# Effects of Levels of Crude Fiber on Growth Performances and Intestinal Carbohydrases of Domestic Goslings

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**ABSTRACT :** This study was conducted to examine the effects of dietary crude fiber levels on the growth and intestinal carbohydrases of goslings. Thirty-two, 2 week old female White Roman goslings were divided into four groups of 4 goslings with 2 replicates. Diets were isocaloric and isonitrogenous, containing 40, 80, 120 or 160 g/kg crude fiber. At the end of the 4 weeks of the experimental period, all goslings were sacrificed and the carbohydrases activities were measured. Feed intake was significantly higher in the 120 and 160 g/kg crude fiber groups over that in the 40 and 80 g/kg groups ($p<0.05$). The average daily gosling weight gain significantly increased with increasing crude fiber levels from 40 to 120 g/kg. However, both the daily gain and feed conversion of the 160 g/kg crude fiber diet group decreased significantly. Amylase, maltase and $\alpha$-glucosidase activities in the duodenum significantly decreased as the dietary crude fiber level increased. The maltase and $\alpha$-glucosidase activities in the jejunum-ileum showed a similar trend with those in the duodenum. By increasing the levels of crude fiber, cellulase activity in the caecum content significantly increased. There was, however, an adverse effect on the amylase activity. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 10 : 1450-1454)*

**Key Words :** Goslings, Crude Fiber, Carbohydrases

## INTRODUCTION

It has been shown that crude fiber produces beneficial feathering effects and protection from cannibalism in chicks (Ewing, 1963). Several reports have been published on the effect of dietary crude fiber on the lipid metabolism (Akiba and Matsumoto, 1982) and digestion and absorption of lipids and carbohydrates in chicks (Cummings, 1978). Geese can be successfully raised on forage and can derive a considerable portion of their nutrient requirements from high fibrous feed. They can digest plant structural substance better than other avian species (Jamroz et al., 1992). Hollister et al. (1984) pointed out that there was no difference in feed efficiency between geese fed with diets containing 200 g/kg Kentucky blue grass or dehydrated alfalfa and those fed with a low fiber diet. Chen et al. (1992) indicated that goslings gained more body weight and increased total volatile fatty acid (VFA) concentration in the caecum as level of dietary crude fiber increased from 40 to 120 g/kg in an isocaloric and isonitrogenous diet. Previously, it has been reported that high dietary crude fiber level significantly reduced feed passage time in goslings (Chen et al., 1991). Carre et al. (1990) suggested that geese depended upon non-starch-polysaccharide (NSP) utilization in fibrous diets for an energy source. The indigestible NSP passes through the gastro-intestinal tract faster in geese than in the other avian species. In some cases, digesta passage through the gastro-intestinal (GI) tract was as short as 30 min (Owen, 1995). Geese then spend most daytime (90%) hours eating to compensate for limited cell wall digestion (Cowan, 1980). Sue et al. (1995) showed that the availability of amino acids in growing goslings significantly decreased when the dietary crude fiber level increased. The utilization of dry matter, ether extract, gross energy, neutral detergent fibers (NDF) and acid detergent fiber (ADF) were also influenced by high dietary crude fiber (Sue et al., 1996). Jamroz et al. (1992) indicated that geese digested different components of crude fiber to different extents, from 0.2 to 0.4% in cellulose and 0.4 to 0.57 % in hemicellulose. Chiou et al. (1996) also showed that different sources of dietary fiber significantly influenced the intestinal morphology of domestic geese. The geese that were fed diets with alfafa meal, rice hull or pectin supplements had longer villi than a lignin supplemented group. Mattocks (1971) showed that there was no cellulolytic activity in the caeca of domestic geese and concluded that geese cannot digest cellulose. However, studies on the effects of levels of dietary crude fiber on the activities of the digestive enzymes of geese are limited. Thus, this study was designed to assess the effects of levels of dietary crude fiber on the growth performances, and carbohydrase activities in the digestive tract, of goslings.

