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Original Article

Partially Dehulled Sunflower Seeds in Diets for Grazing Chickens: Effect in Meat Quality

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ABSTRACT

The effect of including partially dehulled sunflower seeds in the diet of grazing chickens in meat quality was evaluated. Two hundred and forty, one-day-old, Ross 308 chickens were used, randomly distributed into four treatments with six replicates of 10 birds each. Seventy-two birds were slaughtered at seven weeks of age, 18 per treatment, extracting the *Pectoralis major* muscle to analyze meat quality. The treatments were completely randomized in a 2x2 factorial arrangement, where type of rearing (confinement or grazing) and diet (base diet or base diet substituting 10% soybean meal for partially dehulled sunflower seeds) were the independent variables. The grazing chickens spent 8 hours a day in a white clover (*Trifolium repens*) paddock. Including sunflower seeds improved (p<0.05) the color and crude protein (CP) in breast meat (p<0.05), while grazing increased (p<0.05) CP, dry mater (DM), and shear force (SF), and the percentage of breast fat decreased (p<0.05) by up to 50%. Additionally, grazing increased (p<0.05) saturated fatty acids (SFA) and reduced (p<0.05) lipid oxidation by up to 50%. Partially replacing soybean meal with partially dehulled sunflower seeds in the diet of grazing chickens with white clover improves the physicochemical characteristics and nutritional quality of the breast meat; it also decreases lipid oxidation, extending the shelf life of the meat.

INTRODUCTION

Chicken meat, mainly the breast (*Pectoralis major*), is one of the products with the highest demand in the meat industry worldwide, and normally comes from intensive production systems, where rearing is carried out in confinement with food based on soybean meal and corn. Grazing can be an alternative for this production system, since in addition to reducing production costs (Rocchi *et al.*, 2019), it allows obtaining safe products with better nutritional quality (Küçükyilmaz *et al.*, 2012; Fernandes da Silva *et al.*, 2017). In this sense, white clover (*Trifolium repens*), due to its high protein content (23-25%) (Ponte *et al.*, 2008a), resistance to grazing, and good palatability, is an excellent alternative in the feeding of birds in grazing, since according to reports, it increases the levels of eicosapentaenoic acid (20:5n-3) in meat, inducing a greater amount of α-linolenic acid, essential for the body (Ponte *et al.*, 2008b; Stadig *et al.*, 2016). Additionally, if poultry diet is supplemented with ɵ oilseeds, such as soybean oil and linseed oil (Milczarek *et al.*, 2013), the quality of the meat can be further improved (Tsuzuki *et al.*, 2003). Thus, sunflower seeds (*Helianthus annus* L.), given their high oil (30-45%) and protein (21%) content, can be an alternative to the use of soybean meal. They have the disadvantage of high fibre content (26.2%) (Kalmendal *et al.*, 2011), so it is recommended not to use more than 25%, or alternatively, dehull them to improve their digestibility. It has been shown that including sunflower seeds in the diet of laying birds increases the content of Ω-3 in eggs (Wang & Huo, 2010; Laudadio *et al*., 2014), improves the oxidative stability and sensory quality of the meat (Guyon *et al*., 2016), and increases unsaturated fatty acids (Mahfoudh *et al*., 2016). Therefore, the objective of this research was to evaluate the meat quality of chickens grazing white clover and fed with partially dehulled sunflower seeds as a partial substitute for soybean meal.

