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Research Article

Effect of Different Levels of Germinated Barley on Performance and Egg Quality in Laying Hen

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ABSTRACT

Objective: The experiment was conducted to evaluate the effect of different levels of germinated barley on performance and egg quality in laying hen. **Methods:** One hundred and twenty laying hens, 44-weeks old, Lohmann LSL hens were used in this experiment. Birds were assigned randomly to the groups, each of which consisted of 20 birds (4 replicate cages each containing 5 birds). The experiment was conducted as a randomized complete block design. Six experimental diets were used, diets that contained: corn-soybean meal, barley, barley plus enzyme supplementation (safizym: β-glucanases, Xylanases and Celluloses) and germinated barley replaced barley at 33, 66 and 100 percent. Experimental period was 10 weeks. The performance of laying hens measured weekly, but biweekly for egg quality. **Results:** The results of experiments indicated, by increasing of germinated barley in diets of laying hens feed convention ratio egg production and egg mass production significantly improved as compared to barley treatment ($P<0.05$). Daily feed intake of laying hens was significantly decreased with the increase in germinated barley replacement and enzyme supplementation ($p<0.05$). Egg weight of hens under germinated barley diets was lower than in those fed other treatments ($P<0.05$) and the highest reduction was obtained with 100% inclusion germinated barley. Shell thickness, albumen index and haugh unit reduced in hens fed germinated barley diets ($p<0.05$), but using different levels of germinated barley had not significant effect on shape index, yolk index, breaking strength, specific gravity and yolk color score.

1.Introduction

Cereal grains like corn, barley, wheat and rye are common energy sources and often comprise the most extent proportion of poultry rations, which their use depend on the cost and availability. Barley (*Hordeum vulgare*) uses as poultry feedstuff in some regions of the world and some evidence indicate that its use in laying hen diets may have negative effects on productivity. These negative effects are mainly related to soluble fiber referred to Non-Starch Polysaccharides (NSPs) which classified as arabinixylans and β-gucans (Bedford, 1995).

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The anti-nutritive effects of NSP are probably mediated by a number of mechanisms, including increase digesta viscosity (Smits et al., 1997), decrease nutrient digestibility (Choct and Annison, 1992), binding of bile salts thus reducing lipid solubilisation and absorption (Ebihara and Schneeman, 1989), modification of the intestinal mucosa and increasing fermentation in the small intestine with subsequent decrease in nutrient digestion (Choct et al., 1996). β-glucan is the major component of barley endosperm cell walls and adding enzyme preparations to barley-based diets is common practice for reducing the anti-nutritional effects of NSP (Bedford, 1995) and improving egg quality (Roberts and choct, 2006), egg production and feed efficiency (Lazaro et al. 2003) in laying hens. However, some researches found no beneficial effects of adding enzyme to barley diets in layer hen performance.

Beside of enzyme supplementation, high moisture storage of barley (Svihus et al. 1997), and also germination process of cereal seeds like barley (Celus et al. 2006) and oat seeds (Binqiang et al. 2010) are effective practical methods for improving its nutritional value and digestibility as well as reducing anti nutritional effects. Fengler et al., (1990) reported that apparent retention of dry matter and fat was greater for chickens fed germinated barley than those fed raw barley. During germination process, the activity of inner enzymes such as β-glucanase increase and transgenic grain containing (1,3-1,4)-β-glucanase can be used as alternative to enzyme additives in barley basal diets (Von Wettstein et al. 200٠). There is little information about utilization of germinated barley in egg hen diets. Therefore, the objective of this research was to investigate the effects of feeding different levels of germinated barley to laying hens on egg production and quality.

2.Materials and methods

2.1.Analytical procedures

The chemical compositions of barley and germinated barley were determined according to the methods of the Association of Official Analytical Chemists (AOAC, 1990) and β-glucan contents were measured using methods based on the Megazyme kit (Megazyme international Ireland Ltd., Bray, Ireland).

2.2.Laying hen management

One hundred and twenty laying hens (44 weeks of age; LOHMANN LSL, white egg) were used in this experiment. After a two-week adaptation period to cages (80 cm × 40 cm × 35 cm), the birds were allocated to 6 groups with 4 replicates of 20 birds (4 replicates cages, 5 birds per cage) each and kept for 10 weeks. Light was provided for 16 h daily and the temperature was effort to be maintained at 20-22 °C throughout the experiment. Each cage was equipped with an individual feeder and two trough drinkers. Feed, in mash form, and water were provided ad libitum.

