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MEAT QUALITY OF BREAST FROM BROILERS FED A DIET SUPPLEMENTED WITH ORANGE AND RED GRAPEFRUIT DRIED PEEL

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Abstract

Utilization of agricultural wastes and residues resulted from food industry in animal nutrition is a matter of great concern nowadays. Dried citrus peel (DCP) and flax meal (FM) are potential sources of some valuable bioactive nutrients for animals and poultry. This experiment was conducted to evaluate the effects of dietary supplementation of FM used together with two different DCP: dried orange peel (DOP) and dried red grapefruit peel (DRGP) on few breast meat quality traits of broiler chickens. One hundred-twenty broiler chicks (1 day old) were randomly allocated to three groups for the starter phase (14 d) where they were fed with a standard diet. At day 14, they were individually weighed (average 440.77 g) and homogenous assigned to three dietary treatments comprised of: basal diet (C) with 4% FM, basal diet supplemented with 2% DOP and 4% FM (DOP) and basal diet supplemented with 2% DRGP and 4% FM (DRGP), for both grower and finisher phases. At the end of the experiment (d 42) 6 broilers chicks/group were slaughtered and samples of breast meat were collected, and assayed for chemical composition, texture profile analysis (TPA), color parameter and fatty acid composition. Results of the present study indicated that use of FM together with DOP and DRGP in broiler diets significantly ($P < 0.05$) improved the color and some texture parameters and didn't affected the chemical composition or fatty acids from raw chicken breast meat.

Key words*: food, fatty acids, citrus peel, texture parameters, meat color.*

INTRODUCTION

In recent years there has been an increasing social and ecological pressure for the efficient reuse of residues from the food and agricultural industry (Pfaltzgraff et al., 2013) due to the global intensification of food production leading to the creation of large quantities of co-products and food waste (Waldron, 2007). The use of secondary agro-industrial by-products in the animal feed industry reduces the environmental impact and improves profitability and capitalization of agricultural by-products, since feeding food residue to livestock is an efficient way to upgrade low quality materials into high quality foods (Elferink et al., 2008). They are in line with current legislation that strongly encourages the food industry to find new uses for the resulting by-products (Panouillé et al., 2007). Moreover, these unwanted materials represent a potential serious pollution problem, a loss of biomass and valuable nutrients (Laufenberg et al., 2003). In addition, industrial ecology and circular economy are considered leading principles for Eco-innovation, focusing on a *"zero waste"* society and economy, where waste can be used as raw materials (Mirabella et al., 2014). A number of agro-industrial by-products are generated from fresh *Citrus* fruits, after the main products of interest have been removed or extracted during processing or peeled for direct human consumption (Oluremi et al., 2007). Orange is a *Citrus* fruit consumed in large quantities worldwide in the peeled form and juice. During the production of orange juice, large quantities of residues and wastes (peel, pulp, seeds and whole orange fruits that do not meet the quality requirements) are generated (Rezzadori et al., 2012). The same process takes place in the case of grapefruit. These wastes are generally available in large quantities during the *Citrus* season and can therefore cause an environmental problem because they have no productive use. From a nutritional point of view, oranges are one of the

most abundant sources of vitamin C, carotenoids, flavonoids, essential oils, sugar, fiber and some minerals (Niu et al., 2008). Also, due to they're bioactive phytochemicals, grapefruit has health promoting properties (Chudnovskiy et al., 2014), flavonoids being considered the most important bioactive components present in grapefruit. Because of these abundant carotenoids, they have a positive effect on meat color and on some meat quality parameters when texture profile analysis (TPA) of the meat is tested. Regarding the flax meal it is already very well known that has an increased concentration of polyunsaturated fatty acids, especially α-linolenic acid (Vlaicu et al., 2017). When included in animal feeds, alone or in combination with other residues/wastes/meals it can improve the final product quality (Vlaicu et al., 2017b).

In this context, the present paper presents the potential usage of orange and red grapefruit peel in combination with flax meal in diet of broilers, regarding their effect on the raw breast meat color, texture profile and fatty acids composition.

