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Effect of Two Different Types of Barley on the Performance, Meat Quality and Blood Properties of Broiler Chicken

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Abstract: This study was conducted to evaluate the effects of two different types of barley on the performance, meat quality and blood properties of broiler chicken. A total of 320 Ross x Ross, day old male broiler chickens were divided into five different treatments with four replications (16×4×5 = birds x replications x treatments): commercial diet (control, CONTL); 5% Anthocyanin Fortified Barley (AFB05); 10% Anthocyanin Fortified Barley (AFB10); 5% Whole Crop Barley (WCB05); 10% Whole Crop Barley (WCB10). During the 5 weeks trial, broilers had free access to the different diets and water. In the starter period, weight gain was increased ($p<0.05$) both in 5 and 10% AFB feeding level than that of WCB, 5 and 10% inoculation. But no difference was found in feed intake and feed conversion. Though, the weight gain and feed conversion were not influence in the finisher period but feed intake was inclined ($p<0.05$) in control group and decline in the treatment group (AFB and WCB both 5 and 10% level). During the total period comparison, feed intake and weight gain was significantly higher in control and AFB feeding group than that of the WCB. Thereafter, shear force tended to be lower in AFB and WCB treatments than the control. No differences were apparent on meat color and pH but cooking loss was higher in 5% WCB feeding level. Total protein and albumin content in blood was significantly higher ($p<0.05$) in AFB feeding treatments. Highest liver weight was achieved by feeding 10% WCB. Consequently, abdominal fat deposition was significantly higher in control and 5% AFB feeding treatment. Therefore, AFB could be a dietary ingredient for broiler chickens but further study is necessary to determine the optimum ratio of AFB in the diet.

Key words: Broiler chicken, barley, anthocyanin, performance, breast meat quality

INTRODUCTION

Due to increased consumption of health-related food, consumers are interested in plant-derived biochemical compounds. Flavonoids including anthoxanthins, anthocyanins and catechins are a focus of consumers (Merken and Beecher, 2000; Han *et al*., 2007). Flavonoids are composed of three rings containing 15 carbons and belong to the water soluble polyphenol family (Cook and Samman, 1996; Han *et al*., 2007; Bellido and Beta, 2009). Flavonoids are easily extracted from most plants including the fruit, vegetable and crop. The health related effects of flavonoids are associated with their antioxidant activities. Most antioxidant activities attributed to flavonoids include anti-inflammatory, anti-cancer, anti-allergic and anti-viral effects however these antioxidant effects are concentration dependent as daily intake of flavonoids varies (Cook and Samman, 1996; Han *et al*., 2007; Bellido and Beta, 2009). Many studies have demonstrated that the biochemical and physiological effects of flavonoids are influenced by genetic origin and other environmental conditions (Lee *et al*., 2005; Hadado *et al*., 2009). The genetic origin and other environmental conditions may participate in the concentration of flavonoids thus antioxidant effects may be affected.

Barley is a popular cereal grain that has evolved as an ingredient in beer and other alcoholic beverages when it is fermented. However, about two-thirds of the barley

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harvested has been used in animal diets (Baik and Ullrich, 2008). The anthocyanins in barley provide its color thus barley color differs from yellow to purple and black based on anthocyanin concentration (Bellido and Beta, 2009). Additionally due to the concentration of anthocyanin in the barley hull, highly colored barley has been a focus of functional food processing (Charalampopoulos *et al*., 2002; Baik and Ullrich, 2008). The feed industry has been interested in barley as a feed ingredient and many studies have been conducted in poultry and swine, resulting in the commercialization of hulless barley cultivars (Edney *et al*., 1989; Bowman *et al*., 2001; Yin *et al*., 2001). However, only a few studies have been conducted to clarify the effect of anthocyanins on performance, meat quality and blood parameters of broiler chicken. Therefore, this study provides information related to anthocyanins and their effects on performance, meat quality and blood parameters of broiler chicken.

