Changes of Intestine Dimensions Determined by Barley and Wheat-Based Non Starch Polysaccharides (NSP) in Broilers

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Abstract

The objective of this experiment was to determine the main intestine dimension changes generated by the NSP content of the combined forage and by beta glucanase utilization in concordance with barley and wheat proportion in the structure of the combined forage for broilers. In this viewpoint, we carried out an experiment consisted of 5 experimental variants, as follows: EG1 - fed with a combined forage without barley, EG2 - fed with a combined forage including 60% barley in its structure in the first and second growth periods as well, EG3 - fed with a combined forage similar with the one offered in EG2, but with addition of beta glucanase 75 ppm, EG4 – with the enzyme in a quantity of 100 ppm and EG5 - 50 % of the barley amount was replaced with wheat and we also added beta glucanase 75 ppm. At the end of the experiment, successive to chicken killing, we determined the main changes at intestine dimension level and muscle stomach. By incorporating barley in proportion of 60 % in the combined forage structure, the intestinal dimensions (length, diameter) get changed, and also the width of the muscle stomach. The incorporation of enzymes in the combined forage structure reduces the differences available between the intestinal dimensions in the group fed with enzyme and the one that was not fed with enzyme: there are significant differences ($p<0.05$) between the length of duodenum, cecum and ileonum of the chickens fed with forage including beta glucanase 75 ppm and the chickens fed with forage including barley without beta glucanase, of up to 20 %. There are also significant differences in the case of the muscle stomach diameter, of up to 25 %.

Keywords: barley, broiler, intestine dimensions, non starch polysaccharides, wheat

1. Introduction

The use of enzymes in poultry diets in Europe is now almost universal. The reasons why they are used are manifold and include: to reduce the variation in nutrient quality of ingredients. The response to the use of enzymes is greatest on the poorest quality raw materials [1-4]; to reduce the incidence of wet litter. Feeding diets rich in barley, rye, oats, triticale and to a lesser extent wheat, often results in the production of viscous, wet manure [5-10]. The chemical nature of NSP differs from one ingredient to the other but most NSP generally increase digesta viscosity which interferes with nutrient intake and body growth [11; 12]. The effects of NSP on intestinal structure and function as well as measures aimed at reducing their impact on animal productivity have been reported in previous studies [13,14]. Although the effects of viscous NSP on poultry have been evaluated by previous researchers [15-18], the impact of these compounds at the intestinal level has not been widely reported. In the rat, viscous NSP were shown to increase intestinal weight and mucosal cell proliferation rate [19,14]. Over a longer duration of feeding, the response to NSP may vary with duration of adaptation and responses could be transient rather than permanent [14].

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2. Materials and methods

In order to complete the objective of this work, we organized an experiment consisted of 5 experimental groups, as follows: EG1 fed combined forage without barley, EG2 fed combined forage with 60 % barley in its structure during the first growth period and the second growth period as well, EG3 fed combined forage that was similar with the one in EG2, but with addition of beta glucanase in quantity of 75 ppm, EG4 where the enzyme quantity increased to 100 ppm and EG5 where 50 % of the barley quantity was replaced by wheat, with supplementation of beta glucanase in quantity of 75 ppm. These amounts are available for the period 0-3 weeks and for 3-6 weeks as well. At the age of 6 weeks old, we killed 5 chickens from each experimental variant and determined the intestine dimensions: length, diameter of duodenum, jejunum, ileonum, cecum, muscle stomach length, width, stomach wall width. Analyses of combined forages' nutritive content . To determine the nutritive value of the combines forages offered to broiler chickens in our experiments, we applied the standard methods according to WEENDE scheme, respectively:

- DM (%) – stove-drying at 105 ^{0} C
- CP (%) – Kjeldahl method
- CF (%) – Soxhlet method
- CC (%) – Van Soest method.

Determination of intestine dimensions in broiler chickens

- Length, diameter of duodenum, jejunum, ileonum, cecum
- Muscle stomach length, width, stomach wall width.

Biological material used in experiment

The hybrids used for meat production in intensive system are tetra-linear biracial, obtained through the simple hybridation of two White Cornish lines (paternal genotype) and two White Plymouth Rock lines (maternal genotype). Actually, the cross-breeding occurs between hybrid Cornish cocks and hybrids Plymouth Rock hens. The experiments were carried out on meat chickens, the hybrid Ross 308, at the Department of Animal Nutrition and Alimentation, from the Didactic Station of Banat's University of Agricultural Sciences and Veterinary Medicine Timişoara.