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## MATERIALS AND METHODS

### Animals and diets

Thirty-two, 2-week-old female White Roman goslings were randomly divided into four groups of 4 birds each. Each group of goslings had two replicates and were fed one of four isocaloric, isonitrogenous diets containing 40, 80, 120 or 160 g/kg crude fiber. Rice hull was a major fiber source in the diet. Goslings were raised individually in wire cages under 25±2℃. Feed and water were supplied *ad libitum*. The experimental diets were formulated according to the nutrient requirements of geese (NRC, 1994) as shown in table 1 and calculated to be isocaloric and isonitrogenous at 12.13 ME MJ/kg and 200 g/kg crude protein. During a four-wk feeding period, all geese were weighed individually and group feed consumption was recorded weekly.

**Preparation of crude enzymes**

At the end of the experiment, all goslings were sacrificed. At necropsy, the various segments of the intestine (with digesta) were immediately removed for determination of the activities of carbohydrases. The crude enzymes of the duodenum, jejunun-ileum mucosa and contents as well as caecum content were prepared according to the method of Kidder and Manners (1980). Samples were weighed and homogenized with Potter Elvenhjem (TRI-R, Intruments, Model-k41) at 4℃ in a 0.9% saline solution which was 4 times the sample weight. Thereafter, the homogenates were centrifuged at 2,000 g for 30 min and the resulting clear supernatants were used for assaying the carbohydrase activities.

**Chemical analysis**

The proximate analyses of the feed samples were determined using the AOAC methods (1988). The NDF and ADF contents were determined according to the method of Van Soest et al. (1991). The $\alpha$-glucosidase (EC 3.2.1.20), $\beta$-glucosidase (EC 3.2.1.21) and maltase activities were assayed using the method of Nagayami and Saito (1968) with p-nitrophenyl-$\alpha$-D-glucopyranose ($\alpha$-PNP-Glu, Sigma N-1377), p-nitrophenyl-$\beta$-D-glucopyranose ($\beta$-PNP- Glu, Sigma N-7006) and maltose, respectively, as substrates. The $\alpha$-amylase (EC 3.2.1.1), cellulase (EC 3.2.1.4) and cellubiohydrolase (EC 3.2.1.21) activities were determined according to the method of Onodera et al. (1988) using soluble starch (Wako pure chemical Industry Ltd. Japan), carboxymethyl cellulose (Wako pure chemical Industry Ltd. Japan) and avicel (Fluka Chemie AG. Ind.), respectively, as substrates. The activity of one unit of $\alpha$-glucosidase and $\beta$-glucosidase was expressed as 1 $\mu$mole D-nitrophenol released per min at 37℃. One unit of maltase and $\alpha$-amylase was expressed as 1 mg glucose and 1 mg reducing sugar (maltose as standard reducing sugar) released, respectively, per min at 37℃. The activity

**Table 1.** Composition of experimental diets (g/kg)

| | Levels of crude fiber (g/kg) | | | |
|---|---|---|---|---|
| Ingredients | 40 | 80 | 120 | 160 |
| Yellow corn | 620.4 | 453.8 | 294.5 | 148.0 |
| Soyabean meal | 251.6 | 241.0 | 197.0 | 50.0 |
| Fish meal (65%) | 40.0 | 40.0 | 40.0 | 40.0 |
| Full fat soyabean meal | 40.0 | 80.0 | 160.0 | 360.0 |
| Soyabean oil | 0.3 | 44.8 | 79.0 | 86.0 |
| Dicalcium phosphate | 15.4 | 15.5 | 14.8 | 12.3 |
| Calcium carbonate | 4.7 | 4.2 | 4.2 | 5.8 |
| Sodium chloride | 4.0 | 4.0 | 4.0 | 4.0 |
| DL-Methionine | 1.1 | 1.2 | 1.2 | 1.2 |
| Choline chloride (50%) | 1.0 | 1.0 | 1.0 | 1.0 |
| Premix* | 1.5 | 1.5 | 1.5 | 1.5 |
| Rice hull | 20.0 | 113.0 | 203.0 | 290.2 |
| Total | 1000.0 | 1000.0 | 1000.0 | 1000.0 |
| Calculated value | | | | |
| Crude protein | 200.9 | 200.6 | 200.8 | 200.9 |
| Metabolizable energy (MJ/kg) | 12.13 | 12.13 | 12.13 | 12.13 |
| Analysis value | | | | |
| Crude protein | 205.0 | 202.0 | 205.0 | 206.0 |
| Crude fiber | 40.9 | 80.7 | 120.0 | 160.7 |
| Neutral detergent fiber | 109.0 | 173.0 | 253.0 | 309.0 |
| Acid detergent fiber | 45.0 | 91.0 | 125.0 | 173.0 |

