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Improvement of Laying Hen Performance by Dietary Prebiotic Chicory Oligofructose and Inulin

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Abstract: Sixty White Leghorn hens (57 wk of age) were selected and divided randomly into three groups with two birds per cage. Twenty birds were assigned to each of the following diet treatments: 1) basal diet (control); 2) basal diet with 1.0% (w/w) of an oligofructose-type commercial prebiotic supplementation (Raftifeed®OPS); and 3) basal diet containing 1.0% (w/w) inulin, which was administered as 1.3% (w/w) of a semipurified chicory root extract (Raftifeed®IPE). The feeding trial lasted for 28 d. Oligofructose and inulin increased ($P<0.05$) weekly egg production by 13.35% and 10.73%, respectively as compared to the control. The rapidly fermented (cecum) oligofructose and the slowly fermented inulin also increased ($P<0.05$) cumulative weekly egg weight per bird by 12.50% and 10.96%, respectively, as compared to the control. There were no significant ($P>0.05$) differences in average egg weight, feed consumption, or albumen quality during the extended storage among the treatments. Both prebiotics improved ($P<0.05$) the feed conversion ratio. No differences in the percentages of changes in live body weight (%) were recorded after a 4-wk feeding trial. Interestingly, both prebiotic supplementations elongated ($P<0.05$) small and large intestinal lengths. This concomitant increased absorption of capacity could be at the basis of the observations reported here. In conclusion, dietary oligofructose and inulin can increase ($P<0.05$) egg production and feed efficiency of layers without impairing egg quality.

Key words: Egg production, oligofructose, inulin, feed conversation ratio, albumen quality, intestinal length

Introduction

The chicken industry is one of the most dynamic parts of world agribusiness trade. As stated by Aho (2001), the world chicken egg industry ended the 1900s with total production of an estimated 50 million metric tons (MMT), an increase of 56% from 32 MMT at the beginning of the 1900s. The annual average production per layer in 2002 was 257 eggs, and the total value of egg production at the end of 2002 was $4,262.66 million.[1]Egg production in the USA during the year 2003 totaled a high of 87.20 billion eggs, up only 0.02 % from the previous year.[2]The layer numbers during 2003 averaged 335.37 million, down 0.60 % from 2002.

A prebiotic has been defined as "non-digestible food that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon" (Gibson and Roberfroid, 1995). Inulin and oligofructose are considered the archetypal prebiotics,and they are occur naturally in many food plants. Inulin is extracted from chicory roots with hot water. It is composed of linear chains of β (2-1) linked fructose molecules. The chain length of inulin varies between 2 and 65 fructose moieties, the average chain length is 10. Raftifeed®IPE is a spray-dried unrefined chicory extract, and contains 74% inulin. The remaining 26% is composed of mono- and disaccharides, mineral, and organic acids. Oligofructose is a partial enzymatic hydrolysate of inulin. The chain length varies between 3 and 8, with an average chain length of 4. Raftifeed®OPS is a refined oligofructose and contains >93.5% oligofructose, and the rest is mono- and disaccharides (Van Loo *et al*., 1995). Inulin and oligofructose are not digested by digestive enzymes of vertebrates in general, and human (Ellegard *et al*., 1997) and birds in particular. As such, they are completely available for fermentation by the intestinal flora. The unique properties of inulin and oligofructose are that they selectively stimulate the growth of bifidobacteria, lactobacilli, and certain butyrate-producing bacteria (Hold *et al*., 2003). At the same time, they suppress the growth of proteolytioc bacteria such as the *Clostridium perfringens* group (Gibson *et al*., 1995). Similar observations on gut flora were made in poultry (Oyarzabal and Conner, 1996). These properties (non-digestibility and selective interaction with intestinal bacteria) are considered to be at the basis of their use in animal feed.

[1]United States Department of Agriculture, 2003. http://www.nass.usda.gov/tx>/tckegsan.htm
[2]United States Department of Agriculture, 2004. http://www.nass.usda.gov/tx/> tpoulpdi.htm

The β(2-1) fructans improved percentage hot carcass weight and breast weight in male broilers, while lowering the fat pad percentage (Ammerman *et al.*, 1989). Recent research has indicated that supplementing oligofructose (Raftifeed®OPS) and inulin (Raftifeed®IPE) improved body weight gain, feed conversion ratio, carcass weight, and carcass percentage of female broilers (Yusrizal and Chen, 2003). It was reported that they also elongated small intestinal length.

