Interaction of Breed-by-chitosan Supplementation on Growth and Feed Efficiency at Different Supplementing Ages in Broiler Chickens

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ABSTRACT : Three experiments were conducted to investigate the interaction of breed-by-chitosan supplementation on the major economic traits in broiler chickens. In experiment 1, one-day-old broiler chicks were fed *ad libitum* on a basal diet (CON-group) or basal diet containing chitosan at an inclusion level of 10.5 mg/bird/day (EXP-group). The EXP-group birds in experiments 2 and 3 were supplemented from 15 day-old by the same amount of chitosan used in experiment 1. In experiment 1, the mean body weight of the EXP-group chickens was significantly ($p<0.05$) heavier in comparison with those of CON-group birds from day 21 of the experiment. Especially in 35 day-old mean body weight, the EXP-group birds of Arbor Acres, Peterson, and Ross were significantly ($p<0.05$) heavier by 121.8 g, 118.5 g, and 242.8 g than the CON-group birds, respectively. However, the mean body weights in experiments 2 and 3 did not significantly differ between the CON-group birds and the EXP-group birds fed with chitosan supplementation from day 15 post birth. In the comparisons among breeds on the mean body weight at 35 day-old, the birds of Arbor Acres were significantly ($p<0.05$) heavier than ones of Peterson or Ross; however, there were no significant differences between Peterson and Ross or Cobb and Ross birds in overall in the experiments. The mean 15-35 d FCR of the EXP-group birds in experiment 1 were significantly ($p<0.05$) lower at least in two of the three breeds (Arbor Acres and Ross breeds) than that of the CON-group birds. None of the mean 15-35 d FCR in either experiment 2 or 3 showed significant differences between groups within a breed. In all three experiments, the differences amongst breeds in the mean 15-35 d FCR were not great either. Significant differences were not generally shown in the mean percentage of abdominal fat deposition between groups within a breed in overall experiments except in the Cobb breed in experiment 3. The mean percentages of abdominal fat deposition were significantly ($p<0.05$) lower in Ross birds than in Arbor Acres or Peterson birds and in Cobb birds than in Ross birds. By the results of the analysis of variance, the interaction of breed-by-diet (chitosan) supplementation on any of the major economic traits including mean percentage of abdominal fat deposition was not significant in overall experiments. Results of these experiments indicate that dietary supplementation with chitosan for the improvement of growth or feed conversion ratio in broilers has an efficacy when the supplementation begins from day-old. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 12 : 1705-1711)***

Key Words : Broiler, Breed, Chitosan, Body Weight, Feed Conversion Ratio

INTRODUCTION

For the improvement of growth rate and carcass fatness problem in domestic animals including broiler chickens, many different ways have been tried for last several decades (Blow and Glazener, 1952; Adams et al., 1962; Becker et al., 1981; Washburn, 1990; Bryner et al., 1992; Hicks et al., 1999; Seo et al., 2001; Baik et al., 2002; Liu et al., 2002; Wang et al., 2002; Kaushik and Khanna, 2003; Bhuiyan et al., 2004; Kim et al., 2004; Lee and Kim, 2004; Wang et al., 2004; Yang et al., 2004). Both growth and the extent of carcass fat in broiler chickens are affected by genetic, physiological, and environmental factors. These factors interact with each other to affect growth and extent of carcass fat in broiler chickens. The breed and strain within a breed are very important genetic variables on the growth and carcass fat of chickens. However, carcass fat is mostly deposited around the abdominal area. In consideration of breed and strain differences on growth rate and carcass fatness (Asmundson and Lerner, 1934; Marks, 1988), the heritability (h^2) range of growth in chickens summarized by Siegel (1962) and Kinney (1969) is generally high (h^2=0.4~0.7), and the h^2 range of abdominal fat is also very high (0.5-0.8) (Cahaner, 1988; Leenstra, 1988; Whitehead, 1988). Physiological factors involving age, sex, and body condition are also not able to be disregarded in those traits. Environmental effect on chicken growth and carcass fat is a very important variable too. This environmental effect involves many variables such as rearing temperature, humidity, and nutritional factors. Among these environmental elements, nutritional factors such as protein level, lipid level, energy level, amino acids, vitamins, and minerals in diet can greatly contribute to growth rate or carcass fat in broilers. In broiler and layer farming, varieties of diet supplementations have been widely used for an improvement in chicken growth, increase in laying eggs, and prevention of diseases. Akiba et al. (2001) especially suggested that a proper utilization of newly developed feed additives and feedstuffs designed to achieve better performance and carcass quality, further enhance the development of broiler production. One of the dietary supplements, chitosan, is a polyglucosamine derived from chitin and a cellulose-like polymer located in the exoskeletons of arthropods such as crabs, shrimps, lobsters, and insects (Furda, 1983; Weiner, 1992).

