

Effects of dietary inclusion of probiotic and synbiotic on growth performance, organ weights, and intestinal histomorphology of broiler chickens

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ABSTRACT A feeding trial was conducted to investigate the effects of dietary supplementations of synbiotic and probiotic on broiler performance, carcass yield, organ weights, and histomorphological measurements of small intestine. Six hundred 1-d-old broiler chicks were randomly assigned to 1 of 3 dietary treatments for 5 wk. The dietary treatments were 1) control, 2) basal diets supplemented with synbiotic (1 kg of Biomin IMBO/ton of the starter diets and 0.5 kg/ton of the grower diets), 3) basal diets supplemented with probiotic (1 kg of a homofermentative and a heterofermentative *Lactobacillus* sp./ton of feed). The BW, average daily weight gain, carcass yield percentage, and feed conversion rate were significantly ($P < 0.05$) increased by the dietary inclusion of the synbiotic compared with the control and probiotic-fed broilers. Moreover, a slight improvement in performance traits was observed in broilers fed the probiotic compared with control birds. The absolute and relative weight of spleen and thymus tended to be greater ($P < 0.1$) for the probiotic-supplemented group compared with the synbiotic-supplemented group. The relative liver weight was greater ($P < 0.05$) for probiotic-fed birds compared with synbiotic-fed birds.

Additionally, the weight of small intestine was greater for either probiotic- (3.17) or synbiotic-fed birds (3.11) than the controls (2.89). Furthermore, dietary treatments influenced the histomorphological measurements of small intestinal villi. The addition of either probiotic or synbiotic increased ($P < 0.05$) the villus height: crypt depth ratio and villus height in both duodenum and ileum. The duodenal crypt depth remained unaffected ($P > 0.05$). However, the ileal crypt depth was decreased by dietary supplementations compared with control. In conclusion, synbiotic or probiotic displayed a greater efficacy as growth promoters for broilers. Furthermore, the dietary supplementations resulted in an increase in the villus height and crypt depth of intestinal mucosa of broilers. The increase in the villus height and villus height: crypt depth ratio was associated with improvement of growth performance for both synbiotic and probiotic. This indicates that the synbiotic and probiotic can be used as a growth promoter in broiler diets and can improve the gut health. These products show promising effects as alternatives for antibiotics as pressure to eliminate growth-promotant antibiotic use increases.

Key words: poultry, probiotic, synbiotic, performance, organ weight

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INTRODUCTION

In the poultry industry, antibiotics are used worldwide to prevent poultry pathogens and disease so as to improve meat and egg production. However, the use of dietary antibiotics resulted in common problems such as development of drug-resistant bacteria (Sorum and Sunde, 2001), drug residues in the body of the birds (Burgat, 1999), and imbalance of normal microflora

(Andremont, 2000). As a consequence, it has become necessary to develop alternatives using either beneficial microorganisms or nondigestible ingredients that enhance microbial growth. A probiotic was defined as a live microbial feed supplement that beneficially affects the host animal by improving its microbial intestinal balance (Fuller, 1989). On the other hand, a prebiotic was defined as nondigestible food ingredient that beneficially affects the host, selectively stimulating the growth or activity, or both, of one or a limited number of bacteria in the colon (Gibson and Roberfroid, 1995).

The efficacy of probiotics may be potentiated by several methods: the selection of more efficient strains, gene

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manipulation, the combination of several strains, and the combination of probiotics and synergistically acting components. This approach seems to be the best way of potentiating the efficacy of probiotics and is widely used in practice. A way of potentiating the efficacy of probiotic preparations may be the combination of both probiotics and prebiotics as synbiotics, which may be defined as a mixture of probiotics and prebiotics that beneficially affects the host by improving the survival and implantation of live microbial dietary supplements in the gastrointestinal tract. Those effects are due to activating the metabolism of one or a limited number of health-promoting bacteria or by selectively stimulating their growth, which improved the welfare of the host, or both (Gibson and Roberfroid, 1995).

