Effect of low-fiber sunflower meal and phytase addition on broiler carcass traits, and meat quality

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SUMMARY

In need of identifying alternatives to conventional protein sources (soybean meal; SBM), due to the high costs and low availability, low fiber sunflower meal (LFSFM) could be a key to solve this issue. The present research was done in order to provide information and to evaluate the impact of graded replacement of SBM by LFSFM, with or without enzyme (microbial phytase; PHY) on broiler breast meat quality. Eight hundred one-day old broiler chicks (Cobb 500) were randomly assigned in a 4 × 2 factorial design, including four levels of LFSFM (0, 25, 50 and 75% in replacement of SBM) and two levels of PHY addition, (0 or 0.2 g/kg diet), in a 42-d feeding trial. Breast samplings were subjected to physicaly test on meat: pH, color, texture and evaluated for sensory quality. There was no significant effect ($P > 0.05$) between the main factors interaction (LFSFM × PHY) on breast meat pH, colour and TPA analysis. Enzyme addition had no beneficial effects on carcass and meat quality. Sensory evaluation of preserved breast meat presented similar ($P > 0.05$) results between SBM and experimental LFSFM diets, in terms of quality attributes (meat and fat appearance, odour, consistency, juiciness and tenderness). However, increasing the level of LFSFM (50 and 75% respectively) in diets reduced the abdominal fat ($P < 0.001$). It is concluded that the diets with LFSFM led to meat quality comparable with diet contained SBM.

Keywords: low-fiber sunflower meal, enzyme, breast meat quality, chickens.

INTRODUCTION

Consumer choice is the current concern of researchers and meat producers in order to establish new quality and nutritional aims targets that allow production performance with the least financial effort without decreasing the animal product quality. In this direction, finding substitution for ideal protein compound (soybean meal; SBM) and enhancing bioavailability with an enzymatic supplementation might be a solution in order to maintain the growth performance and quality within health, natural and low-cost resources. Sunflower meal (SFM), a by-product of sunflower oil extraction, is important as a source of vegetable protein and fibre for humans and animals (Kalmendal et al., 2011). Its content of protein depends by dehulling, air-classification, and oil extraction processes (Laudadio et al., 2013). SFM contains low antinutritional compounds and it is more resistant to contaminants, compared to SBM (Canibe et al., 1999). Nevertheless, the use of SFM in poultry diet is limited by variations in its chemical composition and the two main components restricting its use are high fiber and low lysine contents (Rezaei et al., 2007 and de Morais et al., 2016). One of these issues may be overcome by reducing the fibre content of SFM. The application of micronisation coupled to air fractionation was considered a useful tool for improving some technological performance and nutritional properties as well as to enrich the meal fractions of healthy compounds (Rizzello et al., 2012). Furthermore high sunflower meal levels in broiler diets require the addition of high oil levels in order to compensate the low energy content of SFM.

Phosphorus (P) is the third most expensive nutrient in poultry diets after energy and protein (Biehl et al., 1998). Pythic acid (*myo*-inositol hexaphosphate) is an important plant P storage form and accounts for 50 to 80% of total P present in plant seeds commonly used in livestock animal feeds. However, phytate-P has low bioavailability and is underutilized due to the lack of endogenous phytate degrading enzymes in nonruminant livestock, including poultry (Selle et al., 2006). Phytase (*myo*-inositol-exakis-phosphohydrolase), a specific phosphohydrolase, degrades phytate to yield inositol monophosphate and orthophosphate via inositol penta to monophosphates as intermediary products (Liu et al., 1998). In-feed administration of microbial phytases to improve digestibility of pythic acid is widely used in the production of poultry and other livestock (Selle et al., 2007 and Cowieson et al., 2011). However, best of our knowledge no research appears to be reported on the application of PHY in diets containing low-fiber SFM. Thus, the objective of this study was to evaluate in chicks' diet an appropriate inclusion level of low-fiber SFM as an

alternative protein source instead of SBM with or without microbial phytase supplementation on the carcass traits and meat quality.