MATERIALS AND METHODS

The study was carried out at the Animal Nutrition Laboratory of the Colegio de Postgraduados, Campus Montecillo, located in Texcoco, the State of Mexico (19°29′ N, 98° 53′ W, at 2250 masl). Two hundred and forty, one-day-old, Ross 308 broilers were used, distributed into four treatments with six replicates each, and 10 birds per replicate. The treatments were based on two types of rearing (confinement or grazing) and two diets (base diet or base diet substituting 10% soybean meal for partially dehulled sunflower seeds). The base diet consisted of soybean meal and sorghum (Tables 1 and 2). The birds in confinement received feed *ad libitum*, while those grazing were restricted by 40% to induce the consumption of white clover. Water was offered *ad libitum* in plastic troughs. The grazing birds spent three weeks in confinement at the beginning of the experiment, and then four weeks grazing until completion. The grazing time was 8 hours a day (from 8:00 a.m. to 4:00 p.m.) in a 3.5-month-old white clover (*Trifolium repens*) paddock, whose chemical composition is presented in Table 2.

At seven weeks of age, 72 birds were randomly selected for slaughter, 18 per treatment, extracting the *Pectoralis major* muscle for analysis of the physicochemical and quality characteristics. The slaughter was carried out according to the Official Mexican standard NOM-033-ZOO-1995 (Humane slaughter of domestic and wild animals).

Physicochemical characteristics of the meat

Breast pH was measured 4 and 24 h *post-mortem* using a portable potentiometer with a penetration electrode (HANNA, mod. HI99163). Breast colour was obtained 4 h *post-mortem* with the Minolta CR-400 colorimetry meter (Chroma Meter CR 200, Tokyo, Japan), recording values of L* (lightness), a* (redness), and b* (yellowness), based on the CIE system (Robertson, 1977). Subsequently, the breasts were stored at -20 °C, until their analysis.

The water holding capacity (WHC) was determined using 5 g of finely chopped breast meat, which had been frozen for 15 days. The meat sample was mixed with 8 mL of 0.6 M sodium chloride solution, and then placed in centrifuge tubes and stirred with a rod glass. Subsequently, they were placed in an ice bath for 30 min. They were then centrifuged for 15 min at 10.062 g (Beckman Coulter J2-HS, USA). The volume of supernatant was decanted and the difference was reported as mL of NaCl solution retained per 100 g of meat. The water activity (Aw) was determined using the Rotronic HygroLab kit (C1-SET-40 CH-8303 Bassersdorf, Switzerland).

Shear force (SF) was obtained with a texture meter (TA-XSGCi Stable Micro Systems, Godalming, England) and a Warner-Bratzler blade (Blade Set with 'V' slot blade for USDA Standard). Fat, crude protein, dry matter, moisture and collagen were determined using the FoodScan™ meat analyser spectrophotometer (Foss, Copenhagen, Denmark). The antioxidant capacity was determined by the DPPH (2,2-diphenyl-1-picrylhydrazyl) method (Brand-Williams *et al*., 1995) at 0, 3, 5, and 9 days of refrigeration, by spectrophotometry (Visible spectrophotometer Varian Cary 1E UV, USA) at 517 nm.

Table 1 – Composition of the experimental diets supplied to the broilers.

Ingredient (%)	Confinement		Grazing	
	CPS	CPSG	GPS	GPSG
Sorghum	60.62	62.36	61.23	61.82
Soybean meal	30.13	23.20	30.01	24.12
G*	0.00	10.00	0.00	10.00
Vegetable oil	5.00	0.00	4.81	0.00
Dicalcium phosphate	1.58	1.54	1.58	1.53
Calcium carbonate	0.93	0.98	0.94	0.98
L-lysine HCl	0.37	0.55	0.38	0.50
DL-methionine	0.34	0.32	0.34	0.31
**Pre-mixed vitamins and minerals	0.30	0.30	0.30	0.30
Pigment	0.30	0.30	0.00	0.00
Sodium chloride (NaCl)	0.30	0.30	0.30	0.30
L-threonine	0.08	0.11	0.08	0.09
Coccidiostat (Salinomycin 12%)	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00

