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ORIGINAL PAPER

Evaluating the anti-nutritive effect of non-starch polysaccharides (NSP) correlated with the nutritional, digestive and productive performance indices in broilers

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STEF LAVINIA[1], DRINCEANU DAN[1], CORCIONIVOSCHI NICOLAE[2] , SIMIZ ELIZA, STEF DUCU[1], JULEAN CĂLIN[1]
[1]Banat's University of Agricultural Sciences and Veterinary Medicine, Faculty of Animal Sciences and Biotechnology,Timisoara, Romania
[2]The Children's Research Centre, Our Lady's Hospital for Sick Children, University College Dublin, Dublin, Ireland
Corresponding author e-mail address: laviniastef@gmail.com

Abstract

The aim of this experiment was to assess the antinutritive effect of non-starch polysaccharides (NSP) from wheat grains on productive and digestive indices in broilers. The proportion of wheat into the feeding mixture was between 0 and 40%. Also the correlation coefficients between different digestive indices (e.g. intestinal viscosity) and NSPs, NSPi and NSPt as a result from participation in various proportions in the structure of wheat feed (0-40%) were closely analysed. The increase in the NSP content of broiler feed resulted in feed consumption decreases by up to 4.94% in LE2 group who consumed feed containing 30% wheat. Body weight decreases (with 4.1%) following an increase in the NSPi and NSPs content of broiler feed, but the data is not statistically significant. The feed conversion increased at the experimental groups that have consumed feed containing at a level of 2.91%. At 3 weeks of age the intestinal viscosity increased (by 53.07%) at the experimental group, fed with 40% wheat, and at 6 weeks of age the duodenal viscosity increased by 49.04% and the jejuna viscosity increased by 33.15%. At the age of 3 weeks the correlation coefficients between the NSP content and viscosity in the duodenum are positive, the highest correlation coefficient was detected for NSPs (0.995), which shows that the viscosity of the intestinal tract is influenced by the feed content in NSPs. At 6 weeks of age the correlation coefficients between the NSP content and duodenal and jejunal viscosity are positive, the highest correlation coefficient being recorded for NSPs (0.942). Following these experiments we have concluded that wheat incorporation into broilers feed can change the main nutritional, productive and digestive indices especially until the age of 3 weeks, which recommends the need for enzymes incorporation on order to combat the non-nutritive effect of NSP.

Introduction

Wheat grains contain relatively high concentrations of non-starch polysaccharides (NSP), which are indigestible by broilers. These complex carbohydrates can lead to reduced digestibility of nutrients when included in broiler diets. Wheat is primarily used in broiler feeds for its content of available energy and there is considerable variation in the metabolisable energy (ME) of different wheat samples (Pirgozliev *et al.*, 2003). The main NSP found in wheat are arabinoxylans and typically, the grain contains approximately 66 g/kg arabinoxylan. The total NSP content of wheat is ranging between 8.3-9.8% (Steenfeldt, 2001). In wheat grains the starch and proteins are entrapped by cell wall polysaccharides and has been suggested as an important factor by which NSP exert their antinutritive properties. In this context, the use of multi-carbohydrase preparations to target various fractions of wheat NSP may provide a potential for further improvements in the nutritive value of wheat. In monogastrics these are mainly fermented by microbes in the hindgut (Bakker *et al.*, 1998). It was demonstrated that addition of soluble NSP to a broiler chicken diet increased volatile fatty acid (VFA) production in the ileum, which was easily reversed when the NSP were