MATERIALS AND METHODS

The study protocol was approved by the Local Ethical Committee for Animal Experiments in Balotesti, and was in accordance with the principles of the EU Directive 2010/63/EU and Romanian Law on Animal Protection.

Birds, experimental design, husbandry, and experimental diets

Day-old Cobb 500 broiler chickens (n=800) of mixed sexes, obtained from a commercial hatchery, were individually weighed (43.4±0.23 g/chick) and randomly distributed to receive one of the 8 dietary treatments in a 42-d feeding trial. Each treatment was subdivided into five replicates reared in pens on wood shavings litter of equal size and considered as one block. Except for day 1, a 23-h light to 1-h dark lighting program was applied during the experiment. Temperature was maintained at 32°C at placement followed by a 3°C decrease each week to archive 20-21°C by using thermostatically controlled heaters, fans, and adjustable sidewall inlets. The diets were arranged in a 4 × 2 factorial design, with the variable being low-fiber SFM (LFSFM) substituted for SBM at four levels (0%, 25%, 50% and 75%, respectively) and enzyme (AXTRA PHY 5000 L) supplementation at two levels (0 and 0.2 g/kg diet, respectively). The microbial phytase (AXTRA PHY 5000 L, a *Buttiauxella* sp. bacterium, expressed in a Trichoderma reesei fungus) was produced by Danisco Animal Nutrition, DuPont Industrial Biosciences (Marlborough, UK), at 1000 phytase units (**FTU**)/kg of final feed. The commercial powdered enzyme was added at 200 g/to (on top; 1000 FTU/kg feed), as recommended by the manufacturer.

The feeding program was divided into 3 feeding phases: starter (d 1 to 10), grower (d 11 to 22), and finisher (d 23 to 42). Diets (Table 1) for each feeding phase were formulated to be isocaloric, isonitrogenous, with similar content of total lysine, total sulphur amino acids (methionine + cysteine; TSAA), calcium and available phosphorous, and to meat or exceed breeder guidelines (Cobb Vantress Europe Ltd, UK). Feeds and water were provided ad libitum throughout the entire trial.

Laboratory Analysis, Sampling and Measurements

Samples of ingredients, and feed were analysed in duplicate, for ist content of dry matter, crude protein (N × 6.25), ether extract and ash, using standard procedures according to the methods of the Commission Regulation (EC) no. 152 (Official Journal of the European Union L 54,

2009). Amino acids (AA; excluding tryptophan, which not determined) were analysed using a HPLC (Thermo Finnigan, MA, USA), according to the conditions described by Ciurescu and Pană (2017).

At 42 d of age, 3 broiler chickens (mixed sexes) per replicate pen (nearest to the average weight of the same pen) were selected, fasted for 3 h with water, and slaughtered severing the right carotid artery and jugular vein. Slaughtered birds were weighed and their internal organs including, gizzard, liver, pancreas, and spleen were removed, cleaned from adhering tissues, and individually weighed. Carcasses were weighed without head, neck, and feet, and carcass yield was determined, and abdominal fat was weighed.

Carcass yield and relative weight of digestive organs were expressed as the percentages of live body weight. Samples of meat (*pectoralis major* muscle; right-side), were taken from the carcass and packaged individual in polythene zip lock bags and stored at 4°C during 24h and frozen at −20°C for further analysis.

Meat sensory evaluation

The sensory examination consists of verifying all the conditions included in the standards of meat and meat preparations that can be appreciated by the senses. The examination was carried out in Research and Training Center for Food Science and Safety (Faculty of Food Engineering, Stefan cel Mare University, Suceava) by a committee set up for this purpose, composed of eleven students, acquainted with products characteristics concerned and exercised sense organs for this purpose. The analytical method employed in this evaluation was a descriptive method-appreciation of the quality by the scoring scale (from 1 to 5; 1 for the lowest score and 5 indicating maximum score) (ISO 6658:2017). The sensory examination was accomplished in a bright, clean, odourless, panel-room at ambient temperature equal to 20°C (ISO 8589:2010). Thawed samples were displayed all in the same way [(100g of breast meat) on white disposable sample dishes] and encoded in order not to induce influence or eventual error. The samples were placed side by side, randomized order, on a white, planar surface until examination. The scoring was established according to the properties of the poultry raw meat: meat appearance, fat appearance, odour, consistency, juiciness and tenderness (Table 2).

