ventilation, lighting and relative humidity were automatically regulated. During the starter period chickens were placed in a single floor pen. On day 28 two equal groups were randomly formed in three replicates each, having an approximately equal sex ratio: control group (CON), fed by standard feed, and experimental group (EXP), fed with the addition of 6% of extruded flaxseed mixture (Croquelin, Walorex SAS, La Messaayais-35210 Combourg, France). Some research studies indicate that extruded flaxseed level in poultry diet of 5% and more could adversely influence some sensory characteristics of broiler meat such as flavour and aroma (Anjum *et al.*, 2013). In view of these data, the addition of 6% of extruded flaxseed mixture (3% of extruded flaxseed) to the diet was chosen to

avoid such changes. The composition of their diet is presented in Tables 1 and 2. At the age of 45 days, 15 male (CONM & EXPM) and 15 female (CONF & EXPF) chickens from each group (5 from each replicate) were selected by the average weight of the group ($\pm 5\%$) and marked before being slaughtered and then eviscerated. The carcasses were air-chilled for about 2 hours until the temperature of below 4 °C was reached within the breast muscle. After weighing, 12 male and 12 female processed carcasses from each group were randomly selected (4 from each replicate); the meat was apportioned into cuts: back, two leg-thighs, two wings and breasts. Breasts (white meat) and leg-thighs (dark meat) were then deboned, the skin was removed and the meat was used for physicochemical analysis. From each group 3 male and 3 female processed carcasses were used for the sensory evaluation of the meat.

Physicochemical analysis of meat

It was explained in *Experimental design and animal management* section. The chemical composition of meat was determined in the following manner: water content by drying samples at 105 °C (*ISO 1442, 1997*); protein content by the Kjeldahl method and multiplying by factor 6.25 (*ISO 937, 1978*); fat content by the Soxhlet method (*ISO 1443, 1973*); ash content by sample mineralization at 550–600 °C (*ISO 936, 1998*). pH value was measured by pH-meter Hanna, HI 83141 (Hanna Instruments Srl, Sarmeola di Rubano, Italy).

Table 1. Ingredients and composition (%) of diets (finisher)

Ingredients	CON	EXP
Corn	61.00	57.00
Soybean meal	12.00	12.00
Soybean grit	13.00	13.00
Sunflower meal (33% protein)	4.00	4.00
Croquelin ¹	-	6.00
Livestock yeast	3.00	1.00
Monocalcium phosphate	0.80	0.80
Limestone	1.30	1.30
Soybean oil	3.00	3.00
Premix ²	1.00	1.00
Iodized Salt	0.30	0.30
Lysine	0.10	0.10
Methionine	0.19	0.19
Threonine	0.16	0.16
Tryptophan	0.02	0.02
Phytase	0.01	0.01
Mineral clay (Minazel)	0.20	0.20
Crude protein	17.53	17.43
Moisture	10.75	10.58
Crude fat	7.83	7.82
Ash	4.68	4.47
Calcium	0.66	0.60
Total phosphate	0.44	0.52

¹ extruded flaxseed (TRADI-LIN®) 50%, wheat flour 30%, sunflower meal 20%. ² Composition of premix provided (per kg of premix): vitamin A1, 200,000 IU; vitamin D3, 300,000 IU; vitamin E, 3,000 mg; vitamin K3, 250 mg; vitamin B1, 200 mg; vitamin B2, 600 mg; pantothenic acid, 1,500 mg; nicotinic acid, 2,500 mg; vitamin B6, 600 mg; folic acid, 100 mg; choline chloride, 31,000 mg; vitamin B12, 2,000 µg; biotin, 3,000 µg; Fe, 6,000 mg; Cu, 800 mg; Zn, 6,000 mg; Mn, 8,000 mg; I, 60 mg; Se, 15 mg; Ca, 100 mg; BHT (E321), 10,000 mg.