depolymerized with an enzyme (Choct *et al.*, 1996). It was shown for example that 7% NSP of defatted rice bran had no antinutritive effect on nutrient digestibility but positively influences the metabolizable energy of the diet (Adrizal *et al.*, 1996). The antinutritional effect of the NSP has been always in the nutritionist atention and they have noted that into a combined forage based in wheat, barley, rye, soybean, their proportion can reach 12-16% of dry substance of the combined forage and to (?) determine a growth if the digetive viscozity of the intestin. It has been also demonstrated that because of viscozity the combined forages with high content of NSP do have a lower digestibility, which can affect the economical and productive indicators of the chicken or pigs farms. There are two mechanisms proposed for the anti-nutritional effect of soluble NSPs. One mechanism reffers to the fact that starch and protein in wheat endosperm are encapsulated by the cell wall NSPs. The second mechanism, which is important for this study, is related to higher digesta viscosity as a direct effect of soluble NSPs because the difussion of the digestive enzymes is reduced (Amerah *et al.*, 2008). The aim of this paper was to study the antinutritional effect of wheat NSP with regards to intestinal viscosity, productive and digstive indices in broilers, in order to justify the possibility of enzyme usage in poultry nutrition. Enzymes will improve nutrient utilisation and apparent metabolisable energy following NSPs degradation in the cell wall matrix.

Material and methods

The experiment was conducted over a period of six weeks, on 120 chickens divided into four experimental groups (LM, LE1, LE2 and LE3). 308 Ross broilers were used. Broilers of the four experimental groups were fed as follows: first 3 weeks from hatching with feed providing between 3117-3175 kcal ME and CP 22.26-22.69%. In the second period from 3 to 6 weeks feed provided 3161-3212 kcal ME and 19.99-20.16% CP. The difference between groups was the rate of wheat incorporation in the combined feed structure which is between 0 and 40% throughout the experiment, respectively from hatching up to 6 weeks of age. The more detailed experimental design is presented in table 1 and also the feed composition in table 2.

Table 1. Experimental design

0-3 weeks			
Control	LE1	LE2	LE3
0 % wheat	20 % wheat	30 % wheat	40 % wheat
3-6 weeks			
Control	LE1	LE2	LE3
0 % wheat	20 % wheat	30 % wheat	40 % wheat

Table 2. Combined forages structure and their nutritive characteristics

Component	LM		LE1		LE2		LE3	
	0- 3 weeks	**3-6 weeks**	**0- 3 weeks**	**3-6 weeks**	**0- 3 weeks**	**3-6 weeks**	**0- 3 weeks**	**3-6 weeks**
Corn	54.18	60.26	35.69	43.26	26.7	34.27	17.7	24.77
Wheat	0	0	20	20	30	30	40	40
Soybean meal	34	31	32	28	31	27	30	26
Fish meal	5	2	5	2	5	2	5	2
Sunflower oil	3.5	3.5	4	3.5	4	3.5	4	4

Calcium carbonate	1	1	1	1	1	1	1	1
Di-calcium phosphate	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL Methionin	0.27	0.19	0.26	0.19	0.25	0.18	0.25	0.18
Vitamin and mineral premix	1	1	1	1	1	1	1	1
Nutritive characteristics								
ME (kcal/kg feed)	3175	3212	3160	3177	3138	3165	3117	3161
Crude protein (%)	22.26	20.16	22.45	19.98	22.57	19.99	22.69	19.99
Lysine (%)	1.2	1.05	1.22	0.99	1.21	0.98	1.19	0.98
Methionine+ cysteine (%)	0.9	0.72	0.89	0.72	0.89	0.72	0.89	0.72
Calcium (%)	1.01	0.8	1	0.8	1	0.81	1	0.81
Total phosphorous (%)	0.68	0.5	0.69	0.59	0.7	0.59	0.71	0.6

Results and discussions

Combined forages content in non-starch polysaccharides (NSP)

The aim of this experiment was to determine the NSP content (NSPs, NSPi and NSPt) from the combined forages. The information available in the literature is referring mainly to individual crops and quite confusing in regards to most of the combined forages commercially available at present (table 3).

