Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X Oct - Dec 2011 / v.13 / n.4 / 219-226

Effect of Squash Seed Meal (*Cucurbita Moschata*) on Broiler Performance, Sensory Meat Quality, and Blood Lipid Profile

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Keywords

Broilers, feeding, lipids, squash seed meal.

Submitted: December/2010
Approved: September/2011

ABSTRACT

In this experiment, 240 Cobb-500® broilers reared from1 to 49 days, and distributed according to a completely experimental randomized design with four treatments of four replicates each in order to evaluate the effect of the dietary inclusion of 0, 33, 66 or 100 g/kg of squash seed meal (SSM) (*Cucurbita moschata*) on the performance, carcass yield, serum lipid profile and sensory meat quality of broilers. Significant differences ($p<0.05$) were detected in performance, carcass weight, weight and breast yield, and leg weight. The best results were obtained with 33 and 66 g/kg as compared to the control diet and 100 g SSM /kg. Abdominal fat decreased with the inclusion of 66 and 100 g SSM / kg, but the sensory quality of breast and thighs was not affected by the inclusion of SSM. The serum levels of total cholesterol, very low density (VLDL) and low density (LDL) lipoproteins, triglycerides, glucose and atherogenic index decreased with the inclusion of 100 g/ kg of SSM, except for high density lipoproteins (HDL), which increased. The inclusion of 0, 33, 66 and 100 g/kg of SSM in broiler diets, partially replacing soybean meal and vegetable oil, improved live performance and edible portions yield. In addition, abdominal fat and serum levels of harmful lipids were reduced, whereas serum levels of beneficial lipids increased. There was no effect on meat sensory quality.

INTRODUCTION

Squash pulp is consumed in Cuba since pre-Colombian times; however, seed are not used as human food or animal feed, and consequently, thousands of tons of seeds, containing 940 g/kg dry matter and significant amounts of proteins, amino acids, unsaturated lipids, phytosterols, squalene, dietary fiber, and minerals, are wasted. Squash seeds produce 225 to 248 kg crude protein/hectare and 240 to 255 kg ether extract/hectare, which could potentially be used for poultry feeding (Martínez *et al*., 2008; Martínez, 2009).

Squash seed meal is rich in proteins, but its inclusion in diets for monogastric animals have shown poor results (Bressani & Arroyave, 1963; Rossainz *et al*., 1976; Manjarrez *et al*., 1976; Bernal *et al*., 1977). However, literature search has not retrieved sufficient information on the use of full-fat squash seeds in poultry diets, particularly in broiler diets.

Hrdinka *et al*. (1996) and Ayerza *et al*. (2002), using oil seeds such as linseed and chia, observed better performance, reduced levels of harmful lipids and better meat quality in broilers. It should be mentioned that the chemical composition of feeds strongly influences blood levels of triacylglycerides, total cholesterol, phospholipids and low- and high-density lipoproteins (LDL and HDL, respectively) in poultry (Murata *et al*., 2003 e Martínez *et al*., 2010).

The aim of this study was to evaluate the effect of squash seed meal (SSM) (*Cucurbita moschata*) on broiler performance, sensory meat quality, and blood lipid profile.

MATERIALS AND METHODS

Location

The experiments were carried out at the Poultry Experimental Unit of the Center of Biological and Agricultural Sciences of the University of Guadalajara (Unidad Experimental Avícola del Centro Universitario de Ciencias Biológicas and Agronómicas (CUCBA) de la Universidad de Guadalajara), Mexico, N 20.67°, W 103.34°. An average relative humidity of 70 %, and average minimum and maximum temperatures of 16.9 °C and 27.9 °C, respectively, were recorded using a hygro-thermometer placed inside the experimental house.

Squash seeds

Six samples of whole squash seeds of different lots of the variety Tapatía, moschata species, stored for 12 months, were collected, ground, and mixed. Their chemical composition was analyzed by Martínez (2009).

Birds and diets

A total number of 240 one-day-old female Cobb-500® chicks were reared until 49 days of age. Birds were distributed, according to a completely randomized experimental design, into four treatments with four replicates each.