2.3.Diets preparation

A control corn-soybean meal diet and a barley basal diet were formulated to have similar nutrient value per kg of feed according to LOHMANN LSL guideline manual. Then for preparing other treatments, the barley basal diet was supplemented by 0.08 percent safizym enzyme as well as germinated barley was replaces at 33, 66 and 100 percent to barley in the barley basal diet. Therefore, 6 dietary treatments consisted of a control corn-soybean meal diet (corn diet), barley basal diet (barley diet), barley basal diet plus enzyme supplementation (Enzyme diet) and three germinated barley diets which prepared by replacing germinated barley to the barley basal diet at 33, 66 and 100 percent, referred to GB33, GB66 and GB100 diets, respectively (Table 1). A batch of barley and germinated barley (cultivar Reyhaneh) was obtained from a local malt producing factory. Briefly, barley was soaked in water for 48 h and then germinated 72 h, finally the grains were dried to stop the seed internal enzymes activity (Briggs, 1998).

Table 1. Composition of the experimental diets (g/kg, as fed basis)[1]

Ingredients	Corn diet	Barley diet
Maize	53.3	-
Barley	-	60.6
Wheat bran	5	-
Soybean meal	20.82	18.71
Fish meal	3	3
Soybean oil	1.93	6.82
Calcium carbonate	9.21	9.36
Dicalcium phosphate	0.75	0.54
Salt	0.29	0.26
Vitamin premix[2]	0.25	0.25
Mineral primix[3]	0.25	0.25
DL-Methionine	0.1	0.11
Vitamin E	0.01	0.01
Chemical content and ME		
ME (MJ/kg)	11.51	11.51
Crude protein (%)	16.7	16.7
Calcium (%)	3.9	3.9
Phosphorus available (%)	0.34	0.34
Lysine (%)	0.75	0.75
Methionine (%)	0.37	0.37
Cystine + Methionine (%)	0.69	0.69

1-Experimental diets were including a control corn-soybean meal diet (corn diet), basal barley diet (Barley diet), The basal barley diet plus safizym4 enzyme (Enzyme diet) and three other experimental diets containing germinated barley as 33, 66 and 100 percent, (GB33, GB66 and GB100, respectively).
2-Each Kg of vitamin premix contained: vitamin A, (Retinyacetate) 7.04 g; vitamin D3, (Cholecalciferol) 2 g; vitamin E, (Tocopheryl) 8.8 g; vitamin K3, 880 mg; vitamin B1, 561 mg; vitamin B2, 1600 mg; vitamin B3, 3136 mg; vitamin B5, 13860 mg; vitamin B6, 985 mg; vitamin B9, 192 mg; vitamin B12, 4 mg; choline, 160000 mg; biotin, 60 mg.
3-Each Kg of mineral premix contained: manganese 26760 mg; iron, 30000 mg; zinc, 28870 mg; copper, 2400 mg; iodine, 347 mg; selenium, 80 mg.
4- Enzyme safizym contained: main activity: β-glucanases; 3500000 U. β -glu/kg and additional activities: Xylanases; 1600000 U.Xyl/kg, Cellulases: 25000 U. FPase/kg.

2.4.Egg production and egg quality measurement

Egg production was recorded daily and calculated on a hen-day basis (% hen-d). Egg weight was determined daily by weighing all eggs, except soft-shelled eggs, double yolked or yolkless eggs, for each cage. Feed consumption and feed conversion (g feed/g egg) were recorded weekly. Egg mass production was calculated by multiplying egg production to average egg weight in each replicate. Three eggs were randomly collected from each replicate biweekly to measure egg quality parameters. Egg specific gravity was determined by the following formula: SG = ew/ (ew-eww), where SG = specific gravity; ew = egg weight; eww = average weight of eggs weighted in water (Holder and Bradford, 1979). Breaking egg shell strength (kg/cm^2) was measured by egg shell strength tester (Ogawa Seiki Co., LTD. OSK 13469). Shell thickness was measured at three points of egg shell (air cell, equator, and sharp end) then the average was used as egg shell thickness by using an egg shell thickness meter (OSK, 13473 R). Shape index was determined by dividing width to length of egg. Lengths of eggs were measured by vernier caliper. Albumen and yolk heights were measured by Spherometer. Length and width of albumen and yolk were also measured by Vernier Caliper. The albumen index (the ratio of average albumen height to the average of the width and length) and yolk index (the ratio of yolk height to its average width) were determined as described by Helman and Carver (1936). Visual yolk color was determined with a yolk color fan (scale 1 to 15). Haugh Units were calculated from the records of albumen height and egg weight using the formula: HU = 100 log10 (H - 1.7 W $^{0.37}$ + 7.56), where HU = Haugh Unit, H = height of the albumen (mm) and W = egg weight (g).