MATERIALS AND METHODS

Experimental procedures were approved by the Ethical Committee of the National Research and Development Institute for Biology and Animal Nutrition, in accordance with the Romanian legislation (Law 206/2004, ordinance 28/31.08.2011, law 43/11.04.2014, Directive 2010/63/EU).

Materials. Fresh citrus fruits (oranges and grape fruits) were purchased from a local market in Bucharest, Romania. The juice was manually extracted with a press and the remained peels were chopped with a knife and spread on the floor at sun for drying. After drying, the peels were milled to the powder in a hammer mill with a 1-mm screen and stored in eremitic bags at room temperature until used.

Animals, diets and experimental design. A total of 120-day-old Ross 308 broiler chicks were purchased from a local hatchery. The broiler chicks were housed in an experimental hall with floor rearing, under controlled microclimate. They were reared on permanent litter of wood shaves (10-12 cm thick). The light regimen was according to the breeding guide, 23 h light/1 h dark. The day-old chicks were fed during the starter period (1-14 days) with a compound feed with corn, soybean meal and gluten, having 20.56% crude protein and 3140.03 kcal/kg metabolizable energy. At 14 days of age, birds were weighed individually and randomly divided into three equal treatments as follows: commercial control diet supplemented with 4% flax meal (C), a diet containing 4% flax meal and 2% dried orange peel (DOP), and a diet containing of 4% flax meal and 2% dried red grapefruit peel (DRGP). Diet was composed to meet the requirements suggested by the National Research Council (1994). The experimental feed and clean drinking water were available *ad libitum* throughout the experimental period.

Table 1. Ingredients of commercial diet for grower and finisher phases (15-42 days)

Ingredient, % as fed-basis	Grower	Finisher
	%	
Corn	35.50	39.34
Flax meal	4.00	4.00
Wheat	20.00	20.00
Soy meal	27.03	20.81
Gluten	4.00	6.00
Oil	4.20	4.70
Monocalcium phosphate	1.54	1.45
Calcium carbonate	1.40	1.33
Salt	0.36	0.33
Methionine	0.29	0.26
Lysine	0.41	0.48
Choline	0.05	0.05
Threonine	0.22	0.25
Premix for broilers	1.00	1.00
Total	**100.00**	**100.00**
Calculated analysis, %		
Metabolizable energy, kcal/kg	3126,76	3215,78
Crude protein, %	21.5	20
Crude fat, %	6.34	6,86
Lysine, %	1.29	1.19
Methionine, %	0.63	0.39
Methionine + cysteine, %	0.99	0.94

*DCP were added to basal diet at the expense of ground corn in the experimental diets.

**1 kg premix vitamin-mineral contains: = 1.350.000 IU/kg vit. A; 300.000 IU/kg vit. D3; 2700 IU/kg vit. E; 200 mg/kg Vit. K; 200 mg/kg Vit. B1; 480 mg/kg Vit. B2; 1485 mg/kg pantothenic acid; 2700 mg/kg nicotinic acid; 300 mg/kg Vit. B6; 4 mg/kg Vit. B7; 100 mg/kg Vit. B9; 1.8 mg/kg Vit. B12; 2500 mg/kg Vit. C; 7190 mg/kg manganese; 6000 mg/kg iron; 600 mg/kg copper; 6000 mg/kg zinc; 50 mg/kg cobalt; 114 mg/kg iodine; 18 mg/kg selenium; 50 g sodium monensin/kg.

By using a completely randomized design, the experiment was conducted on 40 birds per group. At the end of the trial, according to the experimental protocol, 6 broiler chicks/group

were slaughtered and samples of breast were collected in order to determine the proximate composition, color parameters, texture profile analysis (TPA) and the fatty acids composition in the raw breast chicken meat.

Proximate composition. The basic chemical composition analyses were determined on samples dried at 65^0C. Standardized methods complying with Regulation (CE) 152/2009 (Sampling and analytical methods for the official inspection of feeds) and ISO standards were used to determine the nutrient concentration. The dry matter (DM) was determined with the gravimetric method according to Regulation (CE) nr. 152/2009 and standard SR ISO 6496:2001; the crude protein (CP) was determined by the Kjeldahl method according to Regulation (CE) nr. 152/2009 and standard SR EN ISO 5983-2:2009; the crude fat (EE) was determined by extraction in organic solvents - the method complies with Regulation (CE) nr. 152/2009 and standard SR EN ISO 6492:2001; the meat ash was determined by calcinations at 5500 C (SR ISO 936, 2009).

