

Efficacy of Wheat Based vs. Corn Based Diet Formulated Based on Digestible Amino Acid Method on Performances, Carcass Traits, Blood Parameters, Immunity Response, Jejunum Histomorphology, Cecal Microflora and Excreta Moisture in Broiler Chickens

Research Article

M.H. Mohammadi Ghasem Abadi¹, M. Riahi¹, M. Shivazad^{1*}, A. Zali¹ and M. Adibmoradi²

¹ Department of Animal Science, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran

² Department of Basic Science, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran

Received on: 18 Oct 2013

Revised on: 25 Nov 2013

Accepted on: 30 Nov 2013

Online Published on: Mar 2014

*Correspondence E-mail: shivazad@ut.ac.ir

© 2010 Copyright by Islamic Azad University, Rasht Branch, Rasht, Iran

Online version is available on: www.ijas.ir

ABSTRACT

A study was conducted to evaluate efficacy of wheat based vs. corn based diets on growth performance, carcass traits, blood parameters, jejunum morphological development, immunity, cecal microflora and excreta moisture in broiler chicks fed according to digestible essential amino acid profile. One hundred forty day old Ross 308 male broiler chicks randomly distributed into ten separated floor pens based on a completely randomised design. Each treatment consisted of five replicates with fourteen birds each. Body weight (BW), body weight gain (BWG), feed intake (FI), feed conversion ratio (FCR), immunity and excreta moisture were determined at different periods of ages. At the day 44, five birds of each group were sacrificed to evaluate carcass traits, jejunum histomorphology and cecal microflora. Blood parameters, mortality rate (MR) and European production efficiency factor (EPEF) were measured and determined at day 42 of age, respectively. The results of this study showed that BW, BWG, FI, FCR, MR and EPEF were not significantly different between two groups on the day 42 of age, but BW, BWG and FI were significantly higher ($P < 0.05$) in corn based than wheat based diets on starter phase of feeding and also FI and FCR on the growing phase. Most of carcass traits were not significantly different ($P > 0.05$) between two groups except for abdominal fat (AF) percentage which was significantly higher ($P < 0.05$) in corn-based diet. Despite a reduction of triglyceride, total cholesterol, high density lipoprotein (HDL) and low density lipoprotein (LDL) concentration in the serum of broilers fed the wheat base diet, there were no statistically significant differences between two groups ($P > 0.05$). Humeral immunity response, Newcastle titer, jejunum histomorphology, cecal microflora and excreta moisture were not significantly different ($P > 0.05$) between two groups. In conclusion, wheat based diet is as efficient as corn based diet when diets are formulated based on digestible amino acids method.

KEY WORDS broiler, corn, digestible amino acid, wheat.

INTRODUCTION

One of the main concerns of animal nutritionist is whether to use wheat or corn as a proper feed for broiler chickens, a-

lthough wheat based diet is mainly used in some parts of the world such as Europe, Canada and Australia (Pirgozliev *et al.* 2001; Ball *et al.* 2013). Comparing to corn, variations in nutritive values and nature of non starch polysaccharide

(NSP) of wheat result in inefficiencies in diet formulations, particularly in terms of energy and amino acid (Mollah *et al.* 1983; Yegani and Korver, 2012). Some previous studies (Choct and Annison, 1992; Choct *et al.* 1996; Iji, 2001; Preston *et al.* 2001; Teirlynck *et al.* 2009) showed that anti-nutritive effects of soluble NSP on intestinal microflora, Gut histomorphology, excreta moisture and performance. In fact, soluble NSPs produce high digesta viscosity in intestine and inhibit digestion and absorption of nutrients such as lipids, protein and starch (Hetland *et al.* 2004; Kalmendal *et al.* 2011). Furthermore, wheat has been recommended not be used above 30% level for young broiler chickens (Leeson and Summers, 2005). Gregoire *et al.* (1976) mentioned that the lower performance of chickens fed high protein wheat based diet in comparison to corn based diet, while both diets were formulated base on iso caloric and iso nitrogenous, was due to low quality of their wheat amino acids profile. Formulating diet base on digestible amino acid supplies better amino acid requirement of bird, improves feed conversion ratio, reduces nitrogen output in excreta and decreases environmental pollution (Lemme *et al.* 2004; Maiorka *et al.* 2005).