2.5.Statistical analysis

Data were subjected to statistical analysis using MIXED procedure of SAS software (SAS Institute, 2001). Means comparisons among treatments were done by Tukey test. The following model was assumed in the analysis of all traits.

$Y_{ijkl} = \mu + T_i + B_j + W_l + (TW)_{il} + \leq_{ik} + e_{ijk}$

Where, Y_{ijkl} = observed value for a particular character, μ= overall mean, T_i = fixed effect of treatment, B_j = random effect of block, W_l = fixed effect of week, TW*il* the effect of the *i*th T with the *l*th W, $\leq_{ik}$ = experimental error with zero mean and variance $\leq_{\leq}^2$, Variance between the animals tested, the treatment and e_{ijk} = the random error.

3.Results

3.1.Chemical compositions

The chemical composition of barley and germinated barley are shown in table 2. Barley contains lower dry matter, crude protein and ether extract but higher ash and *β*-glucan than germinated barley.

Table 2. Chemical composition of barley and germinated barley

	Barley	Germinated barley
Dry matter (%)	93.07	95.67
Crude protein (%)	10.78	11.81
Crude fiber (%)	5.59	6.84
Ether extract (%)	2.92	2.97
Ash (%)	2.59	2.52
Total *β* -glucan (%)	3.18	1.053

3.2.Laying hen performance

Significant differences were observed among the experimental diets for daily feed intake, feed conversion, egg production, egg weight and egg mass production (Tables 3). Laying hens fed on barley diet had similar performance to hens fed corn diet. Feed intake and feed conversion were significantly higher for the hens fed barley diet (129.68 g and 2.28, respectively) than those birds fed enzyme (124.09 g and 2.13) or GB100 (125 g and 2.04) diets (P<0.05). A significant improvement in feed conversion was detected by supplementing enzyme or complete replacing of germinated barley to barley diet (P<0.05). The best feed conversion among dietary treatments was for layers fed GB100 diet.

Laying hens fed barley diet had 87.61% egg production which was significantly lower than birds fed enzyme diet (92.22%) or other groups. Replacement of germinated barley to barley diet improves egg production. Egg production for birds fed GB33, GB66 and GB100 was 90.97, 91.14 and 95.97%, respectively. So, the more replacement germinated barley the more egg production achieved.

Layers fed barley diet had no significant higher weight egg than those birds fed corn diet (65.29 versus 64.71 g). Enzyme supplementation to barley diet led to small decrease of weight egg (64.54 g). Weight egg for layers fed GB33, GB66 and GB100 diets were respectively 63.74, 64.3 and 63.3 g. So, replacement of germinated barley in 33 and 100%, but not 66%, to barley diet significantly decreased weight egg (P<0.05).

There was similar egg mass production for layers fed corn or barley diets. Laying hens fed enzyme diet had slightly higher egg mass than those birds fed barley diet (59.59 versus 57.67%). So, enzyme supplementation to barley diet led to increase egg mass production. Replacement of germinated barley to barley diet increased egg mass from 58.05% for GB33 diet to 61.08% for GB100 diet. The highest egg mass production was related for birds fed GB100 diet.

Table 3. Effect of dietary treatments on laying hen performance.

	Corn diet	Barley diet	Enzyme diet	Germinate barley GB33 diet	GB66 diet	GB100 diet	SEM	P-value
Daily feed intake (g)	127.72[abc]	129.68[a]	124.09[c]	128.67[ab]	129.14[a]	125.00[bc]	1.44	0.029
Feed conversion (g feed/g egg)	2.26[a]	2.28[a]	2.13[b]	2.20[ab]	2.21[ab]	2.04[c]	0.03	0.0003
Egg production (egg/hen d)	88.48[bc]	87.61[c]	92.22[ab]	90.97[bc]	91.14[bc]	95.97[a]	1.41	0.001
Egg weight (g)	64.71[a]	65.29[a]	64.54[ab]	63.74[bc]	64.63[a]	63.63[c]	0.3	0.001
Egg mass (g/hen/d)	57.47[b]	57.67[b]	59.59[ab]	58.05[b]	58.83[ab]	61.08[a]	0.94	0.064

[a, b, c,] Values with no common superscripts are significantly different (P<0.05).