G*: Partly dehulled sunflower seeds. **Supplies per kg of feed: Vitamin A, 12,000 UI; vitamin D3, 1,000 UI; vitamin E, 60 UI; vitamin K, 5.0 mg; vitamin B2, 8.0 mg; vitamin B12, 0.030 mg; pantothenic acid, 15 mg; niacin, 50 mg; folic acid, 1.5 mg; colin, 300 mg; biotin, 0.150 mg; thiamine, 3.0 mg. Minerals: Fe, 50.0 mg; Zn, 110 mg; Mn, 100 mg; Cu, 12.0 mg; Se, 0.3 mg; I, 1.0 mg. CPS: Confinement base diet - soy-sorghum meal; CPSG: Confinement base diet substituting 10% soybean meal for partly dehulled sunflower seeds; GPS: Grazing base diet - soy-sorghum meal; GPSG: Grazing base diet substituting 10% soybean meal for partly dehulled sunflower seeds.

Table 2 – Chemical composition of the experimental diets and white clover supplied to the broilers.

Component	CPS and GPS	CPSG and GPSG	White clover
Dry matter (%)	89.03	89.02	14.39
Crude protein (%)	19.40	19.10	24.01
Ethereal extract (%)	7.56	7.76	5.71
Crude fiber (%)	2.39	2.64	13.92
Ash (%)	5.13	5.50	11.68
NDF (%)	14.50	15.32	29.21
ADF	7.39	8.65	23.34
Lignin (%)	3.19	3.78	2.98
DPPH (µmol/kg)	2.63	2.68	-
Fatty acids profile (%)			
Palmitic (C16:0)	14.16	10.04	18..07
Stearic (C18:0)	2.98	4.78	-
Oleic (C18:1)	22.21	24.50	-
Linoleic (C18:2)	53.60	59.38	16.59
Linolenic (C18:3)	5.0	1.30	47.81
∑SFA	17.14	14.82	20.20
∑UFA	80.81	85.18	68.16

CPS and GPS: Diet based on soy-sorghum meal; CPSG and GPSG: Base diet substituting 10% soybean meal for partly dehulled sunflower seeds; DPPH: 2,2-difenil-1--picrylhydrazyl; SFA: Saturated fatty acids; UFA: Unsaturated fatty acids.

The fatty acid profile was determined in lyophilized breast samples (Labconco FreeZone 6, USA) using the methylation technique (Sukhija & Palmquist 1988; Palmquist & Jenkins, 2003; Jenkins, 2010), in which fatty acids are presented in the form of methyl esters. To read the samples, a chromatograph (Hewlett Packard 6890 USA), FID Detector, and G2613A automatic injector, silica capillary column (100m x 0.25mm x 0.20µm thick, SPTM-2560, Supelco) were used. For the chromatography, Helium Split ratio 10 was considered as carrier gas, injector temperature 250 °C, and detector temperature 260 °C. Finally, the integration and identification of the fatty acids in the obtained chromatograms were carried out, for which the retention time of the Supelco 37 Components FAME (Fatty Acids Methyl Esters) standard was compared with that of the sample.

Statistical analysis

The results of the variables pH, colour, SF, WHC, Aw, fat, CP, DM, collagen, moisture, and fatty acid profile were analysed using a completely randomized design with a 2x2 factorial arrangement with the GLM procedure (SAS, 1999), where factor A was rearing type (confinement or grazing) and factor B was type of diet (base diet or base diet substituting 10% of soybean meal for sunflower seeds). Furthermore, for antioxidant capacity, a design with repeated measures over time was used utilizing PROC MIXED. The means were compared using Tukey's test ($p<0.05$).

The statistical model was Y ijk = µ + A i + B j + (AB) ij + E ijk, where Y ijk = Response variable in replicate k level j of factor A, level i of factor B; µ = General mean; Ai = Effect of factor A on level i; Bj = Effect of factor B on level j; (AB) ij = Effect of the AB interaction at level i, j; And ijk = Random error.