Table 3. Non-starch polysaccharides (NSP) content of the combined forages

Growth period	Characteristics	NSPs* (%)	%	NSPi** (%)	%	NSPt*** (%)	%
0-3 weeks	Combined forage with 0% wheat	0.722	-	7.9	-	8.62	-
	Combined forage with 20% wheat	1.08	0.358	7.93	0.03	9.01	0.39
	Combined forage with 30% wheat	1.26	0.538	7.96	0.06	9.22	0.6
	Combined forage with 40% wheat	1.44	0.718	7.99	0.09	9.43	0.81
3-6 weeks	Combined forage with 0% wheat	0.66	-	7.56		8.22	-
	Combined forage with 20% wheat	1.005	0.345	7.95	0.39	8.955	0.735
	Combined forage with 30% wheat	1.18	0.52	7.97	0.41	9.15	0.93
	Combined forage with 40% wheat	1.36	0.7	7.98	0.42	9.34	1.12

* soluble NSP
** insoluble NSP
*** total NSP

Evolution of feed consumption

To determine the feed consumption the amount of feed administered to each experimental group was weighted and also the amount of debris at the age of 3 and 6 weeks. Using the data available we have calculated the feed consumption/chick/experimental period. The results are summarised in figure 1. Following these results it can be seen that in the first period of growth, 0 to 3 weeks, LE1 recorded a feed consumption with 8.14% higher compared to the control group and with 5.04% in comparison to LE2 group. The LE3 group had a feed consumption with 11.73% lower compared with the control group. In the second period of growth, 3-6 weeks, LE1 has a lower feed consumption of 0.56% and with 7.85% lower for LE2 compared to control group. LE3 group consumed with 1.55% more feed compared with the control group. Throughout the growth period LE1 feed consumption was higher than the control group (1.86%), but lower for LE2 (4.94%) and LE3 (1.61%). Therefore we can say that increasing the percentage of wheat in feed leads to reduced feed consumption.