Treatments consisted of diets containing 0,33, 66 or 100 g squash seed meal (SSM) /kg feed. The experimental diets (Tables 1-2) were formulated to contain equal protein and energy levels and to supply the requirements recommended in the Cobb-500® manual (2007). The inclusion of SSM was made at the expense of vegetable oil and soybean meal. A four-phase feeding program was used: starter 0-10 days, grower 11-22 days, development 23-42 days and finisher 43-49 days.

Experimental conditions

Each replicate consisted of a pen with deep corn stover litter and 12 birds/m^2. Feed and water were offered *ad libitum*, in tube feeders and nipple drinker, respectively. Brooding lamps were used up to 10 days, after which a lighting program of 23 hours of light was applied. Birds were vaccinated in the hatchery against fowl pox, infectious bronchitis, Newcastle disease and infectious bursal disease. No medication was added to the feed, nor were therapeutic drugs used during the experimental period.

Performance parameters

All birds were weighed in the beginning and end of the experiment (49 days). Feed intake (g/bird/day) was measured daily during the experimental period and calculated as the difference between the amount of feed offered and of feed residue. Feed conversion ratio was calculated as the amount of feed intake to gain one kg body weight. Viability was determined as the difference between the initial number of birds and recorded mortality.

Table 1 - Ingredients and nutritional composition of the starter (0-10 days) and grower (11-22 days) diets on as-fed basis.

Ingredients	Squash seed meal levels (g/kg)							
	Phase 1				Phase 2			
	0	33	66	100	0	33	66	100
Ground corn	575.40	564.60	567.40	571.20	604.80	599.20	594.20	603.14
Soybean meal	347.00	328.90	300.00	269.50	310.00	288.00	266.00	245.00
Vegetable oil	30.00	26.00	19.50	12.50	39.00	34.00	28.50	23.80
SSM	0.00	33.00	66.00	100.00	0.00	33.00	66.00	100.00
Salt	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
L-lysine	1.10	1.10	1.20	1.40	0.80	0.80	0.80	0.80
DL-methionine	2.30	2.30	2.20	2.10	2.30	2.20	2.10	1.90
Dicalcium phosphate	19.80	19.80	19.80	19.80	18.50	18.50	18.50	1.86
Calcium carbonate	11.50	11.40	11.00	10.60	11.70	11.40	11.00	10.60
Choline	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Premix[1]	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Nutritional levels (g/kg)								
Metabolizable energy (MJ/kg)	12.50	12.50	12.50	12.50	12.90	12.90	12.90	12.90
Crude protein	210.00	210.00	210.00	210.00	190.00	190.00	190.00	190.00
Calcium	10.00	10.00	10.00	10.00	9.60	9.60	9.60	9.60
Phosphorus	5.00	5.00	5.00	5.00	4.80	4.80	4.80	4.80
Methionine+cystine	8.90	8.90	8.90	8.90	8.40	8.40	8.40	8.40
Lysine	12.00	12.00	12.00	12.00	11.00	11.00	11.00	11.00
Ether extract	23.00	34.00	45.00	57.00	24.00	35.00	46.00	57.00
Crude fiber	37.00	41.00	45.00	48.00	35.00	39.00	43.00	47.00

1 - Each kg contains: vitamin A, 13,500 IU; vitamin D3, 3,375 IU; vitamin E, 34 mg; B2, 6 mg; pantothenic acid, 16 mg; nicotinic acid, 56 mg; Cu, 2,000 mg; folic acid , 1.13 mg; vitamin B12, 34 μg; Mn, 72 mg; Zn, 48 mg.

Table 2 - Ingredients and nutritional composition of the development (23-42 days) and finisher (43-49 days) diets on as-fed basis.