Color determination. The breast raw meat color was measured by means of the CIE-Lab method, where L* (100 = white, 0 = black) represents the brightness, and a* (+ red, - green) and b* (+ yellow, - blue) are color parameters. The determinations were performed using the Konica Minolta Chroma Meter CR-400 device. Lightness (L*), redness (a*), and yellowness (b*) values were obtained using an average value from three repeated measurements taken at different locations on the surface of the meat.
Negative a* and b* values indicate the appearance of green and blue color of the meat.
The instrument was calibrated with a white calibration before the measurements. The total color difference ΔE^* was determined with the next formula:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where:

$$\Delta L^* = L^*_{\text{sample}} - L^*_{\text{control}}$$
$$\Delta a^* = a^*_{\text{sample}} - a^*_{\text{control}}$$
$$\Delta b^* = b^*_{\text{sample}} - b^*_{\text{control}}$$

L* = luminosity; a* = saturation index in (green/red) and b* = saturation index in (blue/yellow).

Warner-Bratzler shear test. This test measures the force (Newtons) necessary to shear a piece of meat. The analyses were carried out on raw chicken breast samples. The meat samples were cut from the breast so that the cross-section measures 20 mm and the muscle fibers are parallel to the length of the sample which was at least 40 mm. The cutting/shearing plane is perpendicular to the muscle fibers. Cutting/shearing test allows to determine the hardness (firmness) of the tissue. Parameter L that is measured is the maximum shear force (highest point on the curve) (N) which indicates the maximum shear strength of the sample. Load cell: 10 kg; Warner-Bratzler shear blade with a triangular slot cutting edge (triangular shear devices). Setting parameter: sample height: 50 mm, starting distance from sample: 5 mm, compression, 60 mm, initial speed: 1.5 mm/s; test speed: 1.5 mm/s; retract speed, 10 mm/s; trigger force, 40 g; date rat: 200 pps. The parameter recorded was the maximum shear force, that is the highest peak of the curve, which is the maximum resistance of the sample to shearing. Each sample was assessed 3 times.

Texture Profile Analysis (TPA). The TPA test simulates the biting action in the mouth. It consists of a 2-cycle compression test. Here the sample should have a smooth level surface with a diameter smaller than the flat faced cylindrical probe. This test gives the textural parameters of tenderness (hardness), adhesiveness, springiness, cohesiveness, chewiness and gumminess. It was determined by using a texture analyzer, Perten TVT 6700 texturometer, from Perten Instruments and a TexCalc 5 software. The TPA parameters of raw chicken breast meat was evaluated as described by Bourne (1978). Three cylinders of 10 mm height and 10.30 mm diameter were prepared from every sample. A double compression cycle test was performed up to 50% compression of the original portion height with a stainless-steel cylinder probe of 20 mm diameter. A time of 5 s was allowed to elapse between the two compression cycles. Force-

time deformation curves were obtained with a 10 kg load cell applied at a cross-head, speed of 2 mm/s. The data obtained from TPA curve were used for the calculation of textural parameters. Among the TPA parameters, hardness (N) is expressed as maximum force for the first compression. Adhesiveness (N × s), is expressed as negative force area for the first bite or the work necessary to pull the compressing plunger away from the sample. Springiness (m), ability of the sample to recover its original form after deforming force was removed and is calculated as the ratio of the time from the start of the second area up to the second sample reversal over the time between the start of the first area and the first sample reversal. Cohesiveness is a measure of the degree of difficulty in breaking down the samples internal structure. Gumminess and chewiness have been reported as products of hardness, cohesiveness. Chewiness is calculated as hardness × cohesiveness × springiness. Resilience reflects the re-deformation capacity of samples tissue after penetration.