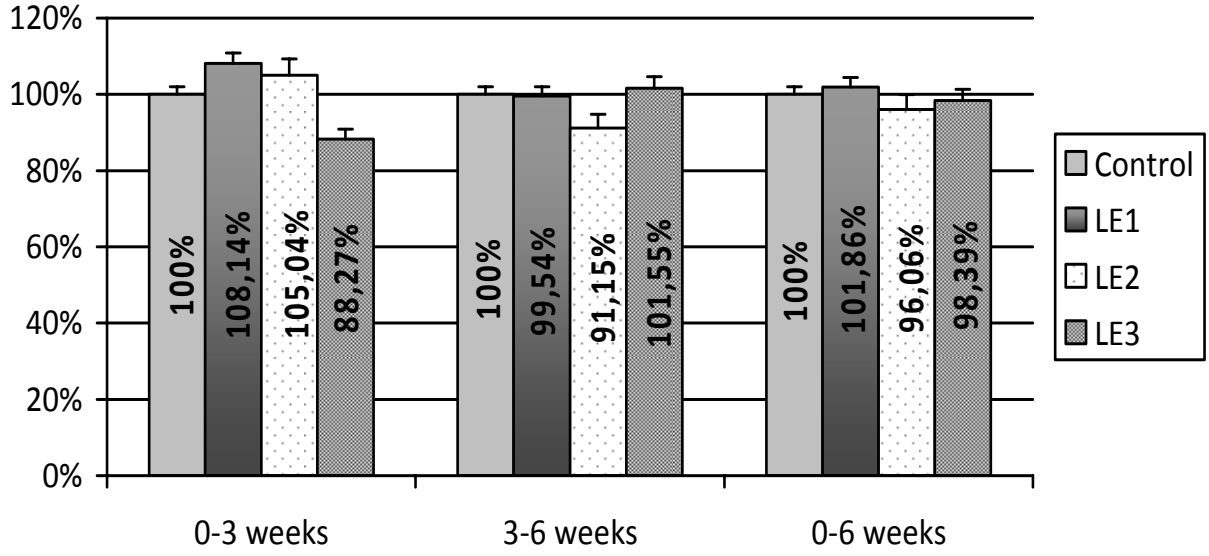

Figure 1. Feed consumption during the experiment

Evolution of Broiler's weight during the experiment

In order to determine the body weight birds were weighted at the age of 3 and 6 weeks. The obtained data are presented in table 4. In the first period of growth, at the age of 3 weeks, LE1 group has a lower body weight (800.57 g) by 3.17% compared with the control group (826.73 g), group LE2 (799.57 g) with 3.29%, and LE3 group (761.89 g) with 7.85%. These differences in body weight between LE1 group and the control group and between LE2 and the control group were not statistically significant, however in the case of LE3 group and the control group the results were statistically significant ($p < 0.05$). At 6 weeks of age, chickens from LE1 group (2210.41 g) had a lower body weight compared with the control group (2224.76 g) with 0.65%, those of LE2 group (2205.15 g) with 0.89 %, while those in LE3 group with 4.1% (2133.625 g). At that age differences in body weight were not statistically significant. Overall it may be noted that at 6 weeks of age most body weight is recorded for the control group who did not consumed wheat (2224.769 kilograms) during the experiment.
Throughout the period of growth it can be observed that the greatest increase in weight is recorded in the control group (2185.769 g), followed by LE1 group (2171.41 g), LE2 group (2166.15 g) and LE3 group (2094.625 g). It can be concluded that the increase in weight stops with the increment in the proportion of wheat in feed composition.

Table 4. Broiler's Weight evolution during the experiment

	Control	LE1	LE2	LE3
n	30	30	30	30
Weight at hatching (g)	39±0.38	39±0.33	39±0.32	39±0.43
n	27	28	29	28
Weight at 3 weeks of age (g)	**826.73±19.06**	**800.57±22.95**	**799.57±27.73**	**761.89±28.87**
%	100	96,83	96,71	92,15
Weight gain through the experiment	787.73	761.57	760.57	722.89
Average daily gain (g)	37.51	36.26	36.21	34.42
Variation (%)	10.05	14.59	15.11	16.51
Statistical differences	-	NS	NS	*
Weight at 6 weeks of age (g)	**2224.769±67.45**	**2210.41±62.09**	**2205.15±84.16**	**2133.625±66.15**
%	100	99.35	99.118	95.9
Weight gain	1437.03	1448.84	1444.58	1410.735
Average daily gain (g)	68.43	68.99	68.78	67.17
Variation (%)	10.93	11.9	15.26	12.4
Statistical differences	-	NS	NS	NS
Total gain 0-6 weeks	2185.769	2171.41	2166.15	2094.625
Average daily gain 0-6 weeks	52.04	51.7	51.57	49.87

NS – $p > 0.05$; * $p - < 0.05$;** $p < 0.01$;*** $p < 0.001$

Broiler's feed conversion efficiency

Feed conversion was recorded during the experiment for all the experimental groups. The data obtained is summarised in figure 2. Regarding the feed conversion of chickens, in the first period of growth, LE1 group (1.52 kg) has a feed conversion with 12.59% higher, LE2 group (1.47 kg) with 8.88% higher compared to the control group. However, LE3 group (1.3 kg) has a feed conversion with 4% lower compared with the control group (1.35 kg). In the second period of growth (3-6 weeks) LE1 group (2.42 kg) recorded a feed conversion efficiency by 2% lower, LE2 group (2.39 kg) with 3% lower compared to the control group (2.46 kg), and LE3 group (2.54 kg) with 3.25% higher. Throughout the experimental period of growth LE1 group (2.1 kg) recorded a higher feed conversion efficiency compared with the control group (2.06 kg) 1.94%, LE2 group (2.07 kg) 0.84% and LE3 group (2.12 kg) to 2.91%. As a partial conclusion it may be noted that incorporation of wheat in feed structure determined an increase in feed conversion efficiency by 2.91%.