The rate of egg production and quality are important determinants of the optimum length of a laying cycle. At the end of the laying cycle, egg production and quality decline significantly. The objective of the present study was to explore the effects of oligofructose and inulin on egg production and quality, layer body-weight change (%), and intestinal length during the later part of the first laying cycle.

Materials and Methods

Birds and diets: Two weeks prior to the feeding trial, White Leghorn layers with similar weight and egg-laying performance were selected. The 60 selected hens at 57 wk of age were divided randomly into three groups. Twenty birds were assigned to each group, with two birds per cage, to one of the following diets.

1) Basal diet (antibiotic and wheat-free regular diet) (Table1).
2) Basal diet with 1.0% (w/w) oligofructose (Raftifeed®OPS, Orafti, Belgium). Chain length varies between degrees of polymerization (DP) of 2 to 8, with an average of 4.
3) Basal diet with 1.3% (w/w) of a semipurified chicory inulin extract (Raftifeed®IPE, Orafti, Belgium); 1.3% (w/w) of this product corresponds to 1.0% (w/w) inulin. Chain length varies between DP 2 and 65, with an average of 10.

The prebiotics were added manually and mixed into the basal diet and stored for less than 3 d. The birds were fed their assigned diet *ad libitum* and had free access to water for 4 wk during the feeding period. A regimen of 16 h light:8 h dark/d was provided throughout the experiment study, which last for 4 weeks. Eggs were collected daily between 8:00 and 8:30 a.m.

Data collection

Egg production (%), cumulative egg weight per bird, and average egg weight: Eggs were collected and weighed daily. Egg production (%), cumulative egg weight per bird, and average egg weight for each treatment were calculated weekly and for all of the experiment.

Feed consumption (g) and feed conversion ratio (kg feed/kg egg): Feed intake per cage was monitored weekly. Weekly and overall feed consumption and feed conversion ratio were determined as described by Haddadin *et al.* (1996). The feed conversion ratio (feed:total egg weight) was calculated by totaling the amount of feed consumed divided by the collected egg weight.

Albumen quality: Eggs were divided randomly into two storage temperatures (12°C and 20°C). The Haugh unit was used for determining interior albumen quality (Haugh, 1937). Haugh units of shell eggs were measured immediately after collection, and those stored at different temperatures were measured at 3-d intervals for 12 d to determine egg quality.

Body weight change (%)/intestinal length: Individual body weight was recorded at the beginning and end of the experiment. Body weight change (%) = body weight change (g)/initial bird body weight (g). At the end of experiment, 10 birds were selected randomly from each treatment and were sacrificed for measuring the length of the intestine, determined by measuring the length of the small intestine from the duodenum to Merck's diverticulum, and the large intestine from the cecum to the rectum.

Experimental design: The experiment was conducted using a completely random design (CRD) (Steel and Torrie, 1980). All data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) (SAS Institute, Inc., 1993). A significant difference was used at the 0.05 probability level. The least significant difference (LSD) was used to separate mean values (Freud and Wilson, 1997).

Results and Discussion

Egg production/cumulative egg number and cumulative egg weight per bird/cumulative egg weight: Supplementing layer diets with 1.0% oligofructose for 4 wk increased ($P<0.05$) egg production by 13.35% when compared with the control. Meanwhile, the weekly egg production also increased ($P<0.05$) 10.91, 13.76, 16.05 and 13.74% for 1st, 2nd, 3rd, and 4th week respectively (Fig. 1). The same increasing ($P<0.05$) effects were observed in the inulin supplemented group (1st week, 10.91%; 2nd week, 9.17%; 3rd week, 12.27%; 4th week, 9.80%; overall, 10.73%). After 4 wk of feeding, both oligofructose and inulin groups produced 13.35% and 10.30% more eggs than the control group, respectively (Fig. 2). The effects of oligofructose and inulin on weekly total egg weight per bird and total cumulative egg weight were summarized in Fig. 3 and 4. Addition of 1.0% oligofructose increased ($P<0.05$) the weekly total egg weight per bird when compared with those of controls (1st week, 7.93%; 2nd week, 14.60%; 3rd week, 14.84%; 4th week, 12.88%; overall, 12.50%), while addition of inulin increased ($P<0.05$) weekly total egg weight per cage (1st week, 8.18%; 2nd week, 10.47%; 3rd week,