MATERIALS AND METHODS

Animal model: A total of 320 Ross x Ross, 1 day old male broiler chickens (*Gallus gallus domesticus*) were purchased and raised to 5 weeks of age. All birds were randomly assigned to five different treatments with four replications in each (16×4×5 = birds x replications x treatments) and fed with a diet containing a corn-soybean based meal and two different levels of anthocyanin fortified barley and whole crop barleys, respectively. All basal diet ingredients were mixed based on the NRC (1994) requirements and then divided into five different treatments as follows: commercial diet (control, CONTL); 5% Anthocyanin Fortified Barley (AFB05); 10% Anthocyanin Fortified Barley (AFB10); 5% Whole Crop Barley (WCB05); 10% Whole Crop Barley (WCB10) (Table 1 and 2). Chickens were allowed free access to feed and water. Broiler performances including weight gain and feed intake were measured at 1, 3 and 5 weeks of age, respectively and feed conversion was calculated based on the weight gain and feed intake. At the end of experiment, blood samples were collected from 20 birds in each treatment and separated serum was stored at -70°C until analysis. Consequently, 20 broilers in each treatment were killed and breast muscle samples were collected and maintained at -80°C until analysis. In addition, liver, spleen, fabricius bursa and abdominal fat were separated and weighed. All right sampled of breast muscles were used for shear force, pH and CIE color space values and breast muscles obtained from the left side were employed for cooking loss experiments.

Breast meat quality determination: The pH value of each breast sample was determined using a digital pH meter (Seven Easy pH, Mettler-Toledo AG, Schwerzenbach, Switzerland). About 5 g of breast muscle sample was thoroughly ground with 45 mL of double distilled water for 30 sec at 13,500 rpm and then the pH was measured. The pH meter was calibrated with a standard buffer, pH 7.0 and triplicate readings per sample were recorded. The average is reported as the pH value per treatment.

Ten 9×4.5×1.5 cm (length x width x height) shaped breast muscle portions from each treatment were prepared

Table 1: Ingredients and composition of the basal starter diets[1]

		AFB (%)		WCB (%)	
Starters	Control	5	10	5	10
Corn	54.603	51.751	48.802	51.354	47.988
Soybean meal	34.167	28.457	23.107	29.069	24.342
Corngluten meal	3.635	7.064	10.220	6.853	9.826
Soybean meal oil	4.000	4.000	4.000	4.000	4.000
Limestone	1.640	1.633	1.626	1.622	1.604
DCP	1.217	1.249	1.279	1.260	1.301
Salt	0.400	0.400	0.400	0.400	0.400
L-Lysine	0.002	0.121	0.249	0.115	0.221
DL-Methionine	0.137	0.124	0.118	0.126	0.117
Vitamin premix[2]	0.100	0.100	0.100	0.100	0.100
Mineral premix[3]	0.100	0.100	0.100	0.100	0.100
Total	100.000	100.000	100.000	100.000	100.000
Calculated value					
ME (kcal kg^{-1})	3,100.000	3,100.000	3,100.000	3,100.000	3,100.000
CP (%)	22.000	22.000	22.000	22.000	22.000
Lysine (%)	1.100	1.100	1.100	1.100	1.100
Methionine (%)	0.500	0.500	0.500	0.500	0.500
Ca (%)	1.000	1.000	1.000	1.000	1.000
Available phosphate (%)	0.450	0.450	0.450	0.450	0.450

Table 2: Ingredients and composition of the basal finisher diets[1]

		AFB (%)		WCB (%)	
Finishers	Control	5	10	5	10
Corn	60.093	57.015	54.173	56.609	53.359
Soybean meal	30.884	25.845	20.129	29.463	21.365
Corngluten meal	2.100	5.068	8.484	4.871	8.090
Soybean meal oil	3.700	3.700	3.700	3.700	3.700
Limestone	1.441	1.399	1.392	1.388	1.370
DCP	1.142	1.225	1.258	1.236	1.279
Salt	0.400	0.400	0.400	0.400	0.400
L-Lysine	0.000	0.105	0.232	0.092	0.205
DL-Methionine	0.039	0.042	0.031	0.042	0.031
Vitamin premix[2]	0.100	0.100	0.100	0.100	0.100
Mineral premix[3]	0.100	0.100	0.100	0.100	0.100
Total	100.000	100.000	100.000	100.000	100.000
Calculated value					
ME (kcal kg^{-1})	3,100.000	3,100.000	3,100.000	3,100.000	3,100.000
CP (%)	20.000	20.000	20.000	20.000	20.000
Lysine (%)	1.000	1.000	1.000	1.000	1.000
Methionine (%)	0.380	0.380	0.380	0.380	0.380
Ca (%)	0.900	0.900	0.900	0.900	0.900
Available phosphate (%)	0.350	0.350	0.350	0.350	0.350