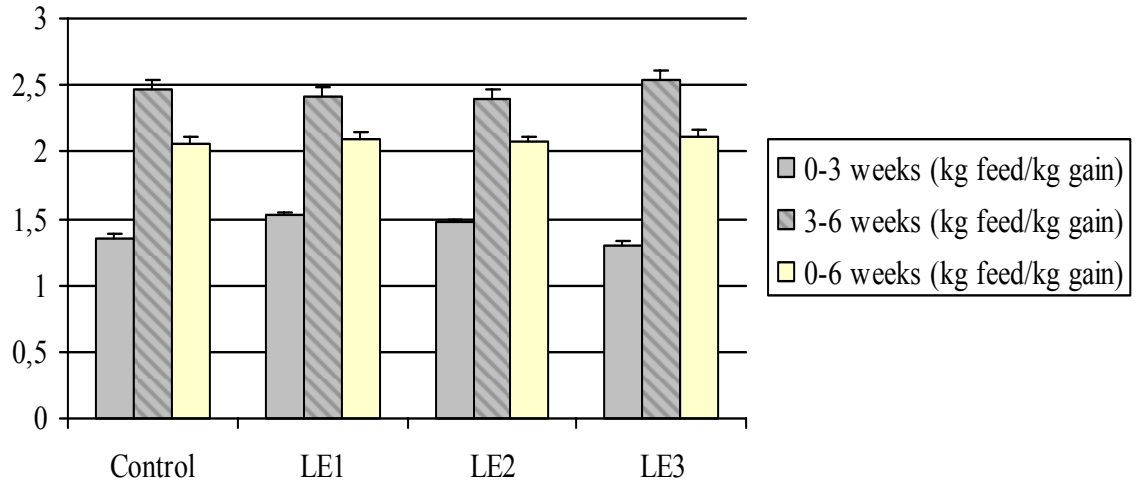

Figure 2. Graphic representation of feed conversion during the experimental period

Intestinal viscosity at duodenal and jejunal level and the correlation with the NSP content of broiler feed

Soluble arabinoxylan from wheat is believed to be responsible for most antinutritive activities of the NSP in poultry industry, due to their ability to increase intestinal viscosity and modify the intestinal microflora (Choct *et al.*, 1992, Choct *et al.*, 1996). Increased viscosity of intestinal contents decreases the rate of diffusion of substances and digestive enzymes and hinders their effective interaction causing changes in the structure and function of different digestive organs (Edwards *et al.*, 1988, Ikegami *et al.*, 1990). To adapt to these changes, the activity of intestinal secretory mechanism may be altered leading to a possible organ hypertrophy. This enlargement of the digestive organs may be an adapted response to increased need for enzymes (Ikegami *et al.*, 1990).

To determine the effect of feed NSPs on the viscosity at three weeks old, the chickens were slaughtered in order to determine viscosity in the duodenum (table 5 and figure 3).

Table 5. Intestinal viscosity at duodenal level for the 3 weeks old broilers

	Experiment	Wheat (%)	Duodenal viscosity	%
1	**Control**	0	1.95	100
2	**LE1**	20	2.515	128.71
3	**LE2**	30	2.82	144.61
4	**LE3**	40	2.985	153.07

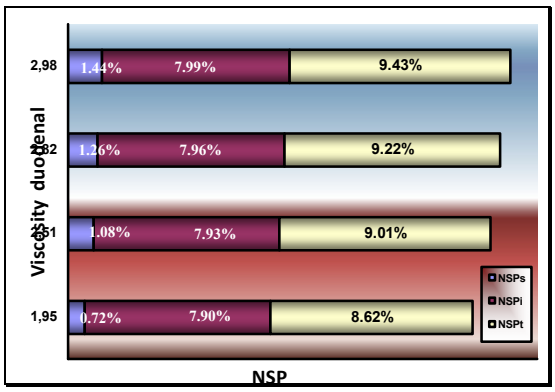

Figure 3. Viscosity at duodenal level at 3 weeks old broilers correlated with the NSP content of feed

From table 5 it can be observed that viscosity increases simultaneously with the increase in the percentage of wheat in broiler's feed, which is 28.71% higher in the group who receive 20% wheat and 53.07% higher than in group with 40 % wheat.
In order to determine the relationship between the NSP content of feed and intestinal viscosity the simple correlation indices has been established (table 6). Graphical representation of regression equations for the three categories of NSP are given in figure 4.