Table 1. Ingredients and nutrient composition (as-dry basis) of experimental diets

Diets	Low-fiber SFM levels as substitute for SBM (%)											
	Starter diets (0-10 d)				Grower diets (11-22 d)				Finisher diets (23-42 d)			
	0	25	50	75	0	25	50	75	0	25	50	75
Ingredients (%)												
Corn	57.62	58.64	58.62	58.76	67.43	68.24	67.94	67.68	68.54	69.05	68.72	68.41
Soybean meal (CP 46%)	31.40	22.50	15.00	7.50	22.0	15.00	10.00	5.00	21.50	15.00	10.00	5.00
Sunflower meal (CP 44%)	0.0	7.50	15.00	22.50	0.0	5.00	10.00	15.00	0.0	5.00	10.00	15.00
Corn gluten meal (CP 62%)	4.00	4.60	4.50	4.30	4.00	5.60	6.00	6.20	3.00	4.20	4.50	4.80
Sunflower Oil	2.00	1.70	1.70	1.70	1.50	1.10	1.00	1.00	2.50	2.20	2.20	2.20
Monocalcium phosphate	1.67	1.56	1.5,3	1.45	1.56	1.50	1.45	1.42	1.38	1.34	1.28	1.25
Calcium carbonate	1.45	1.46	1.4,6	1.46	1.39	1.42	1.42	1.42	1.25	1.28	1.29	1.27
Salt	0.28	0.28	0.2,8	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
L-Lysine (78%)	0.25	0.45	0.60	0.75	0.42	0.56	0.63	0.72	0.27	0.39	0.48	0.55
Dl-Methionine (99%)	0.25	0.23	0.23	0.22	0.24	0.22	0.20	0.20	0.20	0.18	0.17	0.16
Choline chloride	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Premix vit-min.[1]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Phytase[2]	-/+[3]	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+
Calculated composition:												
ME (MJ/kg)	12.69	12.69	12.69	12.70	12.99	13.00	12.98	12.99	13.28	13.28	13.29	13.30
Crude protein	22.25	22.24	22.31	22.32	19.02	19.03	19.08	19.04	18.06	18.04	18.06	18.05
Lysine, total	1.30	1.30	1.30	1.30	1.19	1.19	1.19	1.19	1.05	1.05	1.05	1.05
Lysine, digestible	1.21	1.17	1.16	1.17	1.11	1.11	1.10	1.10	1.00	0.99	0.99	0.99
TSAA	0.98	0.97	0.98	0.97	0.89	0.89	0.88	0.89	0.82	0.82	0.82	0.82
Calcium	0.90	0.90	0.90	0.90	0.84	0.84	0.84	0.84	0.76	0.76	0.76	0.76
Available phosphorous	0.45	0.44	0.45	0.45	0.42	0.42	0.42	0.42	0.38	0.38	0.38	0.38
Crude fat	4.92	4.76	4.89	4.97	4.67	4.40	4.37	4.43	5.67	5.48	5.54	5.61
Crude fiber	2.80	3.30	3.84	4.38	2.53	3.07	3.67	4.27	2.51	3.06	3.66	4.26
Analyzed composition:												
Dry matter	88.2	87.6	88.7	89.2	86.5	87.9	88.6	89.0	86.2	87.4	87.7	87.6
Crude protein	22.12	22.21	22.77	22.65	19.27	19.35	19.42	19.33	18.32	18.39	18.45	18.43
Crude fat	4.88	4.75	4.82	4.94	4.78	4.25	4.23	4.30	5.56	5.34	5.69	5.72
Crude fiber	3.10	3.87	3.93	4.77	2.76	3.45	3.92	4.53	2.67	3.41	3.88	4.37