RESULTS

Physicochemical characteristics of the meat

The pH, Aw and WHC showed no changes between the evaluated treatments ($p>0.05$), but there were differences in colour and shear force from the rearing factor ($p<0.05$), and in colour from the feed factor ($p<0.05$) (Table 3). The lightness (L*) of the breast meat was only different between treatments ($p<0.05$) when partially dehulled sunflower seeds were included, increasing its value ($p=0.035$). The value of a*, representing redness, ranged from 9.31 to 12.6. There was a similar performance for b*, which implies yellowness, whose registered values were from 9.58 to 15.4.

Nutritional characteristics of the breast meat

The percentages of fat, crude protein, dry matter, and moisture of the breast meat were different between treatments from the effect of the rearing factor ($p<0.05$), but not collagen ($p>0.05$) (Table 4). The rearing x diet interaction had a significant effect on the crude protein content ($p<0.05$). The crude protein content which increased to 26.95 in the samples from grazing birds, regardless of the type of diet. The dry matter in the breast meat increased 2.01 percentage units ($p<0.05$) in grazing birds.

Fatty acid profile and lipid oxidation

The fatty acid profile in chicken meat was different between treatments ($p<0.05$) except for 22:6. The rearing x diet interactions were significant, specifically for 16:0, 18:0, and 20:0 (Table 5). The antioxidant activity in the meat was different between treatments ($p<0.005$) (Table 6), where the rearing factor had the greater influence; it decreased by 50% in meat samples from grazing birds, compared to those in confinement (Figure 1).

Table 3 – Physicochemical characteristics of breast meat of broilers reared in confinement or grazing, with or without substituting soybean meal for partly dehulled sunflower seeds

Characteristic		Confinement		Grazing		*p* value			SEM
		CPS	CPSG	GPS	GPSG	FA	FB	FA*FB	
pH (4 h *post-mortem*)		6.43	6.49	6.29	6.43	0.847	0.080	0.520	0.14
pH (24 h *post-mortem*)		5.62	5.71	5.52	5.64	0.847	0.080	0.520	0.14
Colour (24 h *post-mortem*)	L*	50.87[a]	48.19[b]	48.54[ab]	48.34[b]	0.102	0.035	0.065	1.56
	a*	11.54[ab]	12.60[a]	9.31[b]	11.11[ab]	0.003	0.020	0.518	1.39
	b*	15.40[a]	13.38[b]	10.01[c]	9.58[c]	<0.001	0.038	0.071	1.20
WHC (mL/g)		25.76	22.21	28.73	29.61	0.052	0.601	0.388	6.16
Aw		0.94	0.95	0.95	0.94	0.316	0.694	0.073	0.01
SF (N)		10.49[b]	10.40[b]	26.28[a]	29.12[a]	<0.001	0.346	0.329	3.49

[abc] Means with different letters in the same row are statistically different ($p<0.05$); FA: Type of rearing (confinement or grazing); FB: With or without partially dehulled sunflower seeds as part of the diet; SEM: Standard error of the mean; CPS: Confinement base diet - soy-sorghum meal; CPSG: Confinement base diet substituting 10% soybean meal for partly dehulled sunflower seeds; GPS: Grazing base diet - soy-sorghum meal; GPSG: Grazing base diet substituting 10% soybean meal for partly dehulled sunflower seeds. FA*FB: Factor A by Factor B interaction; FA: Type of rearing; FB: Type of feeding; L*: Lightness; a*: Redness; b*: Yellowness; WHC: Water retention capacity given in mL NaCl retained in 100g meat; Aw: Water activity; SF: Shear force.

Table 4 – Nutritional characteristics of breast meat from chickens reared in confinement or grazing and complemented with partially dehulled sunflower seeds.