Table 6. Simple correlation coefficients at age of 3 weeks

Specification	Viscosity
NSPs	0.995 (p=0.005)
NSPi	0.967 (p=0.033)
NSPt	0.994 (p=0.006)

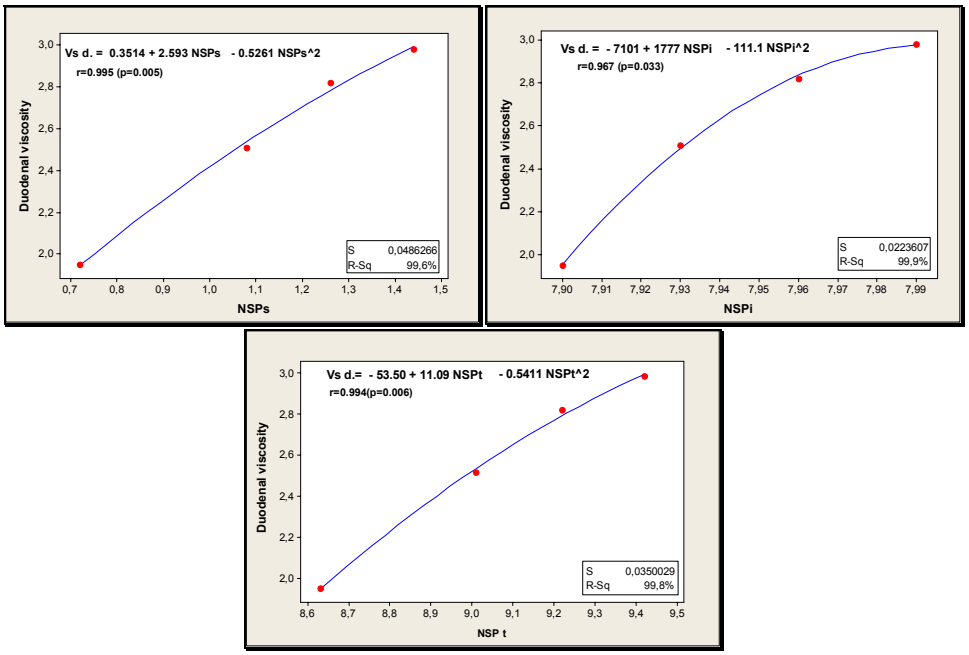

Figure 4. Graphic representation of duodenal viscosity according with the NSP content of feed modelled based on the second degree polynomial regression (at 3 weeks of age)

From table 5 you may notice that the largest correlation coefficient is recorded for NSPs, which means that the viscosity in the duodenum is determined by the NSPs content of feed. NSPi has less influence on intestinal viscosity, having a correlation coefficient of 0.967. Regarding NSPt the correlation coefficient is close to the value of the coefficient for NSPs, but it is slightly lower (0.994). At the 6 weeks of age the chickens were slaughtered and the viscosity of intestinal tract determined. The duodenal and jejunal values are given in table 7 and figure 5.