3.3.Egg quality

The results for egg quality are shown in table 4. Significant differences were observed among the experimental diets for Shell thickness, albumen index, haugh unit and yolk color score (P<0.05), but, no for shape index, breaking strength and yolk index. Layers fed barley and corn diets had similar egg shell thickness (0.404 versus 0.398 mm, respectively). Enzyme supplementation to barley diet not significantly decreased egg shell thickness (0.4 mm), but replacement of germinated barley significantly decreased egg shell thickness (P<0.05). Layers fed GB33 diet had the lowest value of shell thickness (0.391 mm).

Table 4. Effect of dietary treatment on laying hen egg quality from 46 to 55 wk of age

	control	barley	Barley + enzyme	Germinate barley 33	66	100	SEM	P-value
Egg Shape index	73.84	74.18	74.20	73.34	74.67	74.20	0.35	0.16
Breaking strength (Kg/cm^2)	3.94	4.27	4.15	3.99	4.05	4.00	0.009	0.13
Specific gravity	1.082	1.083	1.082	1.083	1.082	1.081	0.0009	0.8
Shell Thickness (mm)	0.398 [ab]	0.404 [a]	0.400 [ab]	0.391 [c]	0.397 [b]	0.396 [bc]	0.002	0.001
Albumen index	9.86 [abc]	10.04 [ab]	9.91 [ab]	10.33 [a]	9.57 [bc]	9.32 [c]	0.19	0.01
Haugh Unit	87.05 [abc]	87.88 [ab]	87.41 [ab]	88.41 [a]	86.16 [bc]	84.97 [c]	0.75	0.02
Yolk color score	9.22 [a]	2.25 [b]	2.34 [b]	2.08 [b]	2.31 [b]	2.33 [b]	0.15	0.0001
Yolk index	42.84	42.14	42.01	42.40	42.47	42.13	0.26	0.25

[a, b, c,] Values with no common superscripts are significantly different (p < 0.05).

There was no significant difference between layers fed barley and corn diets for albumen index (10.04 versus 9.86) and Haugh unite (87.88 versus 87.05). Enzyme supplementation to barley diet not significantly decreased albumen index (9.91) and Haugh unite (87.41), but complete replacement of germinated barley (GB100 diet) significantly decreased albumen index (9.32) as well as Haugh unite (84.97) (P<0.05). Layers fed corn diet had significantly higher yolk color score than those birds fed barley diet or other diets (P<0.05). Neither enzyme supplementation nor germinated barley replacement had significant effect on yolk color score.

Table 5. correlation coefficients index

		Egg Shape index	Shell Thickness (mm)	Breaking strength (Kg/cm^2)	Specific gravity	Albumen index	Yolk index	Haugh Unit	Yolk color score
Egg Shape index	R	1	0.008	0.007	0.33	-0.05	-0.03	0.01	-0.06
	P		0.92	0.93	0.02	0.55	0.72	0.90	0.24
Shell Thickness (mm)	R		1	0.28	0.35	0.04	-0.009	0.02	0.10
	P			0.001	0.01	0.58	0.92	0.75	0.23
Breaking strength (Kg/cm^2)	R			1	0.43	-0.31	-0.35	-0.31	-0.15
	P				0.002	0.0004	<.0001	0.0004	0.100
Specific gravity	R				1	0.20	0.005	0.26	0.03
	P					0.16	0.97	0.07	0.82
Albumen index	R					1	0.47	0.96	0.08
	P						<.0001	<.0001	0.36
Yolk index	R						1	0.46	0.23
	P							<.0001	0.011
Haugh Unit	R							1	0.09
	P								0.30
Yolk color score	R								1
	P								

Pearson correlation coefficients (R) and probabilities of significance (*P*)

4.Discussion

The results of indicated germination roughly increases 10% crude protein and decreases 67% total β –glucan in barley. Tian et al. (2010) reported that protein content of oat seeds increase 16 percent and phytic acid decrease 68 percent during germination. They concluded the increase of proteins might be attributed to the dry weight losses through respiration during germination. Thus, the germinated seeds on a unite weight basis would contain more seeds and therefore more nitrogen than raw seeds. The decrease of phytic acid was attributed to an increase in phytase activity as germination progress.

