Inulins (chicory fructans) improve performance of young broilers

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In a dose-response study, the effects of a chicory fructan preparation (Raftifeed®IPE (IPE)) included in a maize/soya-diet were studied on the growth performance in broilers. The experiment comprised six diets with 0 (control), 1, 2, 5, 10 and 20 g IPE/kg diet and was conducted in males and females over a period from 0 to 35 d of age. The birds were kept in floor pens and each dietary treatment comprised 8 replicates (4 pens of 15 male and 4 pens of 15 female birds per treatment). Feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR) were determined weekly during the 5-wk experimental period.

The results showed a significant ($P \leq 0.05$) improved FI, BWG and FCR over the period 0 to 21 d when levels of at least 10 g IPE/kg diet were included. Diets x gender interactions were significant ($P \leq 0.05$) for feed intake (FI) and body weight gain (BWG) and the effects were particularly observed in males and to a lesser extent in females.

As described in literature, the gastro-intestinal tract (GIT) of bird becomes colonised with the initial microflora in the first weeks of life. In the present study, the beneficial effects of the dietary fructans on performance were observed in that period. The gender dependent effects of fructans are possibly related with the gender-differences with regard to the microbial composition of the digesta as has been described in literature.

In summary: Clear significant positive effects of chicory fructans were demonstrated on performance especially in male broilers during the first weeks of life.

Keywords: chicory fructans, inulin; oligosaccharides; performance; broilers

Introduction

At birth the gastrointestinal tract (GIT) is sterile and in the first weeks of life it becomes colonised with a wide variety of microbes. Van der Wielen *et al.* (2000) described microbial colonisation of the caeca of young broilers and showed a succession in the appearance of bacterial species. They observed remarkable decreases of the numbers of Enterobacteriaceae and Enterococci over the period of 3-15 days of age, while the numbers of *Lactobacillus spp* remained unchanged in the same period. Moreover, they showed that volatile fatty acids derived from carbohydrate fermentation may stimulate the growth of *Lactobacillus spp* and suppress Enterobacteriaceae and Enterococci. Lu *et al*. (2003) demonstrated bacterial succession in the ileal and caecal microbiota of chickens by analysis of 16S rDNA sequences. They observed age-dependent succession of the bacterial species in both intestinal segments with relative high abundance of Clostridiaceae in the ileal and caecal contents of the 3 d-old chickens and relative high abundances of Lactobacillaceae. Mackie *et al.* (1999) reviewed aspects of colonisation in neonates of several animal species. They found a surprising similarity between mammals and chicks regarding the microbial succession during the colonisation of the microbes in the alimentary tract. In correspondence with the observations of Lu *et al*. (2003), they observed that Clostridia and Lactobacilli were present at an early age. They suggested that after the initial

colonisation, the numbers of *Escherichia (E.) coli*, Streptococci, Bacteroides and Clostridia in humans decrease in relation to the dominance of Bifidobacteria and that the appearance of Bifidobacteria marks an important step in the development of microbial colonisation. One factor involved in the development of the colonisation is feed intake and the accompanied increase of substrate for carbohydrate fermentation (Mackie *et al.,* 1999). Dietary fructans, which are indigestible for the host enzymes are repeatedly demonstrated to be bifidogenic (Gibson *et al.,* 1995; 2005; Van Loo, 2004; Verdonk *et al*., 2005) and may stimulate the microbial colonisation. Therefore, in the present study we hypothesised that the effects of fructans in broilers are age dependent (i.e. effects are more pronounced in young chickens than in older chickens). In a dose-response study, the effect of dietary inclusion of an inulin preparation was studied on feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR). Because gender differences were observed regarding the ratios between microbial species in the GIT (Yusrizal and Chen, 2003a), the study comprised separately housed, males and females.