Lactobacilli and enterococci are among the wide variety of microbial species that have been used extensively as probiotics (Patterson and Burkholder, 2003). After feeding of probiotics, improvements in growth performance and feed efficiency have been reported in broiler chickens (Cavazzoni et al., 1998; Jin et al., 1998; Zulkipli et al., 2000; Kabir et al., 2004; Mountzouris et al., 2007; Samli et al., 2007). The proposed modes of action of probiotics in poultry are as follows: 1) maintaining a beneficial microbial population by competitive exclusion and antagonism (Fuller, 1989), 2) improving feed intake and digestion (Nahanshon et al., 1992, 1993), and 3) altering bacterial metabolism (Cole et al., 1987; Jin et al., 1997). However, there is a dearth of information regarding the effects of direct-fed microbials on the histomorphology of the small intestine of broiler chickens.

Recently, Chichlowski et al. (2007) reported that a probiotic containing lactobacilli *Bifidobacterium thermophilum* and *Enterococcus faecium* increased the jejunal villus height and decreased the villus crypt depth compared with salinomycin and control. Moreover, shorter and thinner villi were associated with toxins (Yason et al., 1987; Awad et al., 2006). In contrast, longer villi were found in the ileum of adult male layers with slight improvement in feed efficiency after dietary addition of *Bacillus subtilis* var. *natto* (Samanya and Yamauchi, 2002) and in broilers after addition of *E. faecium* (Samli et al., 2007) or *Eubacterium* sp. (Awad et al., 2006). Inulin and fructooligosaccharides are probably the most commonly used prebiotics; several typical probiotics contain either of these oligosaccharides, thereby comprising a synbiotic. The combination of a pre- and probiotic in 1 product has been shown to confer benefits beyond those of either on its own (Gallagher and Khil, 1999).

The effects of a synbiotic and a probiotic on the intestinal histomorphology in association to their growth-promoting efficiency and carcass yield of broilers are still unclear. Therefore, the present study was conducted to investigate the effects of a synbiotic and a probiotic on broiler performance, carcass yield, organs weights, and the histomorphology of small intestinal mucosa.

MATERIALS AND METHODS

Birds and Housing

Six hundred 1-d-old broiler chicks (Ross 308) were obtained from a commercial hatchery. The birds were randomly divided into 3 groups (200 birds/group) and housed in pens of identical size (1.75 × 6 m) in a deep litter system with a wood shaving floor. Each group had 8 replicates (25 birds/pen). The birds had free access to water and feed. The climatic conditions and lighting program were computer-operated and followed the commercial recommendations. Environmental temperature in the first week of life was 35°C and decreased to 25°C until the end of the experiment. During the first week, 22 h of light was provided with a reduction to 20 h afterward.

Dietary Treatments

The dietary treatments were: 1) basal diet (control), 2) basal diet plus 1 kg of synbiotic product Biomin IMBO/ton of the starter feed (5×10^8 cfu/kg) and 0.5 kg/ton of the grower feed (2.5×10^8 cfu/kg), and 3) basal diet plus 1 kg of probiotic *Lactobacillus* sp. product/ton of starter and grower feeds (1×10^8 cfu/kg). The chicks were fed with the starter diets from d 1 to 13 and grower feed from d 14 to 35 (Table 1). Biomin IMBO (Biomin GmbH, Herzogenburg, Austria) is a combination of the probiotic strain *E. faecium* (DSM 3530), a prebiotic (derived from chicory), and immunomodulating substances (derived from sea algae). The probiotic *Lactobacillus* product is a combination of heterofermentative and homofermentative *Lactobacillus* sp.

Growth Performance Traits

All birds were weighed individually after their arrival from the hatchery to the experimental farm (initial weight) and on d 35. Daily weight gain for each dietary treatment was calculated. Feed consumption was recorded in the course of the whole experiment for each treatment, and the feed conversion rates were calculated subsequently.