Table 7. Intestinal viscosity at the duodenal and jejunal level at 6 weeks old broilers

	Experiment	Wheat (%)	Viscosity	%
Duodenum				
1	**Control**	0	1.90	100
2	**LE1**	20	2.10	140
3	**LE2**	30	2.14	148.09
4	**LE3**	40	2.53	149.04

Jejuna				
1	**LM**	0	2.10	100
2	**LE1**	20	2.94	110.52
3	**LE2**	30	3.11	112.63
4	**LE3**	40	3.13	133.15

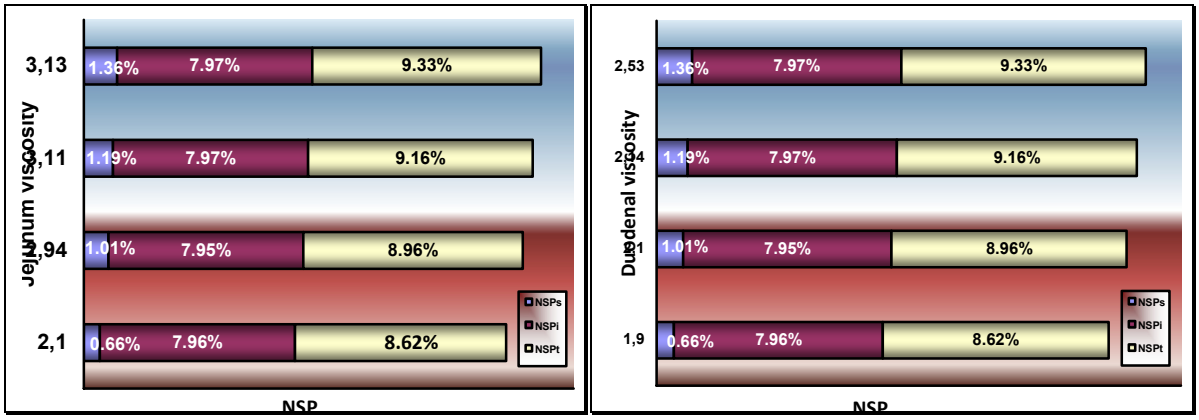

Figure 5. Intestinal viscosity at duodenal and jejunum level for the 6 weeks old broilers

The table above reveals that the chickens from the LE1 had a duodenal viscosity of 2.1 cP, which is 40% higher than in the control group (1.9 HP). The broilers from LE2 group (2.14 cP) had a viscosity with 48.09% higher and LE3 group (2.53 cP) with 49.04% higher, compared with the control group. The jejunal and duodenal viscosity increases with 33.15% in the experimental group fed with 40% wheat in feed (LE3 - 3.13 cP) compared with the group fed without wheat (2.1 cP). The polynomial regressions are presented in figures 6 and 7, showing the correlations of NSP with viscosity at duodenal and jejunal level.

