Intestinal and body growth of broiler chickens on diets supplemented with non-starch polysaccharides

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Summary

A study was conducted to test the relative effects of different pure non-starch polysaccharides on gastrointestinal tract and body growth of broiler chickens. Seven-day old chicks were fed a commercial diet supplemented with alginic acid (AA), gum arabic (GA), guar gum (GG) or gum xanthan (GX) at 5% (7 days) and 2.5% (14 days).

Over 21 days of feeding there were significant differences ($P<0.001$) between the duodenal and ileal digesta viscosity of chicks on the different diets. Chicks fed the GA diet significantly ($P<0.001$) gained more weight and were heavier than chicks on the other diets. Small intestinal weight ($P<0.001$) and ingesta capacity ($P<0.01$) differed significantly between chicks on the different diets. There were also differences ($P<0.05$) in ileal crypt depth, villus height and surface area in chicks fed the different diets.

These findings may partly explain the differences between the growth of chicks fed diets containing different types of structural carbohydrates.

Introduction

The inclusion of low-cost alternative ingredients in poultry diet has been observed to depress body growth. This has been attributed to the presence of non-starch polysaccharides (NSP) in many of the ingredients (1, 2). The degree of growth depression depends on the concentration and chemical nature of the NSP (3). NSP generally increase digesta viscosity and may interfere with nutrient digestion and absorption (4). It is not known what effects these factors have on development of gastrointestinal structure and function in poultry.

In the present study, we investigated the intestinal and body growth of broiler chicks exposed to purified NSP of varying chemical characteristics.

Materials and methods

Seventy-two 7-day-old broiler chicks (Steggles x Ross) were reared on a commercial diet (Milling Industry Stockfeeds, Murray Bridge, South Australia) diluted with alginic acid (AA; a non-viscous NSP), gum arabic (GA, predominantly galacto-araban), guar gum (GG, galacto-mannan) or gum xanthan (GX, gluco-mannan) at 5%. Three cage replicates of six birds each were randomly assigned to the diets for a period of seven days after which the dietary supplements were reduced to 2.5% and the diets fed for 14 days.

At the end of each phase, three birds per cage (nine birds per treatment) were randomly selected and euthanased. The combined weight of the proventriculus and gizzard as well as weight of small intestine were recorded, full and empty. The liver was also weighed.

Duodenal and ileal digesta were carefully flushed with equal amounts of phosphate buffered saline (pH 7.0) to avoid damage to tissues which were subsequently used for histology. Supernatants were obtained from the digesta and subjected to viscosity analysis using a Brookfield DV III rheometer (Brookfield Engineering, Mass., USA) fitted with a CP 40 cone. Measurements were conducted at 25°C and shear rate of 0-500 s^{-1}. The viscosity of pure NSP and diets was similarly determined on supernatants derived from 1 and 10% solutions respectively. Faecal samples were collected over the last day of study and analysed for moisture content.

Histology was assessed on 5 μm thick sections obtained from formalin-fixed tissues. The sections were stained with Lilee-Meyer's hematoxylin, counter-stained with eosin yellow and mounted with DePeX (Bayer Diagnostics). Intestinal morphometry was assessed with the aid of a video image programme, Video Pro (Leading Edge, Bedford Park, SA).

Data collected were analysed by ANOVA and differences between mean values were established by the least significant difference.

Results

Feed characteristics and utilisation

The characteristics of the diets fed during the second phase are shown in Table 1. GG and GX, in 1% solution had viscosity values above 2000 cP. Whole diet viscosity was reflective of supplement viscosity, although diet GA had a lower viscosity than diet AA at 2.5% level of supplementation .

Table 1: Characteristics of diets fed, intestinal digesta viscosity and faecal moisture content of chicks during the second phase

	Diet (2.5% NSP)			
	AA	GA	GG	GX
dry matter (g/kg)	925.0	922.0	926.0	925.0
viscosity (cP)				
pure NSP	1.38	2.27	2000+	2000+
entire diet	11.94	1.24	1300+	2000+
duodenal digesta	1.0 ± 0.02^{b}	1.0 ± 0.01^{b}	1.3 ± 0.12^{a}	1.3 ± 0.15^{a}
ileal digesta	1.7 ± 0.06^{b}	1.6 ± 0.10^{b}	3.4 ± 1.22^{b}	21.7 ± 4.56^{a}
faecal moisture (%)	73.5	72.0	79.1	79.6

^{a,b} - Mean values on the same row without common superscripts are significantly different (P<0.001)
Statistical analysis was conducted only for digesta viscosity; $^{+}$Minimum value obtained

At the end of the second feeding phase, duodenal and ileal digesta viscosity were significantly higher (P<0.001) on the GX-supplemented diet than on the other diets (Table 1). The viscosity of the digesta at the ileum was generally higher than that at the duodenum, on similar diets. The faecal matter was least consistent on the GG and GX supplemented diets.