The organization scheme of the experiment is presented in table 1.

Table 1 Organization scheme of the experiment

Period 0-3 weeks				
EG1	**EG2**	**EG3**	**EG4**	**EG5**
CF (0 % barley) ME (kcal/kg) 3204 CP 22.91%	CF (60 % barley) ME (kcal/kg) 2991.55 CP 21.52%	CF (60 % barley plus beta glucanase 75 ppm) ME (kcal/kg) 2991.55 CP 21.52%	CF (60 % barley plus beta glucanase 100 ppm ME (kcal/kg) 2991.55 CP 21.52%	CF (30 % barley 30 % wheat plus beta glucanase 75 ppm) ME (kcal/kg) 3082.28 CP 22.25%
Period 3-6 weeks				
EG1	**EG2**	**EG3**	**EG4**	**EG5**
CF (0 % barley) ME (kcal/kg) 3244 CP 20.16%	CF (60 % barley) ME (kcal/kg) 3038.96 CP 18.94%	CF (60 % barley plus beta glucanase 75 ppm) ME (kcal/kg) 3038.96 CP 18.94%	CF (60 % barley plus beta glucanase 100 ppm ME (kcal/kg) 3038.96 CP 18.94%	CF (30 % barley 30 % wheat + beta glucanase 75 ppm) ME (kcal/kg) 3082.28 CP 22.25%

The nutritional characteristics of the combined forage used in this experiment are presented in table 2.

Table 2. Combined forages nutritive characteristics used for feeding broiler chicken from all five experimental groups

	EG1		EG2		EG3		EG4		EG5	
Specification	**Period 0- 3 weeks**	**Period 3-6 weeks**	**Period 0- 3 weeks**	**Period 3-6 weeks**	**Period 0- 3 weeks**	**Period 3-6 weeks**	**Period 0- 3 weeks**	**Period 3-6 weeks**	**Period 0- 3 weeks**	**Period 3-6 weeks**
Metabolizable energy (kcal/kg forage)	3204	3244	2991.55	3038.96	2991.55	3038.96	2991.55	3038.96	3082.28	3131.21
Crude protein (%)	22.91	20.16	21.52	18.94	21.52	18.94	21.52	18.94	22.25	19.49
Lysine (%)	1.27	1.04	1.18	0.98	1.18	0.98	1.18	0.98	1.17	0.96
Methionine + cystine (%)	0.95	0.73	0.9	0.72	0.9	0.72	0.9	0.72	0.90	0.72
Calcium (%)	1.03	0.84	1.12	0.94	1.12	0.94	1.12	0.94	1.10	0.91
Total phosphorus (%)	0.73	0.65	0.68	0.58	0.68	0.58	0.68	0.58	0.70	0.60

According to the data presented in the table above, we may notice that during the first growth period, from 0 to 3 weeks, the energetic level of the combined forage was 2991.55-3204 kcal metabolisable energy, and the protein level was between 21.52%-22.91%.

During the second growth period, respectively from 3 to 6 weeks, the energetic level of the combined forage was comprised between 3038.96-3244 kcal metabolisable energy, and the protein level was 18.94%-20.16%.

The lysine, methionine + cystine, calcium and phosphorus were provided according the meat chicken requirements [20].

3. Results and discussion

According to tabular data and to the determinations performed in the laboratory from Dublin University, we obtained the soluble, insoluble and total NSP content of the combined forage; these values are presented in table 3. Cereals contain variable amounts of non-starch polysaccharides. Some of them, like wheat, contain big amounts of arabinoxylans (8.1 %), and others, like barley, contain big amounts of beta glucans (4.3 %) [21].Cereals' content in NSP increases with cereals' proportion of participation in the structure of combined forage. So, we may observe that during the growth period 0 - 3 weeks, compared with the forage from LE1 which did not contain barley, the LE2 with 60 % barley presented a bigger NSPs content with 1.914 percentage points, the NSPi with 1.974 and the NSPt with 3.888 percentage points. The replacement of barley with wheat, in proportion of 50% (namely with a participation of 30 % barley and 30 % wheat), determines a NSPs content increase with only 0.522 percentage points. Compared with LE2, whose feed included barley in proportion of 60 %, the NSPi content is smaller with 0.894 percentage points, and the NSPt with 0.938 percentage points. During the period 3 - 6 weeks, LE2 presented a NSPs content that was bigger with 2.501 percentage points compared with LE1, whose forage was not supplemented with barley. The NSPi content was bigger with 1.97 percentage points, and the NSPt with 4.47 percentage points. By substituting barley with wheat, the NSPs amount decreases with 0.631 percentage points, the NSPi with 1.36 percentage points and the NSPt with 1.991 percentage points.