Ingredients	Squash seed meal levels (g/kg)							
	Phase 3				Phase 4			
	0	33	66	100	0	33	66	100
Ground corn	619.30	615.30	610.70	608.10	660.40	656.60	651.80	642.40
Soybean meal	286.00	263.00	240.00	215.00	253.0	229.3	207.0	187.0
Vegetable oil	50.00	44.50	39.50	33.50	42.40	37.10	31.80	27.50
SSM	0.00	33.00	66.00	100.00	0.00	33.00	66.00	100.00
Salt	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
L-lysine	1.20	1.20	1.30	1.40	1.00	1.10	1.10	1.20
DL-methionine	2.40	2.30	2.10	2.00	2.20	2.10	2.00	1.90
Dicalcium phosphate	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
Calcium carbonate	11.20	10.80	10.50	10.10	11.20	11.00	10.50	10.20
Choline	0.40	0.40	0.40	0.40	0.30	0.30	0.30	0.30
Premix[1]	10.00	10.00	10.00	10.00	1.00	1.00	1.00	1.00
Nutritional levels (g/kg)								
Metabolizable energy (MJ/kg)	13.29	13.29	13.29	13.29	13.29	13.29	13.29	13.29
Crude protein	180.00	180.00	180.00	180.00	170.00	170.00	170.00	170.00
Calcium	9.00	9.00	9.00	0.90	9.00	9.00	9.00	9.00
Phosphorus	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Methionine+cystine	8.20	8.20	8.20	8.20	7.80	7.80	7.80	7.80
Lysine	10.5	10.50	10.50	10.50	10.00	10.00	10.00	10.00
Ether extract	24.00	35.00	46.00	58.00	25.00	36.00	47.00	59.00
Crude fiber	34.00	38.00	41.00	45.00	32.00	36.00	40.00	44.00

1 - Each kg contains: vitamin A, 13,500 IU; vitamin D3, 3,375 IU; vitamin E, 34 mg; B2, 6 mg; pantothenic acid, 16 mg; nicotinic acid, 56 mg; Cu, 2,000 mg; folic acid , 1.13 mg; vitamin B12, 34 µg; Mn, 72 mg; Zn, 48 mg.

Edible cuts and total viscera weight and yield and sensory quality of breast and leg meat

Ten birds per treatment were sacrificed by bleeding of the jugular vein after four hours of feed fasting (water was offered *ad libitum*).

Carcass and viscera weights were determined by weighing the birds before slaughter, after which carcass, total viscera, liver, breast, leg, and abdominal fat pad were weighed. Leg and breast samples were kept frozen at -20 °C.

Breast and leg sensory quality was determined by a panel of 15 tasters selected from Centro Universitario de Ciencias Biológicas and Agronómicas, Universidad de Guadalajara, Mexico. Meat samples were thawed, and cooked in water with no salt for 30 minutes at 80 °C (Ruiz *et al*., 2001). Panel members were selected according to the following criteria: healthy, non-smokers, did not have the habit of consuming coffee and/or alcoholic beverages, mean and women between 25 and 55 years.

The sensory quality parameters surveyed were: aroma (normal or abnormal), flavor (normal or abnormal), tenderness (normal, tough, very tough, very soft), color (normal, pale or intense).

Analysis of blood lipids

When broilers were slaughtered on day 49, 10 ml of blood were collected from the jugular vein of 10 birds per treatment. Blood samples were kept for one hour in 20-ml tubes, and were then centrifuged (Eppendorf centrifuge) at 10,000 rpm and 20 °C for 25 min. Sera were stored at -20 °C until analyses in the laboratory.

Triglyceride, total lipid, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), very low-density lipoprotein (VLDL) and glucose serum levels were determined by enzymatic colorimetric methods, using kits and an ultraviolet spectrophotometer (Humalyzer 2000). The atherogenic index was calculated according to the ratio reported by Salma *et al*. (2007): IA=LDL/HDL. All analyses were conducted in quintuplicate.

Data were submitted to one-way analysis of variance (Anova) according to a completely randomized experimental design. The test of Duncan (1955) was used to compare means, using the SPSS version 17.0 statistical package.

RESULTS AND DISCUSSION

Table 3 shows that viability was not influenced by the inclusion of SSM in the feed. Live weight, cumulative feed intake and cumulative feed conversion ratio were significantly different ($p<0.05$), with birds fed 33 and 66 g SSM/kg presenting better results as compared to those fed the control and 100 g SSM /kg diets.

Viability results (Table 3) show the lack of detrimental effects of the squash seed used in the present experiment in birds. Bressani and Arroyave (1963) & Rossainz *et al*. (1976) included 200 g/kg squash seed meal in broiler diets and observed 90 % morbidity due to thiamine deficiency. This may be related to the excessive temperature (200 °C) used for the mechanic extraction of fat from squash seeds (Murkovic *et al*., 2004), considering that thiamine is the water-soluble

Table 3 - Live performance of Cobb-500 broilers fed different SSM levels.