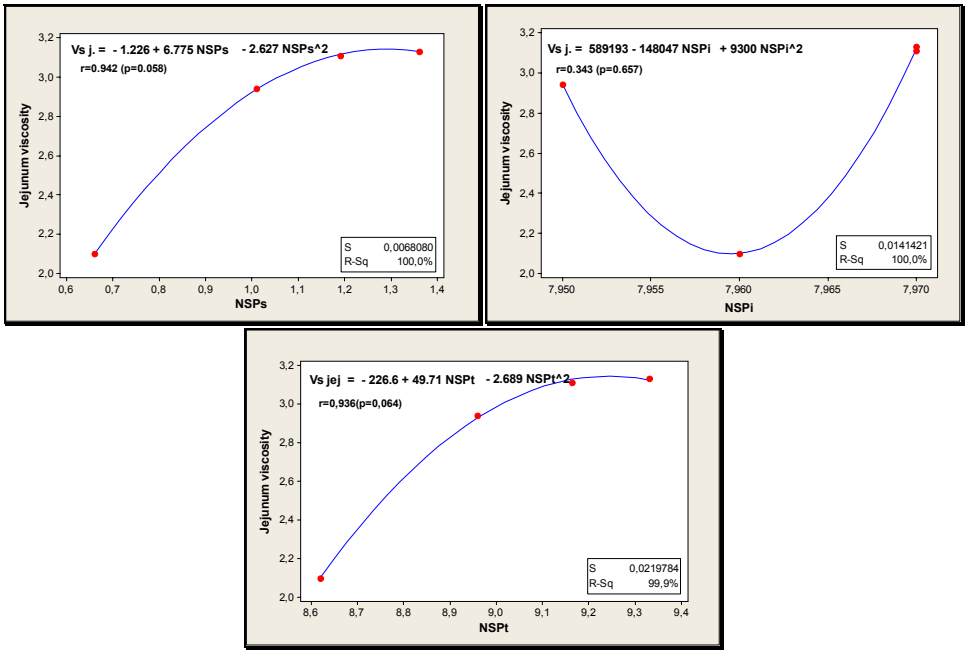

Figure 6. Graphic representation of the jejunum viscosity according with the NSP content of feed modelled based on the second degree polynomial regression (at 6 weeks of age)

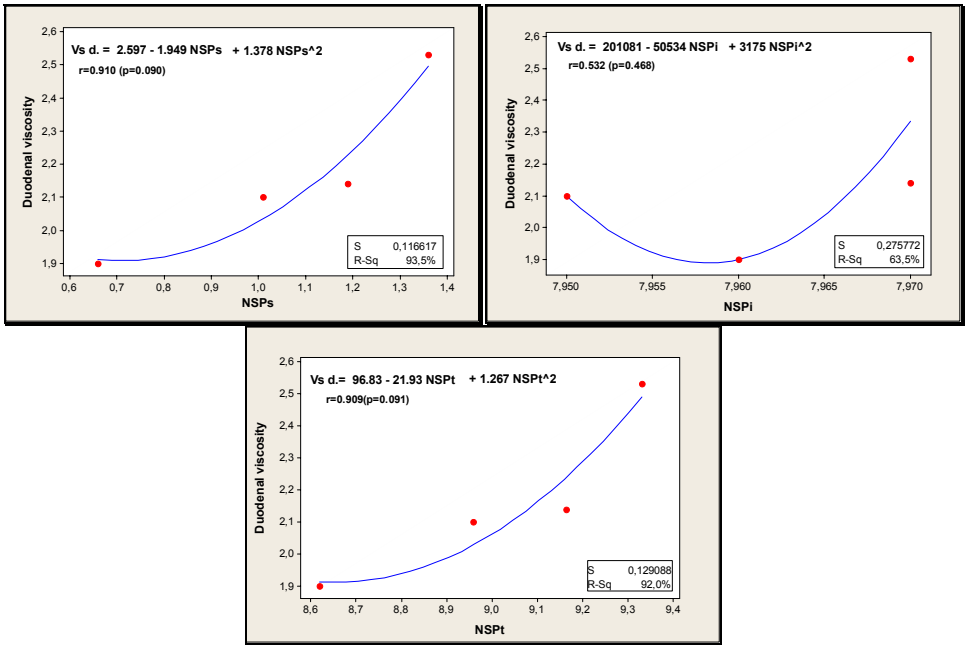

Figure 7. Graphic representation of duodenal viscosity according with the NSP content of feed modelled based on the second degree polynomial regression (at 6 weeks of age)

Conclusion

The present study showed that the wheat composition of the broiler's diet have a direct influence on the intestinal viscosity at duodenal and jejunal viscosity. In recent literature is stated that there is a significant interaction between cereal and enzyme on the ileal digesta viscosity of the chickens. The wheat-based diet resulted in the highest digesta viscosity among diets based on other cereals (Shakouri *et al.*, 2009). The effect of wheat based diets on the intestinal viscosity and subsequently on the growth performance of broiler chickens is associated with its ability to alter intestinal morphology. Increasing the percentage of wheat in feed leads to reduced feed consumption during the experiment, this reduced consumption being mainly associated with the amount of NSP present in the diet. The viscosity in the duodenum is determined by the NSPs content of feed, as an example NSPi has less influence on intestinal viscosity, having a correlation coefficient of 0.967.

Acknowledgements

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