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Original research paper

EFFECTS OF DIETARY SORGHUM AND TRITICALE ON PERFORMANCE, CARCASS TRAITS AND MEAT pH IN BROILER CHICKENS

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ABSTRACT: The study was conducted to evaluate the effects of dietary partial corn replacement by white sorghum (WS) or triticale (T) on growth performance, carcass parameters and pH of meat in broilers. One-day-old unsexed Cobb 500 broilers (n=600) were randomly assigned to 3 groups with 4 replicates per treatment. The broilers were fed with isocaloric and isonitrogenous corn-soybean meal control diets (C), corn-WS-soybean meal diets (WS) or corn-T-soybean meal diets (T) for 35 days. The WS or T partially replaced corn; proportions in diets were 275.4 g/kg or 284.0 g/kg (starter), 307.0 g/kg or 308.2 g/kg (grower) and 332.7 g/kg or 335.0 g/kg (finisher). Results showed that performance (body weight gain, feed intake and feed conversion ratio) or carcass traits (carcass yields, breast, leg, wings, liver and abdominal fat percentage) at 35 d were not affected by the inclusion of WS or T in diets. The pH values of breast (*Pectoralis major*) and thigh (*Biceps femoris*) muscle at 30 min and 24 h after slaughter were not influenced by the dietary treatments. In conclusion, partial corn replacement with white sorghum or triticale are suitable options for broiler chicken diet, with no adverse effects on growth performance, carcass characteristics or meat pH, as important quality parameters.

Key words: *broilers, white sorghum, triticale, carcass parameters, meat pH*

INTRODUCTION

The prices volatility and changes in the availability of corn, as major energy source used in poultry feeding, have increased interest in using other feed ingredients produced in large scale (Ravindran, 2013b). Sorghum *(Sorghum bicolor L. Moench*) and triticale (*genus X Triticosecale*) are interesting energy ingredients for poultry and pig's diet due to its similar nutritional composition to corn or wheat (Leeson and Summers, 2005; Barneveld and Cooper, 2002). Furthermore, in the current context of climate change, it is expected that in the near future heat resistant crops such as sorghum or triticale are routinely utilized as food and feed resources for humans and animals (Selle et al., 2010; García et al., 2013). Previous study reported that the relatively high amount of antinutritional factors contained in old varieties of sorghum (condensed tannins) or triticale (soluble non-starch polysaccharides, NSP) grain can negatively influence the nutritive value of cereals (García et al., 2013; Selle et al., 2010; Korver et al., 2004). However, the use of new varieties of sorghum (low-tannin) or triticale in broiler diet as partial or total

corn substitute have been associated with controversial results. Some studies showed a reduction in weight gain and feed intake and in-creased feed conversion in sorghum-based diets (Jacobs and Parsons, 2013; Robertson and Perez-Maldonado, 2010), or negative effects on performance and the intestinal mucosa (Torres et al., 2013), whereas others indicated similar performance (Fernandes et al., 2013; Rocha et al., 2008; Garcia et al., 2005). Several studies suggested that triticale may be incorporated in broiler diets with no major effect on the nutritive value of the diet or bird performance (Çiftci et al., 2003; Pourreza et al., 2007; Zarghi and Golian, 2009), while other findings (Korver et al., 2004; Santos et al., 2008) shown no effect on carcass parameters and quality of poultry meat.

This study was conducted to evaluate the effects of dietary partial corn replacement by white sorghum (WS) or triticale (T) on growth performance, carcass parameters and pH of meat in broilers.

MATERIAL AND METHODS

The experimental protocol was approved by the Animal Care Committee of the National Research-Development Institute for Animal Biology and Nutrition (Balotesti, Romania) and birds were treated in accordance with EU Directive 2010/63/EU (OJEU, 2010).

Broilers, diets and sampling

Six hundred one-day-old unsexed Cobb 500 broilers (42.61±1.15 g), housed in environmentally controlled conditions, were randomly assigned to 3 groups and kept in floor pens (2.5 m x 0.8 m) with wood shavings. Each dietary treatment was replicated 4 times with 50 birds per replicate pen.