There is lack of information whether digestible amino acids method able to remove or alleviate the effect of high inclusion level of wheat instead of corn without using NSPase and phytase enzymes in poultry industries or not. The objective of this study was to compare wheat and corn based diet based on digestible essential amino acid formulation methods.

MATERIALS AND METHODS

Bird and diets

All procedure used in this study were approved by the Animal Care and Welfare of Committee of University of Tehran.

One hundred and forty day-old Ross 308 male broiler chicks were categorized according to two different diets (corn based vs. wheat based) with five replications and housed in deep litter pens 1.56 m². The temperature was set at 32 °C on first day, gradually was reduced to 22 °C by the end of experiment.

The light program was started at 3 day of age for 23 h light: 1 h dark. Chicks had free access to water and fed starter (0-10 d), grower (11-24 d) and finisher (25-42 d) diets based on corn and wheat based diet in mash form (Table 1). Essential amino acid's profile of all ingredients were predicted by digestible amino acid's profile prediction (Amino Dat® 4.0 platinum version, Germany) and nutrient suggestions of Ross 308 (Anonymous, 2009) were used for feed programming. Proximate analysis of ingredients was done according to AOAC (2000).

Wheat and corn (as fed) each contains 95.7% dry matter (DM), 12.1% crude protein (CP), 2.5% crude fiber (CF), 1.3% ether extract (EE), 2.05% ash, 93.5% DM, 7.5% CP, 1.5 CF, 2.3% EE, 2.4 ash, respectively.

Performance

Data on performance (average body weight, body weight gain and feed intake) were recorded for each group weekly by digital scale with accuracy of ± 5 g until week 3 and ± 25 g for the rest of trial and also feed conversion ratios were calculated according to hen day methods weekly and are presented here on periodic basis (0-10, 11-24, 25-42 and 1-42) in Table 2.

Carcass traits

At 44 days of age, five birds were selected randomly from each treatment (one from each replicate) and were sacrificed via cervical dislocation. All organs were weighted by digital scale with accuracy of ± 0.1 g and are presented here according to relative organ weight (% BW) in Table 3.

Blood sample

At 42 days of age, five birds from each treatment were bled (10 mL blood samples) from right and left brachial vein and 5 ml of the samples pour into a tube contain EDTA as anti-clotting agent. Rest of the blood samples were immediately centrifuged at 2000 \times g for 15 min and plasma samples were stored at -20 °C until further analysis. Cholesterol and triglyceride by enzymatic colorimetric end point method (ELITech *in vitro* diagnostic reagent, France) and HDL and LDL by immune-inhibition method (Wako stable liquid reagent, Germany) were determined quantitatively by biochemistry analyzer (Hitachi® 717, Japan). May Grünwald Giemsa staining (Lucas and Jamroz, 1961) was used for white blood cell, lymphocyte, monocyte, heterophil and eosinophil then all was counted by Carl Zeiss Microscope, Germany. Humoral immunity responses against sheep red blood cell were measured by injection of 0.1 ml of 5% (v/v, suspension in sterile PBS) sheep red blood cell (SRBC) into the breast muscle of one bird from each replicate for the first and second time at 21 d and 28 d. Seven days after each injection birds were bled from brachial vein for determination of antibody produced against SRBC (SRBC-titer) by micro haemagglutination test as described by Wegmann and Smithies (1966). Newcastle disease titers (NDV-titer) were measured by HI test at 35 d and 42 d as described by Xu (1998).

Jejunum histomorphology

Due to absorption of most nutrients from middle part of the gut, jejunum section of five birds from each group was fixed on formalin solution 10% at day 44.

Table 1 Ingredient and chemical composition of the experimental diets (%)