Fatty acid composition. Fatty acids composition from meat samples was determined by gas chromatography. After lipid extraction from the samples, the fatty acids were transformed into methyl esters by transmethylation, and the components were separated in the capillary chromatograph column. The fatty acids (FA) were determined by gas chromatography by transforming the fatty acids from the sample in methyl esters, followed by component separation in capillary column, identification by comparison with standard chromatograms and quantitative determination of the fatty acids according to SR CEN ISO/TS 17764 -2: 2008, using Perkin Elmer Clarus 500 gas chromatograph, with capillary column injection system, high polarity stationary phase (BPX70: 60 m x 0.25 mm inner diameter and 0.25µm thick film).

Statistical analysis. The analytical data were compared by variance analysis (ANOVA) using Stat View for Windows (SAS, version 6.0). The difference between the means was considered significant at $P<0.05$. The results were expressed as mean ± standard deviation.

RESULTS AND DISCUSSIONS

In order to determine the quality of the raw chicken meat, the breast samples were analyzed to determine their proximate chemical composition (Table 2). From the data obtained it can be observed that the samples collected from group DRGP (4% FM and 2% DRGP), had the highest concentration of fat, being with 32.19% higher than group C and with 26.88% higher than DOP group. The same differences were also found in the analysis of DM, CP and Ash. Mourão et al. (2008) determined the chemical composition of some carcass traits by using 5% *Citrus* peels and he obtained similar values regarding the CP (22.90%) and DM (33.20%) in raw chicken meat. According to same authors, when the *Citrus* supplement was increased at 10% in the broilers diet, the results of proximate analyses had higher values.

Table 2. Proximate composition of raw breast meat

Item	C	DOP	DRGP
	g/100 g DM		
DM	25.79	26.43	27.40
OM	24.72	25.24	26.18
CP	22.56	22.87	23.29
EE	2.17	2.34	3.20
ASH	1.07	1.19	1.21

Where: DM = dry matter; OM = organic matter; CP = crude protein; EE - ether extractives; Ash.

Color parameters of the raw breast meat samples are shown in Table 3. Incorporation of DOP and DRGP in broiler diets had a significant impact on the color profile. Color parameter L* measured for chicken breast meat shows insignificant color variations in experimental groups compared to C group. The luminosity of the chicken breast meat from group DRGP, where the feed was supplemented with 2% grapefruit peel, decreased ($P<0.05$) significantly compared to that of group C. A significant increase ($P>0.05$) of the luminosity compared to the value of group C occurred in DOP where the chicken feed was supplemented with orange peels. The increase of the parameter a* in the DOP group indicates the intensification of the red color of the breast meat. Also, a significant decrease in yellow (b*) shows the chicken breast meat from DRGP group, followed by DOP group.

Table 3. Color parameters of the raw breast chicken meat samples in relation to the DCP added in broiler diet

Group	L*	a*	b*	ΔE*
C	54.34 ± 4.09[a]	2.22 ± 2.37[a]	13.44 ± 2.49[a]	0.00
DOP	54.01 ± 1.19[a]	2.61 ± 1.88[a]	12,64 ± 1.63[a]	0.95
DRGP	51.30 ± 3.50[b]	1.21 ± 0.81[b]	10.78 ± 1.67[b]	4.16

Means within a row with no common superscript differ ($P < 0.05$).

The chicken breast has a less intense yellowish hue when supplementing the chicken with grapefruit peel, which intensifies when supplementing the feed with orange peel (DRGP). Overall, the data showed a reduction of breast meat yellowness in animals consuming DRGP, showing that the usually undesirable yellow tones in the meat were less developed. This observation could be due to low levels of yellow bioactive molecules in grapefruit peel, which could reduce intestinal absorption of pigments. Castañeda et al. (2005) demonstrated that differential absorption of pigments may lead to differences in skin or meat pigmentation. Garrett et al. (1999) stated that the pigment solubilization and subsequent absorption in the intestine occurs with the lipid phase, because soluble fibers negatively affect fat digestion and absorption of lipid soluble pigments. In contrast, diets with 2% DOP significantly ($P < 0.05$) increased the yellow and red color of broiler breast meat. The yellowness in breast chicken meat is a good indicator of the xanthophylls content (up to 90% of total carotenoids in some cultivars, Rodrigo et al., 2013) of the ingested feed (Pérez-Vendrell et al., 2001). Oranges compared to other *Citrus* are a good source of carotenoids and vitamin C (Rodrigo et al., 2013). Therefore, the more intense yellow tones of broiler meat from the DOP diet suggest a higher intake of yellow pigments, which may result from the intrinsic richness of it bioactive compounds peels. The addition of 2% DOP to the broilers diet improved the breast meat color while 2% DRGP had a visible total color difference ($\Delta E > 2$). Živković et al. (2017) stated that the use of 6% linseed in COBB 500 broilers diet had effect on the breast meat color ($P < 0.05$). Same authors stated that the sex of animals influenced the breast color when male chickens were compared with females, they had statistically significantly lighter breast meat.