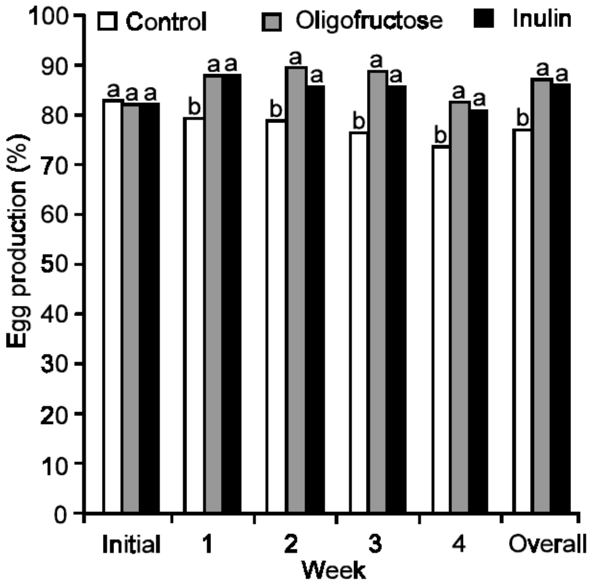

Fig. 1: Egg production as affected by dietary oligofructose and inulin.

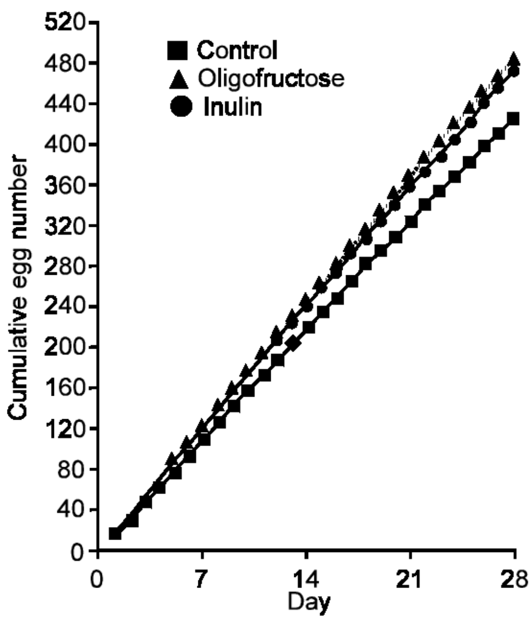

Fig. 2: Cumulative egg number as affected by dietary oligofructose and inulin.

12.84%; 4th week, 12.61%; overall, 10.96%) (Fig. 3). At the end of the 4-wk trial, the total egg weights for oligofructose and inulin were 12.54% and 10.96% heavier for 20 birds, respectively, than those of controls (Fig. 4).

Supplementing layers with *Lactobacillus*-type probiotics has been reported to improve layer performance. Abdularahim *et al*. (1996) reported that an improvement in egg production was observed when a liquid culture of

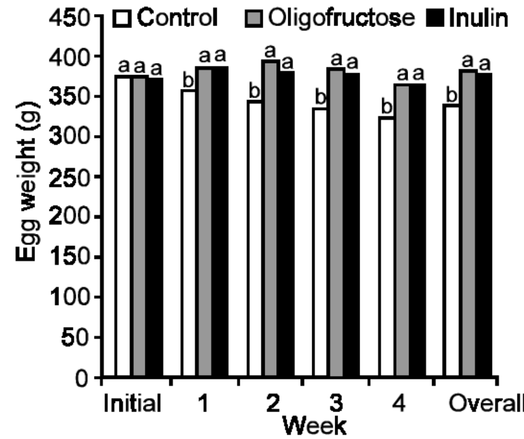

Fig. 3: Cumulative egg weight per bird as affected by dietary oligofructose and inulin.