Characteristic (% wet base)	Confinement		Grazing		P value			SEM
	CPS	CPSG	GPS	GPSG	FA	FB	FA*FB	
Fat	1.58[a]	1.56[a]	1.12[b]	1.23[b]	<0.001	0.582	0.402	0.18
CP	24.23[c]	25.02[b]	26.97[a]	26.94[a]	<0.001	0.031	0.020	0.40
DM	26.14[b]	26.86[b]	28.55[a]	28.47[a]	<0.001	0.144	0.070	0.52
Moisture	73.85[a]	73.13[a]	71.44[b]	71.53[b]	<0.001	0.144	0.070	0.52
Collagen	0.71	0.65	0.66	0.65	0.536	0.461	0.589	0.10

[abc] Means with different letters in the same row are different ($p<0.05$); FA: Type of rearing (confinement or grazing); FB: Presence or absence of partially dehulled sunflower seeds as part of the diet; SEM: Standard error of the mean; CPS: Confinement base diet - soy-sorghum meal; CPSG: Confinement base diet substituting 10% soybean meal for partly dehulled sunflower seeds; GPS: Grazing base diet - soy-sorghum meal; GPSG: Grazing base diet substituting 10% soybean meal for partly dehulled sunflower seeds. FA*FB: Factor A by Factor B interaction; FA: Type of rearing; FB: Type of feeding; PC: Crude protein; DM: Dry matter.

Table 5 – Fatty acid composition of breast meat from grazing broilers fed with dehulled sunflower seeds.

Fatty acid (%)	Confinement		Grazing		*p* value			SEM
	CPS	CPSG	GPS	GPSG	FA	FB	FA*FB	
14:0	0.33[b]	0.45[a]	0.13[c]	0.23[bc]	<0.001	0.002	0.790	0.07
16:0	19.00[b]	19.25[b]	21.13[a]	21.42[a]	0.034	0.014	0.002	0.79
16:1	1.18[a]	1.62[a]	0.33[b]	0.67[b]	<0.001	0.002	0.653	0.27
18:0	12.67[a]	9.75[b]	14.25[a]	14.07[a]	<0.001	0.001	0.003	0.10
18:1	22.68[a]	23.67[a]	18.05[b]	19.20[b]	<0.001	0.140	0.905	1.70
18:2	26.23[b]	32.67[a]	24.35[b]	27.55[b]	<0.001	<0.001	0.076	2.12
18:3	1.08[a]	0.78[ab]	0.50[ab]	0.18[b]	0.012	0.166	0.969	0.53
20:0	6.00[bc]	4.48[c]	9.08[a]	8.00[ab]	<0.001	<0.001	<0.001	1.40
22:6	0.85[a]	0.92[a]	0.70[a]	0.98[a]	0.680	0.094	0.289	0.24
∑SFA	34.65[b]	29.45[c]	35.50[ab]	37.51[a]	<0.001	0.015	<0.001	1.47
∑UFA	52.03[b]	59.65[a]	43.93[c]	48.3[bc]	<0.001	<0.001	0.318	3.60

[abc] Means with different letters in the same row are different ($p<0.05$); SEM: Standard error of the mean; CPS: Confinement base diet - soy-sorghum meal; CPSG: Confinement base diet substituting 10% soybean meal for partly dehulled sunflower seeds; GPS: Grazing base diet - soy-sorghum meal; GPSG: Grazing base diet substituting 10% soybean meal for partly dehulled sunflower seeds. SFA: Saturated fatty acids; UFA: Unsaturated fatty acids: the results are expressed as percentages based on the total fatty acid content. FA*FB: Factor A by Factor B interaction; FA: Type of rearing (confinement or grazing); FB: Presence or absence of partially dehulled sunflower seeds as part of the diet.

Table 6 – Antioxidant activity – DPPH (µM Trolox / 100g meat dry base) in breast meat from chickens reared in confinement o grazing and supplemented with partially dehulled sunflower seeds, per treatment and time period.