[1] Supplied per kg diet: retinyl acetate, 4.47 mg; cholecalciferol, 0.12 mg; DL-α-tocopheryl acetate, 80 mg; menadione sodium bisulphite, 4 mg; thiamine mononitrate, 4 mg; riboflavin, 9 mg; pyridoxine-HCl, 4 mg; cyanocobalamin, 0.020 mg; Ca-panthotenate, 15 mg; niacin, 60 mg; folic acid, 2 mg; Mn, 100 mg; Zn, 100 mg; Fe, 40 mg; Cu, 15 mg; I, 1.0 mg; Se, 0.30 mg; Co, 0.25 mg.
[2] Phytase added to diets were 0 or 0.2 g/kg (1000 FTU/kg feed)
[3] - = enzyme not included in the diet; + = enzyme included in the diet.

Meat pH and color

Muscle pH as measured at 24h after slaughter (initial pH; pH_i) and after 3 months post slaughter (ultimate pH; pH_u). A portable digital pH meter (model HI 99163, Hanna Instruments, Romania), with a combined glass-penetrating electrode (FC 099 stainless steel blade tip) was calibrated using 2-point method against standard buffer solutions with pH values of 4.0 and 7.0. The pH value was expressed as the average of the 3 measurements.

Meat colour determination was carried out in Research and Training Center for Food Science and Safety (Faculty of Food Engineering, Ştefan cel Mare University, Suceava). Surface breast meat color (CIE LAB sistem, 1978) as evaluate by CR-400 portable colorimeter (Minolta CR-400 chromameter, Konica Minolta Camera Co., Osaka, Japan) with illuminant D65, as the light source, 0° observation angle, and calibrated against a standard white tile. Color were expressed as L* (luminosity), a* (redness-shades) and b* (yellowness-saturation) values.

Table 2. Sensory scale description

Score	Meat appearance	Fat appearance	Odor	Consistency	Juiciness	Tenderness
5	Excellent	Excellent	Characteristic pleasant	Ferm, elastic	Juicy	High tender, desirable
4	Verry good	Verry good	Less pleasant	Elastic	Less juicy	Desirable tender
3	Fair	Fair	Trace of strange scent	Slack, apparent elastic	Mate, juiceless	Medium tender
2	Slightly poor	Slightly poor	Unpleasant odor	Slack apparent flaccid	Mate, slightly dry	Less tender
1	Poor	Poor	Unpleasant, putrid	Sticky-flaccid	Dry, compact	Undesirable tenderless

Meat mechanical properties

Shear force and texture profile analyses (TPA) of breast meat samples were carried out with a TVT 6700 Texture Analyzer (Perkin Elmer, Hägersten, Sweden). All textural procedures were performed in the Research and Training Center for Food Science and Safety (Faculty of Food Engineering, Ştefan cel Mare University, Suceava). Meat parameters such as: shear force (firmness) and (TPA) were determined by following methods:

(a) Shear force was measured using a Warner-Bratzler shear blade with a triangular slot cutting edge. Three rectangular slices per treatment (2.0 cm long×1.0 cm wide×1.0 cm high) were used to evaluate shear force; sample cuts were made parallel to the direction of the muscle fibres. Shear force (g) was calculated from the maximum point of the curve obtained from the test.

(b) In general, four cylinders 1.5 cm high and 2 cm wide were prepared from every sample. A double compression cycle test was performed up to 50% compression of the original portion height with an aluminium cylinder probe of 2 cm 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 following parameters were quantified: hardness (g) maximum force required to compress the sample, springiness (dimensionless), ability of the sample to recover its original form after deforming force was removed. Cohesiveness (dimensionless), resilience (dimensionless), gumminess (g) and chewiness (g) are secondary parameters provided from TPA by mathematic formulas using distance and areas between first and second cycle peak reporting the TPA analysis, with the provided instrumental software.

Statistical analyses

Data were analysed by a mixed-effects model using the GLM procedure of SPSS/IBM software (version 20 Inc. Chicago, IL, U.S.A, 2011). Levels of SFM, enzyme and their interactions were included in the statistical model. Samples were considered as the experimental unit. Effects were considered statistically significant at $P < 0.05$. *Post hoc* multiple comparisons as performed by Tukey's test.