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Although Razdan and Pettersson (1994, 1996) and Razdan et al. (1997) reported that chitosan had a reducing effect in the body weight gain of broiler chickens, Patton and Chandler (1974) obtained a reverse result in growth as compared with the above studies when they fed chitosan to dairy cattles. Hirano et al. (1990) confirmed that the broiler chickens could digest chitosan by 88-89%. In human studies on chitosan's effect on the reduction of body weight, it was concluded that there was no significant weight reduction (Pittler et al., 1999; Wuolijoki et al., 1999).

Chitosan, which is largely deacetylated, possesses cationic NH_4^+ groups located on the polychain (Sugano et al., 1980). As a result, chitosan may have a bile acid-binding capacity, causing entrapment or disintegration of mixed micelles in the duodenum and ileum (Furda, 1983). This interruption in enterohepatic bile acid circulation would lead to reduce lipid absorption (Razdan and Pettersson, 1996). The reduced lipid absorption was suggested or supported by other previous or recent studies (Johnson and Gee, 1981; Lee and Son, 1998; Lee et al., 1998). Besides the above findings, Khajarern et al. (2003) obtained the result that the dietary FERMKIT, fermented chitin-chitosan, supplementation effectively alleviated overall toxicity induced by aflatoxin in ducks.

In most of the previous chitosan supplementing studies on growth and carcass fat of broiler chickens, the chicks were supplemented chitosan from day-old. However, the comparisons of differences in this study were tried the chitosan supplementation from day-old or 15-day-old. The present study was performed in order to determine the influences of the supplementing age of chitosan and of breed differences and the interactive effects of breed-by-chitosan supplementation in growth, feed conversion, and abdominal fat of broiler chickens.

MATERIALS AND METHODS

In experiment 1, Arbor Acres, Peterson and Ross breeds were used as experimental stocks. 80 birds of mixed sex from each breed were equally divided into two groups and randomly allocated into two batteries (21 cm H×94 cm W×60 cm D) for the first 14 days. At 14 day-old, twenty-four birds containing half males and half females from each group were selected without mean body weight differences between groups within a breed, and randomly relocated to individual cages (54 cm H×33 cm W×45 cm D) and raised until 35 day-old. In experiments 2 and 3, Arbor Acres and Ross breeds or Cobb and Ross breeds were used as experimental stocks, respectively. In those experiments, 160 birds of mixed sex from each breed were reared with the same manner and same stocking density as experiment 1 for the first 14 days. At 14 day-old, 52 birds containing half males and half females from each group were selected without the mean body weight differences between groups within a breed, and then moved into individual cages that were used in experiment 1. The control group birds (CON-group) were fed with basal diet only and the experimental group birds (EXP-group) were fed with basal diet supplemented with 10.5 mg of 90% deacetylated chitosan/bird/day; the birds were supplemented the chitosan through the nipple drinkers. The EXP-group birds were fed with the chitosan supplemented diet from one-day-old in experiment 1, but in two other experiments the birds were fed with that supplemented diet from 15 day-old. The chitosan (EZ Life Science Co., Ltd., 2F Woosung B/D, 335 Yangjae-Dong, Seocho-Gu, Seoul 137-132, Korea) was composed of 400 to 600 centipoise 2.3% liquids dissolved by acetic acid. All birds had *ad libitum* access to a 19.5% CP and 3,000 kcal ME/kg of diet and water from day-old to 14-day-old, and access to a 18.5% CP and 3,000 kcal ME/kg of diet and water from 15-day-old. During the experiments, all birds were given 24 h of artificial lighting per day for the first two days, and then 23 h of lighting per day were given until 35 day-old. However, the room temperature was not controlled.