Ingredients	Starter		Grower		Finisher	
	C-B	W-B	C-B	W-B	C-B	W-B
Corn grain	52.28	-	56.68	-	60.42	-
Wheat grain	-	59.37	-	65.94	-	68.60
Soybean meal (44%)	40.69	33.12	36.37	27.39	32.00	24.19
Vegetable oil	2.42	3.06	3	2.67	3.73	3.47
Dicalcium phosphate	2.00	1.45	1.60	1.19	1.60	1.09
Calcium carbonate	1.20	1.46	1.02	1.24	1.00	1.21
Sodium bicarbonate	0.12	0.07	0.11	0.12	0.11	0.12
Sodium chloride	0.30	0.25	0.29	0.20	0.29	0.20
Vitamin premix ¹	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix ²	0.25	0.25	0.25	0.25	0.25	0.25
L-lysine-HCl	0.14	0.23	0.11	0.28	0.08	0.22
DL-methionine	0.29	0.35	0.26	0.33	0.23	0.29
L-threonine	0.06	0.14	0.06	0.14	0.04	0.11
Calculated values						
AMEn (kcal/kg)	2900		2975		3050	
Crude protein (%)	22.50		20.77		19.06	
Digestible lysine (%)	1.21		1.09		0.97	
Digestible Met + Cys (%)	0.90		0.83		0.76	
Digestible threonine (%)	0.79		0.72		0.65	
Calcium (%)	1.00		0.85		0.81	
Available phosphorus (%)	0.48		0.42		0.40	
DCAB (mEq/kg)	295.0	285.0	272.8	270.0	255.0	251.0

¹ Supplied per kg diet: vitamin A: 9000 IU; vitamin D₃: 2000 IU; vitamin E: 18 IU; vitamin K₃: 2 mg; vitamin B₁: 1.8 mg; vitamin B₂: 6.6 mg; vitamin B₃: 10 mg; vitamin B₅: 30 mg; vitamin B₆: 3 mg; vitamin B₉: 1 mg; vitamin B₈: 0.1 mg; vitamin B₁₂: 0.015 mg; Choline: 250 mg and Antioxidant: 100 mg.

² Supplied per kg diet: Mn: 99.2 mg; Fe: 50 mg; Zn: 84.7 mg; Cu: 10 mg; I: 1 mg; Se: 0.2 mg and Choline: 250 mg.

C-B: cornbased diet and W-B: wheat based diet.

DCAB: dietary cation anion balance.

Table 2 Effects of dietary treatments on body weight (BW, g), body weight gain (BWG, g), feed intake (FI, g), feed conversion ratio (FCR), mortality rate (MR, %) and European production efficiency factor (EPEF) of male broiler chicks

Groups	IBW (g)	BW (g)				BWG (g)				FI (g)			
		10	24	42		0-10	11-24	25-42		0-10	11-24	25-42	0-42
C-B	44.4	257.4	1028.2	2629.8	212.9	770.7	1601.6	2585.3	299.3	1208.2	2935.3	4600.4	
W-B	42.3	236.5	1047.8	2695.2	194.2	811.3	1647.3	2652.9	262.4	1109.7	3027.2	4549.8	
SEM	0.9	5.04	14.59	35.65	5.50	13.73	28.76	35.43	6.15	26.67	149.66	89.16	
P-value	0.1	0.01	0.36	0.23	0.04	0.07	0.29	0.21	0.002	0.03	0.67	0.68	
Groups	FCR				MR (%)				EPEF				
	0-10	11-24	25-42	0-42	0-42				0-42				
C-B	1.40	1.56	1.93	1.77	2.85				336.2				
W-B	1.35	1.38	1.92	1.71	4.28				353.6				
SEM	0.03	0.02	0.04	0.02	2.36				7.83				
P-value	0.29	< 0.0001	0.86	0.16	0.68				0.15				

IBW: initial body weight (g/chick) and BW: body weight (g/chick/period).

C-B: corn based diet and W-B: wheat based diet.

SEM: standard error of means.

Table 3 Effects of dietary treatments on carcass traits of male broiler chicks at day 44

Groups	BW (g)	CW (g)	CY (%)	BY (%)	LY (%)	AF (%)	Gizzard (%)	Pancreas (%)	Spleen (%)	Bursa of F (%)
C-B	2927.4	2141.8	73.1	24.6	21.5	1.9	1.2	0.19	0.13	0.23
W-B	2862.2	2085.2	73.0	25.4	21.1	1.3	1.1	0.18	0.11	0.15
SEM	92.0	53.4	0.88	0.58	0.26	0.09	0.06	0.01	0.01	0.03
P-value	0.62	0.47	0.90	0.40	0.29	0.003	0.32	0.77	0.27	0.12

BW: body weight (n=5); CW: carcass weight; CY: carcass yield; BY: breast yield; LY: legs yield; AF: abdominal fat; and Bursa of F: bursa of Fabricius.