[1]AFB = Anthocyanin Fortified Barley; WCB = Whole Crop Barley. [2]Contains per kg: Vit. A, 12,000,000 IU; Vit. D_3, 5,000,000IU; Vit. E, 50,000 mg; Vit. K_3, 3,000 mg; Vit. B_1, 2,000 mg; Vit. B_2, 6,000 mg; Vit. B_6, 4,000 mg; Vit. B_{12}, 25 mg; biotin, 150 mg; pantothenic acid, 20,000 mg; folic acid, 2,000 mg; nicotinicacid, 7,000 mg. [3]Contains per kg: Fe, 66,720 mg; Cu, 41,700 mg; Mn, 83,400 mg; Zn, 66,720 mg; I, 834 mg; Se, 250 mg

and heated at 100°C (Euro-Grill Tg101, Fri-Jad BV., Etten-Leur, The Netherlands). All breast samples were removed when their internal temperature reached 74°C and then cooled in a cooler for 1 h (GR49-2JT, LGE, Seoul, Korea). Cooking loss was determined based on the formula:

$$\text{Cooking loss} = \frac{\text{Cooked weight}}{\text{Initial weight}} \times 100$$

Ten breast samples from each treatment were cylindrically shaped (1.0×1.0×1.0 cm) and left at room temperature for 30 min. An Instron 3343 (US/MX50, A&D Co., San Jose, CA, USA) equipped with a Warner Bratzler shearing device (100 mm min^{-1} crosshead speed) was used once and the average of each shearing value per treatment was expressed as kg/cm^2.

CIE L* (lightness), a* (redness) and b* (yellowness) color space values for breast samples collected at 5 weeks of growth were obtained using a Minolta colorimeter (Minolta Chroma Meter CR-300, Minolta Co., Ltd. Ramsey, NJ, USA). The color value was determined after calibration using a white tile expressed as Y = 92.8, x = 0.3134 and y = 0.3193 and duplicate readings per sample were determined. Each treatment reading was averaged and expressed as CIE L*, a* and b* color space values, respectively.

Biochemical blood parameters: All blood samples were centrifuged at 1,500 rpm for 15 min and the top layer was collected. Biochemical blood parameters including Total Protein (TPN, g dL^{-1}), Albumin (ALB, g dL^{-1}), Total Cholesterol (TCL, mg dL^{-1}), Triacylglyceride (TAG, mg dL^{-1}), High Density Lipoprotein (HDL, mg dL^{-1}) and Low Density Lipoprotein (LDL, mg dL^{-1}) content were measured on a Konelab 20 analyzer (Thermo Fisher Scientific Oy, Vantaa, Finland) using a Turbidimetric Method as described by the manufacturer's guideline.

Statistical analysis: Data from the five treatments (16×4×5 = sample x replication x treatment) were collected for the broiler performance analysis and blood bio-chemical composition determination were analyzed using the Generalized Linear Model (GLM) procedure of SAS Version 6.12 (SAS Institute, Cary, NC, USA, 1998; SAS, 1998). The $p<0.05$ were considered significant.

RESULTS AND DISCUSSION

Performance and organ and abdominal fat weight of broiler chickens: Two different types of barley effects on broiler chicken performance and weight of organs and abdominal fat are described in Table 3 and 4, respectively. Weight gain and feed intake were influenced by adding AFB and/or WCB but significant differences were not found for feed conversion ($p>0.05$) (Table 3). Weight gain of broiler chickens fed starter and finisher WCB, showed significantly lower weight gain compared to control and AFB diets ($p<0.05$). However, only a numerical difference was observed for feed intake when starter was supplied to broilers ($p>0.05$) however, significance was established in the middle and the end of growth ($p<0.05$). The feed intake trend was similar to that of weight gain when finisher was provided to broiler chickens. The broiler chickens in the control and AFB groups were fed more and their feed intakes ranged from 2879±42.59 to 3001±22.71 g, respectively.