DPPH	Treatments				SEM	Period (days)				SEM	*p* value		
	Confinement		Grazing										
	CPS	CPSG	GPS	GPSG		0	3	5	9		T*	P**	TP
µmol/kg	5.75[a]	6.19[a]	3.42[b]	3.47[b]	0.25	4.54[b]	4.30[bc]	5.90[a]	4.08[c]	0.17	<0.001	<0.001	<0.001

[ab] Means with different letters in the same row are different ($p<0.05$). DPPH: 2, 2 –difenil-1 picrylhydrazyl; CPS: Confinement base diet - soy-sorghum meal; CPSG: Confinement base diet substituting 10% soybean meal for partly dehulled sunflower seeds; GPS: Grazing base diet - soy-sorghum meal; GPSG: Grazing base diet substituting 10% soybean meal for partly dehulled sunflower seeds. SEM: Standard error of the mean; T*: P value between treatments; P**: P value between periods; TP: P value of the treatment-period interaction.

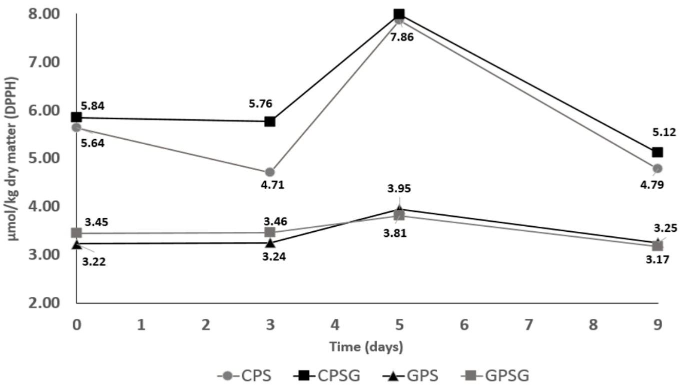

Figure 1 – Performance of the DPPH inhibition coefficient (µM Trolox / 100g meat dry base), in breast meat of chickens reared in confinement or grazing and supplemented with partially dehulled sunflower seeds. CPS: Confinement base diet - soy-sorghum meal; CPSG: Confinement base diet substituting 10% soybean meal for partly dehulled sunflower seeds; GPS: Grazing base diet - soy-sorghum meal; GPSG: Grazing base diet substituting 10% soybean meal for partly dehulled sunflower seeds.

DISCUSSION

Physicochemical characteristics of the meat

The mean pH values at 4 and 24 h, 6.41 and 5.62 respectively, coincide with those reported in the literature for chicken meat, 6.4 and 5.7, respectively (Ponte *et al*., 2008d).

The lightness (L*) of the breast meat was different between treatments when partially dehulled sunflower seeds were included, due to the reflection effect from the high fat content, mainly in the samples from animals in confinement (Luciano *et al*., 2009).

The colour response is directly related to the amount of pigments in the feed, as evidenced by the chicken breast in confinement, where the feed supplied contained carotenoids from marigolds (*Tagetes erecta*), causing more redness and yellowness hue. Unlike white clover, despite containing carotenes and xanthophylls (Stødkilde *et al*., 2018), the amount consumed by grazing birds was not enough to cause evident changes in a* or b* (Bampidis *et al*., 2019), since its consumption was only 19.9 g DM / day / bird (González-León *et al*., 2019), and consequently the consumption of pigments decreased. Furthermore, it is important to mention that the feed provided to the birds in this treatment did not contain additional pigments. In this regard, Ponte *et al*. (2008d) reported an increase of up to 60% in the yellow tones in chicken breast meat when the birds were grazing in a *Trifolium subterraneum* and *Trifolium repens* paddock, compared to those in confinement. This, despite the fact that the birds only grazing 28 days prior to slaughter, but without restricting concentrated feed containing additional pigments. In our study, including sunflower seeds in the diet of confined chickens increased the value of a* by 1.06 percentage units and reduced the value of b* by 2.02, because the seed provided extra pigment, the highest concentration of which was found in the cotyledon of the seeds, providing chlorophyll and carotenoids, 30 mg kg^{-1} DM, and 10 mg kg^{-1} DM, respectively (Sağlam, 2009; Weisz *et al*., 2013; Pająk *et al*., 2014). The dehulling of the sunflower seeds improved the availability of pigments for their absorption and deposition in the meat, due to an increase of around 17% of pigments, compared to the use of whole seeds (Weisz *et al*., 2009).