The birds were vaccinated according to the usual protocol against Newcastle disease and infectious bursal disease. Light schedule during the experimental period was 23 h of light and 1 h of dark.

Table 1.
Chemical composition and amino acid profile of cereals grain used in broiler diets

Item (%)	Corn	White Sorghum	Triticale
Dry matter	87.63	87.15	89.15
Crude protein	8.24	9.91	11.61
Crude fat	3.56	3.20	1.01
Crude fiber	1.96	2.56	3.83
Ash	2.33	1.14	1.84
Nitrogen free extractive	71.54	70.43	70.86
Calcium	0.03	0.02	0.03
Phosphorus	0.42	0.32	0.44
Metabolizable energy (kcal/kg)	3268	3207	2986
Amino acids (g/100g)			
Lysine	0.212	0.266	0.451
Methionine	0.170	0.180	0.250
Cysteine	0.180	0.164	0.322
Threonine	0.269	0.457	0.505
Arginine	0.388	0.387	0.776
Isoleucine	0.278	0.389	0.484
Leucine	0.969	1.229	0.816
Valine	0.368	0.490	0.538
Phenylalanine	0.408	0.520	0.507
Tyrosine	0.305	0.376	0.261
Essential amino acids	***3.877***	***4.802***	***4.910***
Glycine	0.330	0.343	0.387
Serine	0.410	0.451	0.650
Alanine	0.629	0.708	0.547
Aspartic acid	0.580	0.662	0.780
Glutamic acid	1.554	1.895	3.291
Non-essential amino acids	***3.502***	***4.059***	***5.655***

Table 2.
Ingredient and nutrient composition of broiler diets for different growth phases

Ingredients (g/kg)	Starter (1-10 d)			Grower (11-22 d)			Finisher (23-35 d)		
	C	WS	T	C	WS	T	C	WS	T
Corn	560.0	275.4	284.0	600.0	307.0	308.2	657.6	332.7	335.0
White sorghum	-	275.4	-	-	307.0	-	-	332.7	-
Triticale	-	-	284.0	-	-	308.2	-	-	335.0
Soybean meal	310.0	300.0	288.4	269.0	250.0	240.0	220.0	210.0	200.0
Corn gluten meal	50.0	59.3	52.0	46.0	50.0	50.0	36.0	35.0	33.0
Sunflower oil	28.0	37.8	39.8	35.0	36.0	44.0	40.0	43.0	50.0
Monocalcium phosphate	18.2	17.9	18.2	17.0	16.2	16.6	15.0	14.6	14.8
Calcium carbonate	14.7	14.8	14.7	13.9	14.0	13.9	12.7	12.8	12.7
Salt	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Vitamin-mineral premix[1]	10.0	10.0	10.0	10.0	10.0	10.0	-	-	-
Vitamin-mineral premix[2]	-	-	-	-	-	-	10.0	10.0	10.0
DL-methionine	1.5	1.5	1.3	2.0	2.3	1.8	1.9	2.1	1.6
L-lysine HCl	4.0	4.3	4.0	3.5	3.9	3.7	3.2	3.5	3.3
Choline HCl	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Calculated composition (g/kg)									
ME (MJ/kg)[3]	12.61	12.62	12.63	12.97	12.98	12.95	13.31	13.32	13.29
Crude protein	220	220	220	200	200	200	180	180	180
Lysine, total	13.2	13.2	13.2	11.9	11.9	11.9	10.5	10.5	10.5
Lysine, digestible	11.8	11.8	11.8	10.5	10.5	10.5	9.5	9.5	9.5
Met + cys, total	9.8	9.8	9.8	8.9	8.9	8.9	8.2	8.2	8.2
Met + cys, digestible	8.8	8.8	8.8	8.0	8.0	8.0	7.4	7.4	7.4
Calcium	9.0	9.0	9.0	8.4	8.4	8.4	7.6	7.6	7.6
Available phosphorus	4.5	4.5	4.5	4.2	4.2	4.2	3.9	3.9	3.9
Crude fiber	35.4	34.3	39.2	33.1	33.7	36.9	30.4	31.6	35.3
Crude fat	56.7	60.8	59.9	63.8	62.6	63.9	70.1	70.6	70.2