Significant differences were observed only in liver and abdominal fat weights when broiler chickens were raised on the five different diets for 5 weeks (Table 4). Liver weights were 2.16±0.07~2.37±0.13 g however, the heaviest weight was determined in broiler livers sampled from WCB10 (2.84±0.07 g) ($p<0.05$). In contrast, abdominal fat of broiler chickens was lowest in WCB10 ($p<0.05$).

Table 3: Effects of two different types of barely in broiler chicken diets on broiler chicken performance

Treatment[1]	Weight gain (g)	Feed intake (g)	Feed conversion
Starter			
CONTL	680±6.41^{ab}	1,081±17.03	1.591±0.03
AFB05	699±14.19^{a}	1,115±70.71	1.595±0.09
AFB10	722±5.93^{a}	1,001±76.11	1.387±0.11
WCB05	580±22.13^{c}	931±20.63	1.609±0.08
WCB10	625±37.32^{bc}	920±69.85	1.471±0.04
Grower			
CONTL	982±24.39	1,956±23.06^{a}	1.956±0.03
AFB05	954±2.25	1,789±15.66^{b}	1.874±0.02
AFB10	947±8.17	1,857±39.46^{ab}	1.960±0.04
WCB05	932±22.48	1,786±25.95^{b}	1.918±0.02
WCB10	883±48.68	1,767±45.75^{b}	2.016±0.09
Finisher			
CONTL	1,702±22.36^{a}	3001±22.71^{a}	1.764±0.02
AFB05	1,693±9.38^{a}	2879±42.59^{a}	1.701±0.03
AFB10	1,709±11.48^{a}	2933±44.63^{a}	1.716±0.02
WCB05	1,572±21.34^{b}	2717±17.51^{b}	1.728±0.02
WCB10	1,568±45.90^{b}	2688±88.82^{b}	1.715±0.04

Table 4: Effects of two different types of barely in broiler chicken diets on liver, spleen, fabricius bursa and abdominal fat weights of broiler chicken (g)

Treatment[1]	Liver	Spleen	Fabricius bursa	Abdominal fat
CONTL	2.37±0.13^{b}	0.12±0.02	0.20±0.02	2.09±0.21^{a}
AFB05	2.33±0.05^{b}	0.16±0.01	0.23±0.03	1.81±0.20^{ab}
AFB10	2.16±0.07^{b}	0.17±0.01	0.25±0.04	1.65±0.10^{ab}
WCB05	2.30±0.11^{b}	0.15±0.01	0.24±0.01	2.07±0.14^{a}
WCB10	2.84±0.07^{a}	0.20±0.02	0.18±0.01	1.42±0.03^{b}

Values are mean±standard error. [1]CONTL = Control; AFB05 = 5% Anthocyanin Fortified Barley; AFB10 = 10% Anthocyanin Fortified Barley; WCB05 = 5% Whole Crop Barley; WCB10 = 10% Whole Crop Barley. [a-c]Mean values within a column followed by the same letter are not significantly different ($p>0.05$)

Broiler breast meat quality and biochemical blood properties: No significantly different effects of pH, shear force or CIE L* (whiteness), a* (redness) and b* (yellowness) were observed for the two different barley treatment ($p>0.05$) (Table 5). Nevertheless, significantly higher cooking losses were found in the control and WCB treatments than those in the AFB treatments. The greatest cooking loss was observed for the WCB05 broiler breasts (7.43±0.13%) whereas the least cooking loss was found in AFB05 (5.76±0.31%).