There were significant (P<0.001) differences between the chicks after seven days of feeding, in terms of feed consumption and body growth but not intestinal structure (data not shown). At the end of the second feeding phase, there were also significant differences (P<0.001) between chicks in terms of final body weight, weight gain and feed consumed per weight gained (Table 2). Feed intake also varied (P<0.01) with the diet and was highest on diet GX.

Table 2: Feed intake and growth of chicks on different diets

	Diet (2.5% NSP)				
	AA	GA	GG	GX	SEM
7-day body weight (g)	149.0	150.9	147.8	149.8	2.54
28-day body weight (g)	842.7^{a}	960.9^{a}	525.2^{b}	476.2^{b}	81.68***
weight gain (g)	693.7^{a}	810.0^{a}	377.4^{b}	326.4^{b}	42.33***
feed intake (g/100g body weight)1	418.7^{bc}	370.5^{c}	600.4^{ab}	7555.3^{a}	78.52**
feed per weight gain	2.24^{b}	2.04^{b}	4.14^{ab}	6.25^{ab}	0.451***

[1] Feed intake (g/head) in relation to liveweight on day 14; ^{a,b,c} - Mean values on the same row without common superscripts vary significantly (**P<0.01; ***P<0.001)

Visceral organ weight and capacity

Chicks on the GG-supplemented diet had a significantly higher (P<0.001) small intestinal weight than chicks fed the other diets (Table 3). Small intestinal ingesta capacity was highest (P<0.01) in chicks on the GX-supplemented diet.

Table 3: Weight of body (g) and visceral organs (g/100 g body weight) of chicks on different diets

	Diet				
	AA	GA	GG	GX	SEM
proventriculus/gizzard	2.8	2.8	3.4	3.6	0.54
small intestine (empty)	3.4^{b}	3.3^{b}	6.7a	5.5^{ab}	0.67***
liver	3.1	3.2	3.1	3.0	0.50
ingesta weight (g/100 g body weight)					
proventriculus/gizzard	1.4	1.3	1.4	2.4	0.71
small intestine	1.9^{b}	1.7^{b}	3.3ab	5.8^{a}	0.84**

^{a,b} - Mean values on the same row without common superscripts vary significantly (**P<0.01; ***P<0.001).

Intestinal mucosal morphometry

The intestinal morphometry of chickens on the different diets by the end of the trial is shown in Table 4. There were no major differences in jejunal structure (Table 4) but ileal crypt depth, villus height and surface area varied (P<0.05) with the diet fed to the chicks.

Table 4: Intestinal mucosal morphometry of 28-day old chicks

	Diet (2.5% NSP)				
	AA	GA	GG	GX	SEM
A. Jejunum				3.6	
crypt depth (μm)	148.0	157.5	170.8	187.0	14.68
villus height (μm)	1444.2	1548.3	1354.0	1398.5	133.07
villus surface area (mm^2)	0.25	0.27	0.27	0.32	0.044
B. Ileum					
crypt deptyh (μm)	107.9^{b}	122.5^{b}	155.2^{a}	134.6^{b}	13.53*
villus height (μm)	563.0^{b}	733.1^{a}	677.9^{ab}	620.2^{ab}	56.52
villus surface area (mm^2)	0.10^{b}	0.12^{ab}	0.15^{a}	0.10^{b}	1.018*

$^{a, b}$ - Mean values on the same row not sharing a superscript differ significantly (*P<0;05; ***P<0.001)

Discussion and conclusion

Dietary NSP have long been recognised to negatively affect poultry growth through an increase in digesta viscosity. An increased digesta viscosity may depress nutrient digestion and absorption, leading to reduced body growth (5). The results obtained in this study provide some insight into the mechanisms of NSP-induced retardation of growth in poultry at the animal tissue level. Rats fed diets containing gums similar to the ones used in the current study were found to compensate for inefficient digestion and absorption through hyperplasia and hypertrophy of digestive organs (6). These cellular changes lead to an increase in mucosal surface area in a bid to improve digestion and absorption of nutrients and may be assessed by changes in intestinal weight or mucosal morphometry. In the present study, both intestinal weight and villus height tended to be higher in chicks on diets containing NSP other than AA.

The impact of the tested supplements appears to be more pronounced in the distal intestine than at proximal site, judging by the differences in digesta viscosity and mucosal morphometry. Since NSP are poorly digested in poultry, there would be a tendency to accumulate and form a viscous solution as the digesta progresses through the gastrointestinal tract.

The variation in growth of broiler chicks on diets containing NSP can be partly attributed to differences in intestinal mucosal structure and digesta viscosity. It is not known if the digestive and absorptive potential of intestinal mucosal cells are altered.

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