Effect of Chitin in Shrimp Meal on Growth Performance and Digestibility in Growing Broilers

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In order to clarify whether chitin in shrimp meal (SM) affects growth performance of broilers adversely, body weight gain, feed intake, digestibility and nitrogen retention were measured in broilers given diets containing 3 levels of SM and chitin. In addition, meat and skin color was also measured in the expectation of color intensification by astaxanthin in SM. Body weight gain, feed intake and feed efficiency decreased numerically in birds given SM diets, but did not change in birds given chitin diets. Dry matter (DM) digestibility decreased with increasing levels of SM and chitin. Chitin digestibility was low (at most 24%) and tended to decrease with increasing levels of SM and chitin. Ash digestibility decreased with increasing levels of SM but unchanged with increasing levels of chitin. N retention decreased with increasing levels of SM and chitin. The redness of thigh meat was increased by feeding SM. In conclusion, the results obtained here showed that decreased DM digestibility observed in birds given SM diets seemed to be explained by the low digestibility of chitin in SM, and SM may be useful to improve meat color of broilers.

Key words : broiler, chitin, digestibility, meat color, shrimp meal

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Introduction

Shrimp meal (SM) made from shrimp waste has been studied as a potential protein source for use in poultry feed. However, growth performance in birds given diets containing SM varies among studies. Our previous study (Khempaka *et al.*, 2006) showed that body weight gain, feed intake, feed efficiency and dry matter (DM) digestibility of growing broilers were decreased when given diets containing more than 8% of SM. Chitin is one of the major components in SM and is recognized to be a non-digestible amino polysaccharide. Therefore, it is likely that chitin affects growth performance adversely, but unfortunately, information on the effects of chitin on growth performance is limited (Kobayashi and Itoh, 1991 ; Razdan and Pettersson, 1994). Chitin digestibility in chickens is controver-

sial : Jeuniaux and Cornelius (1978) and Hirano *et al.* (1990) measured 28% and 92%, respectively. In addition, it is well-known that SM contains astaxanthin, which is a natural carotenoid with red pigmenting properties. Consequently, SM may have the potential to improve visual appearance of broiler meat, because astaxanthin in yeast intensified mainly the redness of broiler meat (Akiba *et al.*, 2001). The present study was conducted to clarify whether chitin in SM is a factor to decrease growth performance of broilers, and whether SM can modify meat and skin color of broilers.

Materials and Methods

This research was conducted in accordance with guidelines for regulation of animal experimentation of Shinshu University, Japan.

Experimental Diets

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Table 1. Ingredient and chemical composition of experimental diets (g/kg)

Ingredients and analyses	Control	Shrimp meal			Chitin		
		4%	8%	12%	1.3%	2.6%	3.9%
Commercial diet ¹	600.0	600.0	600.0	600.0	600.0	600.0	600.0
Soybean meal	80.5	54.2	27.8	1.5	87.2	93.9	100.5
Corn	304.8	279.6	254.5	229.4	275.5	246.2	217.0
Shrimp meal	—	40.0	80.0	120.0	—	—	—
Chitin	—	—	—	—	13.0	26.0	39.0
Corn oil	—	11.5	23.0	34.4	9.6	19.2	28.8
Premix ²	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Determined analyses (dry matter,%)							
Crude protein	22.67	22.74	22.80	22.93	22.30	22.70	23.12
Ether extract	5.25	6.09	7.36	8.22	5.92	7.05	8.57
Crude fiber	2.90	3.86	4.74	5.82	3.99	5.15	6.38
Ash	5.84	6.41	7.36	8.28	5.73	5.83	5.59
ME, kcal/kg ³	3189	3189	3189	3189	3189	3189	3189
Chitin	0.00	1.36	2.42	3.23	1.36	2.46	3.23
Calcium ³	0.91	1.14	1.37	1.60	0.91	0.90	0.90
Available phosphorus ³	0.58	0.60	0.63	0.66	0.58	0.58	0.57

¹ Supplied from Nippon Formula Feed Mfg, Kanagawa, Japan.² NRC (1994).³ Calculated value.

SM was made from headless shells of black tiger shrimp (*Penaeus monodon*). Details about the SM were given in our previous report (Khempaka *et al.*, 2006). Seven diets (1 control, 3 SM and 3 chitin diets) containing a commercial broiler starter diet (CP $\geq$ 23.5%, ME $\geq$ 3050 kcal/kg, Nippon Formula Feed Mfg, Kanagawa, Japan) as a basal diet, were provided in the present study (Table 1). In SM diets, SM was added at 40, 80 and 120 g/kg of diet at the expense of soybean meal. In chitin diets, purified chitin (Nacalai tesque, Kyoto, Japan) was added at 13, 26, 39 g/kg of diet to match the same levels of chitin as in SM diets containing 40, 80 and 120 g/kg of SM, respectively. Levels of corn and corn oil in experimental diets were also changed to adjust the chemical composition. In all experimental diets, chitin nitrogen was ignored when CP content of the diets was calculated, because chitin is generally recognized to be non-digestible.