RESULTS AND DISCUSSION

Low fiber sunflower meal nutrient composition

The chemical composition and the AA profile of LFSFM, used for this study are shown in Table 3 and Table 4. LFSFM was found to contain appreciable content of crude protein than in SBM (44 - 48.5%) as recorded by NRC (1994). In comparison with SBM, LFSFM had lower metabolized energy content (7.10 vs 10.2 MJ) and three-fold higher fibre content (11.31 vs 3.9 %). The metabolizable energy (ME) content of LFSFM was estimated based on the following equation (NRC, 1994):

ME = 6.28 (DM) - 6.28 (ash) + 25.38 (CP) + 62.62 (EE), where DM, CP, and EE are dry matter, crude protein, and ether extract, percentage of LFSFM, respectively.

Table 3. Composition and nutritional value of LFSFM, as-fed basis (n=2)

	DM	**CP**	**EE**	**Fiber**	**Ash**	**NFE**	**NDF**	**ADF**	**ME(MJ)**
LFSFM	96.4	43.4	0.68	11.3	7.96	33.08	24.18	12.71	7.10

Table 4. LFSFM amino acid profile

AA	LFSFM	AA	LFSFM
Lysine	1.636	Phenylalanine	2.359
Methionine	0.715	Tyrosine	1.192
Cysteine	0.659	Serine	2.592
Threonine	2.923	Glycine	2.650
Leucine	3.322	Alanine	2.326
Arginine	4.077	Aspartic acid	4.701
Isoleucine	1.905	Glutamic acid	9.991
Valine	1.958		

All essential AA, except the lysine (3.7 - 4 % of the protein) were present in excessive amounts. LFSFM had higher sulphur-containing amino acids (methionine and cysteine: 2%), compared to the requirements of broilers in the starter phase.

Carcass and digestive organs size

The interaction between the main factors (LFSFM × phytase) had no significant effects ($P > 0.05$) on carcass yield, breast yield and abdominal fat as well as digestive organ weights of broilers (data not shown). However, increasing the level of LFSFM (50 and 75%) in diets reduced the abdominal fat ($P < 0.001$), whereas, the weight of small intestine was increased ($P < 0.001$) and tended ($P = 0.096$) to increase gizzard weight. Broilers fed diets containing or not phytase had no effect on carcass yield, breast yield, abdominal fat and digestive organ weights (*i.e.* gizzard, liver, pancreas and spleen) or caeca pH ($P > 0.05$). The findings of the present study agree with those of Alagawany et al. (2017) who reported that broiler chickens which received diet containing high LFSFM level had lower abdominal fat percentage than those fed SBM diet. In this study, the increased weights of the small intestine when feeding diets with LFSFM (50 and 75%, replacing SBM), could be the result of the dietary fibre (DF). DF ingestion leads to increased size and length of the digestive organs, including the small intestine, caecum and colon of chickens (Iji et al., 2001). These effects are often associated with modification of the gut epithelium morphology, and consequently with the hydrolytic and absorptive functions of the epithelium. On the same context, Ciurescu et al. (2017) observed an increase in the relative weight of the small intestine in bird fed with other ingredient, such as lentil (*Lens culinaris*; cv. Eston, green-seeded and cv. Anicia, green marbled-seeded).

Meat sensory evaluation

Meat sensory evaluation results of broiler chickens fed with different levels of LFSFM (0, 25, 50 and 75%) replacement of SBM, with or without

PHY are presented in Figure 1. In this study, chicks' breast meat sensory attributes (meat and fat appearance, odour, consistency, juiciness and tenderness) were not affected by dietary treatment (P>0.05). Recorded sensory scores of the current study are very high, proving that the breast meat quality of chicks' fed LFSFM are similar to meat of broiler fed SBM diet. In addition, the sensory meat evaluation is sustained by physical meat texture analysis (shear force and TPA), reported below. Similar results for sensory properties were reported by Jankowski et al., 2011 replacing SBM with SFM at dietary levels up to, 14% in turkey diets. Kalakuntla et al., (2017) showed that broiler sensory meat quality was not influenced by dietary use up to 3% oil rich in polyunsaturated fatty acids (n-3). Similarly, studies conducted by Panda et al. (2015) indicated that chicken diet supplemented with linseed oil at 33, 67 and 100% levels, replacing sunflower oil, had no abnormal sensory attributes (appearance, flavour, juiciness, tenderness and overall acceptability.