Material and methods

In the present experiment an inulin preparation, Raftifeed®IPE (IPE), derived from the chicory root and manufactured by the ORAFTI group, Tienen, Belgium, was tested in a growth trial with 0 (control group), 1, 2, 5, 10 and 20 g/kg diet. Native inulin is a fructan industrially isolated by hot-water extraction (Van Loo, 2004) and is a mixture of linear molecules, all with the same chemical structure symbolised as G-Fn with: G, glycosyl moiety; F, fructosyl moiety; n, number of fructose units linked together through β (2-1) bonds. IPE inulin contains >72% inulin on dry matter basis and the inulin molecules have a degree of polymerisation (DP) of 3 to 65 on weight basis and a DP of 10 on average.

Table 1 Ingredients and nutrient composition of starter and grower diets (g/kg).

Feed ingredients	Starter	Grower
Maize	576.8	544.1
Soy bean meal	300.0	275.0
Maize glutenmeal	20.0	-
Peas	-	50.0
Fishmeal	20.0	25.0
Blended animal fat	20.0	50.0
Dextrose	26.0	26.0
Premix[1]	5.0	5.0
Limestone	14.0	10.0
Monocalciumphosphate	11.0	6.0
NaCl	2.1	1.5
$NaHCO_3$	2.0	2.5
L-lysine HCl	1.0	1.0
DL-methionine	1.8	2.5
L-threonine	0.2	0.4
L-tryptophan	0.1	0.1
Calculated contents (g/kg)		
Crude protein	218	207
AME[2] broiler (MJ/kg)	11.6	12.3

[1]Premix according to Kan and Hartnell (2004), [2]Apparent Metabolisable Energy.

The experiment comprised five weeks and was conducted with conventional one-d-old Ross male and female broiler chickens in separate pens. The one-d-old broiler chickens were vaccinated against New Castle Disease (NCD) and Infectious Bronchitis (IB) and birds were raised in floor pens of 0.75 m^2 situated in a fully climate controlled animal room. The floor pens had wood shavings as bedding. Temperature decreased gradually from 33^0C in week 1 to 20^0C in week 5 and relative air humidity was maintained at 55%. During the first 48 hours the room was continuously illuminated and subsequently

this was changed into a light schedule comprising of two hours of light alternated by one hour of darkness while light intensity decreased.

The starter diet was fed from 1-14 d of age and subsequently, the grower diet was fed onwards till the end of the experiment (Table 1). The diets were formulated to meet the nutrient requirements of broiler chicks based on data from Central Bureau for Livestock Feeding (2002; 2003) and National Research Council (1994). The diets were iso-energetic by exchanging dextrose from the control diet against inulin and fat for the treatment diets. The diets were steam-pelleted at 70-80^{o}C with a pellet diameter of 2.5 and 3 mm for the starter and grower diet, respectively. Feed and water were supplied for *ad libitum* intake. Antimicrobial growth promoters and coccidiostats were not included in the diets.

Five graded levels of IPE inulin in the diets were studied against a control diet without inulin. Each dietary group comprised 8 replicates: 4 pens of 15 male birds and 4 pens of 15 female birds in the starter period (1-14 d of age) and in the grower period (15-35 d of age) pens of 11 birds. Response parameters for production performance were statistically analysed (analyses of variance, Genstat 2002), using the following statistical model:

$Y_{ijkl} = \mu + Bloc_i + Diet_{j:i} + Gender_{k:i} + Interaction_{jk:i} + Error_{ijkl}$, where: Y = Response parameter, μ = general mean, Bloc = effect of the location in the experimental room, Diet = Effect of diet, Gender = Effect of gender, Interaction = interaction effect, and Error = Error term. For each of the response parameters, the P-value of the statistical model is given and treatment effects with P-values ≤0.05 were considered as statistically significant.

All treatments and procedures were performed with approval of the Ethical Committee on Animal Welfare, ID Lelystad, The Netherlands.

Results and discussion

The weekly results of FI, BWG and FCR and the results over the period from 1-35 d are given in Table 2. Significant interactions (P≤0.05) between diet and gender were observed. Therefore, Figure 1 presents the effect of dietary inclusion level of IPE inulin on BWG for the male birds and female birds separately.