C-B: corn based diet and W-B: wheat based diet.

SEM: standard error of means.

All procedures were done according to Iji *et al.* (2001) for measuring villus height (VH), crypt depth (CD), goblet cell numbers (GN) and epithelium thickness (ET).

Cecal microflora

Samples of cecal contents of five birds from each group were blended each in 9 mL of sterilized physiological saline

solution using a bag mixer. Decimal dilutions were prepared in the same diluent. Duplicate plate per sample, containing the selective media; was inoculated with 0.1 mL of suspension. Man Rogosa Sharpe agar media (MRS agar, Difco) by pour plate methods, Brilliant Green Bile agar media (BGB agar, Sigma-Aldrich) and Sulphitecycloserin agar (SCA, Sigma-Aldrich) were used for *Lactobacilli*, *E. coli* and *Clostridia*, respectively. The plates were incubated at 37 °C for 48 h in anaerobic conditions for lactobacilli and clostridia and 24 h in aerobic condition for *E. coli*. After incubation, the total number of colonies from duplicated plates per sample was averaged, and the results were expressed as log₁₀ of colony forming units per gram of cecal content.

Excreta moisture

Excreta moisture of each replicate was measured, by putting them in the oven at 65 °C for 48 h and weighting with scale accuracy of ±0.1 g, immediately after collecting.

Statistical methods

All statistical analyses were carried out with the two sample t-test using TTEST procedure by SAS 9.1 (SAS, 2003).

RESULTS AND DISCUSSION

Performance

Feeding broilers with corn based or wheat based diets had no significant ($P>0.05$) effect on final BW, BEG, FCR, MR and EPEF at 42 days of age and also BW and BWG on grower phase of feeding (Table 2). Although in starter period corn based diet improved significantly ($P<0.05$) BW and BWG, it has no significant effect on FCR. These results are in agreement with the data of Wu *et al.* (2003) and Abdollahi *et al.* (2010) who observed a significant improvement ($P<0.05$) in BWG of broilers fed corn based diets at starter period.

It seems that lack of synthesis of endogenous enzyme specially amylase and lipase until the first 10 days of age (Gutierrez-Alamo *et al.* 2008) resulting lower performance of birds fed wheat based diets in comparison to corn based diets.

Therefore, maybe simultaneous increase in endogenous enzymes synthesizes as the bird get older resulting better digestion and consequently increases bird's performance. No significant differences are detected on final BW, BWG, and FCR in broiler feed iso caloric and iso nitrogen corn based and wheat-based diet (Chiang *et al.* 2005).

Although Singh *et al.* (2003) study showed significant improvement on final BW in broiler feed iso caloric and iso nitrogenous corn-based in comparison to wheat-based diets, it has no significant effect on FCRs.

Peng *et al.* (2003) study showed corn based diet improves FCR significantly than wheat based diet, but no significant effect from type of diet was detected on final BW, BWG and FI.

Moreover, FI was significantly lower in broilers fed wheat based diets. The result of this study seems to disagree with some studies (Choct and Annison, 1992; Allen *et al.* 1997; Preston *et al.* 2001) which found significant differences in broiler performance when wheat substituted by corn. The reason for giving this contrast result maybe duo to lack of NSP content of this wheat or a proper content of nitrogen free extract of that (768.8 g/kg DM) in this trial.

Carcass traits

Feeding broilers with corn-based or wheat-based diets had no significant ($P>0.05$) effect on carcass traits except for AF (% BW) (Table 3).

These results are in agreement with Saki *et al.* (2011) who reported a reduction in AF (% BW) of broilers fed wheat-based diets. Salih *et al.* (1991) suggested that the low lipid digestibility in broiler chicks feed diets with a high content of NSPs may be due to bacterial overgrowth in the small intestine and subsequent excessive deconjugation of bile acids which reduces their efficacy in solubilizing lipids. In addition, certain NSP can bind bile salts, lipids and cholesterol which could result in increased hepatic synthesis of bile acids from cholesterol to re-establish the composite pool of these metabolites in the enterohepatic circulation. The continued "drain" of bile acids and lipids by sequestration, and increased elimination as fecal acidic and neutral sterols, may ultimately influence the absorption of lipids and cholesterol in the intestine (Choct *et al.* 2010).