Layers fed barley diet had equal performance to those birds fed corn diet. This may be related to their ability to intake sufficient amount of feed. Barley has high β-glucan content and may be expected to feed intake decrease because of reducing feed passage rate associated with viscous intestinal environment. However this effect was observed mainly in broiler chicks and young layers, not older layers like our experiment which birds were 44 weeks of age. Jeroch and Danicke (199٦) in their review article about barley in poultry feeding demonstrated in the majority of comparative experiments, the layers fed diets containing barley or corn as the single grain component had an equal or similar egg production performance. In our experiment, supplementing of β-glucanase enzyme to barley diet containing 60.6% barley significantly improved egg production, egg mass and feed conversion ($P<0.05$). There are some evidence indicated enzyme supplementation to layers barley diets resulted to improve egg production, egg mass and feed conversion (Tortuero and Fernández, 1995; Mathlouthi et al., 2002).) Also, The enzyme-induced lower viscosity limited microbial proliferation which otherwise would compete for nutrients, thus improving digestibility of DM, EE, total NSP and energy and ultimately performance of laying hens (Danicke et al., 1997; Langhout et al., 1997; Lazaro et al., 2003). However some researchers found no significant benefits on egg layer performance by adding enzymes to barley basal diet (Benabdeljelil and Arbaoui, 1994; Vukic and Wenk, 1995; Mathlouthi et al., 2003).

Lazaro et al. (2003) reported that cereals containing soluble fiber (wheat, barley and rye) can replace maize successfully in laying hen diets, and that enzyme supplementation improves digestibility and productive traits when added to soluble fiber cereals based diets.

However, Brufau et al. (1993) reported that Egg production, feed consumption, feed efficiency and egg weight of the hens were not affected by enzyme supplement and were similar to those of hens fed the corn diet. There were also no significant effects on feed consumption per gram of egg or per bird per day. In addition, Lazaro et al. (2003) reported that use of soluble fiber cereals (wheat, barley and rye) in the diet instead of maize did not affect egg production or food efficiency, but hens fed on soluble fibre cereals diets exhibited a higher incidence of dirty eggs than hens fed on the maize diet. This improvement could be due to an increase in both energy and fibre digestibilities with enzyme supplementation to barley diets (Vukic Vranjes and Wenk, 1996). As Germinated barley substitution affected signicantly some production factors including, daily feed intake, egg weight, egg production and egg mass, without any significant effect on Feed conversion. Using different levels of substitution of Germinated barley for barley had significant increased in egg production and egg mass but significant decreased egg weight and daily feed intake. Svihus et al. (1997) reported that performance was very similar in chickens given germinated and enzyme-treated barley, it is likely that the increased nutritional value after germineted was caused mainly by the reduced β-glucan content and viscosity of the barley. Fengler et al. (1990) reported that chick performance, as measured by feed to gain (F: G) ratio and apparent retention of dry matter and fat, was greater for chicks fed on diets containing germinated barley. Reduction in β-glucan content and viscosity after germinated demonstrates the effectiveness of endogenous enzymes activated during germinated (Svihus et al., 1997). Moreover, Svihus et al. (1997) observes that the ileal digestibility of protein, fat, and ash, and the digestible energy content were also higher with germinated of barley. Enzymes supplementation and germinated of barley reduce intestinal viscosity and decrease retention time of digest in the gut allowing for lower consumption and therefore improving feed conversion. Also, a reduce viscosity will improve contact between nutrients and digestive enzymes leading to improving digestibility.

Shell Thickness, albumen index and haugh unit reduced in hens fed on germinated barley diets, but using different levels of substitution of germinated barley for barley had relatively little or no effect on shape index, yolk index, Breaking strength, specific gravity and yolk color score.

Shell thickness of eggs from hens on germinated barley diets was lower than in those fed on barley diets. This decrease may be due increase Egg production in hens give germinated barley diet than those fed barley, increased egg production is reduced egg shell thickness.

Albumen index and haugh unit reduced in hens fed on germinated barley diets than in those fed on barley diet. Hammershoj and Kjaer (1999), who reported that albumen quality decreased with higher dietary protein content, we found lower haugh unit values in egg from hens on the diet with the high protein ratio. Svihus et al. (1997) reported that the ileal digestibility of protein were also higher with germinated of barley.