Birds, Feeding and Sampling

Thirty-five 11 d-old male broiler chicks were placed in individual cages. After a 4 day adaptation period, all chicks were randomly allotted to an experimental diet (5 birds per diet), such that the mean body weight did not differ among dietary groups. Feed and water were provided *ad libitum* throughout the experimental period. Body weight and feed intake of individual chick were recorded on experimental days 1 to 10 (15 to 25 days old).

Excreta were collected on experimental days 7 to 10 (22 to 25 days old), sprayed with 5% HCl and dried at 55°C. Dried excreta was stored at -20°C until analyses.

Analysis

At the end of the experimental period, birds were fasted for 24 h with free access to water, sacrificed and eviscerated. Carcasses were weighed and then chilled at 4°C for 24 h. Color of breast skin and breast (*M. pectoralis superficialis*) and thigh (*M. biceps femoris*) meat of chilled carcasses were measured using a reflectance colorimeter (Chroma Meter CR-200b, Minolta, Japan). Values were reported according to the CIE L*a*b* system, where L*, a* and b* represent lightness (or brightness), redness-greenness and yellowness-blueness, respectively. This system is derived from the CIE (Commission Internationale de l'Eclairage) standard color table by transforming the original X, Y and Z coordinates into the three new reference values of L, a and b. In order to determine meat color uniformly, measurements were performed at 10 fixed locations on each component. CP, crude ash and crude fat were analyzed according to standard methods of AOAC (1990). Chitin in excreta was measured by the method of Hornung and Stevenson (1971).

Statistical Analysis

Data were analyzed by ANOVA using General Linear Models (GLM) procedures (SAS Institute,

Table 2. Growth performance, digestibility and nitrogen retention of growing broilers given dietary shrimp meal and chitin^{1,2}

	Control	Shrimp meal			Chitin			Pooled SEM
		4%	8%	12%	1.3%	2.6%	3.9%	
Body weight gain, g	707	666	610	621	641	628	707	13.39
Feed intake, g/bird/day	103	95	91	91	97	93	100	1.65
Gain/Feed	0.69	0.70	0.67	0.68	0.66	0.67	0.71	0.006
Digestibility, %								
DM ³	76.1 ^a	76.1 ^a	74.7 ^{bc}	74.2 ^{cd}	75.7 ^{ab}	75.3 ^{abc}	73.1 ^d	0.23
Ash	39.1 ^a	34.2 ^b	30.2 ^c	29.9 ^c	37.2 ^{ab}	40.1 ^a	37.6 ^{ab}	0.79
Chitin	—	22.1	19.4	18.1	24.0	19.1	18.4	1.51
N retention, % ⁴	64.5 ^{ab}	64.1 ^a	61.3 ^{abcd}	60.5 ^{bcd}	61.2 ^{cd}	62.0 ^{abc}	59.1 ^d	0.32

¹ Values are means of 5 observations. ² Means with different superscripts in a row are significantly different ($P < 0.05$).

³ DM digestibility decreased linearly with increasing levels of SM ($P = 0.0001$) and chitin ($P = 0.0001$). ⁴ N retention decreased linearly with increasing levels of SM ($P = 0.002$) and chitin ($P = 0.002$).

1996). Significant differences among treatments were assessed by least significance difference and orthogonal polynomials were used to determine linear response trends due to SM or chitin supplementation levels in the diets.

Results and Discussion

Body weight gain, feed intake and feed efficiency decreased numerically, but not significantly, with increasing levels of SM (Table 2), although they decreased significantly in our previous study (Khempaka *et al.*, 2006). This may be due to the shorter experimental period (10 days in the present study, but 21 days in the previous study). Considering animal welfare, the experimental period in the present study was shortened to remove unnecessary distress caused by feeding SM, but 10-day-experimental period was too short to obtain significant differences in these parameters. These parameters did not change when chitin diets were given. This is in agreement with results of previous studies, which showed that body weight, feed intake and feed efficiency changed little in birds given diets containing 3% (Razdan and Pettersson, 1994) and 5% (Kobayashi and Itoh, 1991) chitin. Consequently, chitin in SM seems to have little adverse effect on growth performance.

The results of orthogonal polynomials revealed that DM digestibility decreased linearly with increasing levels of SM ($P = 0.0001$), as shown in our previous study (Khempaka *et al.*, 2006). A similar trend was found with increasing levels of chitin ($P = 0.0001$); the each value in SM groups was similar to the corresponding value in chitin groups (Table 2).

This suggests that chitin in SM was the main factor to decrease DM digestibility. Chitin may decrease DM digestibility by means of its own low digestibility and/or by the suppression of digestion of some other nutrients (see below). Decreased digestibility should lead to decreased growth performance, but this was not observed as mentioned above. It seems likely that the decrease in DM digestibility was too small to affect growth performance.