Parameters	Squash seed meal level (g/kg)				
	0	33	66	100	SE± Sig.
Livability (%)	95.00	95.00	95.00	95.00	2.81
Cumulative feed intake (g/bird)	4837.00b	4971.00a	4976.00a	4831.00b	30.02**
Cumulative feed:gain	2.13a	2.10b	2.09b	2.13a	0.012**
Live weight (g)	2268.00b	2366.00a	2376.00a	2265.00b	14.00*

a,b - Means followed by different letters in each row as significantly different at p<0.05 (Duncan, 1955). *p<0.05; **p<0.01.

vitamin that is most destroyed by processing (up to 50 %) (McCourt *et al*., 2006). In the present experiments, no signs of thiamine deficiency were detected, as also found by Martínez *et al*. (2010), who used similar inclusion levels in layer diets.

The performance results obtained with the diet containing 100 g SSM/kg were as to those produced with the control diet, but were inferior as compared to the 33 and 66 g SSM/kg inclusion levels, which may have been due to the supply of 44 to 48 g/kg CF in that diet (Tables 1 and 2). Ayerza *et al*. (2002) reported that, when using linseed and dietary crude fiber levels higher than 50 g/kg, broiler performance was poor. It must be mentioned that chia seeds contain higher CF levels than SSM, Tapatía variety (221.0 g/kg and 162.4 g/kg, respectively) (Martínez, 2009).

According to Savón *et al*. (2007), there is a high correlation (R^2=0.75) between dietary neutral detergent fiber (NDF) content and the volume they occupy in the gastrointestinal tract, which may trigger satiety signs in poultry, reducing their voluntary feed intake. In addition, Smith & Sales, (1996) stress that the efficiency of fiber utilization in broilers is related to intestinal transit time (12 to 24 horas), which is higher than in other poultry species. Squash seeds (Tapatía var.) contain 362.00 g NDF /kg (Martínez, 2009), and this may explain the poorer performance of broilers fed 10 % SSM relative to those fed 33 and 66 g SSM /kg diet.

The better performance obtained with the inclusion of 33 and 66 g SSM /kg feed as compared to control diet may be due to the flavor enhancement promoted by unsaturated fats. Rosebrough *et al*. (1999) and Crespo & Esteve-García (2002) showed that, when unsaturated fat levels were increased in broiler diets, feed intake and final body weight was higher than that obtained with the control treatment. Mateos & Sell (1980) and Latshaw (2008) demonstrated a linear increase in broiler daily gain with increasing dietary fat inclusion levels. Mateos *et al*. (1995) mentioned that fats improve diet palatability as they reduce dust formation and hide undesirable flavors. The results of the present study showed that SSM acts as a natural growth promoter in broilers when added up to 66 g/kg of feed.

The broilers fed 33 and 66 g SSM /kg of feed presented higher ME, CP, lysine, methionine+cystine, Ca and P intakes (Table 4) relative to the control group and those fed 100 g SSM /kg. The diets containing 66 and 100 g SSM /kg de promoted higher ether extract and crude fiber intakes.

Crude fiber intake increased in the broilers fed 66 and 100 g SSM /kg due to the higher supply of this component in these diets (Tables 1 and 2). In this sense, Savón *et al*. (2007) demonstrated higher CF intake when fiber-rich feedstuffs were added to poultry feeds; however, high CF levels reduce energy intake, and consequently impair performance. The CF content of the diets containing 100 g SSM /kg reduced broiler compensatory growth.

Higher ether extract intake, particularly of unsaturated fats, promotes better broiler performance, as shown by the broilers fed 33 and 66 g SSM /kg in the present experiment. López-Ferrer *et al*. (2001a) reported higher weight gain and final body weight in broilers consuming diets with high ether extract levels.

The lysine intake of the broilers fed SSM in the present study was similar as to that reported by Ayerza *et al*. (2002) when including 10% chia seed in broiler diets. Martín *et al*. (2002) observed higher lysine and methionine+cystine intake in the pre-starter phase when increasing CP (25 %), lysine (1.46 %) and methionine+cystine (1.08 %) levels of broiler diets. However, Corzo *et al*. (2002) did not determine significant differences (p<0.05) in lysine intake when dietary lysine levels was increased from 0.75 to 1.15 % in broiler diets.