C, control; WS, white sorghum; T, triticale
[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, lasalocid sodium, 60 mg;
[2]Supplied per kg diet: retinyl acetate, 2.90 mg; cholecalciferol, 0.12 mg; DL-α-tocopheryl acetate, 50 mg; menadione sodium bisulphite, 3 mg; thiamine mononitrate, 2 mg; riboflavin, 8 mg; pyridoxine-HCl, 3 mg; cyanocobalamin, 0.015 mg; Ca-panthotenate, 12 mg; niacin, 50 mg; folic acid, 1.5 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;
[3]calculated using regression equations (NRC, 1994)

A 3-phase feeding regimen was used with the formulation of starter (1–10 d), grower (11–22 d) and finisher (23–35 d) diet. Broilers were fed with 3 diets: a control diet (C) based on corn-soybean meal, a corn-white sorghum-soybean meal diet (WS) and a corn-triticale-soybean meal diet (T) for 35 d. The WS and T that partially (50%) replace corn in the experimental diets were obtained from local cultivars. The analysed chemical composition and concentration of amino acids of white sorghum and triticale compared with corn are presented in Table 1. The diets were isocaloric and isonitrogenous, formulated to meet similar content of digestible sulphur amino acids, lysine, calcium and available phosphorus (Cobb-Vantress, 2015). The ingredients and calculated composition of the diets are shown in Table 2. Feed and water were provided *ad libitum* throughout the experimental period. Feed was withdrawn during 12 h before slaughter.

Evaluated performance parameters were body weight (BW) and feed intake (FI) for grower phases and overall period, from which body weight gain (BWG) and feed conversion ratio (FCR) were calculated. Mortality was recorded daily.

At 35 d of age, six broilers per replicate were randomly selected for carcass evaluation and muscle pH measurements. The broilers were weighed, killed by cervical dislocation, bleed and manually eviscerated. The weight of the whole carcass was determined. Carcass yield, breast and legs (with skin and bone), wings, liver and abdominal fat percentage were calculated based on final live body weight (BW).

Chemical analysis

Standardized methods according to EU Regulation 152/2009 (OJEU, 2009) were used to determine the chemical composition of feed ingredients and diet samples: dry matter (gravimetric method; SR ISO 6496:2001), crude protein (Kjeldahl method; SR EN ISO 5983-2:2009), crude fat (an improved version of classical method by continuous extraction in solvent; SR ISO 6492:2001), crude fibre (Fibertec-Tecator method; SR EN ISO 6865:2002), crude ash (gravimetric method; SR EN ISO 2171:2010).

Amino acid content of ingredients was determined by reversed phase chromategraphy RP-HPLC) method, using high performance liquid chromatograph, Finnigan Surveyor Plus HPLC (Thermo-Electron Corporation, Waltham, USA).

Muscle pH

A portable HACCP compliant pH meter for meat (HI 99163, Hanna Instruments, EU) with a pH electrode (FC 232D, Hanna Instruments, EU) and stainless-steel penetration blade (FC 099, Hanna Instruments, EU) was used to measure muscle pH at 30 min and 24 h after slaughter. The pH meter electrode was introduced directly into the left breast (*Pectoralis major*) and thigh (*Biceps femoris*) muscle at a depth of 2.0 cm below the surface.

Statistical analysis

The data obtained were analysed using the GLM procedure (SPSS, 2011). One-way analysis of variance (ANOVA) with the Tukey's comparison test was used to evaluate statistical significance of differences between dietary treatments. The results are given as means and standard error of the mean (SEM). Differences were considered significant at P≤0.05.

RESULTS AND DISCUSSION

Growth performance

The average body weight gain (BWG), feed intake (FI) and FCR (feed conversion ratio), during respective growth phases and overall period are shown in Table 3.