* Supplied per kilogram of diet ; vit. A, 25,000 I.U.; vit. $D_3$, 5,000 I.C.U.; vit. E, 10 mg; vit. K, 2 mg; vit. $B_1$, 2 mg; vit, $B_2$, 5 mg; vit. $B_6$, 2 mg; vit. $B_{12}$, 10 $\mu$g; folic acid, 1 mg; biotin, 50 $\mu$g; niacin, 40 mg; Zn, 100 mg; pantothenic acid, 10 mg; Mn, 80 mg; Fe, 50 mg; Se, 0.1 mg; Cu, 5 mg; I, 5 mg and Co, 1 mg.

unit of each of the fiber related hydrolases (cellulase and cellubiohydrolase) were expressed as 1 $\mu$g of reducing sugar (glucose as standard sugar) released per min at 50℃ and pH 5.0.

**Statistical analysis**

A completely randomized block design for this experiment was used to examine the dietary crude fiber level effects. The data were analyzed using the General Linear Models procedure of the statistical analysis system (SAS, 1985). Duncan's New Multiple Range Test was used to determine significant differences among treatments.

## RESULTS AND DISCUSSION

**Growth performance**

The dietary crude fiber level effects on feed intake, body weight gain and feed conversion ratio in goslings are shown in table 2. The feed intake and feed conversion (feed/gain) increased as the crude fiber level increased. Goslings fed 120 or 160 g/kg dietary crude fiber diets consumed significantly ($p<0.05$) more feed than those fed 40 or 80 g/kg dietary crude fiber diets. The average daily gain of goslings significantly ($p<0.05$) increased with increasing dietary crude fiber level from 40 to 120 g/kg. However, the daily gain of goslings decreased in the 160 g/kg dietary crude fiber group.

An increase the dietary crude fiber level resulting in an increase in the feed intake of goslings is in agreement with observations in chicks (Dvorak and Bray, 1978) and rats (Schneeman and Gallaher, 1980). It has been reported that goslings fed a high crude fiber diet had a higher passage rate and shorter digesta retention time than those fed a low crude fiber diet (Chen et al., 1991). Feeding a high dietary crude fiber diet increased the GI tract volume in rats (Hansen et al., 1992) and pigs (Pekas and Wray, 1991) because of the bulk density of the fiber. Decreasing the digesta retention time or increasing the volume of GI tract would seem to be the most likely explanations for an increase in feed intake. The 160 g/kg crude fiber diet included more oil than the 40 g/kg crude fiber treatment, and the palatability of high oil in the higher fiber diet might have increased the feed intake. Daily body weight gain of goslings significantly ($p<0.05$) increased as dietary crude fiber level increased from 40 to 120 g/kg in this trial. This result agrees with the findings of Chen et al. (1992) who reported that increasing dietary crude fiber level from 30 to 120 g/kg significantly ($p<0.05$) increased body weight gain of goslings. This probably is due to goslings consuming more feed and deriving more nutrients. However, the daily gain of goslings fed with 160 g/kg crude fiber diet tended to decrease compared with the 120 g/kg crude fiber diet treatment group. It is possible that this level of crude fiber is in excess of what is required for growth. The daily weight gain in this study showed a quadratic response to the crude fiber levels in diets ($Y=19.75-0.33x+0.0025x^2$, $r^2=0.35$, $p<0.05$; where Y=daily weight gain(g), x=crude fiber level, %). The optimal amount of crude fiber for daily gain in goslings was 88 g/kg. It has been demonstrated that an increase in crude fiber level resulted in suppressing the availability of amino acids in geese (Sue et al., 1995, 1996). This phenomenon could explain why a diet with high crude fiber reduced efficiency of feed conversion in this study.

**Table 2.** Effects of dietary crude fiber levels on growth performance of goslings

| | Dietary crude fiber levels (g/kg) | | | | |
|---|---|---|---|---|---|
| Items | 40 | 80 | 120 | 160 | SE |
| Daily feed intake (g/bird/day) | 198.7$^b$ | 211.3$^b$ | 230.2$^a$ | 236.0$^a$ | 3.2 |
| Daily gain (g/bird/day) | 82.3$^b$ | 86.4$^{ab}$ | 91.9$^a$ | 84.6$^{ab}$ | 1.4 |
| Feed conversion (feed/gain) | 2.40$^b$ | 2.46$^b$ | 2.50$^b$ | 2.84$^a$ | 0.08 |

a,b Means within the same row without the same superscripts are significantly different ($p<0.05$).