The results consistently demonstrate increased (P≤0.05) FI and BWG of the birds fed the diets with 20 g/kg a dietary inclusion of IPE inulin over the whole experimental period (1-35 d) but particularly in weeks 1-4. Moreover, FCR was significantly (P≤0.05) reduced during from 1-21 d when 20 g/kg of IPE inulin was included. A negative effect of inulin on FCR was observed in week five. The FI, BWG and FCR responses of the dietary groups with inclusion levels of ≤5 g/kg IPE were in general small and not significantly (P>0.05) different from the control group.

The results showed greater FI and BWG responses in male relative to female broilers. Also FCR was significantly lower in males compared to female birds (1.451 g/g in male versus 1.501 g/g in females) and a significant diet x gender interaction was observed for each of these parameters. The gender differences in performance parameters are known and also shown by Yusrizal and Chen (2003b) and by Kan and Hartnell (2004). These gender effects are possibly related to differences in the expression of genes encoding anabolic properties (Morpurgo and Porter, 1995). Assuming that the effects of inulin on performance are related to its effect on the composition and metabolic activity of the intestinal microbiota, it implies that in the chicken there are gender (e.g. of genetic or hormonal origin) differences in the way the host reacts on microbial activity. This agrees with the results from studies of Yusrizal and Chen (2003a), who fed diets with and without inulin to males and females, respectively. They observed a decrease (P≤0.05) in the numbers of *E. coli* in the caecal contents of females and a decrease (P≤0.05) in the numbers of *Campylobacter jejuni* in caecal contents in the male broiler chickens when a diet with chicory fructans was fed relative to a control diet without inulin.

In our study, the diets were formulated isocaloric and identical in feedstuff composition and therefore the improved FCR of the IPE inulin fed broilers indicates strongly that IPE inulin improved nutrient utilisation. Because there is consensus in literature that inulin selectively modifies the microbial composition in the GIT (Gibson *et al.,* 1995; Van Loo, 2004), the most plausible explanation for the

Table 2 Feed intake, body weight gain and feed conversion ratio when different levels of Raftifeed®IPE were fed.

Days of age	Inclusion levels of Raftifeed®IPE (g/kg)						$P_{diet\ (d)}$	$P_{gender\ (g)}$	$P_{d\ x\ g}$
	0	1	2	5	10	20			
Feed intake (FI; g/day)									
1- 7	15.6^{ab}	14.9^{a}	15.2^{a}	15.3^{a}	16.3^{b}	18.8^{c}	***	**	n.s
8-14	44.8^{b}	42.0^{a}	43.3^{ab}	43.6^{ab}	49.4^{c}	55.4^{d}	***	**	*
15-21	95.2^{ab}	93.3^{a}	92.4^{a}	95.1^{ab}	97.1 ^{bc}	100.5^{c}	***	***	n.s.
22-28	137.8^{a}	138.9^{ab}	139.0^{ab}	142.3^{bc}	140.9^{ab}	145.8^{c}	**	***	n.s.
29-35	162.8	162.7	162.4	163.7	163.7	165.7	n.s.	***	*
1-35	91.7^{a}	91.0^{a}	91.1^{a}	92.6^{ab}	94.6 ^{b}	98.2^{c}	***	***	*
Body weight gain (BWG; g/day)									
1- 7	14.4^{a}	13.7^{a}	14.1^{a}	14.3^{a}	15.7^{b}	18.4^{c}	***	n.s.	*
8-14	34.0^{b}	31.7^{a}	33.3^{b}	33.9^{b}	38.4^{c}	44.3^{d}	***	n.s.	**
15-21	67.6^{ab}	68.1^{ab}	67.1^{a}	68.7^{ab}	70.0^{b}	72.6^{c}	***	***	n.s.
22-28	93.0^{a}	94.9^{a}	94.1^{a}	96.6^{bc}	95.6^{ab}	98.4^{c}	**	***	*
29-35	97.0	98.7	98.4	98.1	98.1	97.4	n.s.	***	**
1-35	61.7^{a}	61.9^{a}	61.8^{a}	62.8^{a}	64.3^{b}	66.9^{c}	***	***	***
Feed conversion ratio (FI/BWG)									
1- 7	1.083^{cd}	1.091^{d}	1.078^{cd}	1.070^{c}	1.041^{b}	1.015^{a}	***	n.s.	n.s.
8-14	1.317^{c}	1.320^{c}	1.300^{bc}	1.291^{b}	1.288^{b}	1.252^{a}	***	***	n.s.
15-21	1.408^{b}	1.370^{a}	1.377^{a}	1.385^{a}	1.388^{a}	1.385^{a}	**	***	n.s.
22-28	1.482	1.465	1.478	1.475	1.475	1.485	n.s.	***	n.s.
29-35	1.687^{ab}	1.654^{a}	1.654^{a}	1.674^{a}	1.676^{a}	1.717^{b}	*	***	*
1-35	1.488	1.472	1.473	1.477	1.473	1.474	n.s.	***	*