Table 3.
Effects of dietary treatments on growth performance of broilers[1]

Item	Dietary treatments			SEM	*P-Value*[*]
	C	WS	T		
Starter (1-10 d)					
BWG (g/bird)	220.05	211.47	209.54	3.02	*0.174*
FI (g/bird)	274.45	265.95	264.18	1.99	*0.254*
FCR (g feed:g gain)	1.24	1.25	1.27	0.22	*0.129*
Grower (11-22 d)					
BWG (g/bird)	677.18	684.35	672.67	5.33	*0.109*
FI (g/bird)	1020.41	1030.67	1034.44	4.21	*0.780*
FCR (g feed:g gain)	1.50	1.51	1.54	0.05	*0.492*
Finisher (23-35 d)					
BWG (g/bird)	998.63	987.58	983.79	2.31	*0.178*
FI (g/bird)	2027.05	2036.28	2041.45	8.05	*0.890*
FCR (g feed:g gain)	2.03	2.06	2.07	0.02	*0.930*
Overall period (1-35 d)					
BWG (g/bird)	1895.86	1883.40	1866.00	7.47	*0.272*
FI (g/bird)	3321.91	3332.81	3340.07	6.26	*0.930*
FCR (g feed:g gain)	1.75	1.77	1.79	0.03	*0.092*

[1]*Means of 50 broilers per replicate;*
C, control diet; WS, white sorghum diet; T, triticale diet; SEM-standard error of mean;
BWG, body weight gain; FI, feed intake; FCR, feed conversion ratio;
[*]*Means within rows do not differ significantly (P>0.05)*

Table 4.
Effects of dietary treatments on carcass characteristics of broilers at 35 d[1]

Item %	Dietary treatments			SEM	*P-Value*[*]
	C	WS	T		
Carcass yield	70.71	70.40	70.20	0.20	*0.602*
Breast	25.10	24.39	23.25	0.58	*0.459*
Legs	19.61	19.11	19.32	0.17	*0.548*
Wings	7.65	7.79	8.10	0.11	*0.256*
Liver	2.12	2.10	2.06	0.04	*0.830*
Abdominal fat	1.37	1.27	1.26	0.03	*0.302*

[1]Means of 6 broilers per replicate;
C, control diet; WS, white sorghum diet; T, triticale diet; SEM-standard error of mean;
[*]Means within rows do not differ significantly (P>0.05)

Table 5.
Effects of dietary treatments on muscle pH of broilers at 35 d[1]

Item	Dietary treatments			SEM	*P-Value*[*]
	C	WS	T		
Breast *(Pectoralis major)*					
$pH_{30\ min.}$	6.067	6.025	6.037	0.011	*0.263*
$pH_{24\ h}$	5.913	5.857	5.863	0.014	*0.437*
Thigh *(Biceps fermoris)*					
$pH_{30\ min.}$	6.132	6.157	6.166	0.012	*0.783*
$pH_{24\ h}$	5.948	5.959	5.968	0.010	*0.879*

[1]Means of 6 broilers per replicate; [*]Means within rows do not differ significantly (P>0.05);
pH 30 min, pH 24 h - pH values measured at 30 min and 24 h post mortem;
C, control diet; WS, white sorghum diet; T, triticale diet; SEM-standard error of mean

There were no significant differences in BWG, FI and FCR (P>0.05) among the dietary treatments during the experimental period, suggesting that partial corn replacement with sorghum or triticale did not negatively affect broilers performance. Mortality percentage was low and did not differ significantly (P>0.05) among the dietary treatments (data not shown).

The results of our study are consistent with previous reports of others (Garcia et al., 2013; Torres et al., 2013; Stringhini et al., 2009; Rocha et al., 2008; Santos et al., 2006) who did not find any differences in feed intake, weight gain or feed conversion when evaluating the growth performance of broilers fed sorghum as partial corn replacement in diets. Zarghi and Golian, (2009) also, revealed that 50% corn replacement with triticale had no negative effect on broiler growth performance. Mierlita, (2008) suggested that replacing 30% of the corn with triticale did not significantly influence performance and carcass traits, while 60% substitution ratio affected weight gain, feed intake, FCR, carcass parameters and carcass fat quality. Conversely, Baser and Yetisir (2014) showed that partial or total replacement of corn with triticale in diet impaired broilers growth performance and carcass parameters.