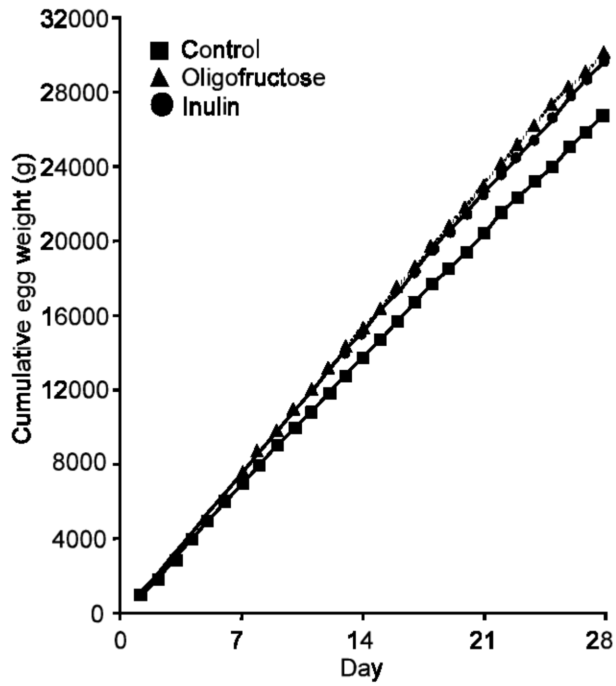

Fig. 4: Cumulative egg weight as affected by dietary oligofructose and inulin.

Table 1: Major ingredients of the basal layer diet

Ingredients	Composition (g/kg)
Corn	676
Soybean meal	190
Dicalcium phosphate	22
Limestone	90
D L-Methionine	0.5
Vitamin mixture	3.5
Salt	5
Fat	13
Calculated nutrient content	
Crude protein (g/kg)	150
Metabolizable energy (MJ/kg)	11.99

Table 2: Average egg weight, feed consumption, and feed conversion ratio as affected by dietary oligofructose and inulin

Treatment[1]	Control	Oligofructose	Inulin
Average egg weight (g)			
1st week	64.45	62.60	62.72
2nd week	62.70	62.93	63.18
3rd week	62.52	61.99	62.80
4th week	62.75	63.05	63.37
Overall	63.09	62.61	63.01
Feed consumption (g/hen/d)			
1st week	98.37	99.10	98.38
2nd week	99.99	99.86	99.60
3rd week	99.92	99.71	99.30
4th week	99.90	99.69	99.71
Overall	99.54	99.58	99.25
Feed conversion ratio (kg food/kg egg)			
1st week	1.96[a]	1.83[b]	1.81[b]
2nd week	2.08[a]	1.80[b]	1.86[b]
3rd week	2.17[a]	1.84[b]	1.88[b]
4th week	2.26[a]	1.94[b]	1.95[b]
Overall	2.09[a]	1.84[b]	1.87[b]

[a-b]Means within a row of each parameter followed by unlike letters differ significantly (P<0.05).
[1]Each reading is a mean of 10 replications.

Table 3. Albumen quality (Haugh units) of eggs upon storage as affected by dietary oligofructose and inulin

Storage time (d)	Storage temperature					
	12°C			20°C		
	Control	Oligofructose	Inulin	Control	Oligofructose	Inulin
0	86.60	87.70	87.35	86.60	87.70	87.35
3	78.15	80.10	80.55	67.40	68.40	68.05
6	76.05	76.45	77.25	62.55	62.00	62.50
9	71.25	70.70	70.75	52.35	52.75	54.90
12	69.90	70.45	71.20	47.45	49.45	48.10

No differences were observed between the groups within a row (P>0.05).

Table 4: Mean lengths of the small and large intestine, and body weight change of layer receiving dietary oligofructose and inulin

Parameters	Control	Oligofructose	Inulin
Length of small intestine (cm)[1]	150.12b	157.13a	157.25a
Length of large intestine (cm)[1]	5.33b	6.06a	6.43a
Body weight change (%)[2] (57-61 wk)	-6.74	-8.06	-8.63

[a-b]Means with different letters in the same row differ significantly (P<0.05).
[1]Each reading is a mean of 10 replications. [2]Each reading is a mean of 20 replications.