Our results showed no difference among treatments, leading to the conclusion that the students preferred meat of all tested samples, ranking high score for all groups.

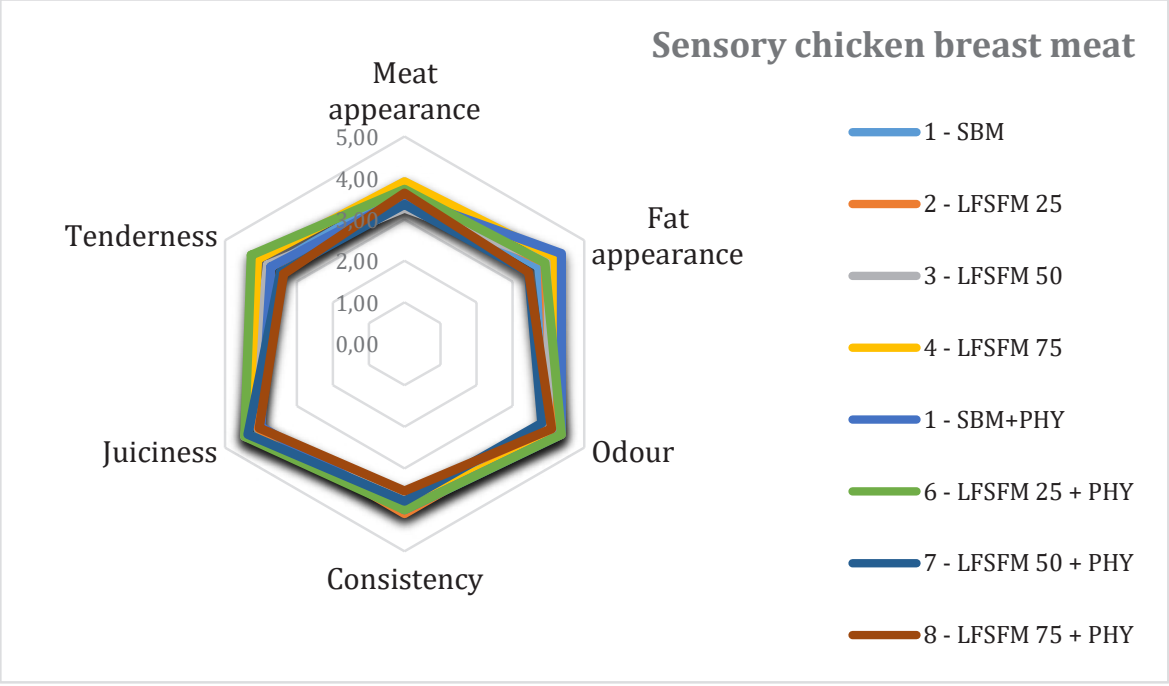

Figure 1. Broiler breast meat sensory evaluation

Meat pH and colour

As a meat quality indicator, pH values reflect meat quality condition. In our study, no interaction between the main factors (LFSFM × phytase) was found for breast meat pH_i and pH_u values (Table 5). At pHi, the mean pH of breast meat did not differ (P > 0.05) between treatment, recorded values

from 5.93 to 5.99. These values are very close to those reported in other studies (Corzo et al., 2009). It has been found that pH is an indicator of meat quality, and a low pH (<5.7) at 24 h postmortem is indicative of poor meat quality (Fernandez et al., 1994; Alvarado et al., 2007). Also, Muth and Zárate (2017) state that normal values pH for chickens meat range from 5.91 to 6.36. In the present study, no breast meat had a pH below 5.7 at 24h post slaughter. This indicates that there were no quality problems with the meat from each treatment group.