Organ Weights and Carcass Yield Percentages

At the end of experiment, after weighing, 10 birds per treatment were randomly selected and killed by cervical dislocation. The gizzard, heart, liver, pancreas, spleen, thymus, bursa of Fabricius, small intestine (duodenum, jejunum, and ileum), cecum, and colon were excised and weighed. The gastrointestinal tract was weighed after removal of the content. Afterward, the birds were scalded, defeathered, and carcasses were eviscerated. The head, neck, and feet were removed, and the carcass subsequently was ready to cook (RTC). The RTC car-

Table 1. Composition (%) of the basal experimental diet

Ingredient	Starter	Grower
Corn	57.93	59.75
Soybean meal high protein	31.25	29.60
Soy oil	2.50	2.00
Megafat	1.25	2.50
Monocalcium phosphate	0.25	
Lysine	0.38	0.15
Methionine	0.08	
Threonine	0.13	
Premix ¹	6.25	6.00
Calculated composition ²		
DM	88.7	89.1
CP	22.1	21.5
ME (MJ/kg)	14.28	14.66
Crude fat	7.6	8.4
Ca	1.56	1.41
P	0.97	0.83
Na	0.30	0.28
Mg	0.32	0.28

¹Each kilogram contains calcium, 196 g; phosphorous, 64 g; sodium, 30 g; magnesium, 6 g; copper, 400 mg; zinc, 1,200 mg; iron, 2,000 mg; manganese, 1,200 mg; cobalt, 20 mg; iodine, 40 mg; selenium, 8 mg; vitamin A, 200,000 IU; vitamin D₃, 80,000 IU; vitamin E, 1,600 mg; vitamin K₃, 34 mg; vitamin C, 1,300 mg; vitamin B₁, 35 mg; vitamin B₂, 135 mg; vitamin B₆, 100 mg; vitamin B₁₂, 670 µg; nicotinic acid, 1,340 mg; calcium pantothenic acid, 235 mg; choline chloride, 8,400 mg; folic acid, 34 mg; biotin, 3,350 µg; and methionine, 30 g.

²Based on a DM content of 88%. BR 5 Universal Vetmed, Biomin GmbH, Herzogenburg, Austria.

cass weight was then determined, and the carcass yield percentage was calculated by dividing the RTC weight by the live BW of birds multiplied by 100.

Histomorphological Samples

The tissue samples for histology were taken from the duodenum and ileum. The segment from the gizzard to pancreatic and bile ducts was referred to as the duodenum and 10 cm proximal to the ileocecal junction (from Meckel's diverticulum to the ileocecal colonic junction) was referred to as the ileum.

Light Microscopy

The samples were fixed in 4% buffered formalin for 48 h. The processing consisted of serial dehydration, clearing, and impregnation with wax. Tissue sections, 5 µm thick (3 cross-sections from each sample), were cut by a microtome and were fixed on slides. A routine staining procedure was carried out using hematoxylin and eosin. The slides were examined on an Olympus AX70 microscope (Olympus Corporation, Tokyo, Japan) fitted with a digital video camera (Sony DXC-930P, Sony Corporation, Tokyo, Japan). The images were analyzed using stereological image software, Cast Image System (Version 2.3.1.3, Visiopharm Albertslund, Hørsholm, Denmark).

Histomorphological Measurements

The total of the intact well-oriented crypt-villus units were selected in triplicate for each intestinal cross-section

for each sample. The criterion for villus selection was based on the presence of intact lamina propria. Villus height was measured from the tip of the villus to the villus-crypt junction, whereas crypt depth was defined as the depth of the invagination between adjacent villi.

Statistics

Statistical analyses were conducted with the Statistical Package for Social Science (SPSS for Windows Version 15; SPSS GmbH, Munich, Germany) to determine if variables differed between groups. The Kolmogorov-Smirnov test was used to test the normal distribution of the data before statistical analysis was performed. Results are expressed as means ± SEM. The BW gain, feed intake, feed conversion, organ weights, and the height and crypt depth of the villi were compared between groups by 1-way ANOVA and subsequent Duncan's multiple range test. Probability values of less than 0.05 ($P < 0.05$) were considered significant.

RESULTS

Growth Performance

The initial BW of chicks did not differ ($P > 0.05$) between the dietary treatments (Table 2). At the end of the experiment (d 35), birds supplemented with the synbiotic had a greater ($P < 0.05$) BW (1,846.53 g) compared with controls (1,753.64 g). Moreover, probiotic-supplemented birds had a greater BW (1,763.51 g) than control birds (Table 2).