Table 2. Fatty acid composition* of diets (finisher)

Fatty acid	CON	EXP
C14:0	0.06	0.06
C16:0	10.90	11.10
C16:1	0.07	0.07
C17:0	0.07	0.07
C18:0	4.22	4.49
C18:1cisω-9	26.25	24.71
C18:2ω-6	49.96	51.49
C20:0	0.32	0.31
C18:3ω-3	6.72	8.22
C20:2ω-6	0.04	0.04
C22:0	0.33	0.34
C20:3ω-6	0.05	0.07
C20:5ω-3	0.03	0.00
SFA	15.90	16.37
MUFA	26.32	24.78
PUFA	56.80	59.82
ω-6	50.05	51.60
ω-3	6.75	8.22
ω-6/ ω-3	7.41	6.28

*g/100g total fatty acids

Determination of meat colour

The CIE L*a*b* colour coordinates were determined by MINOLTA Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan) using an 8 mm aperture size, illuminant D65 and a 2° standard observer angle. The Chroma Meter was calibrated using a Minolta calibration plate (Y=87.2, x=0.3173; y=0.3348;). C* (chroma) and h (hue angle) were calculated according to Tapp *et al.* (2011). The colour was measured on two breast muscles (*m. pectoralis superficialis* – MPS and *m. pectoralis profundus* – MPP) and one leg muscle (*m. biceps femoris* – MBF), with two measurements on each sample.

Sensory evaluation

Meat is sensory evaluated by a quantitative descriptive analysis (ISO 6658, 2005) using the scales with 5 or with 8 points, depending on the sensory property. Sensory evaluation was performed by eight assessors, previously trained for detection and recognition of various tastes (ISO 3972, 2011) and odours (ISO 5496, 2006a). Samples of leg-thigh and breast meat with bones and skin were thermally treated in the oven at 150 °C until the temperature of 80 °C was achieved in the

inner part of the meat pieces. Then, samples were served to the assessors in an identical way on white plastic plates.

Meat colour

Meat colour was evaluated by a 5-point scale: 5 – very good, 4 – good, 3 – acceptable, 2 – slightly acceptable, 1 – unacceptable; **Meat structure** was evaluated by a 5-point scale: 5 – very fine, 4 – fine, 3 – neither fine nor rough, 2 – rough, 1 – very rough; **Meat juiciness** was evaluated by an 8-point scale: 8 – very juicy, 7 – juicy, 6 – moderate juicy, 5 – slightly juicy, 4 – slightly dry, 3 – moderately dry, 2 – dry, 1 – very dry; **Meat softness** was evaluated by an 8-point scale: 8 – very soft, 7 – soft, 6 – moderately soft, 5 – slightly soft, 4 – slightly tough, 3 – moderately tough, 2 – tough, 1 – very tough; **Acceptability of taste and odour** of meat was evaluated by an 8-point scale: 8 – very good, 7 – good, 6 – moderate, 5 – still good, 4 – slightly bad, 3 – moderately bad, 2 – bad, 1 – very bad.

Statistical analysis

The results of the chemical composition, pH value, instrumental colour measurement and sensory analysis were processed by a two-factorial analysis of variance (ANOVA). Tukey's HSD test was used to identify significant ($P < 0.05$ and $P < 0.01$) differences between groups. Calculations were done with software Statistica 6.0 (2001).

Results and discussion

Chemical composition

Chemical composition is an important meat characteristic, not only because of the nutritional value, but also because of its effect on the sensory quality. The results of the analysis of the impact of nutrition and gender on the chemical composition of white and dark meat of broilers are presented in Table 3.

The diet to which extruded flaxseed was added did not have a large influence on the chemical composition. Statistically significant influence was established only in terms of ash content in the white meat of male broilers and protein in the dark meat of females. *Crespo and Esteve-Garcia (2002)* reached rather similar results and concluded that the protein content in meat was somewhat higher in animals fed by the control diet.