Table 4 - Average ME and nutrient intake of Cobb-500 broilers fed different SSM levels (1-49 days).

Average intake	Squash seed meal levels (g/kg)				SE± Sig.
	0	33	66	100	
ME (MJ/bird/day)	1.30b	1.34a	1.34a	1.30b	0.008***
CP (g /bird/day)	17.86b	18.36a	18.37a	17.85b	0.110***
Lysine (g /bird/day)	1.04b	1.07a	1.07a	1.04b	0.006***
Methionine+cystine (g /bird/day)	0.81b	0.83a	0.83a	0.81b	0.005***
Calcium (g/bird/day)	0.90b	0.93a	0.93a	0.90b	0.006***
Available phosphorus (g /bird/day)	0.45b	0.46a	0.46a	0.45b	0.003***
Ether extract (g /bird/day)	2.38d	3.56c	4.67b	5.71a	0.027***
Crude fiber (g /bird/day)	3.36d	3.85c	4.20b	4.47a	0.024***

a,b - Means followed by different letters in each row as significantly different at p<0.05 (Duncan, 1955).***p<0.001.

Table 5 - Weight and yield of edible parts and total viscera of Cobb-500 broilers fed different SSM levels (1-49 days).

Parameters	Squash seed meal levels (g/kg)				SE± Sig.
	0	33	66	100	
Final live weight (g)	2277.00b	2376.00a	2380.00a	2274.00b	14.17***
Carcass weight (g)	1634.00b	1722.00a	1720.00a	1625.00b	23.41***
Carcass yield (%)	71.77	72.38	72.34	71.50	0.73
Breast weight (g)	388.00b	422.00a	417.80a	380.80b	4.57***
Breast yield (%)	23.73b	24.56a	24.380a	23.52b	0.32***
Leg weight (g)	511.00b	544.00a	551.00a	519.00b	3.51***
Leg yield (%)	31.77	31.76	32.03	32.05	0.35
Abdominal fat weight (g)	35.20[a]	35.60[a]	32.40b	31.40b	0.596***
Abdominal fat yield (%)	2.15a	2.06a	1.93b	1.88b	0.046***
Total viscera weight (g)	188.00	189.00	189.00	191.00	2.28
Total viscera yield (%)	8.27a	7.96b	7.97b	8.41a	0.72***
Liver weight (g)	52.00	52.00	49.00	48.00	4.69
Liver yield (%)	2.28	1.85	2.19	2.10	0.19

a,b Means followed by different letters in each row as significantly different at p<0.05 (Duncan, 1955) ***p<0.001. Carcass is considered here with no viscera, head, or feet. Breast, leg, and abdominal fat yields are expressed as carcass percentage. Total viscera and liver yield are expressed as final weight percentage.

Carcass and leg yields, total viscera weight, and liver weight and yield were not influenced (p<0.05) by the treatments (Table 5). Final body weight, carcass weight, breast weight and yield, leg weight, and total viscera yield were significantly higher (p<0.05) in birds fed 33 and 66 g SSM /kg as compared to those fed the control diet and that containing 100 g SSM /kg, whereas abdominal fat weight and yield were reduced in the treatments with 66 and 100 g SSM/kg inclusion relative to the control and the 33 g SSM /kg treatments.

The increase in breast weight of the broilers fed with 33 and 66 g SSM /kg may be explained by their higher lysine intake. Berri *et al*. (2008) observed similar increase in breast weight when dietary lysine level (0.3 %) and lysine intake were increased.

Vieira *et al*. (2004) detected an increase in breast yield and reduction of abdominal fat yield when the methionine+cystine to lysine ratio was reduced in 0.77% in the diet of finisher Cobb-500® broilers, similarly to the findings of the present study.

It is also possible that the SSM content of unsaturated fats in the feed indirectly resulted in higher lysine intake, and consequently, higher breast yield. López-Ferrer *et al*. (2001a) and López-Ferrer *et al*. (2001b), using linseed oil and fish oil rich in polyunsaturated fatty acids, obtained breast and leg yield responses similar to the findings of the present study.

Despite the higher supply of ether extract in the diets containing 66 and 100 g SSM / kg, the abdominal fat yields were lower as compared to the other treatments (Tables 1 and 2). According to Crespo & Esteve-García (2003), abdominal fat increase is directly proportional to the reduction in the serum levels of very low-density lipoproteins (VLDL). The diets with 66 and 100 g SSM /kg reduced serum VLDL relative to the control diet (Table 7).