Chitin digestibility was 22% in birds given 4% SM diet, and 24% in birds given 1.3% chitin diet. These values decreased numerically, but not significantly, to 18% with increasing levels of SM and chitin (Table 2), which is similar to observations in American kestrels (Akaki and Duke, 1999). Interestingly, it is reported that 92% of chitin was digested by chicken (5-month-old white leghorn) (Hirano *et al.*, 1990). Chitinolytic activity involved in chitin digestion in chickens exists in the gizzard (Han *et al.*, 1997), soybean seeds (Hirano *et al.*, 1988) and probably intestinal bacteria, suggesting that chitin digestibility is altered by rearing and feeding conditions. Increased chitin digestibility is desirable in practical use of SM. Further studies about chitin digestibility in chickens are needed.

Because of low chitin digestibility, it was expected that decreased DM digestibility when SM and chitin diets were given, can be explained by low digestibility of chitin *per se*. Therefore, assuming that chitin digestibility was equal to DM digestibility of the control group, DM digestibility was recalculated. As the results, the values in 4%, 8% and 12% SM groups were 76.8%, 76.1% and 76.1%, respectively, and those in 1.3%, 2.6% and 3.9% chitin groups

Table 3. Meat colors of growing broilers given dietary shrimp meal^{1,2}

	Control	Shrimp meal			Pooled SEM
		4%	8%	12%	
Lightness (L* value)					
Breast meat ³	57.6 ^a	56.1 ^{ab}	55.0 ^b	55.2 ^b	0.44
Thigh	51.3	48.9	49.9	49.9	0.45
Skin	64.1	65.0	64.7	65.4	0.45
Redness (a* value)					
Breast meat	3.9	4.1	3.6	5.0	0.25
Thigh ³	5.7 ^b	7.3 ^a	7.4 ^a	7.2 ^a	0.25
Skin	5.2	5.0	4.9	4.6	0.29
Yellowness (b* value)					
Breast meat	4.9	5.6	5.7	5.2	0.37
Thigh	3.7	3.5	3.9	3.8	0.35
Skin	6.8	7.0	6.6	8.7	0.63

¹Values are means of 5 observations. ²Means with different superscripts in a row are significantly different ($P < 0.05$). ³Linear treatment responds for L* value of breast meat and a* value of thigh meat were $P = 0.04$ and $P = 0.002$, respectively.

were 76.4%, 76.7% and 75.0%, respectively. These values in 3 SM groups did not differ significantly from the value in control group, suggesting that chitin decreased DM digestibility by means of its low digestibility rather than suppression of digestion of some other nutrients. A similar trend was found in chitin groups, but the value in 3.9% chitin group was significantly lower than that in control group. Consequently, a detailed study on the mechanism for the inhibition of DM digestion by chitin should be performed to obtain a conclusive answer.

The results of ANOVA showed that ash digestibility decreased significantly with increasing levels of SM, but this was not a linear decrease. On the other hand, ash digestibility unchanged with increasing levels of chitin (Table 2). This may be due to increased level of ash in SM diets, because ash content in SM diets increased with increasing levels of SM, while those in chitin diets unchanged with increasing levels of chitin. This suggests that chitin had little effect on ash digestibility. SM contained high levels of calcium, which accounted for 50% of ash (Ngoan *et al.*, 2000). Effect of calcium in SM on performance is worth studying, because high levels of calcium affected growth performance adversely (Smith and Taylor, 1961; Watkins *et al.*, 1989).

The results of orthogonal polynomials revealed that N retention decreased linearly with increasing levels of SM ($P = 0.002$) and chitin ($P = 0.002$), when chitin N in diets and excreta were taken into

consideration in calculation of N retention (Table 2). This suggests that decreased N retention by feeding SM was caused by chitin in SM. Even when chitin N in diets and excreta were ignored in calculation of N retention, much the same values were obtained (data not shown), suggesting that the adverse effect of chitin on N retention was not explained by low digestibility of chitin.

Meat and skin color was measured in control and 3 SM groups in expectation of improved visual appearances (Table 3). The lightness (L* value) decreased only in breast meat and the redness (a* value) increased only in thigh meat with feeding SM. Other values changed little with feeding SM. Akiba *et al.* (2001) reported that redness of breast and thigh meats of broilers increased by feeding yeast containing high concentrations of astaxanthin for more than 2 weeks, and yellowness also increased when the feeding period was prolonged. Taking this into account, the feeding period of SM diets in the present study (10 days) may be too short to intensify meat color markedly. In addition, concentration of astaxanthin in SM, which was not measured, might be involved in the color intensification.

In conclusion, the results obtained here showed that decreased DM digestibility, which is one of the adverse effects of SM, seemed to be explained by the low digestibility of chitin in SM, and SM may be useful to improve meat color of broilers.

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