Table 3. Basic chemical composition (%) of broiler meat

	Control group (CON)		Experimental group (EXP)		P-values of model effects		
	Male (CONM)	Female (CONF)	Male (EXPM)	Female (EXPF)	tmt	gen	tmt*gen
<i>White meat</i>							
Protein %	21.19±0.53 ^{ab}	22.02±0.57 ^b	21.06±0.63 ^a	21.65±0.51 ^{ab}	NS	0.006	NS
Moisture %	76.16±0.54 ^A	74.77±0.52 ^B	76.09±0.62 ^A	75.65±0.62 ^{AB}	NS	<0.001	NS
Fat %	1.02±0.34 ^a	0.94±0.17 ^a	0.68±0.41 ^a	0.81±0.59 ^a	NS	NS	NS
Ash %	1.30±0.08 ^a	1.44±0.09 ^{ab}	1.50±0.16 ^b	1.48±0.12 ^{ab}	0.021	NS	NS
<i>Dark meat</i>							
Protein %	17.89±0.77 ^a	19.27±0.7 ^B	17.59±0.84 ^A	17.76±0.44 ^A	0.005	0.013	0.047
Moisture %	74.27±0.81 ^a	72.72±1.16 ^a	74.43±1.41 ^a	73.39±1.31 ^a	NS	0.015	NS
Fat %	4.75±1.05 ^a	6.30±1.05 ^a	5.23±1.24 ^a	6.36±0.83 ^a	NS	0.050	NS
Ash %	1.19±0.23 ^a	1.22±0.18 ^a	1.26±0.21 ^a	1.23±0.11 ^a	NS	NS	NS

^{a,b} Values (mean±SD) within the same row with different uppercase letter in superscript differ significantly at $P < 0.01$; tmt – treatment, gen – gender.

^{a,b} Values (mean±SD) within the same row with different small or small and upper letter in superscript differ significantly at $P < 0.05$.

Instrumental colour and pH value

Colour is one of the most important sensory characteristics of meat; it is the first thing we perceive about food, it attracts buyers or puts them off, and is often related to flavour, tenderness and safety (*Girolami et al., 2013*). A whole series of factors affect the colour of meat, some independently, and some through mutual interactions. The physical and chemical characteristics of meat have an additional impact on colour (*King and Whyte, 2006*), while the pH value of meat also plays an important role. It is known that animal feed can affect meat colour, but there are few data about the effect of the addition ω -3 FA to the feed. The results of instrumental colour measurements and pH values are presented in Table 4.

Lightness (L^* values) increased in light muscles due to the addition of extruded flaxseed, though significantly only in males ($P < 0.05$). No differences were established between genders in either group or in either light or dark muscles. Measured pH values were between 5.67 and 5.77 (MPS) and somewhat higher in MPP, 6.00–6.15, while the differences in either case were not statistically significant which indicates that the pH value was not significantly changed by the diet and that different values of lightness can be most likely attributed to nutrition. Our results correspond to the data of *Betti et al. (2009)* who established that the addition of flaxseed, as well as the length of the feeding period, affects the increase of lightness of white meat. The redness, a^* values, in the MPS of CON groups was somewhat lower (2.48 and 2.08) relative to MPP (3.77 and 3.54). The addition of extruded flaxseed to the diet resulted in a decrease of a^* values in both of the tested muscles of both genders, but significantly ($P < 0.01$) only in MPP – “the redder” muscle. The yellowness, b^* values, was higher in test groups, though considerably

only in MPS (both genders). In general, the white meat of test groups of both genders had slightly poorer characteristics in terms of colour – it was lighter, less red and more yellow.

The influence of diet on changes in parameters of instrumental colour of dark meat (MBF) differs relative to white meat. Significant changes were not determined in terms of lightness and hue angle. The a^* values in EXP were considerably lower in the meat of males, while b^* values were significantly higher in the meat of females. pH values of dark meat were higher (6.11–6.26) than those of white meat, which contributed (in addition to higher myoglobin content) to lower lightness and a more intensive red colour (Dadgar *et al.*, 2012). As was the case with both white meat muscles, the diet did not significantly affect the change in the pH value of MBF.