Carcass characteristics

Carcass yield and carcass cut-up parts yield of broiler chickens at 35 d (Table 4) were not significantly affected by the dietary treatments (P>0.05). In previous studies related with dietary partial corn replacement with sorghum (Torres et al., 2013; Garcia et al., 2013; Stringhini et al. 2009; Kumar et al. 2005) or triticale (Zarghi and Golian, 2009) no negative effect on carcass yield and/or cut-up parts was observed.

Muscle pH

An important factor in chicken meat quality evaluation is pH. Functional properties of meat dependent on glycolytic reactions which occur during *rigor mortis,* affecting meat pH directly. Also, the fasting period is related to meat pH and affects the incidence of pale soft exudative (PSE) meat in broiler chickens (Komiyama et al., 2008). As shown in Table 5 the pH values of breast (*Pectoralis major*) and thigh (*Biceps femoris*) muscle at 30 min and 24 h after slaughter were not influenced by the treat-

ments. Breast and thigh muscle pH was not affected (P>0.05) by the partial corn replacement by white sorghum or triticale in the diet. The pH values obtained were in the normal limits for this parameter (5.7-5.96 for breast and 6.0-6.2 for thigh meat; Fletcher et al., (2000). Similarly, Garcia et al., (2013) reported that partial substitution of corn by sorghum in the diet did not influence breast and thigh meat pH values.

CONCLUSIONS

In conclusion, partial corn replacement with white sorghum or triticale are suitable options for broiler chicken diets, with no adverse effects on growth performance, carcass characteristics or meat pH, as important quality parameters.

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ЕФЕКАТ ДОДАТКА СИРКА И ТРИТИКАЛЕА У ИСХРАНИ БРОЈЛЕРА НА ПРОИЗВОДНЕ ПЕРФОРМАНСЕ, ПОКАЗАТЕЉЕ КВАЛИТЕТА ТРУПА И pH ВРЕДНОСТ МЕСА

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Сажетак: Приказана студија изведена је како би се испитао ефекат делимичне замене кукуруза белим сирком (БС) или тритикалеом (Т) у исхрани бројлера, на производне перформансе, показатеље квалитета трупа и pH вредност меса. Једнодневни Cobb 500 бројлерски пилићи истог пола (600 комада) су насумично подељени у три групе, са по четири понављања по третману. Бројлери су храњени изо-калоричним и изо-азотним оброцима 35 дана: контролни оброци на бази кукуруза и сојине сачме (К), кукуруз-БС-сојина сачма оброци (БС), или кукуруз-Т-сојина сачма оброци (Т). Кукуруз је био парцијално замењен са БС или Т на следећи начин: односи у оброцима су били 275,4 g/kg или 284,0 g/kg (стартер), 307,0 g/kg или 308,2 g/kg (гровер) и 332,7 g/kg или 335,0 g/kg финишер, редом. Резултати су показали да производне перформансе (принос масе, унос хране и конверзија хране), као и показатељи квалитета трупа (принос масе трупа и процентуални удео груди, ногу, крила, јетре и абдоминалне масноће) нису зависили од уноса БС или Т у исхрану. Начин исхране није утицао ни на pH вредност меса груди (*Pectoralis major*) и карабатака (*Biceps femoris*) мерено после 30 минута и 24 сата након клања. Може се извести закључак да је парцијална замена кукуруза белим сирком или тритикалеом у исхрани бројлерских пилића адекватна и да нема негативне ефекте на производне перформансе, карактеристике трупа и pH вредност меса, као важне показатеље квалитета.

Кључне речи: *бројлери, бели сирак, тритикале, параметри трупа, pH вредност меса*

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