**Carbohydrase activities**

Table 3 shows the effects of dietary crude fiber levels on some carbohydrase activities in the mucosa and digesta contents of the duodenum and jejunum-ileum of goslings. The carbohydrase activities in the mucosa were higher than those in the contents of the duodenum, with the exception of amylase. The amylase, maltase and $\alpha$-glucosidase activities in the mucosa and contents of duodenum or jejunum-ileum significantly ($p<0.05$) decreased or tended to decrease when the dietary crude fiber level increased. $\beta$-glucosidase activity in the duodenum, as well as amylase in jejunum-ileum mucosa and contents or $\beta$-glucosidase in jejunum-ileum mucosa were not detected.

The activities of determined carbohydrases in the duodenum mucosa were higher than those in the contents (table 3), suggesting that the carbohydrases are distributed mainly in the mucosa rather than in the contents except for amylase which is secreted from the pancreas and released directly into the intestinal lumen. In general, the enzyme activity per milligram of intestinal content was lower in the high crude fiber diet than those on the low fiber diet, indicating that a dilution of enzyme activity existed due to indigestible fiber. On the other hand, crude fiber might limit or somehow cause a loss of enzyme activity (Schneeman and Gallaher, 1980). In this study, it appears that the observed decrease in the carbohydrase activities in the intestinal content of goslings fed the high crude fiber diet was associated with the characteristic fiber dilution and binding effect. The level of crude fiber also significantly influenced intestinal mucosa carbohydrase activities. The cause of the dietary crude fiber effects on mucosal enzyme activities is not well known. A direct interaction due to the presence of fiber component limiting hydrolysis of the substrates or the presence of enzyme inhibitors, especially in natural fibers, has been shown *in vitro* studies (Hansen, 1987). On the other hand, the lower enzyme activities in the mucosa of the intestine might suggest that turnover rate of enterocytes tended to be higher in the high fiber group than in the low fiber group. It has been reported that the reduction in brush border enzyme activities may be due to an increase the rate of cell proliferation and cell-turnover induced by some fiber components (Johnson and Gee, 1986).

The effects of dietary crude fiber levels on cellulase, cellubiohydrolase and amylase activities in the caecum content of goslings are shown in table 4. Increasing the dietary crude fiber levels significantly increased the cellulase activity in the caecum content ($p<0.05$). The cellobiohydrolase activity also tended to increase ($p>0.05$); however, there was an adverse effect on the amylase activity. Bedbury and Duke (1983) reported that protozoa were not isolated in the caecum of turkeys. In our laboratory, protozoa were not isolated in the caecum of goslings either (unpublished data). It can be expected that fiber related enzyme groups are secreted by other micro-organisms in the caecum. Bedbury and Duke (1983) reported that turkeys fed the high fiber diet harbored significantly higher numbers of facultative micro-organisms than did low fiber-fed birds. In this experiment, goslings fed the high fiber diets had higher cellulase activities than those fed low fiber diets. These results might be due to high fiber-fed groups possessing higher numbers of microorganisms in the caecum and secreting higher activity of cellulases than low fiber groups. However, the amylase activity decreased with an increase in the crude fiber level in this experiment. The result from duodenum