Hens fed on barley diets consistently laid eggs of lighter yolk color than those fed on the control diets ($p<0.05$). Benabdeljelil and Arbaoui, (1994) reported that yolk color was reduced when hens were fed on diets containing 40 or 50% barley. Enzyme supplementation preparations did not sustain similar yolk color when added to barley diets. However, enzyme supplementation to barley based diets improved egg yolk color significantly ($p>0.05$). Low egg yolk colour can be attributed to a lack of carotenoids in barley. Enhancement of egg yolk colour by enzyme addition may be due to better availability of fats as well as other fat-soluble compounds, such as vitamins and carotenoids, as a result of viscosity reduction. As expected, egg yolk colour score was higher in germinated barley 100% diets than that of other treatments ($p>0.05$). Svihus et al. (1997) reported that germinated of barley decreased the soluble and total β-glucan content. Germinated in the presence of enzymes produced the lowest β-glucan content and viscosity.

Germinated barley had no significant effect on Specific gravity, Breaking strength, yolk index or egg shape index of the laying hens during the experiment.

The results of this experiment confirm that barley can replace corn successfully in laying hen diets.

Accomplished by decreasing of feed intake. This effect may be related to release of nutrients Barley has a high concentration of β-glucan which surrounding nutrients in gut and cause low nutrient digestion and absorption. , because of the high β-glucan concentration in barley which interferes with nutrient digestion and absorption.

The present study feed intake was higher for the hens fed barley diets than for those fed maize (P> 0.05). These results agreed with reports Mohammed et al (2010) that feed consumption of laying hens was significantly increased with the increase in barley replacement. This increase may be due to utilization of soybean oil in the present study had a higher palatability than maize feed. Also, Rising et al. (1989) found that animal fat supplementation significantly improved energy balance (retention) of laying hens fed all formulations compared with the diets without added fat. Egg weight for the hens fed barley diets was similar to those fed maize.

References

Association of Official Analytical Chemists (AOAC). 1990. Official Methods of Analysis, 15th e Association of Official Analytical Chemists (AOAC) 1990. Official Methods of Analysis, 15th edn. Washington, DC, USA.

Bamforth, C.W., Martin, H.L., 1983. The degradation of B-glucan during malting and mashing: The roleof B-glucanase. J. Institute of Brewing. 89, 303-307.

Bedford, M.R., 1995. Mechanism of action and potential environmental benefits from the use of feed enzymes. Animal Feed Science and Technology.53:145-155.

Benabdeljelil, K., Arabaoui, M.I., 1994. Effects of enzymes supplementation of barley-based diets on hen performance and egg quality. Anim. Feed Sci. Technol. 48, 325-334.

Briggs, D.E., 1998. Malts and Malting. Blackie Academic and Professional, London.

Celus, I., Brijs, K., and Delcour, J.A., 2006. The effects of malting and mashing on barley protein extractability. Journal of Cereal Science. 44:203-211.

Choct, M., and Annison, G., 1992. The inhibition of nutrient digestion by wheat pentosans. British Journal of Nutrition. 67:123-132.

Choct, M., Annison, G., 1990. Anti-nutritive activity of wheat pentosans in broiler diets. Br. Poult. Sci. 31, 811–821.

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

Coon, C.N., Obi, I., Harm, M.L., 1988. Use of barley in laying hen diets. Poult. Sci. 67, 1306—1313.

Danicke, S., Simon, O., Jeroch, H. Bedford, M., 1997. Interactions between dietary fat type and xylanase supplementation when rye-based diets are fed to broiler chickens. 2. Performance, nutrient digestibility and the fat-soluble vitamin status of livers. Br. Poult. Sci. 38, 546–556.

Ebihara, K., Schneeman, B.O., 1989. Interaction of bile acids, phospholipids, cholesterol and triglyceride with dietary fibers in the small intestine of rats. J. Nutr. 119, 1100–1106.

Fengler, A.I., Aherne, F.X., and Robblee, A.R. 1990. Influence of germination of cereals on viscosity of their aqueous extracts and nutritive value. Animal Feed Science and Technology. 28:243–253.

Francesch, M., Perez-Vendrell, A.M., Esteve-Garcia, E., Brufau, J., 1994. Effects of cultivar, pelleting and enzyme addition on nutritive value of barley in poultry diets. Br. Poult. Sci. 35:259-272.

Hamilton, R.M.G., Proudfoot, F.G., 1993. Effects of dietary barley level on the performance of Leghorn hens. Can. J. Anim. Sci. 73:625-634.