Table 4. Colour characteristics (CIE L^{*}a^{*}b^{*}) and pH values of broiler white and dark meat

	Control group (CON)		Experimental group (EXP)		P-values of model effects		
	Male (CONM)	Female (CONF)	Male (EXPM)	Female (EXPf)	tmt	gen	tmt*gen
<i>m. pectoralis superficialis</i> (MPS)							
L*	53.53±1.97 ^a	52.95±2.02 ^a	56.83±3.86 ^b	54.70±2.33 ^{ab}	0.020	NS	NS
a*	2.48±0.35 ^c	2.08±0.12 ^{ab}	2.26±0.31 ^{bc}	1.94±0.23 ^a	0.024	<0.001	NS
b*	5.15±0.64 ^{AB}	5.10±0.58 ^a	6.07±0.63 ^C	5.85±0.71 ^{bc}	<0.001	NS	NS
C*	5.72±0.66 ^a	5.51±0.54 ^a	6.49±0.56 ^b	6.17±0.69 ^{ab}	<0.001	NS	NS
h	64.17±3.24 ^A	67.68±2.53 ^B	69.42±3.70 ^{BC}	71.49±2.64 ^C	<0.001	0.003	NS
pH	5.67±0.08 ^a	5.77±0.07 ^a	5.67±0.18 ^a	5.72±0.15 ^a	0.033	NS	NS
<i>m. pectoralis profundus</i> (MPP)							
L*	51.89±1.58 ^a	51.27±3.18 ^a	55.45±3.56 ^b	53.09±2.65 ^{ab}	0.002	NS	NS
a*	3.77±0.33 ^A	3.54±0.27 ^A	2.88±0.32 ^B	2.73±0.39 ^B	<0.001	0.047	NS
b*	5.41±0.96 ^a	5.74±1.23 ^a	5.96±0.65 ^a	6.05±0.56 ^a	NS	NS	NS
C*	6.62±0.81 ^a	6.78±1.04 ^a	6.62±0.69 ^a	6.64±0.63 ^a	NS	NS	NS
h	54.65±5.21 ^A	57.56±6.22 ^A	64.11±2.13 ^B	65.75±2.42 ^B	<0.001	NS	NS
pH	6.04±0.12 ^a	6.12±0.11 ^a	6.00±0.16 ^a	6.15±0.22 ^a	NS	0.010	NS
<i>m. biceps femoris</i> (MBF)							
L*	50.80±2.68 ^a	49.89±2.02 ^a	49.14±0.59 ^a	49.32±1.09 ^a	NS	NS	NS
a*	14.63±1.33 ^b	13.05±1.25 ^{ab}	12.35±0.93 ^a	13.22±1.43 ^{ab}	0.051	NS	0.026
b*	10.58±0.87 ^{ab}	9.05±1.38 ^a	10.39±0.32 ^{ab}	10.74±1.07 ^b	NS	NS	0.030
C*	18.08±1.10 ^B	15.95±0.93 ^A	16.14±0.75 ^a	17.07±1.28 ^{ab}	NS	NS	0.002
h	35.95±3.63 ^a	34.80±5.74 ^a	40.14±2.27 ^a	39.15±4.18 ^a	0.050	NS	NS
pH	6.26±0.21 ^a	6.20±0.14 ^a	6.11±0.30 ^a	6.21±0.18 ^a	NS	NS	NS

^{A,B} Values (mean±SD) within the same row with different uppercase letter in superscript differ significantly at $P < 0.01$; tmt – treatment, gen – gender.

^{a,b} Values (mean±SD) within the same row with different small or small and upper letter in superscript differ significantly at $P < 0.05$.

Sensory Evaluation

When assessing white meat, no statistically significant differences were detected in any of the observed parameters (data not shown). The panellists

assessed the colour of white meat with relatively high grades, from 4.19 (CONF) to 4.31 (EXPM), while the structure of meat of all groups was assessed as fine [3.69 (CONF)–4.06 (EXPF)]. Juiciness and softness were assessed as being between juicy and moderately juicy [6.06 (CONF)–6.50 (EXPF)] and soft and moderately soft [6.13 (CONF)–6.56 (EXPF)], respectively. Taste and odour were given high grades, between good and very good (6.81–7.31).