TPN, ALB and TAG content were influenced significantly by adding either anthocyanin-fortified barley or whole crop barley ($p<0.05$) (Table 6). However, no significant effects of barley were found for TCL, HDL and LDL ($p>0.05$). High TPN, ALB and TAG levels were found in the AFB05 broiler chicken treatment blood. The control and AFB10 blood samples were significantly lower in TPN, ALB and TAG content than those of blood samples derived from AFB05 ($p<0.05$). The TPN, ALB and TAG values of WCB blood samples were similar to those of the control ($p>0.05$).

Anthocyanins, a common water soluble pigment group generally collected from fruits, vegetables and grains which is also found at high levels in barley. Weight gain and feed intake of broiler chicken were influenced by adding the two different types of barley to the diet and sampled from the WCB treatments showed the lowest weight gain and feed intake compared to those of the control and AFB broilers (Table 3). Leeson and Proulx (1994) reported that barley contained 3232-3271 kcal kg^{-1} Metabolizable Energy (ME) which is similar to that of corn (3350 kcal kg^{-1}) (Blair and Paulson, 1997). However, due to β-glucan activity as an anti-nutritive substance, barley digestibility tends to be lower in apparent ME by disturbing the apparent digestibility of lipid (Friesen *et al*., 1992). It seemed that the weight gain of broiler chickens from the control and AFB treatments was not affected due to β-glucan but was influenced by feed intake which was high in the control and AFB treatments. Although, it was not clearly identified, the anthocyanins of 1.77±0.00 mg % in AFB play a critical role with β-glucan in the barley and feed uptake of broiler chickens. Broiler chickens fed the control and AFB finishing diets, showed high feed intake and weight gain compared to those of WCB containing 0.08±0.00 mg% anthocyanin. Anthocyanins in AFB bind to β-glucan, interrupting attachment of β-glucan to lipid or other nutritive compounds (Aura, 2005).

Liver weight increased with the WCB10 diet but the weight of other organs was not influenced (Table 4). Ikegami *et al*. (1990) reported that increase in the viscosity of the digestive organs induces bile juice secretion which in turn may increase liver weight in rats. As more bile juice was generated by adding barley to the broiler chicken diet, the absorption of available nutrients via the small intestine is affected (Heath and Morris, 1963; Gracia *et al*., 2003). Therefore, broiler chickens fortified-barley fed diets may generate over-estimated nutrients levels which may stored as fat in the abdomen.

As shown in Table 5, moisture losses during cooking in AFB broiler breast samples. However, adding whole crop barley induces negative effects on protein structure and solubility changes in broiler breast muscle resulting in moisture loss (Murphy *et al*., 2001). Moisture is absorbed in the broiler breast muscle or evaporated from

Table 5: Shear force, pH, cooking loss and CIE color space values of breast muscle from broiler chickens fed two different barley diets for 5 weeks

				CIE Color		
Treatment[1]	pH	Cook loss (%)	Shear force (kg/cm^2)	L*	a*	b*
CONTL	5.98±0.04	6.79±0.50^{ab}	2.92±0.55	53.59±0.52	1.58±0.41	15.11±0.34
AFB05	5.99±0.03	5.76±0.30^{b}	2.17±0.27	52.92±1.24	2.35±0.38	14.48±0.55
AFB10	5.85±0.05	6.05±0.47^{b}	2.54±0.32	53.53±0.90	1.05±0.14	14.96±0.51
WCB05	5.94±0.02	7.43±0.13^{a}	2.49±0.06	53.40±0.98	1.44±0.34	14.12±0.62
WCB10	5.90±0.08	6.41±0.31^{ab}	2.62±0.44	54.09±1.31	5.14±0.95	12.61±0.82

Values are mean±standard error. [1]CONTL = Control; AFB05 = 5% Anthocyanin Fortified Barley; AFB10 = 10% Anthocyanin Fortified Barley; WCB05 = 5% Whole Crop Barley; WCB10 = 10% Whole Crop Barley. [a-c]Mean values within a column followed by the same letter are not significantly different ($p>0.05$)

Table 6: Biochemical blood parameters[1] of broiler chickens fed two different barley diets for 5 weeks