The mean value of Aw found (0.94) does not correspond to the mean value in fresh meat (0.98), consequently modifying the WHC (Jiang *et al*., 2018), with lower values in this study (26.57 mL/g) than the reported by Carvalho *et al*. (2017).

The sheer force of the breast meat of grazing birds was higher than that from birds in confinement, with averages of 27.7 vs. 10.44 N, respectively; classifying it as extremely tough meat (Jiang *et al*., 2018). This response is due to the physical activity of grazing chickens, which demand a greater amount of energy in the search, selection, consumption, and digestion of food, subtracting energy for the accumulation of fat in muscle, thus the lesser tenderness (Ponte *et al*., 2008b; Englmaierová *et al*., 2020), since the fat content is positively related to the tenderness of the meat. Moreover, the fact of reducing the fat content causes a dilution effect in the muscle fibers, actin and myosin, compacting them and therefore, making them more resistant to cutting (Fernandes da Silva *et al*., 2017).

Nutritional characteristics of the breast meat

The increase in protein crude by the rearing x diet interaction is due to a complementary effect on the contribution of amino acids in the diet, provided by the sunflower seed and white clover, while the first is deficient in lysine, the second contributes up to 7% of the total amino acids including lysine (120-127 g kg^{-1} DM) (San Juan & Villamide, 2001). Additionally, the decrease of fat in the meat leads to an increase in the percentage of protein. In the case of birds in confinement, the protein content was higher in those fed the base diet compared to those supplemented with partially dehulled sunflower seeds.

The fat content decreased 0.4 percentage units in the breast meat from grazing birds, regardless of the type of diet, because the activities of grazing birds demanded more energy than that of those in confinement, consequently the accumulation of fat in the muscle of grazing birds was lower due to the different activities involved in their maintenance (Fernandes da Silva *et al*., 2017). The dry matter in the breast meat increased as a result of the physical activity that causes greater loss of water for thermoregulation (Ponte *et al*., 2008b). It is important to mention that the current demand for meat requires lean products from sustainable systems, where animal welfare is an important factor to consider, thus obtaining better quality and safe products (Küçükyilmaz *et al*., 2012; Stubbs *et al*., 2018).

Fatty acid profile and lipid oxidation

The inclusion of partially dehulled sunflower seeds in the diet increased the percentages of 14:0 and 18:2, and decreased for 18:0. The percentages of 18:0 was lower in the breast meat of birds fed with the diet containing sunflower seeds, more so in birds in confinement. Furthermore, the percentages of 14:0, 18:2, and UFA increased. In the specific case of 18:2, it increased 6.44 percentage units in breast samples of birds in confinement, while such increase was 3.2 percentage units in meat of grazing birds, due to the higher content of this acid in the diet by including sunflower seeds. This phenomenon is due to the chemical structure, apolarity, and melting point of the UFA, since the double bonds in their structure decrease the melting point and increase their apolarity, making them more digestible (Pająk *et al*., 2014) and absorbable for the organism, depositing at a higher percentage in the meat (Mikulski *et al*., 2011). Additionally, dehulling facilitates the degradation of the seed and consequently the absorption of FA increases by decreasing the percentage of fiber (Pająk *et al*., 2014). However, 18:1, despite its high content (70%) in sunflower seeds (Figueiredo *et al*., 2019), did not increase in the meat.