Dark meat grades (data not shown) were very similar to the grades for white meat, and none of the observed parameters of the sensory evaluation showed statistically significant differences.

Our results confirm to the findings of *Betti et al. (2009)* who compared the sensory characteristics of pates made from the white meat of broilers fed by flaxseed, and concluded that texture, flavour, aftertaste, liking and the overall opinion of breast samples were not different across the range of treatments compared. *Stanaćev et al. (2014)* also concluded that the addition of 4% of flaxseed oil in finisher diet did not lead to major changes of sensory characteristics of breast meat. *Schreiner et al. (2005)* observed that panellists noticed the differences between the sampled variants of chicken meat quite rarely and with difficulty, while *Lopez-Ferrer et al. (1999)* believe that the use of fish oil can have bad sensory effects, and that the use of plant oils considerably improves the sensory parameters of meat compared to fish oil.

Conclusion

The addition of extruded flaxseed to broiler diet affected the instrumental characteristics of colour, most notably in white meat. Both breast muscles of male broilers were significantly lighter. Breast muscles (*m. pectoralis superficialis* and *m. pectoralis profundus*) of both EXP groups were more yellow – higher *b** values and significantly higher *h* values, whereas *a** values were significantly reduced in *m. pectoralis profundus*. However, these changes did not cause significant differences during the sensory evaluation of the colour of white meat. As for the dark meat of males, *a** values were significantly higher in CON, while *b** values in the meat of females were significantly higher in EXP. Based on the results of this experiment, we may conclude that the addition of extruded flaxseed to chicken feed did not led to major changes in the sensory characteristics of meat.

Uticaj ishrane obogaćene ekstrudiranim lanenim semenom na fizičko-hemijska i senzorna svojstva mesa brojlera

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Rezime

Cilj ovog ogleda je bio da ispita efekat dodavanja ekstrudiranog lanenog semena u ishranu pilića, na fizičko-hemijska i senzorna svojstva mesa. Na početku tova 1000 jednodnevnih pilića linijskog hibrida Ros-308 imali su *ad libitum* pristup vodi i hrani. Metodom slučajnog uzorka 28. dana su formirane dve jednake grupe (sa po tri ponavljanja svaka) i približno jednakim udelom polova: kontrolna grupa (CONM – mužjaci, CONF – ženke) hranjena standardnom hranom i ogledna (EXPM – mužjaci, EXPF – ženke) hranjena sa dodatkom 6% komercijalne mešavine ekstrudiranog semena lana. Ispitivan je osnovni hemijski sastav, pH vrednost, instrumentalna boja i senzorna ocena belog mesa (grudi) i tamnog mesa (batak sa karabatkom). U pogledu osnovnog hemijskog sastava utvrđen je jedino značajno manji sadržaj proteina tamnog mesa EXPF u odnosu na CONF. Način ishrane nije uticao na pH vrednost. Oba mišića (*m. pectoralis superficialis* i *m. pectoralis profundus*) muških pilića brojlera statistički su značajno svetlijia ($P < 0.05$). Udeo crvene boje značajno se smanjuje kod *m. pectoralis profundus*, a žute povećava kod *m. pectoralis superficialis*, oba pola ($P < 0.001$). U tamnom mesu (*m. biceps femoris*) udeo crvene boje značajno se smanjuje ($P < 0.05$) kod mesa mužjaka, a udeo žute značajno raste ($P < 0.05$) kod mesa ženki. Nije utvrđen značajan uticaj načina ishrane na senzorsku ocenu belog i tamnog mesa.

Ključne reči: pileće meso, ekstrudirano seme lana, instrumentalno određena boja, senzorna ocena

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References

- ANJUM F.M., HAIDER M.F., KHAN M.I., SOHAIB M., ARSHAD M.S. (2013): Impact of extruded flaxseed meal supplemented diet on growth performance, oxidative stability and quality of broiler meat and meat products. *Lipids in Health and Disease*, 12, 13.
- BETTI M., SCHNEIDER B.L., WISMER W.V., CARNEY V.L., ZUIDHOF M.J., RENEMA R.A. (2009): Omega-3-enriched broiler meat: 2. Functional properties, oxidative stability, and consumer acceptance. *Poultry Science*, 88, 1085-1095.