**Table 3.** Effect of dietary crude fiber levels on carbohydrase activities in the small intestine of goslings

| | Dietary crude fiber levels (g/kg) | | | | |
|---|---|---|---|---|---|
| Items | 40 | 80 | 120 | 160 | SE |
| Duodenum | | | | | |
| Amylase activity[1] | | | | | |
| Unit/g mucosa | 4.93[5,ab] | 5.65[a] | 4.10[b] | 4.02[b] | 2.64 |
| Unit/g content | 6.74 | 5.82 | 5.85 | 6.52 | 0.38 |
| Maltase activity[2] | | | | | |
| Unit/g mucosa | 44.33[a] | 40.68[a] | 29.11[b] | 29.55[b] | 2.01 |
| Unit/g content | 37.90[a] | 31.30[ab] | 25.22[b] | 24.87[b] | 1.91 |
| $\alpha$-glucosidase activity[3] | | | | | |
| Unit/g mucosa | 2.77 | 2.29 | 2.38 | 2.48 | 0.14 |
| Unit/g content | 2.40 | 2.04 | 1.81 | 1.86 | 0.12 |
| Jejunum-ileum | | | | | |
| Maltase activity[2] | | | | | |
| Unit/g mucosa | 29.66[a] | 25.27[ab] | 19.32[bc] | 17.32[c] | 1.11 |
| Unit/g content | 10.40 | 8.71 | 8.41 | 7.24 | 0.67 |
| $\alpha$-glucosidase activity[3] | | | | | |
| Unit/g mucosa | 4.44[a] | 4.17[a] | 3.20[b] | 3.28[b] | 0.15 |
| Unit/g content | 1.62 | 1.61 | 1.55 | 1.37 | 0.07 |
| $\beta$-glucosidase[4] | | | | | |
| Unit/g content | 0.022 | 0.023 | 0.022 | 0.020 | 0.001 |

[1] Activity unit expressed as 1 mg of reducing sugar liberated from a substrate of soluble starch per minute at 37℃.
[2] Activity unit expressed as 1 mg of glucose liberated from a substrate of maltose per minute at 37℃.
[3] Activity unit expressed as 1 $\mu$moles of p-nitrophenol liberated from a substrate of $\alpha$-PNP-Glu per minute at 37℃.
[4] Activity unit expressed as 1 $\mu$moles of p-nitrophenol liberated from a substrate of $\beta$-PNP-Glu per minute at 37℃.
[5] Values of enzyme activity are means of 8 goslings in each treatment and 3 duplicate determination per gosling.
[a,b,c] Means within the same row without the same superscripts are significantly different ($p<0.05$).

**Table 4.** Effect of dietary fiber levels on cellulase and amylase activities in caecal content of goslings

| | Dietary crude fiber levels (g/kg) | | | | |
|---|---|---|---|---|---|
| Items | 40 | 80 | 120 | 160 | SE |
| Endoglucanase[1] Unit/g content | 67.81[4,c] | 76.41[bc] | 102.00[ab] | 111.86[a] | 5.11 |
| Cellobiohydrolase[2] Unit/g content | 33.80 | 37.75 | 39.38 | 42.18 | 1.09 |
| Amylase[3] Unit/g content | 1.94[a] | 1.81[ab] | 1.75[ab] | 1.29[b] | 1.04 |

[1] Activity unit expressed as 1 $\mu$g of reducing sugar liberated from a substrate of CMC per minute at 50℃.
[2] Activity unit expressed as 1 $\mu$g of reducing sugar liberated from a substrate of avicel per minute at 50℃.
[3] Activity unit expressed as 1 mg of reducing sugar liberated from a substrate of soluble starch per minute at 37℃.
[4] Values of enzyme activity are means of 8 goslings in each treatment and 3 duplicate determination per gosling.
[a,b,c] Means within the same row without the same superscripts are significantly different ($p<0.05$).

examinations showed a similar trend. A low fiber diet may induce amylase secretion for fermentation of more digestible carbohydrate residue in the caecum, which is indigestible in the small intestine. This amylase is secreted not only from the pancreas, but also from microorganisms in the caecum.

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## REFERENCES

Akiba, Y. and T. Matsumoto. 1982. Effects of dietary fibers on lipid metabolism in liver and adipose tissue in chicks. J. Nutr. 112:1577-1585.

AOAC. 1988. Official Methods of Analysis. 14th ed. Association of Official Analysis Chemists. Washington, DC. pp. 134-135.

Bedbury, H. P. and E. Duke. 1983. Cecal microflora of turkeys fed low or high fiber diets: Enumeration, identification, and determination of cellulolytic activity. Poult. Sci. 62:675-682.

Carre, B., L. Derouet and B. Leclerco. 1990. The digestibility of cell-wall polysaccharides from wheat (bran or whole grain), soybean meal, and white lupin meal in cockerals, muscovy ducks, and rats. Poult. Sci. 69:623-633.

Chen, Y. H., J. C. Hsu and L. L. Lu. 1991. The effect of high and low dietary fiber level on digesta passage through alimentary canal of goslings. Res. Bull. Tunghai Univ. 32:101-109. (in Chinese).