The textural properties of the *Citrus* effect supplement on raw breast meat samples analyzed with Warner-Bratzler are presented in Figure 1. The Warner-Bratzler Shear Force values ranged from 40.95 N (DOP group) to 47.41 N (C group). Between C and DOP samples Warner-Bratzler, significantly ($P < 0.05$) decreased. As it can be observed from the Figure 1, the firmness (N) is corelated with the cutting/shearing. This aspect may be caused due to denaturation of both myofibrillar proteins and connective tissue from the samples (Wheeler et al., 1997). Usually firmness of meat decrease after 10 h, because of mechanical stability of raw meat (firmness) which is mainly influenced by its content of the connective tissues and by the length and integrity of the sarcomeres (Belk et al., 2001). According to Großklaus (1979), the content of connective tissues in broiler breast meat without the skin is almost negligible. Early changes in firmness could be caused by the state of contraction of the sarcomeres, which are changing the length in the rigor mortis stadium. Honikel et al. (1986) have demonstrated this phenomenon for meat from other species.

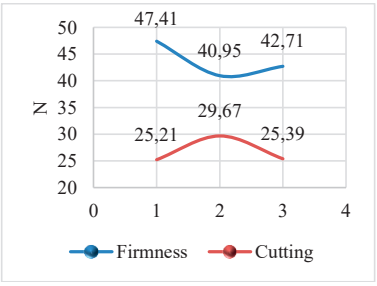

Figure 1. The textural properties of raw breast chicken meat samples after Warner-Bratzler test was applied

Regarding the TPA obtained after the tests were applied, it can be observed that in experimental groups (DOP and DRGP), the samples from raw breast meat had a significant ($P < 0.05$) higher level of hardness (firmness), compared to C group (Figure 2). The modifications for gumminess and cohesiveness (Figure 3) are insignificant, the variations of this parameters being very small. The values for springiness of raw breast meat samples were between 2.70 and 2.98. This parameter is important because is correlated with chewiness and has as a target older people. Furthermore, the resilience (Figure 4) had almost similar

values in all groups. The differences between the values of the groups were almost insignificant (P < 0.2027).

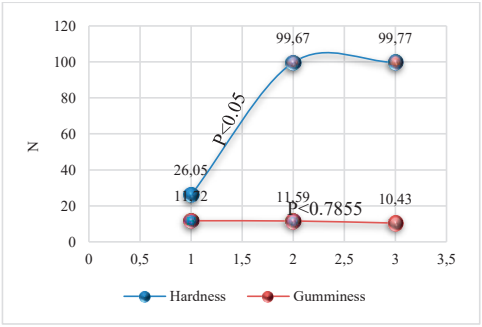

Figure 2. Hardness and gumminess of raw breast chicken meat (N)

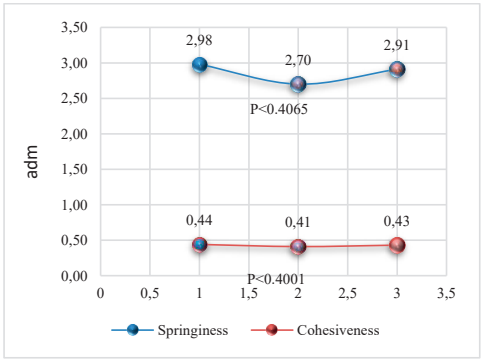

Figure 3. Springiness and Cohesiveness of raw breast chicken meat (adm)