[a,b]Mean values within a row with no common letter differ significantly (P≤0.05); * ≤ 0.05; ** <0.01; *** <0.001; n.s., not significant (P>0.05).

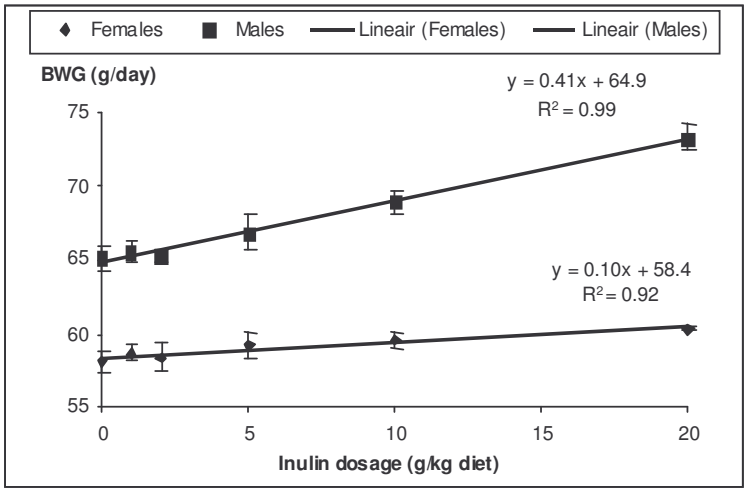


Figure 1 Body weight gain (BWG) over the 35-day experimental period (y-axis) of broilers fed diets with different inclusion levels of IPE (x-axis); bars are representing the SE between pens.

improvement of the feed utilisation during the first weeks of life is an effect of inulin on the microbial activity. Moreover, Yusrizal and Chen (2003a) suggested that inulin may reduce the volatile ammonia concentrations in faeces in the first 2-4 weeks of life by fixation of ammonia as biomass. Because ammonia is characterised as a toxic waste product of bacteria (Anderson *et al.,* 2000), the lower ammonia concentration due to the inulin inclusion can be explained as beneficial for bird's health and may improve FCR. However, in week 5, the inclusion of 20 g IPE per kg had a negative effect on FCR indicating that the effects of IPE inclusion change with age and the development of the bird's intestinal microbiota.

The present study with broiler chickens hypothesised that if microbial colonisation of the GIT is beneficial regarding performance, the effects of fructans in broilers are age dependent (i.e. effects are more pronounced in young chickens than in older chickens). The results demonstrated that the main improvements of IPE inulin on FI, BWG and FCR were derived in young birds over the period 1-21 d of age and therefore the hypothesis was accepted. But, microbiota competes with the host for nutrients (Anderson *et al.,* 2000) and therefore the stimulated microbial activity may have resulted in an increased FCR after d 28. The studied parameters of the present experiment were limited to the zootechnical performance, however, the observation that the period in which the positive effects of dietary inulin were observed coincide with the period of colonisation and the development of the intestinal surface at least suggest relations between these aspects.

In summary, the present experiment aimed to quantify the effect of dietary inulin on performance in healthy broilers. The results of the experiment showed positive effects of inulin on performance in the first weeks of life in which the GIT become colonised with the microbiota.

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