The individual body weight and the feed consumption were measured on a weekly basis from day-old and from 15 day-old, respectively. At 36 day-old, all the birds were slaughtered and the abdominal fat pads were separated from the crop to the cloaca that surrounded the intestines, and then weighed. The data was collected and analyzed by using SAS program (SAS Institute, 2002). The comparisons in experiment 1 were carried out by using the LSD-test for among breeds and the t-test for between groups within a breed, and the comparisons between groups within a breed or between breeds in experiments 2 and 3 were conducted by a t-test. Statements of significance were based on $p<0.05$. The statistical model was as follows:

$$Y_{ijk} = \mu+B_i+G_j+BG_{ij}+\varepsilon_{ijk}$$

Where, Y_{ijk} = the measurement of k^{th} bird of j^{th} group within an i^{th} breed,

μ = the overall mean,

B_i = the effect of i^{th} breed,

G_j = the effect of j^{th} group within a breed,

BG_{ij} = the interactive effect of i^{th} breed-by-j^{th} group,

ε_{ijk} = the random error effect.

RESULTS AND DISCUSSION

Growth rate

Changes in body weight by 7 day interval basis for experiment 1, 2, and 3 are presented in Table 1. In experiment 1, the mean initial (day-old) body weights when compared amongst the three breeds showed significant

Table 1. Associations of breed with chitosan supplementation on the change of growth rate in broilers (Mean±SD)

Exp	Breed	Group	Body weight (day-old)					
			1	7	14	21	28	35
1	Arbor Acres	CON	50.8±2.7 [a]	122.4±6.8 [a]	310.3±27.6 [a]	493.5±61.7 [a]	956.5±121.4 [a]	1,502.8±224.2 [a]
		EXP	50.4±3.4 [a]	129.1±10.8 [a]	316.9±19.8 [a]	571.4±47.4 [b]	1,038.8±71.7 [b]	1,613.6±147.2 [b]
		Mean	50.6±3.1 [x]	126.3±9.8 [x]	314.2±23.0 [x]	541.4±64.9 [x]	1,007.1±100.3 [x]	1,571.0±184.7 [x]
	Peterson	CON	47.6±3.7 [a]	146.4±73.0 [a]	304.1±33.1 [a]	420.9±67.2 [a]	827.6±106.4 [a]	1,350.5±187.4 [a]
		EXP	48.1±4.7 [a]	128.6±10.1 [a]	300.5±23.9 [a]	527.9±61.1 [b]	926.2±105.8 [b]	1,497.8±148.5 [b]
		Mean	47.9±4.2 [y]	136.8±50.4 [x]	302.2±28.2 [x]	478.3±83.1 [y]	880.5±116.0 [y]	1,429.6±181.4 [y]
	Ross	CON	39.0±2.8 [a]	94.4±8.6 [a]	293.3±35.1 [a]	534.9±108.5 [a]	799.6±141.7 [a]	1,307.9±226.6 [a]
		EXP	39.9±3.4 [a]	98.6±8.7 [a]	305.4±36.9 [a]	540.1±53.5 [a]	979.7±79.5 [b]	1,560.9±117.7 [b]
		Mean	39.5±3.1 [z]	96.7±8.8 [y]	299.8±36.1 [x]	537.9±80.0 [x]	903.9±140.9 [y]	1,454.4±211.4 [y]
2	Arbor Acres	CON	48.3±4.1 [a]	182.6±14.9 [a]	412.1±37.4 [a]	869.9±88.6 [a]	1,420.3±137.3 [a]	1,906.1±197.7 [a]
		EXP	47.6±4.2 [a]	179.7±15.8 [a]	412.1±41.4 [a]	842.2±83.8 [a]	1,324.8±168.7 [a]	1,861.5±192.1 [a]
		Mean	48.0±4.2 [x]	181.2±15.4 [x]	412.1±39.1 [x]	856.0±86.8 [x]	1,374.0±159.5 [x]	1,883.8±194.6 [x]
	Ross	CON	45.8±4.1 [a]	167.0±20.0 [a]	381.0±45.6 [a]	818.8±89.9 [a]	1,321.7±157.6 [a]	1,811.8±208.1 [a]
		EXP	46.2±3.3 [a]	164.6±16.3 [a]	380.3±43.7 [a]	808.8±87.7 [a]	1,272.7±109.1 [a]	1,822.9±162.0 [a]
		Mean	46.0±3.7 [y]	165.8±18.2 [y]	380.7±44.4 [y]	813.8±88.4 [y]	1,298.8±138.5 [y]	1,817.2±185.9 [y]
3	Cobb	CON	44.8±3.3 [a]	207.3±21.0 [a]	438.0±48.1 [a]	867.5±104.6 [a]	1,335.9±172.7 [a]	1,912.5±261.2 [a]
		EXP	45.2±3.2 [a]	204.3±22.8 [a]	439.1±46.2 [a]	836.3±156.9 [a]	1,323.6±202.8 [a]	1,867.3±291.7 [a]
		Mean	45.0±3.2 [x]	205.8±21.9 [x]	438.6±46.9 [x]	851.8±133.8 [x]	1,329.8±187.3 [x]	1,889.9±276.3 [x]
	Ross	CON	43.0±3.3 [a]	197.8±16.6 [a]	437.7±36.4 [a]	862.6±86.9 [a]	1,343.6±143.5 [a]	1,914.8±245.4 [a]
		EXP	43.5±3.5 [a]	198.5±18.2 [a]	437.6±36.2 [a]	866.8±76.9 [a]	1,356.9±109.1 [a]	1,927.2±212.3 [a]
		Mean	43.2±3.4 [y]	198.1±17.3 [y]	437.6±36.1 [x]	864.7±81.8 [x]	1,350.4±126.7 [x]	1,921.3±227.4 [x]