At pH_u (3 months post slaughter), the mean pH of breast meat did not differ ($P > 0.05$) among treatments (values range from 5.91 to 6.08). In current study pH values, were higher than that reported by Jankowski et al. (2011) who recorded pH values between 5.36-5.89, in breast fillets samples (after thawing) of turkeys fed different dietary levels of SFM (0, 7, 14 or 21%). Significantly differences between treatments for L* (P=0.023), a* (P=0.001) and b* (P=0.001) colour parameters of meat samples were reported (Table 5). The L* values of breast muscle were between 48.59 and 49.26.

Higher L* values were present in meat samples of LFSFM groups, compared with SBM groups, indicating a significant difference and imprinting a lighter colour of breast meat. Redness (a*) and yellowness (b*) colour parameters recorded lower values for LFSFM meat samples (a* between 1.35 to 1.42 and b* from 13.38 to 13.70, respectively), than SBM meat samples (a*=2.49 and b*=14.15, respectively), indicating a faded breast meat colour.

The interaction between the main factors (SFM × PHY) had no significant effects (P>0.05) on broiler meat colour. Likewise pH, meat colour also represents a main factor in order to determine meat quality, influencing consumers' acceptance. Early studies indicate significant correlations between colour traits, pH and textural properties of meat, suggesting that it might be possible to indicate the functionality of meat properties (Qiao et al., 2001 and Barbin et al., 2015). Previous studies have used L* as a measure to estimate the incidence of paleness or the pale, soft, and exudative condition, or both, in broiler breast meat (Barbut, 1998; van Laack et al., 2000; Woelfel et al., 2002), van Laack et al. (2000) reported that breasts appearing to be normal had L* values of 55 and those appearing to be pale had CIE L* values of 60 and stated that high L* values and low ultimate pH (<5.7) were indicative of broiler breast meat that was pale in colour.

The L* and mean pH_u values for all treatments during the current study were similar to values that have been reported by previous researchers as characteristic of normal broiler breast meat at 24 h post slaughter (van Laack et al., 2000 and Woelfel et al., 2002).

Table 5. Effects of dietary LFSFM levels and phytase addition on broiler chicks breast meat pH and colour[1]

Treatments	LFSF(%)	Phy[2]	pH_i	pH_u	L^*	a^*	b^*
1[3]	0	No	5.99	6.05	46.95	2.55	14.07
2	25	No	5.96	5.97	48.93	1.31	13.32
3	50	No	5.93	5.98	48.59	1.46	13.66
4	75	No	5.97	6.08	47.49	1.40	13.34
5	0	Yes	5.95	5.98	46.15	2.44	14.22
6	25	Yes	5.93	5.91	49.76	1.38	13.53
7	50	Yes	5.94	5.99	49.14	1.30	13.75
8	75	Yes	5.95	5.98	49.46	1.44	13.42
SEM			0.07	0.09	0.22	0.20	0.32
Main effects[4]							
Inclusion level (L)							
0			5.97	6.01	46.55[b]	2.49[a]	14.15[a]
25			5.95	5.94	49.34[a]	1.35[b]	13.43[b]
50			5.94	5.74	48.87[a]	1.38[b]	13.70[b]
75			5.96	5.76	48.48[a]	1.42[b]	13.38[b]
Phytase (Phy)							
No			5.96	6.02	47.99	1.68	13.60
Yes			5.94	5.97	48.63	1.64	13.73
P-value							
L effect			0.383	0.266	0.023	0.001	0.001
Phy effect			0.250	0.113	0.132	0.264	0.232
L x Phy effect			0.544	0.405	0.753	0.865	0.748

[a,b] Means in columns with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of 15 broilers for each treatment.
[2]Axtra® PHY 5000 L (1000 FTU/kg feed).
[3]Control group
[4]Data were analysed as 4 × 2 factorial arrangement.