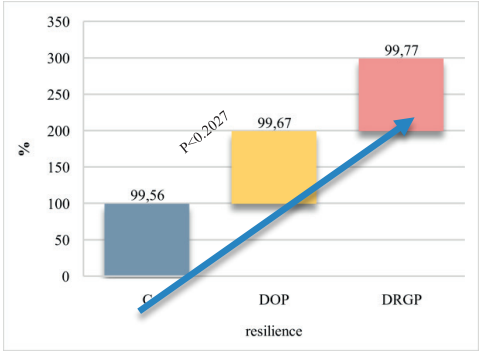

Figure 4. Resilience of raw breast chicken meat (%)

The quality of meat is determined by a number of factors that affect palatability (tenderness, juiciness and flavor). Such factors include the degree of maturity, color of lean, texture, and finally the degree and distribution of marbling (Caine et al., 2003). The determining factors for meat quality however, are multi-factorial and complex. This is because of the highly organized and complex structure of muscle tissue and the various processes the raw meat will undergo such as slaughter methods, storage time, storage temperature (freezing, chilling), amongst others all of which will affect the final texture. De Avilla et al. (2014) stated that meat hardness can be influenced by the fat content in the tissue muscles, which in our case the fat content in the samples was between 2.14 (C) and 3.20 (DRGP). Also, the springiness parameter in more likely in general to be affected. In our case the DOP group had slightly lower values compared to other two groups.

Tenderness can vary from animal to animal, from muscle to muscle within an animal, and from area to area within a muscle (Bourne, 1978), and is further affected by the processing treatment applied to the animals.

Fatty acid composition of raw breast meat from chickens fed diets containing 4% flax meal and 2% orange peel or 2% grapefruit peel at same level are presented in Table 4. The predominant fatty acids in chicken breast in all treatments were palmitic (16:0) and stearic (18:0) acids as SFA, oleic acid (18:1) as monounsaturated fatty acid (MUFA), and linoleic (18:2n-6) and arachidonic (20:4n-6) acids as PUFA. These effects could be caused by the use of supplements and the level of inclusion in diet. At 4% FM and 2% DCP incorporation rate, a significantly increase (P < 0.05) in the sum of MUFA in relation to the C was observed, whereas the levels of PUFA and SFA have maintained close values in relation to the C sample of raw breast meat.

Table 4. Fatty acid composition of raw breast meat from broilers fed DCP

Fatty acids	C	DOP	DRGP	SEM	P-value
	g/100 g total fatty acids				
C 8:0	0.06[a]	0.05[a]	0.03[b]	0.005	0.0569
C 10:0	0.02	0.03	0.03	0.002	0.2220
C 12:0	0.08[a]	0.03[b]	0.05[c]	0.006	0.0006
C 14:0	0.51	0.55	0.56	0.008	0.6339
C 14:1	0.08	0.11	0.12	0.008	0.1214
C 15:0	0.47	0.43	0.37	0.023	0.1991
C 15:1	0.15	0.20	0.17	0.017	0.5384
C 16:0	18.93	19.54	20.25	0.373	0.3736
C 16:1	2.87[a]	3.46	4.01[b]	0.203	0.0640
C 17:0	0.16	0.17	0.17	0.004	0.7747
C 17:1	0.15[a]	0.13	0.10[b]	0.009	0.0243
C 18:0	7.09[a]	6.42	6.06[b]	0.177	0.0433
C 18:1n9c	32.73[b]	34.98[a]	34.79[a]	0.412	0.0363
C 18:2n6	27.77	26.54	26.37	0.557	0.5603
C 18:3n6	0.15	0.15	0.14	0.008	0.6709
C 18:3n3	1.92	1.81	1.86	0.050	0.6995
C 18:2	0.25	0.21	0.19	0.014	0.2702
C 18:4n3	0.36[b]	0.55[a]	0.54[a]	0.026	0.0002
C 20:2n6	0.18	0.24	0.19	0.021	0.4583
C 20:3n6	0.60	0.46	0.47	0.035	0.2376
C22 (1n9)	0.07[a]	0.06	0.04[b]	0.004	0.3249
C 20:3n3	0.48[a]	0.37	0.31[b]	0.031	0.5643
C20:(4n6)	2.19[b]	1.38[a]	1.29[a]	0.160	0.0291
C22:(2n6)	0.24	0.26[a]	0.17[b]	0.018	0.0953
C22:(3n6)	0.17	0.12[a]	0.19[b]	0.014	0.0593
C 20:5n3	0.23	0.23	0.20	0.009	0.1685
C 24:0	0.26	0.26	0.23	0.011	0.2931
C 24:1n9	0.73[b]	0.45[a]	0.36[a]	0.059	0.0156
C22 (4n6)	0.16[b]	0.09[a]	0.08[a]	0.015	0.0389
C 22:5n3	0.35[a]	0.23[a]	0.24	0.025	0.0703
C 22:6n3	0.27[b]	0.18[a]	0.19[a]	0.16	0.0329
Others	0.17	0.13	0.10	0.015	0.1500
Raw breast meat fatty acids profile (% of total FAMEs)					
SFA	27.62	27.53	27.81	0.341	0.9520
MUFA	36.82[b]	39.41[a]	39.61[a]	0.545	0.0559
PUFA, from which:	35.38	32.90	32.47	0.789	0.2812
Ω:3	3.63	3.39	3.34	0.085	0.3398
Ω:6	31.50	29.29	28.94	0.708	0.2938
Ω:6/Ω:3	8.68	8.63	8.64	0.072	0.9706