- BOU R., CODONY R., TRES A., DECKER E.A., GUARDIOLA F. (2009): Dietary strategies to improve nutritional value, oxidative stability, and sensory properties of poultry products. *Critical Reviews in Food Science and Nutrition*, 49, 800-822.
- CRESPO N., ESTEVE-GARCIA E. (2002): Nutrient and fatty acid deposition in broilers fed different dietary fatty acid profiles. *Poultry Science*, 81, 1533-1542.
- DADGAR S., CROWE T.G., CLASSEN H.L., WATTS J.M., SHAND P.J. (2012): Broiler chicken thigh and breast muscle responses to cold stress during simulated transport before slaughter. *Poultry Science*, 91, 1454-1464.
- DELGADO-PANDO G., COFRADES S., RUIZ-CAPILLAS C., TERESA SOLAS M., JIMÉNEZ-COLMENERO F. (2010): Healthier lipid combination oil-in-water emulsions prepared with various protein systems: an approach for development of functional meat products. *European Journal of Lipid Science and Technology*, 112, 791-801.
- FAO (2010): Agribusiness Handbook – Poultry Meat & Eggs. Food and Agriculture Organization, Rome.
- GIROLAMI A., NAPOLITANO F., FARAOONE D., BRAGHIERI A. (2013): Measurement of meat color using a computer vision system. *Meat Science*, 93, 111-118.
- ISO 936. (1998): Meat and meat products. Determination of total ash (reference method). International Organization for Standardization, Geneva.
- ISO 937. (1978): Meat and meat products. Determination of nitrogen content (reference method). International Organization for Standardization, Geneva.
- ISO 1442. (1997): Meat and meat products. Determination of moisture content (reference method). International Organization for Standardization, Geneva.
- ISO 1443. (1973): Meat and meat products. Determination of total fat content (reference method). International Organization for Standardization, Geneva.
- ISO 3972. (2011): Sensory analysis. Methodology. Method of investigating sensitivity of taste. International Organization for Standardization, Geneva.
- ISO 5496. (2006a): Sensory analysis. Methodology. Initiation and training of assessors in the detection and recognition of odours. International Organization for Standardization.
- ISO 6658. (2005): Sensory analysis. Methodology. General guidance. International Organization for Standardization, Geneva.
- KING N.J., WHYTE R. (2006): Does It Look Cooked? A Review of Factors That Influence Cooked Meat Color. *Journal of Food Science*, 71, R31-R40.
- LOPEZ-FERRER S., BAUCELLS M., BARROETA A., GRASHORN M. (1999): n-3 enrichment of chicken meat using fish oil: alternative substitution with rapeseed and linseed oils. *Poultry Science*, 78, 356-365.
- PALMQUIST D.L. (2009): Omega-3 Fatty Acids in Metabolism, Health, and Nutrition and for Modified Animal Product Foods. *The Professional Animal Scientist*, 25, 207-249.

- SCHREINER M., HULAN H.W., RAZZAZI-FAZELI E., BÖHM J., MOREIRA R.G. (2005): Effect of different sources of dietary omega-3 fatty acids on general performance and fatty acid profiles of thigh, breast, liver and portal blood of broilers. *Journal of the Science of Food and Agriculture*, 85, 219-226.
- STANAĆEV V. Ž., MILOŠEVIĆ N., PAVLOVSKI Z., MILIĆ D., VUKIĆ-VRANJEŠ M., PUVAČA N., V. S. STANAĆEV V.S. (2014): Effects of dietary soybean, flaxseed and rapeseed oil addition on broilers meat quality. *Biotechnology in Animal Husbandry*, 30, 4, 677–685.
- STATISTICA 6.0 (2001). StatSoft Inc, Tulsa, Oklahoma, USA.
- TAPP III W.N., YANCEY J.W., APPLE J.K. (2011): How is the instrumental color of meat measured? *Meat Science*, 89, 1-5.

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