Liver weight and yield (Table 5) were not affected by the inclusion of SSM as a feedstuff with hypocholesterolemic effects. In this sense, Razani *et al*. (2001) mention that blood cholesterol reduction stimulates the liver to compensate it by increasing the synthesis of cholesterol 7 -hydroxylase, which, if excessive, may cause liver hypertrophy. This results shows that SSM is may efficiently stabilize serum lipids (Table 7), with no gross changes in the liver of Cobb-500® broilers.

Panel members did not detect any differences in the sensory quality of the breast and thighs (Table 6) of broilers fed or not SSM.

These results are consistent with the reports of Ayerza *et al*. (2002) when including 100 g/kg chia seeds in broiler diets. On the other hand, Taga *et al*. (1984) and Shukla *et al*. (1996), when feeding linseed and fish oil to broilers, detected unpleasant flavor

Table 6 - Sensory quality of breasts and muscles of Cobb-500® broilers fed different SSM levels (1-49 days).

Parameters	Squash seed meal levels (g/kg)							
	0		33		66		100	
	Breast	Thighs	Breast	Thighs	Breast	Thighs	Breast	Thighs
Aroma								
Normal	15	15	15	15	15	15	15	15
Abnormal	0	0	0	0	0	0	0	0
Flavor								
Normal	15	15	15	15	15	15	15	15
Abnormal	0	0	0	0	0	0	0	0
Tenderness								
Normal	15	15	15	15	15	15	15	15
Tough	0	0	0	0	0	0	0	0
Very tough	0	0	0	0	0	0	0	0
Very tender	0	0	0	0	0	0	0	0
Color								
Normal	15	15	15	15	15	15	15	15
Pale	0	0	0	0	0	0	0	0
Intense	0	0	0	0	0	0	0	0

The values represent the opinion of the different panelists (15) that participated in the sensory evaluation.

in the meat of these birds. Squash seeds present high concentrations of polyunsaturated fatty acids (Martínez, 2009), particularly of linoleic acid. According to Shukla & Perkins (1998), linoleic and α-linolenic acids are the most resistant to oxidation among the polyunsaturated fatty acids, but are more susceptible as compared to saturated and monounsaturated fatty acids. The high susceptibility of linseed and fish oil to oxidation may be related to their high α-linolenic, docosahexaenoic and eicosapentaenoic acid content, which are comparatively lower in squash seeds.

Table 7 shows that detrimental lipid levels in the serum were reduced when SSM was included in the feed. Triglycerides and total cholesterol levels were significantly lower (p<0.05) with the inclusion of 100 g SSM /kg relative to the control diet. VLDL, LDL, glucose and atherogenic index were lower in broilers fed the control diet as compared to the diets with 66 and 100 g SSM/kg inclusion, while HDL levels were higher with the 100 SSM g/kg diet relative to the control.

The high contents of octadecaenoic, linoleic, and oleic fatty acids and of phytosterols, squalene, and the low levels of α-linoleic acid in the SSM, tapatía variety (Martínez, 2009), reduced the levels of detrimental lipids in the evaluated broilers. Triacylglycerides were reduced in 7.43 mg/dL in the birds fed 100 g SSM /kg relative to those offered the control diet. Viveros *et al*. (2009) mentioned that oleic fatty acid a reduction of triacylglycerides post-feeding, with an increase of the activity of the enzyme lipoprotein lipase (LPL) in the muscle. SSM may have reduced triacylglyceride levels due to its high oleic acid content (8616 mg/100 g), which is much higher than in conventional oil seeds (Martínez, 2009). In addition, the linoleic level determined in squash seeds (15027 mg/100 g) suppresses the synthesis of fatty acids and triacylglycerides in the liver, thereby limiting the synthesis of VLDL (McNamara, 1995).

Table 7 - Serum lipid profile and glucose levels of Cobb-500 broilers fed different SSM levels (1-49 days).