[a, b] Means within a breed between groups with different superscripts significantly differ at p<0.05 in each experiment.
[x-z] Means between or among breeds with different superscripts significantly differ at p<0.05 in each experiment.
CON: Basal diet group, EXP: Basal diet+10.5 mg chitosan/bird/day supplemented group.

(p<0.05) difference in weight. The weights in the order of heaviest were Arbor Acres, Peterson, and Ross birds. The birds of Arbor Acres on the mean final (35 day-old) body weights were also significantly (p<0.05) heavier by 141.4 g or 116.6 g than the ones of Peterson or Ross, respectively; however, the difference between Peterson and Ross birds on the mean 35 day-old body weight was not great. The birds of Arbor Acres had more weight gain of significance (p<0.05) during 1 to 35 day-old or 15 to 35 day-old period than the ones of Peterson or Ross, but the differences on the weight gains in those period between Peterson and Ross birds were insignificant (Table 2). In experiment 1, although the day-old and 14-day-old chicks of CON and EXP-group within a breed were allocated without the mean body weight differences, the 21, 28 and 35 day-old mean body weight of EXP-group birds in Arbor Acres and Peterson or 28 and 35 day-old mean body weight of EXP-group birds in Ross were significantly (p<0.05) heavier than those of the CON-group ones.

However, the mean day-old body weight of Arbor Acres chickens in experiment 2 showed to be significantly (p<0.05) heavier by 2.0 g than that of Ross chickens. The Arbor Acres birds at 35 day-old were also significantly (p<0.05) heavier by 66.6 g than the Ross ones. 1 to 35 day-old or 15 to 35 day-old weight gain in these two breeds revealed similar results with the comparisons on the day-old or 35 day-old mean body weights. Significant (p<0.05) differences were shown in the 1 to 35 day-old weight gain. All of the comparisons between EXP and CON-group birds in both breeds on the 35 day-old mean body weight and 1 to 35 day-old or 15 to 35 day-old weight gain showed non-significant differences. After 7 days of chitosan supplementation (at 21 day-old), the mean body weight of CON-group chickens was a little heavier than that of EXP-group ones in both breeds, but the differences between groups were not significant (Table 1).

In experiment 3, although the mean day-old body weight of Cobb chicks was significantly (p<0.05) heavier by 1.8 g than that of Ross chicks, the 35 day-old mean body weight and 1 to 35 day-old or 15 to 35 day-old weight gains showed a reverse trend when compared to the day-old body weight; but their differences were insignificant. All the comparisons on mean body weight and weight gains between EXP and CON-group chickens within a breed did not show significant differences, either. After chitosan supplementation from 15 day-old, the mean body weights measured at a 7 day-interval basis also did not show significant differences between groups within a breed (Table 1). These results are quite similar to those of experiment 2, but quite contrary to the results of experiment 1. These results might come from the differences on the beginning age of the chitosan supplementation. From the results of experiments 2 and 3, it can be concluded that the chitosan supplemented to broilers after 14 day-old does not greatly affect the growth rate in broilers. The relatively lower mean of the 35 day-old body weight of the birds in experiment 1 than those of the experiments 2 and 3 resulted from the uncontrollable-rearing- temperatures; experiments 1, 2 and 3 were conducted in early Spring, mid Summer, and early Autumn, respectively.