The average daily weight gain (from d 1 to 35) was increased ($P < 0.05$) for birds supplemented with synbiotic (51.61 g) compared with control birds (48.95 g) and birds supplemented with probiotic (49.28 g). Furthermore, probiotic-supplemented birds had a greater daily weight gain than control birds (Table 2).

Feed Conversion Rate

Feed conversion rate (FCR) was lower for birds supplemented with synbiotic (1.75) than control birds (1.89) and birds supplemented with probiotic (1.85). In addition, probiotic-supplemented birds had a lower FCR than control birds (Table 3).

Mortality Rate and European Production Efficiency Factor

The mortality percentage and the European production efficiency factor are presented in Table 3. The mortality rate was lower for the probiotic-supplemented group (3%) than both the synbiotic-supplemented group and control group (3.5%). The European production efficiency factor was greater for the synbiotic group (291) and probiotic-supplemented group (265) than control group (255).

Table 2. Effect of feed supplementations on BW (g), daily weight gain (g), and carcass percentage of the experimental birds¹

Item	Dietary treatment			SEM	P-value
	Control (n = 200)	Synbiotic (n = 200)	Probiotic (n = 200)		
Initial BW	40.32	40.29	40.85	0.207	NS
Weight at d 35	1,753.64 ^b	1,846.53 ^a	1,765.51 ^b	8.454	0.001
Carcass percentage	60.82 ^b	66.77 ^a	59.54 ^b	0.942	0.009
Daily weight gain	48.95 ^b	51.61 ^a	49.28 ^b	0.242	0.001

^{a,b}Within the same row, means with different superscripts are significantly different ($P < 0.05$, ANOVA, Duncan's test).

¹The results are reported as means \pm SEM (n = number of birds).

Carcass Yield Percentage

The means of the carcass weight percentage relative to the BW for control group, synbiotic-, and probiotic-supplemented groups are shown in Table 3. The synbiotic-supplemented group had a greater ($P < 0.05$) carcass percentage (66.77%) compared with the control group (60.82%) and probiotic-supplemented group (59.54%). However, the carcass percentage did not show significant differences between the control group and probiotic-supplemented group (Table 3).

Absolute Weights of Organs

The means of the absolute weights of organs for dietary treatments are presented in Table 4. The weight of proventriculus was decreased ($P < 0.05$) for the synbiotic-supplemented group (6 ± 0.3 g) compared with the control group (8 ± 0.3 g) and probiotic-supplemented group (7 ± 0.3 g). Moreover, the synbiotic-supplemented group showed a decrease ($P < 0.1$) in liver weight (33 ± 1.34 g) compared with either the control group (40 ± 2.6 g) or probiotic-supplemented group (40 ± 2.74 g). The weight of spleen was significantly greater ($P < 0.05$) in the probiotic-supplemented group (2.4 ± 0.37 g) than in the synbiotic-supplemented group (1.4 ± 0.16 g) and control group (1.8 ± 0.25 g). The pancreas weight was decreased ($P < 0.05$) in the synbiotic-supplemented group (4.0 ± 0.26 g) compared with the control group (5.3 ± 0.26 g) and probiotic-supplemented group (5.0 ± 0.26 g). The weight of thymus was increased ($P < 0.05$) in the probiotic-supplemented group (11 ± 0.43 g) compared with the synbiotic-supplemented group (9 ± 0.9 g) and control (10 ± 0.6 g). In addition, the absolute weights of gizzard, heart, small intestine, colon, cecum, and bursa did not show any significant differences between the dietary treatments.

Relative Weight of Organs Percentage

The means of weight of organs percentage relative to the BW are shown in Table 5. The relative weight of liver was significantly greater for probiotic (2.11%)

compared with synbiotic (1.87%)-fed birds and greater than the control (2.04%). The weight of spleen relative to the BW tended to be greater ($P < 0.1$) for probiotic-fed birds (0.12%) compared with synbiotic-fed birds (0.07%) and greater than controls (0.10%). The pancreas weight tended to be lower for synbiotic-fed birds (0.23%) than probiotic-fed birds (0.27%) and controls (0.28%). In addition, the relative weights of proventriculus, gizzard, heart, colon, cecum, thymus, and bursa remained unaffected by dietary supplementations.