Clover consumption by the grazing birds significantly increased 16:0, 18:0, 20:0, and in general SFA in chicken breast meat, with the opposite effect in 14:0, 16:1, 18:1, 18:2, and UFA (Table 5). These results are opposed to those reported by Ponte *et al*., (2008a) and Englmaierová *et al*. (2020), who found that the consumption of green forage increases the content of UFA in meat, as long as they have free access to high quality grazing. According to González-León *et al*. (2019), this result is due to a low consumption of white clover, which means a lower amount of UFA consumed, consequently the percentage of UFA in the chicken breast meat was lower, particularly in 16:1 and 18:1.

The difference in lipid oxidation found in our study is due to the type of rearing. Surprisingly, meat samples from birds in confinement had higher antioxidant activity. We expected the opposite, since theoretically the grazing birds included some compounds such as polyphenols, tocopherols, tocotrienols (Dal Bosco *et al*., 2016), carotenoids, vitamin C, and tyrosol (Mugnai *et al*., 2013; Ahmad et al., 2020) in their diet. These are contained in white clover (Ganhão *et al*., 2010; Young *et al*., 2002), and their concentration can reach up to 62.06 mg g^{-1} (Vlaisavljević *et al*., 2017), which function as natural antioxidants (Ahmad *et al*., 2020), delaying and counteracting the lipid oxidation processes in meat (Englmaierová *et al*., 2021; Ran *et al*., 2021). However, we think that the individual consumption of white clover by the birds used in this research work, approximately 19.9 g DM d^{-1} $bird^{-1}$(González-León *et al*., 2019), equivalent to consuming 1.23 g DM d^{-1} $bird^{-1}$ of polyphenols, was low, basically due to its slow adaptation to grazing (Mingli *et al*., 2021). Consequently, there was no positive effect on the total UFA and antioxidant activity of the meat, as expected, despite a high correlation between lipid oxidation in meat and the fatty acid profile (Guyon *et al*., 2016).

The inclusion of partially dehulled sunflower seeds in the chicken diet did not induce significant changes in the antioxidant activity of the meat ($p<0.05$) (Table 6), despite the increase in the content of UFA in the meat, regardless of the type of rearing (Table 5). Moreover, according to the content of phenolic compounds in the sunflower seeds, such as chlorogenic, quinic, and caffeic acid (Weisz et al., 2009), a decrease in the oxidation process in the meat was expected, but it did not happen. This means that the number of seeds consumed by the birds was insufficient to cause obvious changes in the meat.

It is interesting to note that substituting 10% soybean meal for partially hulled sunflower seed, and considering prices that reflect recent conditions showed an economic advantage in both production systems. In confinement, the cost of the diet (US dollars) was \$0.45 kg^{-1} for the diet based on soybean meal-sorghum (SPC). Replacing 10% soybean meal with partially hulled sunflower seed (CPSG), the cost is reduced to \$0.39 kg^{-1}, obtaining a difference of \$0.06, which represents a 13.3% reduction in costs. Similar result was found in grazing, where the costs were \$0.44 kg^{-1}, and \$0.38 kg^{-1}, for the diets of the

GPS and GPSG treatments, respectively, representing the same 13.3% reduction in diet costs. This difference is mainly due to the fact that in diets that include sunflower seeds, apart from reducing the amount of soybean meal, soybean oil is not used. From this scenery, replacing 10% soybean meal with partially hulled sunflower seems to provide an option for improving the economic viability of chicken system production, and even better, under grazing conditions. However, given the range of factors that have effect on profitability, such as the price of the ingredients used to balance the diet, price for seed, chemicals, animals, machinery, pasture fencing, fuel, and labor, we urge caution in extrapolating the results from the current study to other situations.

In conclusion, this study showed that substituting soybean meal for partially dehulled sunflower seeds by up to 10% in broilers grazing white clover improves meat quality by increasing the crude protein content and the percentage of unsaturated fatty acids. Additionally, under the conditions in which the study was developed, grazing white clover does not offer benefits in total unsaturated fatty acids or in oxidative stability.

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