Chen, Y. H., J. C. Hsu and L. L. Lu. 1992. Effect of dietary fiber levels on growth performance, intestinal fermentation and cellulase activity of goslings. J. Chin. Soc. Anim. Sci. 21:15-28. (in Chinese).

Chiou, P. W. S., T. W. Lu, J. C. Hsu and B. Yu. 1996. Effect of different sources of fiber on the intestinal morphology of domestic geese. Asian-Aus. J. Anim. Sci. 9:539-550.

Cowan, P. J. 1980. The goose : an efficient converter of grass? Worlds Poult. Sci. J. 36:112-116.

Cummings, J. H. 1978. Nutritional implications of dietary fiber. Am. J. Clin. Nutr. 31:S21-29.

Dvorak, R. A. and D. J. Bray. 1978. Influence of cellulose and ambient temperature on feed intake and growth of chicks. Poult. Sci. 57:1351-1354.

Ewing, W. E. 1963. Fiber in the poultry ration. In: Poultry Nutrition (5th ed.). The Ray Ewing Company, California. pp. 548-557.

Hansen, W. E. 1987. Effect of dietary fiber on pancreatic lipase activity *in vitro*. Pancreas. 2:195-198.

Hansen, I., K. E. Bach Knudsen and B. O. Eggum. 1992. Gastrointestinal implications in the rat of wheat bran and pea fiber. Br. J. Nutr. 68:451-462.

Hollister, A. G., H. S. Nakaue and G. H. Arscott. 1984. Studies with confinment-reared growth goslings: 1. Effects of feeding high level of dehydrated alfalfa and Kentucky blue grass to growing goslings. Poult. Sci. 63:532-537.

Jamroz, D., A. Wiliczkiewicz and J. Sharupinska. 1992. The effect of diets containing different levels of structural substances on morphological changes in the intestinal walls and the digestibility of the crude fiber fractions in geese (part III). J. Anim. Feed Sci. 1:37-50.

Johnson, I. T. and J. M. Gee. 1986. Gastrointestinal adaptation in response to soluble non-available polysaccharides in the rat. Br. J. Nutr. 55:497-505.

Kidder, D. E. and M. J. Manners. 1980. The level and distribution of carbohydrases in the small intestine mucosa of pigs from 3 weeks of age to maturity. Br. J. Nutr. 43:141-152.

Mattocks, J. G. 1971. Goose feeding and cellulose digestion. Wildfowl. 22:107-113.

Nagayami, F. and Y. Saito. 1968. Distribution of amylase, $\alpha$- and $\beta$-glucosidase, and $\beta$-galactosidase in fish. Bull. Jap. Soc. Sci. Fisheries. 34:944.

NRC. 1994. Nutrient Requirements of Poultry, 9th ed., National Academy Press, Washington, DC.

Onodera, R., K. Murakami and K. Ogama. 1988. Cellulose degrading enzyme activities of mixed rumen ciliate protozoa from goats. Agric. Biol. Chem. 52:2639-2640.

Owen, M. 1995. Cutting and fertilizing grassland for winter goose management. J. Wildlife Management. 39:163-167.

Pekas, J. C. and J. E. Wray. 1991. Principal gastrointestinal variables associated with metabolic heat production in pigs; statistical cluster analysis. J. Nutr. 121:231-239.

SAS. 1985. SAS Users Guide, version 5ed., SAS Institute Inc., Cary, NC.

Schneeman, B. O. 1978. Effect of plant fiber on lipase, trypsin and chymotrypsin activity. J. Food Sci. 43:634-636.

Schneeman, B. O. and D. Gallaher. 1980. Changes in intestinal digestive enzyme activity and bile acids with dietary cellulose in rats. J. Nutr. 110:584-590.

Sue, C. J., J. C. Hsu and B. Yu. 1995. Effects of dietary fiber levels on nutrient utilization of diet in gosling I. utilization of amino acids. J. Chin. Soc. Anim. Sci. 24: 19-30 (in Chinese).

Sue, C. J., J. C. Hsu and B. Yu. 1996. Effects of dietary fiber levels on nutrient utilization of diet in gosling II. utilization of dry matter, crude fat, gross energy, neutral detergent fiber and acid detergent fiber. J. Chin. Soc. Anim. Sci. 25:129-138 (in Chinese).

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Symposium: Carbohydrate methodology, metabolism and nutritional implications in dairy cattle. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.