Parameters (mg/dL)	Squash seed meal levels (g/kg)				SE± Sig.
	0	33	66	100	
VLDL	10.25a	9.06ab	8.30bc	7.42c	0.47*
Triglycerides	47.30a	43.02ab	41.96ab	39.87b	1.794*
Total cholesterol	132.58a	126.38a	120.30ab	109.42b	4.65***
LDL	98.04a	90.44ab	87.34b	73.32c	3.28***
HDL	45.70b	47.14b	50.60ab	52.44a	1.64***
Atherogenic index	2.17a	1.92ab	1.72b	1.40c	0.096***
Glucose	183a	182a	163b	158b	5.46*

a,b,c - Means followed by different letters in each row as significantly different at p<0.05 (Duncan, 1955) *p<0.05, *** p<0.001.

When 100 g SSM /kg were included in the feed, a VLDL was reduced in 2.28 mg/dL relative to the basal diet. This effect was also observed by Crespo & Esteve-García *et al*. (2003), who compared the dietary inclusion of linseed, olive and sunflower oils and tallow, and detected a reduction in VLDL levels of 5, 3 and 2 mg/dL, respectively, relative to the control, while tallow increased VLDL levels in 15 mg/dL

SSM linoleic acid content (15027 mg/100 g) reduced LDL levels in 24.72 mg/dL, possibly by increasing liver expression of LDL receptors and, consequently, their take-up by the liver (Mustad *et al*., 1996). Palou *et al*. (2005) and Martínez *et al*. (2010) also mention that the liver takes up cholesterol for the synthesis of bile salts, also reducing LDL blood levels, resulting in a favorable change in the serum LDL to HDL ratio.

The squash seed, tapatía variety, contains 293 mg phytosterols/100 g (Martínez, 2009), which is higher compared with soybean and olive oil and with ground corn and soybean meal (Weihrauch, 1978). De Jong *et al*. (2003) mentioned that plant sterols stimulate the excretion of bile acids, promoting lipid digestion. Armstrong & Carey (1987) also suggest that part of cholesterol is precipitated in the intestines, and therefore, it is not absorbed or less absorbed in the presence of plan sterols. This results demonstrates the efficacy of the SSM phytosterols in the reduction of total cholesterol in the blood of broilers and layers, according to Martínez *et al*. (2010).

The 6.74 mg/dL increase in HDL in the serum of broilers may be associated with the increase in essential and omega-9 fatty acids, together with a decrease of low-density lipoproteins (Navab, 2001). This was also observed in layers (Martínez, 2009). According to Von Eckardstein *et al*. (2001), the enzyme lecithin-cholesterol acyltransferase catalyzes the formation of cholesterol esters in HDL from free cholesterol and lecithin, and the liver uptakes the esterified cholesterol by the action of an antioxidant receptor, showing the efficacy of HDL in the reduction of blood cholesterol.

The atherogenic index decreased with SSM inclusion in the diet, as previously reported by Martínez *et al*. (2010) in layers fed up to 100 g SSM /kg, which is associated to a reduction in detrimental lipid levels and increase in beneficial lipids. It must be mentioned that layers and broilers present different lipid profiles. Salma *et al*. (2007) reported lower values for layers, as opposed to Murwani & Bayuardhi (2007), who did not find significant differences (p<0.05) between these birds. However, Martínez *et al*. (2010) observed higher values in layers, as well as Peebles *et al*. (1997), who mentioned that higher lipid blood levels are required during egg production for fat deposition in the yolk and energy maintenance requirements, which are related to blood estrogen levels.

Serum glucose levels decreased in 20 and 25 mg/dL with the inclusion of 66 and 100 g SSM /kg diet. Pál *et al*. (2002) observed the same effect in layers when comparing squash seeds (rich in omega 6) with fish oil (rich omega 3), demonstrating that diets with omega 6 reduce blood glucose in poultry. In addition, the unsaturated fats supplied with the inclusion of SSM reduced digesta passage rate, resulting in slow intestinal release and maintenance of dietary glucose, with consequent lower blood insulin levels (Bird *et al*., 1994), thereby suggesting a direct effect of glucose and added fats.

CONCLUSIONS

The inclusion of 0, 33, 66 and 100 g SSM/kg in broilers diets in partial replacement of soybean meal and vegetable oil improved the performance and increased edible carcass parts, while abdominal fat in the carcass was reduced. Blood levels of detrimental blood lipids were reduced and of beneficial levels were increased. Meat sensory quality was not affected.

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