Anatomical intestine assessment of the broiler chickens used for the experimental groups

At the end of the experiment, we killed a number of 5 broiler chickens from each experimental variant. We determined the main parameters, respectively intestine length and diameter, and in the case of the muscle stomach we determined length, width and muscle stomach wall width. The results obtained were presented in table 4.

Table 3. Combined forages content on the non-starch polysaccharides (NSP)

Growth period	Specification	NSPs[1] (%)	Percentage differences	NSPi[2] (%)	Percentage differences	NSPt[3] (%)	Percentage differences
Period 0-3 weeks	0% barley	0.85	-	9.3	-	10.15	-
	60 % barley	2.764	1.914	11.274	1.974	14.038	3.888
	30 % wheat 30 % barley	3.286	0.522	10.38	- 0.894	13.1	-0.938
Period 3-6 weeks	0 % barley	0.79	-	9.35	-	10.14	-
	60 % barley	3.291	2.501	11.32	1.97	14.611	4.47
	30 % wheat 30 % barley	2.66	-0.631	9.96	- 1.36	12.62	-1.991

1 soluble non-starch polysaccharides
2 insoluble non-starch polysaccharides
3 total non-starch polysaccharides

Table 4. Main parameters of intestine evolution in the broiler chickens used for the experimental variants

Specification	LE1	CV	LE2	CV	LE3	CV	LE4	CV	LE5	CV
	X ± SX	(%)	X ± SX	(%)	X ± SX	(%)	X ± SX	(%)	X ± SX	(%)
Duodenum										
Length (L)	27±3.76	13.92	35.5±2.14	13.49	28.654±0.988	3.45	30.748±1.002	3.26	30.0±2.35	7.82
Diameter (D)	0.85±0.1	11.76	0.99±0.06	13.88	0.866±0.0764	8.82	0.95±0.1451	15.27	0.91±0.02	2.94
Jejunum										
Length (L)	147.6±6.57	4.45	145.5±1.8	2.77	150.65±4.04	2.68	165.56±13.62	8.23	138±9.54	6.91
Diameter (D)	0.91±0.1646	18.09	1.099±0.0743	15.12	0.792±0.0934	11.79	1.222±0.1462	11.96	1.162±0.2	17.33
Ileonum										
Length (L)	22.5±1.931	8.58	20.00±0.447	5	23.696±0.731	3.09	21±0.141	0.67	22.5±2.07	8.92
Diameter (D)	0.82±0.0321	3.89	0.783±0.0377	10.78	0.916±0.0945	10.32	0.85±0.0785	9.22	0.76±0.06	8.68
Cecum										
Length (L)	22.5±1.237	5.5	18.746±0.426	5.08	21.646±1.156	5.34	22.146±1.565	7.07	20.75±1.5	5.35
Diameter (D)	1.09±0.077	7.13	1.411±0.0794	12.59	1.516±0.1316	8.68	1.151±0.0745	6.48	1.50±0.15	9.96
Muscle stomach										
Length (D)	6.5±0.464	7.13	6.9±0.170	5.52	6.6±0.632	9.58	7±0.707	10.1	6.78±0.53	7.81
Width (l)	5±0.748	14.97	5.5±0.272	11.06	5.5±0.608	11.06	5.7±0.604	10.6	5.3±0.308	5.82
Wall width (G)	0.441±0.0534	12.12	0.62±0.0145	5.16	0.463±0.0476	10.29	0.553±0.0887	16.04	0.50±0.0902	17.89

According to this table, we may draw the conclusion that, regarding duodenum length, this is bigger in the group fed barley with 8.5 cm. These differences get smaller in the case of utilization of beta glucanase in quantity of 75, respectively 100 ppm.

In the case of jejunum, barley incorporation in the combined forage structure in proportion of 60 % does not change the dimension, while the addition of enzymes determines an increase of jejunum dimension with 20 cm. Ileonum and cecum dimensions do not present any changes generated by the introduction of barley or enzymes in the combined forage structure. The introduction of beta glucanase in combined forage structure determined a reduction of muscle wall width with 0.157 cm.

The significance of the differences between the intestinal dimensions in the case of chickens from the experimental variants is presented in the following tables.