Where: *Means within a row with no common superscript differ ($P < 0.05$).
**SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

The inclusion of 2% DCP had a marked effect on the fatty acid profile of broiler raw breast meat. The modification involves increasing of palmitic and oleic acids and a decrease of some n-3 and n-6 fatty acid precursors of PUFA especially in DRGP FM group. The α-linolenic fatty acid, had close values in all three groups and it wasn't influenced. These changes do not seem to be related with dietary contribution of both FM and DCP supplements. Both citrus peels have low fatty acid content, although the concentration of linolenic acid (in % of total fatty acids) is consistently low (about 6%) (Murao et al., 2008) and very variable in flax meals (30 to 60%) (Vlaicu et al., 2018; Turcu et al., 2019). But because FM was added at the same level (4%) in all three diets we did not find any differences between groups. Moreover, most of some structural lipids of DCP are probably not available for absorption, requiring fibrolytic fermentation, which is not possible in the upper compartments of the broiler digestive tract. Overall, the changes observed in fatty acid profile of chicken breast meat reported here most possibly result from the inhibition of de novo lipid synthesis (lower 16:0 and 18:1n-9) with an increase in proportion of exogenous fatty acids, mainly

linoleic acid, abundant in the broiler diets (Richards et al., 2003). Islam et al. (2012) stated that the citrus peel oil is rich in oleic acid (57.2 %), palmitic acid (38.6 %), stearic acid (4.1 %), which was reflected also in the meat samples from our study. According to Liu et al. (2012) the major fatty acid profiles in juice are identical in orange and grapefruit. Flax meal is a good source of n-3 fatty acids (Panaite et al., 2019; Vlaicu et al., 2019), but the levels of these fatty acids in breast meat from broiler chicken were not influenced among the treatments. Therefore, the n-6/n-3 ratio of chicken breast meat was not affected by the intake of DCP or FM. At the same time, the levels of the other nutritionally important n-3 fatty acids in meat, particularly of DPA and DHA, were not affected by the citrus peel or flax meal intake. López-Ferrer et al. (2001) stated that the levels of the above-mentioned fatty acids in broiler meat are much lower when compared with the percentages of the long-chain n-3 fatty acids reported in meat originated in birds supplemented with 2 to 4% of fish oil. Therefore, these results suggest that supplementation of broiler diets with DCP at a level of 2%, is unable to improve the n-3 fatty acids of raw broiler meat.

CONCLUSIONS

Supplementation with 2% dried citrus peel and 4% flax meal in diets for broiler chickens were effective in coloring the raw breast meat with more intense yellow tones. The results regarding the impact of flax meal used together with citrus peel, suggest that changed the levels of meat fatty acid profiles, by increasing MUFA and the palmitic acid and decreasing the predominance of total n-6 PUFA. Regarding the texture profile analysis, it seems that hardness and resilience of meat was higher compared to C group samples. These could be a positive effect, but usually it depends on the consumer preference which is usually based on different age of consumers.

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