Blood parameters

The effect of type of diets on blood parameters were shown in Table 4. Although triglyceride, total cholesterol and HDL concentrations were decreased numerically in wheat-based diet, they were not significantly different ($P>0.05$) between corn based and wheat based diets.

Smits *et al.* (1997) reported that the increase in NSP content could reduce cholesterol absorption and plasma cholesterol concentration in broiler chicks. None of blood parameters such as WBC, SRBC-titer and NDV-titer were affected by type of diets.

Jejunum histomorphology

Jejunum histomorphology parameters at day 42 are shown in Table 5. The effect of type of diet on VH, CD, ET and GN was not significant ($P>0.05$). Parsaie *et al.* (2007) study's on non iso energetic and nitrogenous wheat and corn based diet revealed significant effect of corn based diet on the jejunal CD.

Table 4 Effects of dietary treatments on some of blood parameters and immunity responses of male broiler chicks at day 42

Groups	TG (mg/dL)	TC (mg/dL)	LDL (mg/dL)	HDL (mg/dL)	WBC				SRBC-titer		NDV-titer	
					L (%)	M (%)	H (%)	E (%)	28 d	35 d	35 d	42 d
C-B	103.33	139	24.33	81	62.33	7	29.33	1.33	2.33	3	5.66	4.66
W-B	89.33	120	23.33	73	56.00	6	36.33	1.66	2.33	2.66	5.33	5.33
SEM	8.62	14.41	3.97	5.31	6.01	2.94	3.40	0.66	0.52	0.62	1.39	0.78
P-value	0.31	0.40	0.86	0.32	0.49	0.82	0.22	0.74	0.99	0.72	0.87	0.57

TG: total triglyceride (mg/dL); TC: total cholesterol (mg/dL); LDL: low density lipoprotein (mg/dL); HDL: high density lipoprotein; WBC: white blood cells; L: lymphocyte (%); M: monocyte (%); H: heterophil (%); E: eosinophil (%); SRBC-titer: sheep red blood cell titer and NDV-titer: newcastle diseases virus titer.
C-B: corn based diet and W-B: wheat based diet.
SEM: standard error of means.

Table 5 Effects of dietary treatments on jejunum histomorphology parameters, cecal microflora and excreta moisture of male broiler chicks

Groups	Jejunum histomorphology parameters				Cecal microflora (log ₁₀ cfu/g)			Excreta moisture (%)	
	VH (µm)	CD (µm)	ET (µm)	GN	<i>Lactobacilli</i>	<i>E. coli</i>	<i>Clostridia</i>	22 d	35 d
C-B	103.33	139	24.33	81	10.12	5.76	3.55	70.5	67.83
W-B	89.33	120	23.33	73	10.72	6.60	3.58	68.8	60.59
SEM	8.62	14.41	3.97	5.31	0.27	0.24	0.13	2.62	3.98
P-value	0.31	0.40	0.86	0.32	0.19	0.07	0.86	0.70	0.32

VH: villus height (µm); CD: crypt depth (µm); ET: epithelium thickness (µm) and GN: goblet cell number.
C-B: corn based diet and W-B: wheat based diet.
SEM: standard error of means.

Cecal microflora

According to Table 5, the effect of type of diets on *Lactobacilli*, *E. coli* and *Clostridia* as log₁₀ of colony forming units per gram of cecal content at day 42 was not significant (P>0.05), but a little increase was seen in *E. coli* population of wheat based diet compared to corn based diet. These results confirmed the higher activity of negative bacteria specially *E. coli* in the ceca content of boilers fed wheat-based diets as it seen on Mathlouthi *et al.* (2002) study.

Excreta moisture

The results of excreta moisture of grower period and finisher period measured at 22 and 35 days of age revealed no significant differences (P>0.05) between two groups at different periods. Although some researchers (Williams *et al.* 1997; Shirzadi *et al.* 2009) reported that the presence of NSP increase water content of excreta, our result showed no significant difference between excreta moistures of broilers fed wheat and corn based diets.

CONCLUSION

The results of this study suggest that wheat grain can be replaced efficiently instead of corn when the diets are formulated based on digestible essential amino acids even without inclusion of NSPase or phytase enzyme. However, further research is needed to be done for considering the effects of wheat starch and soluble NSPs content while the diets are formulated by digestible amino acid method.