Razdan and Pettersson (1994) reported that supplementing chitosan at an inclusion level of 30 g/kg diet of 76, 82 and 94% chitoisan to the day-old mixed sex Ross broilers resulted in a significant reduction of body weight on days 10 and 18 of the experiment than those of control group birds. In another one of their studies (Razdan and Pettersson, 1996), they obtained a similar result with their previous study on body weight when this was measured on days 11 and 18 of the experiment. Razdan et al. (1997) also found that the broiler chickens fed with a basal diet containing 30 g/kg diet of 89% chitosan had significantly reduced body weights compared with birds fed control diet only on days 5 and 11 of the experiment. The increase in mean body weight in the EXP-group birds supplemented with chitosan from day-old of this study was quite the opposite result from that of Razdan and Pettersson (1994, 1996) or Razdan et al. (1997). The different results between their studies and this study might come from the different chitosan supplementing method or quantity. The chickens in their studies were fed chitosan which was mixed in their diet. Whereas, the birds in this study were supplemented chitosan dissolved through water line. Also in their studies, chitosan dissolved through water line. Also in their studies, it might be assumed that the feed intake of the birds was decreased by the chitosan-mixed diet forming highly viscous solutions (Sugano et al., 1988). The viscous solutions formed by chitosan-mixed diets may cause distension of the duodenum in animals (Sellers, 1977) and thereby increase satiety. Another possibility may be that the strong, astringent and bitter taste (Lee and Son, 1998) of sufficient levels of chitosan supplemented, especially to very young birds, diminishes their appetite. The growth rates of the birds consequently became stunted. However, Kobayashi and Ito (1991) and Kobayashi et al. (2002) reported that a low-viscosity-chitosan supplementation to male broilers from 14 day-old for 3 weeks did not significantly affect the mean body weight gain. Their observations on the weight gain are quite similar to the results from experiments 2 and 3 in this study when birds were fed with chitosan-supplemented diet from 15 day-old for 3 weeks. These observations are also well supported by the findings of Pittler et al. (1999) and Wuolijoki et al. (1999). Conclusively, it is assumed by the results of the other studies and this study that the growth rate in broiler chickens supplemented with chitosan could be affected by the age supplementation occurs, the amount of supplementation, the method of supplementation, and possibly other factors.

Feed conversion

As shown in Table 2, the differences of the 15 to 35-day-old mean FCR in experiment 1 were insignificant among breeds, but in the comparisons between groups within a breed it significantly ($p<0.05$) reduced FCR of EXP-group chickens in two (Arbor Acres and Ross) of three breeds than that of CON-group ones. Whereas, the differences of 15 to 35 day-old mean FCR in experiment 2 and 3 were not significant either between breeds or between groups within a breed. The results of experiments 2 and 3 are quite contrary to the results of experiment 1. These results might be obtained from the differences on the beginning age of chitosan supplementation.

Razdan and Pettersson (1994) reported that the bird-group fed with chitosan containing diet significantly increased the feed conversion ratio on days 10 and 18 of the experiment than those of the control group birds. In another of their studies (Razdan and Pettersson, 1996), they obtained a similar result on the feed conversion ratio with their previous study when feed conversion ratio was measured at days 11 and 18 of the experiment. Razdan et al. (1997) also found that the broiler chickens fed with the control diet containing chitosan had significantly reduced feed intakes or increased FCR compared with birds fed control diet only on days 5 and 11 of the experiment. The decreasing mean feed conversion ratio of chitosan supplemented chickens in this study was not in agreement with the results of Razdan and Pettersson (1994,1996) or Razdan et al. (1997). The results of other studies (Kobayashi and Ito, 1991; Pittler et al., 1999; Wuolijoki et al., 1999; Kobayashi et al., 2002) were insignificant in affecting the mean FCR when birds were fed with a chitosan supplemented diet from 14 day-old for three weeks. The results of their studies showed the same trend with this study when birds were fed with a chitosan supplemented diet post 14 day-old for three weeks. From the observations of experiments 2 and 3 in this study and other studies, it could be concluded that chitosan supplementation after 14 day-old does not contribute much to feed efficiency in broiler birds.