Histomorphological Measurements

Duodenum. The means of duodenal villus height, crypt depth, and villus height:crypt depth ratio are presented in Table 6. The crypt depth was not affected by dietary treatments ($P > 0.05$). However, the villus height and villus height:crypt ratio were increased ($P < 0.05$). Synbiotic and probiotic supplementations increased villus height:crypt depth ratio significantly ($P < 0.05$) and increased the villus height numerically compared with the control.

Ileum. The means of ileal villus height, crypt depth, and villus height:crypt depth ratio for dietary treatments are shown in Table 7. The villus crypt depth was significantly decreased for synbiotic and probiotic supplementations compared with controls ($P < 0.05$). Moreover, synbiotic supplementation increased the villus height and villus height:crypt depth ratio ($P < 0.05$) compared with controls. Furthermore, probiotic

Table 3. Feed conversion rate (FCR), mortality rate, and European production efficiency factor (EPEF) of the experimental birds

Item	Dietary treatment		
	Control (n = 200)	Synbiotic (n = 200)	Probiotic (n = 200)
FCR	1.89	1.75	1.85
Mortality percentage	3.5	3.5	3.0
EPEF ¹	255	291	265

¹EPEF = liveability (%) \times live weight (kg) \times age (d)/FCR \times 100.

Table 4. Effects of dietary treatments on absolute organ weights of broiler chickens (g)¹

Organ	Dietary treatment			P-value
	Control (n = 10)	Synbiotic (n = 10)	Probiotic (n = 10)	
Proventriculus	8 ^a ± 0.3	6 ^b ± 0.3	7 ^{ab} ± 0.3	0.030
Gizzard	44 ± 3.2	40 ± 2.0	43 ± 3.2	0.630
Small intestine	56 ± 3.6	55 ± 3.1	60 ± 3.2	0.527
Liver	40 ^{ab} ± 2.6	33 ^b ± 1.34	40 ^a ± 2.74	0.083
Heart	10 ± 0.5	8 ± 0.6	10 ± 0.8	0.229
Spleen	1.8 ^{ab} ± 0.25	1.4 ^b ± 0.16	2.4 ^a ± 0.37	0.050
Pancreas	5.3 ^a ± 0.26	4.0 ^b ± 0.26	5.0 ^{ab} ± 0.26	0.006
Colon	3.4 ± 0.27	2.9 ± 0.18	3.4 ± 0.22	0.212
Cecum	7.3 ^{ab} ± 0.47	6.6 ^b ± 0.16	7.9 ^a ± 0.43	0.072
Bursa	4.6 ± 0.48	4.0 ± 0.54	4.8 ± 0.59	0.556
Thymus	9.6 ^{ab} ± 0.6	9.2 ^b ± 0.9	11.4 ^a ± 0.43	0.070

^{a,b}Within the same row, means with different superscripts are significantly different ($P < 0.05$, ANOVA, Duncan's test).

¹The results are reported as means ± SEM (n = number of birds).

supplementation increased villus height:crypt depth ratio significantly ($P < 0.05$) and increased the villus height numerically.

DISCUSSION

The primary role of a diet is not only to provide enough nutrients to fulfill metabolic requirements of the body but also to modulate various functions of the body. Probiotics, prebiotics, and synbiotics are either beneficial microorganisms or substrates that facilitate the growth of these microorganisms, which can be suitably harnessed by the food manufacturers and hold considerable promise for the health care industry.

Improvement in growth performance and feed efficiency of broiler chickens fed probiotics (Cavazzoni et al., 1998; Jin et al., 1998; Zulkifli et al., 2000; Kabir et al., 2004; Mountzouris et al., 2007; Samli et al., 2007) is thought to be induced by the total effects of probiotic action including the maintenance of beneficial micro-

bial population (Fuller, 1989), improving feed intake and digestion (Nahanshon et al., 1992, 1993), and altering bacterial metabolism (Cole et al., 1987; Jin et al., 1997).