Hammershoj, m., and kjaer, j.b. (1999) phase feeding for laying hens, effect of protein and essential amino acids on egg quality and production. Acte agriculturae scandinavica, section a, anim. Sci. 49, 31-41.

Holder, D.P., Bradford, M.V., 1979. Relationship of specific gravity of chicken eggs to number of cracked eggs and percent shell. Poult. Sci. 58:250-251.

Jeroch, H. and Danicke, S. 1995. Barley in poultry feeding. World's Poultry Science Journal. 51: 271-291.

Langhout, D.J., Schutte, J.B., Geerse, C., Kies, A.K., Dejong, J., Verstegen, M.W.A., 1997. Effects on chick performance and nutrient digestibility of an endoxylanase added to a wheat- and rye-based diet in relation to fat source. Br. Poult. Sci. 38, 558–563.

Lazaro, R., Garcia, M., Aranibar, M. J., and Mateos, G. G. 2003. Effect of enzyme addition to wheat, barley and rye-based diets on nutrient digestibility and performance of laying hens. British Poultry Science. 44: 256–265.

Lazaro, R., Garcia, M., Aranibar, M.J., Mateos, G.G., 2003. Effect of enzyme addition to wheat-, barley- and rye-based diets on nutrient digestibility and performance of laying hens. Br. Poult. Sci. 44, 256–265.

Mathlouthi N, Mohamed, M.A., Larbier, M., 2003. Effect of enzyme preparation containing xylanase and beta-glucanase on performance of laying hens fed wheat/barley- or maize/soybean meal-based diets. Br. Poult . Sci., 44, 60-66.

Mohammed, Kh.A., Toson, M.A., Hassanien H.H.M., Soliman M.A.H., Sanaa, H.M. El-Nagar, 2010. Effect of barley replacement and energy supplementation on performance and egg quality of laying hens. Egypt. Poult. Sci. 30, 731-745.

NRC, 1994. Nutrient Requirements of Poultry, 9th revised ed. National Academy Press, Washington, DC.

Rising, R., Maiorino, P., Alak, J., Reid, B., 1989. Indirect calorimetry evaluation of dietary protein and animal fat effects on energy utilization of laying hens. Poultry Science, 68, 258-264.

Roberts, J.R., and Choct, M., 2006. Effects of commercial enzyme preparations on egg and eggshell quality in laying hens. Br. Poult. Sci. 47, 501-510.

SAS Institute Inc., 2001. Release 8.2 (TS2MO) of the SAS® System for Microsoft® Windows®. SAS Institute Inc., Cary, NC, USA.

Smits, C.H.M., Veldman, A., Verstegen, M.W.A., Beynen, A.C., 1997. Dietary carboxymethylcellulose with high instead of low viscosity reduces macronutrient digestion in broiler chickens. J. Nutr. 127, 483–487.

Svihus, B., Newman, C.W., Newman, R.K., Selmer-Olsen, I., 1997. Changes in extract viscosity, amino acid content, and soluble and insoluble β-glucan and dietary fibre content of barley during different high moisture storage conditions. Animal Feed Science and Technology. 64: 257-272.

Tian, B., Xie, B., Shi, J., Wua, J., Cai, Y., Xu, T., Xue, S., and Deng, Q. 2010. Physicochemical changes of oat seeds during germination. Food Chemistry. 119: 1195–1200.

Tortuero, F., Fernández, E., 1995. Effects of inclusion of microbial cultures in barley-based diets fed to laying hens. Anim. Feed Sci. Technol. 53, 255-265.

Von Wettstein D., Mikhaylenko, G., Froseth, J.A., Kannangara, G., 2000. Improved barley broiler feed with transgenic malt containing heat-stable (1,3-1,4)-b-glucanase. Proc. of the National Academy of Sciences USA, 97, 13512-13517.

Vukic Vranjes, M., and Wenk, C., 1996. Influence of Trichoderma viridae enzyme complex on nutrient utilization and performance of laying hens in diets with and without antibiotic supplementation. Poultry Science. 75:551–555.

Vukic Vranjes, m., Wenk, C., 1995. Influence of dietary enzyme complex on the performance of broilers fed on diets with antibiotic supplementation. Br. Poult. Sci. 36, 265-275.

Wyatt, C.L., Goodman, T., 1993. Utilization of feed enzymes in laying hen rations. J. of Appl. Poul. Res. 2, 68-74.