ACKNOWLEDGEMENT

Authors are grateful for technical and financial support of University of Tehran. Special thanks to my colleagues: Mr.

R. Akbari, Mr. J. Norghadimi and Mr. H. Kheyri for their cooperation in this study.

REFERENCES

Abdollahi M.R., Ravindran V., Wester T.J., Ravindran G. and Thomas D.V. (2010). Influence of conditioning temperature on the performance, nutrient utilisation and digestive tract development of broilers fed on maize and wheat based diets. *Br. Poult. Sci.* **51**, 648-657.

Allen C.M., McCracken K.J. and Bedford M.R. (1997). Effect of fat type, rate of wheat inclusion and enzyme supplementation on diet metabolisability and broiler performance. *Br. Poult. Sci.* **38**, 25-45.

Anonymous. (2009). Broiler Nutrition Specification, Aviagen. New bridge, Midlothian, EH28 8SZ, Scotland, UK.

AOAC. (2000). Official Methods of Analysis. 17th Ed. Association of Official Analytical Chemists, Arlington, VA.

Ball M.E.E., Owens B. and McCracken K.J. (2013). Chemical and physical predictors of the nutritive value of wheat in broiler diets. *Asian-Australas J. Anim. Sci.* **26**, 97-107.

Chiang C., Yu B. and Chiou P.W. (2005). Effects of xylanase supplementation to wheat-based diet on the performance and nutrient availability of broiler chickens. *Asian-Australas J. Anim. Sci.* **18**, 1141-1146.

Choct M. and Anison G. (1992). Anti-nutritive effect of wheat pentosans in broiler chicken: role of viscosity and gut microflora. *Br. Poult. Sci.* **33**, 821-834.

Choct M., Dersjant-Li Y., McLeish J. and Peisker M. (2010). Soy oligosaccharides and soluble non-starch polysaccharides: a review of digestion, nutritive and anti-nutritive effects in pigs and poultry. *Asian-Australas J. Anim. Sci.* **23**, 1386-1398.

Choct M., Hughes R.J., Wang J., Bedford M.R., Morgan A.J. and Anison G. (1996). Increased small intestinal fermentation is partly responsible for the anti-nutritive activity of nonstarch polysaccharides in chickens. *Br. Poult. Sci.* **37**, 609-621.