In the present study, the beneficial effects of a synbiotic and probiotic product on broiler performance parameters including average daily BW gain, FCR, and BW are in agreement with previous studies (Cavazzoni et al., 1998; Jin et al., 1998; Zulkifli et al., 2000; Kabir et al., 2004; Mountzouris et al., 2007; Samli et al., 2007). However, the synbiotic product displayed a greater growth-promoting effect than the probiotic *Lactobacillus* sp. product and increased the carcass yield percentage. In addition, there was a highly significant difference in the carcass yield (6 to 7%) between synbiotic group and both probiotic and control groups. The main reasons for this may be the following: 1) the greater live BW of the synbiotic group compared with control (about 93 g), 2) the lower absolute weights of organs of the synbiotic group compared with control

Table 5. Effects of dietary treatment on organ weights relative to BW of broiler chickens (%)¹

Organ	Dietary treatment			P-value
	Control (n = 10)	Synbiotic (n = 10)	Probiotic (n = 10)	
Proventriculus	0.39 ± 0.021	0.35 ± 0.001	0.37 ± 0.011	0.158
Gizzard	2.30 ± 0.145	2.24 ± 0.133	2.28 ± 0.127	0.948
Small intestine	2.89 ± 0.141	3.11 ± 0.142	3.17 ± 0.118	0.314
Liver	2.04 ^{ab} ± 0.083	1.87 ^b ± 0.016	2.11 ^a ± 0.060	0.050
Heart	0.50 ± 0.012	0.47 ± 0.027	0.50 ± 0.027	0.538
Spleen	0.09 ^{ab} ± 0.010	0.08 ^b ± 0.009	0.12 ^a ± 0.016	0.038
Pancreas	0.28 ^a ± 0.017	0.23 ^b ± 0.016	0.27 ^{ab} ± 0.014	0.067
Cecum	0.38 ± 0.018	0.37 ± 0.014	0.42 ± 0.018	0.123
Colon	0.18 ± 0.011	0.16 ± 0.009	0.18 ± 0.006	0.408
Bursa	0.24 ± 0.023	0.22 ± 0.029	0.25 ± 0.024	0.761
Thymus	0.50 ± 0.028	0.52 ± 0.049	0.62 ± 0.042	0.113

^{a,b}Within the same row, means with different superscripts are significantly different ($P < 0.05$, ANOVA, Duncan's test).

¹The results are reported as means ± SEM (n = number of birds).

Table 6. Effect of feed additive supplementations on histomorphological parameters of the duodenum in broilers¹

Item	Dietary treatment			P-value
	Control (n = 10)	Synbiotic (n = 10)	Probiotic (n = 10)	
Villus height (µm)	1,640 ± 26	1,647 ± 11	1,678 ± 18	0.325
Crypt depth (µm)	149 ± 32	149 ± 46	145 ± 39	0.390
Villus height:crypt depth	11.45 ^b ± 0.25	12.00 ^{ab} ± 0.28	12.45 ^a ± 0.27	0.025

^{a,b}Within the same row, means with different superscripts are significantly different ($P < 0.05$, ANOVA, Duncan's test).

¹The results are reported as means ± SEM (n = number of birds).

(about 21 g), 3) the carcass yield percentage was investigated only for 10 birds per dietary group, and 4) the weight of ingested materials was not recorded.

The histomorphological changes in the intestine of broiler chickens reported in the present study provide new information regarding the potential for using synbiotics and probiotics in broiler feed. Increasing the villus height suggests an increased surface area capable of greater absorption of available nutrients (Caspary, 1992). The villus crypt is considered as the villus factory and deeper crypts indicate fast tissue turnover to permit renewal of the villus as needed in response to normal sloughing or inflammation from pathogens or their toxins and high demands for tissue (Yason et al., 1987; Anonymous, 1999). The intestinal epithelial cells originating in the crypt migrate along the villus surface upward to the villus tip and are extruded into the intestinal lumen within 48 to 96 h (Imondi and Bird, 1966; Potten, 1998). A shortening of the villi and deeper crypts may lead to poor nutrient absorption, increased secretion in the gastrointestinal tract, and lower performance (Xu et al., 2003). In contrast, increases in the villus height and villus height:crypt depth ratio are directly correlated with increased epithelial cell turnover (Fan et al., 1997), and longer villi are associated with activated cell mitosis (Samanya and Yamauchi, 2002).