Lactobacillus acidophilus at 40 g/kg of feed was fed to the laying hens. Gibson and Roberfroid (1995) indicated that a prebiotic can beneficially affect the host by selectively stimulating the growth and/or activity of healthy bacteria in the colon. Prebiotics, such as inulin or oligofructose, have been shown to change the intestinal microflora and suppress the undesirable bacteria (Bailey, 1991; Gibson *et al.*, 1995), and stimulate mineral absorption, mainly calcium and magnesium (Scholz-Ahrens and Schrezenmeir, 2002). However, it is of interest to note that there are few, if any, reports available related to the effects of prebiotics on egg-laying performance. On the basis of our results, improvements in egg production, expressed as cumulative egg weight, might be due to healthier birds whose feed efficiency and mineral absorption have been improved by the chicory fructans. The results of this study showed that both forms of prebiotic supplementation increased egg production significantly.

Feed consumption and feed conversation ratio: No difference (P>0.05) of feed consumption among treatments with respect to he whole period of the experiment was found (Table 2) but more eggs were produced in treatment groups than the control group. Therefore, addition of oligofructose-type or inulin-type prebiotic supplementation improved (P<0.05) the feed conversion ratio (Table 2). Several studies have reported that the change of microbial ecology in layers' intestine might enhance their health and improve feed efficiency by the use of feeding probiotics (Krueger *et al.*, 1977; Abdularahim *et al.*, 1996). Prebiotics belong to a group of idigestible dietary carbohydrates that exert significant biological effects on humans by selective stimulation of growth or bioactivity of beneficial microorganisms in the intestine (Tomasik and Tomasik, 2003). Hence, we speculated that both prebiotic products could change the microflora in the layer's intestine, which would have effects on its development and absorptive capacity with, as a consequence, the observation of an improved feed conversion ratio.

Egg quality: No (P>0.05) difference in average egg weight was observed in treatments (Table 2). The Haugh unit, which is a measure of the height of albumen after correcting the reading for differences in egg weight, is used for determination of albumen quality. However, regardless of storage temperature (12°C or 20°C) and length of storage time (3 d, 6 d, 9d, and 12 d), Haugh units of shell eggs were not (P>0.05) affected by these three treatments (Table 3). Although both prebiotic supplementations improved (P<0.05) egg production, they did not retard the decline of egg quality.

As soon as an egg is laid, its quality starts to decline. With current knowledge, physical and chemical breakdown account for the decline of egg quality. Petersen (1965) reported that feed formulations or genetic improvement cannot reduce economic loss attributed to moisture loss and a decline in interior egg quality during extended storage. Albumen height decreased significantly with length of storage and the lower albumen weights of eggs were observed in a high-temperature storage environment (Walsh *et al.*, 1995). However, no report was available for effects of prebiotics on egg quality. As stated above, we can indicate that adding oligofructose and inulin can improve layer performance without sacrificing egg size or freshness.

Body weight change (%)/intestinal length: In general, a decreased live body weight (%) was recorded between 57 and 61 wk (Table 4). Several studies have reported that prebiotics (Ammerman *et al.*, 1989; Yusrizal and Chen, 2003) can improve the body weight in broilers. However, little or no reference to an effect of a prebiotic on layer's body weight change was available.

Both oligofructose and inulin elongated (P<0.05) both small and large intestinal lengths compared with the control (Table 4). Recently, as stated by Yusrizal and Chen (2003), increased gut length was recorded only in female broilers with oligofructose supplementation. Our study might be the first available information for the effects of prebiotic on layers' intestinal length.

Summary: White Leghorn hens at 57 wk of age were fed a basal diet with 1.0% oligofructose or 1.0% inulin as 1.3% of a semi-purified chicory extract over 4 wk. Data indicated that supplementing with these prebiotics improved egg production (by 13.35% and 10.73% for oligofructose and inulin, respectively), cumulative egg weight per bird (by 12.50% and 10.96%, respectively), and feed conversion ratio, but neither oligofructose nor inulin affected egg size or interior albumen quality. Meanwhile, no difference in live body weight change (%) was observed among these treatments, while elongating effects on the small and large intestine were recorded in layers fed both prebiotic supplementations.

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