Meat mechanical properties

Texture is an important aspect of meat quality, sometimes even more important than color or flavor (Elzerman et al. 2011). Of the textural features, the most commonly mentioned are hardness, cohesion and juiceness. Hadness is the most important toll to determine comercial value of the meat. Warner's Bratzler test and TPA are useful tools to assess the palatability of a meat product since the objective attributes correlate well with sensory evaluation (Chandra et al., 2015).

Textural properties of the breast meat collected from broiler fed with different levels of LFSFM with or without phytase are shown in Table 6.

There was no interaction between the main factors (LFSFM × phytase) for shear force and TPA analysis (P > 0.05). No significant difference was observed in shear force among the meat samples, but data showed that the level of LFSFM tended to increased gumminess (P = 0.063) and chewiness (P = 0.066) TPA parameters. The hardness revealed similarity between treatments (P > 0.05), displaying values between 2322-2365 g and it can be correlated with sensorial tender attribute associated to chicken breast meat. From the mathematical relation it can be observed that chewiness parameter dynamics depends on the gumminess parameter value, changing values proportionally, both depending on meat hardness. Enzyme addition had no impact (P > 0.05) on broiler meat shear force and TPA analisys. There is a lack of relative information regarding the texture properties of LFSFM.

Therefore, more study is needed to determine the effects of LFSFM on textural properties in broiler breast meat. Our results showed that, at the dietary levels used in the present study, LFSFM may increase meat gumminess and chewiness with-out changing other textural characteristics.

CONCLUSION

The present study indicated that the LFSFM can be a valuable protein source for broilers, particularly in terms of carcass traits, and some quality properties. The *Buttiauxella*-derived phytase addition had no influence on broiler carcass and breast meat quality. Further investigations are required in order to evaluate the impact of LFSFM inclusion in the commercial production.

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Table 6. Effects of dietary LFSFM and Phy addition on shear force and TPA analysis of chicks breast meat[1]

Treat-ments	LFSFM (%)	Phy[2]	Shear force (g)	TPA analysis					
				Hardness (g)	Springiness	Resilience[5]	Cohesiveness[6]	Gumminess[7] (g)	Chewiness[8] (g)
1[3]	0	No	2133	2342	0.999	2.11	0.352	824.38	823.56
2	25	No	2137	2322	0.995	2.15	0.372	863.77	859.45
3	50	No	2141	2332	0.997	2.17	0.373	869.83	867.22
4	75	No	2142	2365	0.999	2.14	0.357	844.30	843.46
5	0	Yes	2137	2339	0.998	2.10	0.351	820.99	819.35
6	25	Yes	2140	2344	0.999	2.11	0.356	834.46	833.63
7	50	Yes	2145	2349	0.999	2.20	0.372	873.82	872.94
8	75	Yes	2147	2354	0.995	2.23	0.369	868.63	864.28
SEM			1.41	1.98	0.07	0.16	0.03	0.59	0.58
Main effects[4]									
Inclusion level (L)									
0			2135	2341	0.999	2.11	0.352	822.68	821.46
25			2138	2333	0.997	2.13	0.364	849.11	846.54
50			2143	2340	0.998	2.19	0.372	871.82	870.07
75			2145	2359	0.997	2.18	0.363	856.46	853.87
Phytase (Phy)									
No			2138	2340	0.998	2.14	0.364	850.57	848.42
Yes			2142	2347	0.998	2.16	0.362	849.48	847.55
P-value									
L effect			0.410	0.501	0.865	0.358	0.895	0.063[T]	0.066[T]
Phy effect			0.544	0.789	0.966	0.843	0.676	0.889	0.691
L x Phy effect			0.465	0.423	0.685	0.591	0.648	0.445	0.343

[a,b] Means in columns with no common superscript differ significantly ($P < 0.05$). [1]Data are means of 15 broilers for each treatment. [2]Axtra® PHY 5000 L (1000 FTU/kg feed). [3]Control group. [4]Data were analysed as 4 × 2 factorial arrangement. [5]Area during the withdrawal of the first peak / Area of the first peak. [6]Area under second peak/ Area under first peak. [7]Hardness × Cohesiveness. [8]Gumminess × Springiness.

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