- Gregoire R.J., Brisson G.J., St Laurent G.J. and Belzile R.J. (1976). Feeding value of purple 606-4, cw red spring and white 607-A wheat cultivars compared to corn in broiler rations. *Canadian J. Anim. Sci.* **56**, 73-80.
- Gutierrez Alamo A., Perez De Ayala P., Verstegen M.V.A, Den Hartog L.A. and Villamide M.J. (2008). Variability in wheat: factors affecting its nutritional value. *World's Poult. Sci. J.* **64**, 20-39.
- Hetland H., Choct M. and Svihus B. (2004). Role of insoluble non-starch polysaccharides in poultry nutrition. *World's Poult. Sci. J.* **60**, 415-422.
- Iji P.A., Hughes R.J., Choct M. and Tivey D.R. (2001). Intestinal structure and function of broiler chickens on wheat based diets supplemented with a microbial enzyme. *Asian-Australas J. Anim. Sci.* **14**, 54-60.
- Kalmendal R., Elwinger K., Holm L. and Tauson R. (2011). High-fibre sunflower cake affects small intestinal digestion and health in broiler chickens. *Br. Poult. Sci.* **52**, 86-96.
- Lemme A., Ravinaran V. and Bryden W.L. (2004). Ileal digestibility of amino acids in feed ingredients for broilers. *World's Poult. Sci. J.* **60**, 423-438.
- Leeson S. and Summers J.D. (2005). Commercial Poultry Nutrition. Nottingham University Press. England.
- Lucas A.M. and Jamroz C. (1961). Atlas of Avian Hematology. Washington, D.C. Department of Agriculture. U.S.
- Maiorka A., Dahlke F., Pen A.M and Kessler A.D.M. (2005). Diets formulated on total or digestible amino acid basis with different energy levels and physical form on broiler performance. *Brazilian J. Poult. Sci.* **7**, 47-50.
- Mathlouthi N., Mallet S., Saulnier L., Quemener B. and Larbier M. (2002). Effects of xylanase and beta-glucanase addition on performance, nutrient digestibility and physico chemical conditions in the small intestine contents and caecal microflora of broiler chickens fed a wheat and barley based diet. *Anim. Res.* **51**, 395-406.
- Mollah Y., Bryden W.L., Wallis I.R., Balnave D. and Annison E.F. (1983). Studies on low metabolizable energy wheats for poultry using conventional and rapid assay procedures and the effects of processing. *Br. Poult. Sci.* **24**, 81-89.
- Parsaie S., Shariatmadari F., Zamiri M.J. and Khajeh K. (2007). Influence of wheat based diets supplemented with xylanase, bile acid and antibiotics on performance, digestive tract measurements and gut morphology of broilers compared with a maize-based diet. *Br. Poult. Sci.* **48**, 594-600.
- Peng Y.L., Guo Y.M. and Yuan J.M. (2003). Effects of microbial phytase replacing partial inorganic phosphorus supplementation and xylanase on the growth performance and nutrient digestibility in broilers fed wheat based diets. *Asian-Australas J. Anim. Sci.* **16**, 239-247.
- Pirgozliev V.R., Rose S.P., Kettlewell P.S. and Bedford M.R. (2001). Efficiency of utilization of metabolizable energy for carcass energy retention in broiler chickens fed different wheat cultivars. *Canadian J. Anim. Sci.* **81**, 99-106.
- Preston C.M., McCracken K.J. and Bedford M.R. (2001). Effect of wheat content, fat source and enzyme supplementation on diet metabolisability and broiler performance. *Br. Poult. Sci.* **42**, 625-632.
- SAS Institute. (2003). SAS[®]/STAT Software, Release 9.1. SAS Institute, Inc., Cary, NC.
- Saki A.A., Hemati H.H., Zamani P. and Mirzaaghatabar F. (2011). Non starch polysaccharides and broiler responses. *World. Appl. Sci. J.* **15**, 192-198.
- Salih M.E., Classen L. and Campbell G.L. (1991). Responses of chickens fed on hullless barley to dietary β -glucanase at different ages. *Anim. Feed Sci. Technol.* **33**, 139-149.
- Shirzadi H., Moravej H. and Shivazad M. (2009). Comparison of the effects of different kinds of NSP enzymes on the performance, water intake, litter moisture and jejunal digesta viscosity of broilers fed barley-based diet. *J. Food Agric. Environ.* **7**, 615-619.
- Singh P.K., Khatta V.K., Thakur R.S., Dey S. and Sangwan M.L. (2003). Effects of phytase supplementation on the performance of broiler chickens fed maize and wheat based diets with different levels of non-phytate phosphorus. *Asian-Australas J. Anim. Sci.* **16**, 1642-1649.
- Smits C.H.M., Veldman A., Verstegen M.W.A. and Beynen A.C. (1997). Dietary carboxymethylcellulose with high instead of low viscosity reduces macronutrient digestion in broiler chickens. *J. Nutr.* **127**, 483-487.
- Teirlynck E., Bjerrum L., Eeckhaut V., Huygebaert G., Pasmans F., Haesebrouck F., Dewulf J., Ducatelle R. and Van Immerseel F. (2009). The cereal type in feed influences gut wall morphology and intestinal immune cell infiltration in broiler chickens. *Br. J. Nutr.* **102**, 1435-1461.
- Wegmann T.G. and Smithies O. (1966). A simple hemagglutination system requiring small amounts of red cells and antibodies. *Transfusion.* **6**, 67-73.
- Williams P.E.V., Geraert P.A., Uzu G. and Annison G. (1997). Factors affecting non starch polysaccharide digestibility in poultry. *Opti. Med.* **26**, 125-134.
- Wu Y.B., Ravindran V. and Hendriks W.H. (2003). Effects of microbial phytase, produced by solidstate fermentation, on the performance and nutrient utilisation of broilers fed maize and wheat based diets. *Br. Poult. Sci.* **44**, 710-718.
- Xu W.Y. (1998). Veterinary Virology. China Agriculture Press, China.
- Yegani M. and Korver D.R. (2012). Review: prediction of variation in energetic value of wheat for poultry. *Canadian J. Anim. Sci.* **92**, 261-273.