In the present study, supplementation of broilers with either synbiotic or probiotic increased the villus height and villus height:crypt depth ratio and increased villus height:crypt depth ratio in duodenum and ileum significantly ($P < 0.05$), suggesting an increased epithelial

cell turnover due to feeding of direct-fed microbials. Furthermore, it was shown that the addition of *E. faecium* to broiler diet increased the ileal villus height and enhanced broiler performance with respect to weight gain and FCR (Samli et al., 2007) and addition of a probiotic containing lactobacilli, *B. thermophilum*, and *E. faecium* to the broiler diet increased the jejunal villus height (Chichlowski et al., 2007). *Lactobacillus* treatment caused similar changes in poultry as described previously (Dobrogosz et al., 1991).

Longer villi were found in the ileum of chicks and turkeys treated with *Lactobacillus reuteri* (Dunham et al., 1993) and in the ileum of adult male layers with slight improvement in feed efficiency after dietary addition of *Bacillus subtilis* var. *natto* (Samanya and Yamauchi, 2002). Feeding of probiotics has been shown to induce gut epithelial cell proliferation in rats (Ichikawa et al., 1999). In addition, longer villi were induced by dietary amylase (Ritz et al., 1995). The concentrations of amylase in broiler intestine were increased after supplementation of diet with either a single strain of *Lactobacillus acidophilus* or a mixture of *Lactobacillus* strains (Jin et al., 2000). However, amylase concentrations were not estimated in the present study, and further experiments are needed to verify this effect.

Interestingly, the weight of small intestine relative to BW in the present study showed a slight increase for birds fed either synbiotic or probiotic, which may reveal the histological changes. It is assumed that an increased villus height is paralleled by an increased digestive and absorptive function of the intestine due to increased

Table 7. Effect of feed additive supplementations on histomorphological parameters of the ileum in broilers¹

Item	Dietary treatment			P-value
	Control (n = 10)	Synbiotic (n = 10)	Probiotic (n = 10)	
Villus height (µm)	614 ^b ± 15	774 ^a ± 10	595 ^b ± 8	0.001
Crypt depth (µm)	128 ^a ± 2	117 ^b ± 2	109 ^b ± 2	0.001
Villus height:crypt depth	4.86 ^c ± 0.11	7.13 ^a ± 0.15	5.84 ^b ± 0.13	0.001

^{a-c}Within the same row, means with different superscripts are significantly different ($P < 0.05$, ANOVA, Duncan's test).

¹The results are reported as means ± SEM (n = number of birds).

absorptive surface area, expression of brush border enzymes, and nutrient transport systems (Pluske et al., 1996). It is understood that greater villus height is an indicator that the function of intestinal villi is activated (Langhout et al., 1999; Yasar and Forbes, 1999; Shamoto and Yamauchi, 2000). This fact suggests that the villus function is activated after feeding of dietary synbiotic or probiotic. Moreover, increased passive absorption of glucose and proline was reported in broiler chickens fed a probiotic containing lactobacilli, *B. thermophilum*, and *E. faecium* (Chichlowski et al., 2007).

In conclusion, the synbiotic treatment significantly increased BW and decreased feed:gain ratios and decreased the mortality. No effects of synbiotic on the relative weights of liver, thymus, bursa, gizzard, and small intestine were found. Probiotic also displayed a growth-promoting effect, but lower than synbiotic. Furthermore, the dietary supplementations resulted in an increase in the villus height and crypt depth of intestinal mucosa of broilers. Therefore, these products might be promising alternatives for antibiotic growth promoters as pressure to eliminate antibiotic growth promoters in animal feed increases. The synbiotic offers a good alternative to improve poultry production.

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