Treatment[2]	TPN (g dL^{-1})	ALB (g dL^{-1})	TCL (mg dL^{-1})	TAG (mg dL^{-1})	HDL (mg dL^{-1})	LDL (mg dL^{-1})
CONTL	2.18±0.11^{c}	0.80±0.04^{b}	120.00±2.76	24.60±0.84^{ab}	88.00±1.48	27.08±2.12
AFB05	2.98±0.12^{a}	1.02±0.03^{a}	133.80±4.79	24.80±1.51^{ab}	106.60±3.41	22.24±2.66
AFB10	2.60±0.11^{b}	0.92±0.04^{ab}	115.00±4.30	18.80±0.87^{c}	91.20±2.45	20.04±2.18
WCB05	2.56±0.16^{b}	0.88±0.06^{b}	123.50±8.72	26.80±0.74^{a}	96.58±8.72	21.64±1.59
WCB10	2.44±0.06^{bc}	0.90±0.03^{ab}	122.80±5.02	22.40±0.87^{b}	98.20±4.25	20.12±2.01

Values are mean±standard error. [1]TPN = Total Protein; ALB = Albumin; TCL = Total Cholesterol; TAG = Triacylglyceride; HDL = High Density Lipoprotein; LDL = Low Density Lipoprotein. [2]CONTL = Control; AFB05 = 5% Anthocyanin Fortified Barley; AFB10 = 10% Anthocyanin Fortified Barley; WCB05 = 5% Whole Crop Barley; WCB10 = 10% Whole Crop Barley. [a-c]Mean values within a column followed by the same letter are not significantly different ($p>0.05$)

the broiler breast muscles during heating which may be due to the heat transfer from hot air to the products. The moisture remaining after cooking, may vary as protein, fat and moisture contents and properties mutually differed and may also fluctuate due to differences in sarcomere length and protein structural changes resulting in shrinkage of the breast (Murphy and Marks, 2000; Murphy *et al*., 2001). Shin (2006) reported that general cooking time up to 74°C for beef patties was increased when sorghum bran was added and then cooked as compared to control beef patties. Moreover, the cooking time and loss of beef patties are significantly influenced by adding sorghum bran therefore anthocyanins derived from sorghum bran may affect cooking time and loss as shown by Shin (2006). Hence, the cooking losses in the AFB treatment seemed to be based on increased anthocyanin content in broiler breasts compared to that in control and WCB breast samples.

TPN and ALB increased but TAG decreased in the diets containing anthocyanins but similar effects were not found when WCB diets were supplied to broiler chickens (Table 6). Therefore, the barley itself and/or the anthocyanins contributed to generate proteins and/or protein ALB compared to those in the control. Attia *et al*. (2011) showed high protein and ALB but low lipid in rabbits based on three different concentrations of bee pollen containing excess anthocyanins.

CONCLUSION

Adding anthocyanin-fortified barley to the broiler chicken diets resulted in similar weight gains and feed intake compared to those of control but lowered cooking losses. Therefore, AFB could be a dietary ingredient for broiler chickens but further study is necessary to determine an AFB accurate ratio in the diet.

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REFERENCES

Attia, Y.A., A. Al-Hanoun, F. Bovera, 2011. Effect of different levels of bee pollen on performance and blood profile of new zealand white bucks and growth performance of offspring their summer and winter months. J. Anim. Physiol. Anim. Nutr., 95: 17-26.

Aura, A.M., 2005. *In vitro* digestion models for dietary phenolic compounds. Ph.D. Thesis, Helsinki University of Technology, Espoo, Finland.

Baik, B.K. and S.E. Ullrich, 2008. Barley for food: Characteristics, improvement and renewed interest. J. Cereal Sci., 48: 233-242.

Bellido, G.G. and T. Beta, 2009. Anthocyanin composition and Oxygen Radical scavenging Capacity (ORAC) of milled and pearled purple, black and common barley. J. Agric. Food Chem., 57: 1022-1028.

Blair, R. and S. Paulson, 1997. Wheat as a replacement for corn in poultry diets. http://www.al.gov.bc.ca/poultry/publications/documents/wheat.pdf.

Bowman, J.G.P., T.K. Blake, L.M.M. Surber, D.K. Habernicht and H. Bockelman, 2001. Feed-quality variation in the barley core collection of the USDA national small grains collection. Crop. Sci., 41: 863-870.