Table 5. Significance differences between the digestive system components of GE2 and GE1

Specification			GE1										
			Duodenum		Jejunum		Ileonum		Cecum		Muscle stomach		
			L	D	L	D	L	D	L	D	L	l	D
GE2	Duodenum	L	+8.5 0.036										
		D		0.075									
	Jejunum	L			0.676								
		D				0.210							
	Ileonum	L					-2.5 0.047						
		D						0.676					
	Cecum	L							-3.75 0.0122				
		D								+0.321 0.0122			
	Muscle stomach	L									0.250		
		l										0.342	
		D											0.122

Table 6. Difference significance between the digestive system components of GE2 and GE3

Specification			GE3										
			Duodenum		Jejunum		Ileonum		Cecum		Muscle stomach		
			L	D	L	D	L	D	L	D	L	l	D
GE2	Duodenum	L	-6.85 0.0122										
		D		0.143									
	Jejunum	L			0.094								
		D				-0.307 0.0216							
	Ileonum	L					+3.696 0.0122						
		D						0.060					
	Cecum	L							+2.9 0.0122				
		D								0.403			
	Muscle stomach	L									0.464		
		l										1.000	
		D											-0.157 0.0122

Table 7. Difference significance between the digestive system components of GE2 and GE4

Specification			GE4										
			Duodenum		Jejunum		Ileonum		Cecum		Muscle stomach		
			L	D	L	D	L	D	L	D	L	l	D
GE2	Duodenum	L	0.117										
		D		0.834									
	Jejunum	L			+20.06 0.028								
		D				0.210							
	Ileonum	L					0.143						
		D						0.210					
	Cecum	L							+3.4 0.021				
		D								-0.26 0.021			
	Muscle stomach	L									0.916		
		l										0.754	
		D											0.210

Table 8. Difference significance between the digestive system components of GE2 and GE5

Specification			GE5										
			Duodenum		Jejunum		Ileonum		Cecum		Muscle stomach		
			L	D	L	D	L	D	L	D	L	l	D
GE2	Duodenum	L	0.094										
		D		0.610									
	Jejunum	L			0.250								
		D				0.530							
	Ileonum	L					+2.5 0.047						
		D						0.834					
	Cecum	L							+2.01 0.036				
		D								0.530			
	Muscle stomach	L									1.000		
		l										0.676	
		D											-0.12 0.021

Barley incorporation in proportion of 60 % in the combined forage destined for the chickens in GE2 also determines some intestinal changes. So, there are significant differences between the duodenum length of the chickens fed barley and those that did not consume barley in the combined forage ($p<0.05$). The same differences are available between the length of the ileonum, cecum and the cecum diameter ($p<0.05$). The differences between the other dimensions are insignificant from a statistical point of view. The addition of beta glucanase in the combined forage structure determines changes of the intestinal dimensions. In this viewpoint, there are significant differences ($p<0.05$) between the length of the duodenum, cecum and ileonum in the chickens that consumed forage with beta glucanase in quantity of 75 ppm and those that consumed forage with barley, without beta glucanase. Also significant differences are between the diameter of jejunum and the diameter of the muscle stomach. The addition of bet glucanase in quantity of 100 ppm reduces the differences between the dimensions of intestines, so that there are significant differences ($p<0.05$) between the lengths of the cecum and jejunum of the two groups. Also, there are differences between the diameters of the cecum of the two experimental groups ($p<0.05$).The substitution of barley with wheat in proportion of 50 % and the addition of beta glucanase in dose of 75 ppm determines some changes of intestinal dimensions, so that the jejunum length and the cecum length differ, with statistically significant differences ($p<0.05$). Also, there are differences between the diameters of the muscle stomach in the case of the two groups (LE2 and LE5). The viscous NSP increased the weight of the small intestine but not the weight of the gizzard + proventriculum or liver. Changes in the empty weight of visceral organs are generally due to variation in rate of cell proliferation, cell size or proien synthesis [22]. [19].had observed an increase in the intestinal length of rats when fed diets that were supplemented with guar gum and traced this to an increase in mitotic activity within the mucosa. Enzyme supplementation of diets based on rye, wheat, barley or oats can reduce the mentioned adverse effects [23,10]. Enzymes decrease the viscosity of gut contents, resulting in improvements in nutrient digestibility and performance when added to poultry diets [24,25, 26].

4. Conclusions

- by incorporating barley in proportion of 60 % in the combined forage structure, we obtain changes of **intestinal dimensions** (the length of duodenum, cecum and ileonum) or of width in the case of the muscle stomach (diameter);
- enzyme incorporation in the combined forage structure reduces with about 25% the differences available between the intestinal dimensions of the group fed with enzyme and the one that did not consume enzyme.

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