Abdominal fat deposition

Table 2 shows the comparisons of control group birds with chitosan supplemented group birds and the comparisons of breeds in each other on abdominal fat deposition. The mean percentages of abdominal fat deposition was significantly ($p<0.05$) lower in Ross birds than in Arbor Acres or Peterson birds in experiment 1, or in Cobb birds than in Ross birds in experiment 3. Although the mean percentage of abdominal fat depositions of Ross birds in experiment 2 was lower by 0.15% than that of Arbor

Table 2. Associations of breed with chitosan supplementation on the body weight gain, feed conversion ratio, and percentage of abdominal fat deposition in broilers (Mean±SD)

Experiment	Breed	Group	Weight gain (g)		FCR	% Abdominal fat
			1-35 d	15-35 d	15-35 d	36 d
1	Arbor Acres	CON	1,452.2±222.0 [a]	1,194.2±202.8 [a]	2.10±0.21 [a]	2.21±0.41 [a]
		EXP	1,563.2±146.4 [b]	1,296.8±141.6 [b]	1.91±0.14 [b]	2.32±0.62 [a]
		Mean	1,520.5±183.4 [x]	1,257.3±171.6 [x]	1.98±0.19 [x]	2.28±0.54 [x]
	Peterson	CON	1,302.9±186.5 [a]	1,046.4±167.8 [a]	1.99±0.16 [a]	2.10±0.52 [a]
		EXP	1,449.7±147.1 [b]	1,197.3±139.5 [b]	1.99±0.12 [a]	2.38±0.71 [a]
		Mean	1,381.7±180.3 [y]	1,127.4±169.4 [y]	1.99±0.14 [x]	2.24±0.71 [x]
	Ross	CON	1,268.9±225.9 [a]	1,016.7±217.9 [a]	2.10±0.20 [a]	1.30±0.54 [a]
		EXP	1,521.1±116.5 [b]	1,255.6±106.0 [b]	1.97±0.18 [b]	1.61±0.53 [a]
		Mean	1,414.9±210.5 [y]	1,155.0±199.8 [y]	2.02±0.19 [x]	1.50±0.55 [y]
2	Arbor Acres	CON	1,857.9±197.9 [a]	1,494.4±179.5 [a]	1.77±0.32 [a]	1.66±0.44 [a]
		EXP	1,814.0±219.6 [a]	1,448.1±181.0 [a]	1.82±1.00 [a]	1.80±0.42 [a]
		Mean	1,835.9±194.0 [x]	1,471.3±180.3 [x]	1.80±0.74 [x]	1.74±0.51 [x]
	Ross	CON	1,766.0±207.4 [a]	1,430.3±182.9 [a]	1.67±0.18 [a]	1.63±0.51 [a]
		EXP	1,776.7±161.6 [a]	1,441.0±144.3 [a]	1.69±0.50 [a]	1.56±0.45 [a]
		Mean	1,771.2±185.3 [y]	1,435.5±164.2 [x]	1.68±0.37 [x]	1.59±0.47 [x]
3	Cobb	CON	1,867.7±261.0 [a]	1,475.7±233.5 [a]	2.01±0.53 [a]	1.67±0.63 [a]
		EXP	1,822.1±291.5 [a]	1,425.3±273.9 [a]	2.03±1.23 [a]	1.38±0.56 [b]
		Mean	1,844.9±276.1 [x]	1,450.5±254.3 [x]	2.02±0.94 [x]	1.52±0.61 [x]
	Ross	CON	1,872.1±244.8 [a]	1,479.6±230.3 [a]	1.80±1.00 [a]	1.69±0.63 [a]
		EXP	1,883.9±212.0 [a]	1,492.1±210.5 [a]	1.87±0.64 [a]	1.77±0.58 [a]
		Mean	1,878.3±227.0 [x]	1,486.2±219.0 [x]	1.83±0.83 [x]	1.73±0.60 [y]

[a, b] Means within a breed between groups with different superscripts significantly differ at p<0.05 in each experiment.
[x, y] Means between or among breeds with different superscripts significantly differ at p<0.05 in each experiment.
CON: Basal diet group, EXP: Basal diet+10.5 mg chitosan/bird/day supplemented group.