Charalampopoulos, D., R. Wang, S.S. Pandiella and C. Webb, 2002. Application of cereals and cereal components in functional foods: A review. Int. J. Food Microbiol., 79: 131-141.

Cook, N.C. and S. Samman, 1996. Flavonoids-chemistry, metabolism, cardioprotective effects and dietary sources. J. Nutr. Biochem., 7: 66-76.

Edney, M.J., G.L. Campbell and H.L. Classen, 1989. The effect of β-glucanase supplementation on nutrient digestibility and growth in broilers given diets containing carley, oat groats or wheat. Anim. Feed Sci. Tech., 25: 193-200.

Friesen, O.D., W. Guenter, R.R. Marquardt and B.A. Rotter, 1992. The effect of enzyme supplementation on the apparent metabolizable energy and nutrient digestibilities of wheat barley oats and rye for the young broiler chick. Poult. Sci., 71: 1710-1721.

Gracia, M.I., M.A. Latorre, M. Garcia, R. Lazaro and G.G. Mateos, 2003. Heat processing of barley and enzyme supplementation of diets for broilers. Poult. Sci., 82: 1281-1291.

Hadado, T.T., D. Rau, E. Bitocchi and R. Papa, 2009. Genetic diversity of barley (*Hordeum vulgare* L.) landraces from the central highlands of Ethiopia: comparison between the *Belg* and *Meber* growing seasons using morphological traits. Genet. Resour. Crop Evol., 56: 1131-1148.

Han, X., T. Shen and H. Lou, 2007. Dietary polyphenols and their biological significance. Int. J. Mol. Sci., 8: 950-988.

Heath, T.J. and B. Morris, 1963. The role of bile and pancreatic juice in the absorption of fat in ewes and lambs. Brit. J. Nutr., 17: 465-474.

Ikegami, S., F. Tsuchihashi, H. Harada, N. Tsuchihashi, E. Nishide and S. Innami, 1990. Effect of viscous indigestible polysaccharides on pancreatic-bilary secretion and digestive organs in rats. J. Nutr., 120: 353-360.

Lee, J.J., K.M. Crosby, L.M. Pike, K.S. Yoo and D.I. Leskovar, 2005. Impact of genetic and environmental variation on development of flavonoids and carotenoids in pepper (*Capsicum* sp.). Sci. Hortic., 106: 341-352.

Leeson, S. and J. Proulx, 1994. Enzymes and barley metabolizable energy. J. Appl. Poultry Res., 3: 66-68.

Merken, H.M. and G.R. Beecher, 2000. Measurement of food flavonoids by High-Performance Liquid Chromatography: A review. J. Agric. Food Chem., 48: 577-599.

Murphy, R.Y. and B.P. Marks, 2000. Effect of meat temperature on proteins, texture and cook loss for ground chicken breast patties. Poult. Sci., 79: 99-104.

Murphy, R.Y., E.R. Johnson, L.K. Duncan, E.C. Clausen, M.D. Davis and J.A. March, 2001. Heat transfer properties, moisture loss, product yield and soluble proteins in chicken breast patties during air convection cooking. Poult. Sci., 80: 508-514.

NRC, 1994. Nutrient Requirements of Poultry. 9th Edn., National Academy Press, Washington, DC., USA., ISBN-13: 9780309048927, Pages: 155.

SAS., 1998. SAS/STAT User Guide to Statistics (Version 6.12). SAS Inst. Inc., Cary, NC., USA.

Shin, D., 2006. Antioxidant, color and sensory properties of sorghum bran in pre-cooked ground beef patties varying in fat and iron content. Ph.D. Thesis, Texas A and M University, College Station, Texas, USA.

Yin, Y.L., S.K. Baidoo, H. Schulze and P.H. Simmins, 2001. Effect of supplementing diets containing hulless barley varieties having different levels of non-starch polysaccharides with β-glucanase and xylanase on the physiological status of gastrointestinal tract and nutrient digestibility of weaned pigs. Livest. Prod. Sci., 71: 97-107.