Table 3. The interaction effect between breed and group on growth rate, feed conversion ratio, and percentage of abdominal fat deposition

Trait	Age (day-old)	Experiment 1			Experiment 2			Experiment 3		
		Breed (B)	Group (G)	B×G	Breed (B)	Group (G)	B×G	Breed (B)	Group (G)	B×G
Body weight	1	0.0001	NS	NS	0.0029	NS	NS	0.0002	NS	NS
	35	0.0044	0.0001	NS	0.0443	NS	NS	NS	NS	NS
Weight gain	1-35	0.0058	0.0001	NS	0.0498	NS	NS	NS	NS	NS
	15-35	0.0055	0.0001	NS	NS	NS	NS	NS	NS	NS
FCR	15-35	0.0133	0.0094	NS	NS	NS	NS	NS	NS	NS
% Abdominal fat deposition	36	0.0001	0.0338	NS	NS	NS	NS	0.0266	NS	NS

Acres birds, the difference was not significant.

In experiment 1, although the mean percentage of abdominal fat deposition of the EXP-group birds in all three breeds was higher than those of the CON-group birds, the differences were statistically insignificant. In experiments 2, the EXP-group birds of Arbor Acres showed greater mean percentage of abdominal fat deposition than the CON-group birds, but the trend in Ross breed was the reverse. However, the differences between groups within a breed were insignificant in both Arbor Acres and Ross breed. In experiment 3, no significant difference was seen in the comparisons between groups within a Ross breed on the mean percentage of abdominal fat depositions, but the EXP-group birds of Cobb was significantly (p<0.05) lower by 0.29% in the mean percentage of abdominal fat deposition than the CON-group birds.

Since excessive carcass fat has been recognized as a major problem in broiler chickens, numerous studies have focused on reducing carcass fat (Suk and Kim, 1981; Siegel, 1984; Marks, 1988; Suk and Washburn, 1995,1998). The breed differences on the degree of abdominal fat in the current study were in agreement with the results of other previous studies (Siegel, 1984; Leclercq, 1988; Marks, 1988). However, the effect of chitosan supplementation for reducing fat in this study was not generally great. This result was in contrast with the results obtained by the studies of Ikeda et al. (1993), Kim and Seol (1994), Razdan and Pettersson (1994,1996), Razdan et al. (1997) and Kobayashi et al. (2002). Riccardo and Muzzarelli (1996) suggested that chitosan had viscous properties leading to a depression in lipid absorption; this suggestion had been supported by the study conducted by Sugano et al. (1988). Also Furda (1983) has ever pointed out that the interruption in enterohepatic bile acid circulation due to the bile-acid binding capacity of chitosan, leads to reduced lipid absorption and increased faecal sterol excretion. In other studies, the chitosan supplemented group chickens had less feed intake than the control ones resulting in decrease growth and fat. The different results of this study with other studies on the effect of chitosan supplementation in the extent of carcass fat might come from the differences in supplementing amounts or methods of chitosan to chickens. However, this is not certain.

Interaction of breed-by-chitosan supplementation

According to the results of the analysis of variance on the major economic traits in broiler chickens (Table 3), the effect of breed in experiment 1 showed significant ($p<0.05$) on all measured traits. These traits include the mean day-old or 35 day-old body weight, 1 to 35 or 15 to 35 day-old weight gain, 15-35 day-old FCR, and the mean percentage of abdominal fat deposition. The effect of group showed significant ($p<0.05$) on the above traits except the mean day-old body weight. Whereas, the mean day-old or 35 day-old body weight and 1 to 35 day-old weight gain for experiment 2, and the mean day-old body weight and the mean percentage of abdominal fat deposition for experiment 3 were greatly ($p<0.05$) affected by breed only. However, the interactive effect of breed-by-diet (chitosan) supplementation on all of the traits measured was not significant in any of the three experiments. The results obtained from this study on the interactive effect of breed-by-diet (chitosan) supplementation could not be compared with the results of other studies because there are few studies on the interaction of breed-by-diet (chitosan) supplementation.

From the results of this study, it can be concluded that chitosan supplementation in broiler diet is helpful in improving growth rate and FCR. Furthermore, chitosan supplementation's interaction with genetic, physiological, and nutritional (environmental) factors can also affect growth rate and feed conversion of broiler chickens if the supplementation begins from day-one post birth.

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