# Evaluation of CM (Cell Mass from Lysine Fermentation) as an Alternative Protein Source in Broiler Diets

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**ABSTRACT** : The experiment was conducted to evaluate CM (Cell Mass from Lysine Fermentation), which is used to produce synthetic lysine in industry, as an alternative protein source in broiler diets. Three different production conditions were employed to produce CMs (CM Ⅰ, Ⅱ, Ⅲ). Treatments were control, CM Ⅰ-1 (1% of CM in the diet), CM Ⅰ-3 (3% of CM in the diet), CM Ⅰ-5 (5% of CM in the diet), CM Ⅱ (3% of CM in the diet), and CM Ⅲ (3% of CM in the diet). It was found that CM products were all high in crude protein content and especially high in lysine and methionine contents, while very low in minerals. For the starter period, all CM groups showed better weight gain, chicks fed CM Ⅰ-1 diets were especially high in weight gain ($p<0.05$). CM groups consumed 14.4 to 18.0% more feed than chicks fed control diets ($p<0.05$). The best FCR was found in CM Ⅰ-1 groups ($p<0.05$), but as CM level was increased, FCR was also increased. For the finisher period, weight gain was similar through all treatments. Through whole experimental period, weight gain and feed intake were higher in all CM groups than control group ($p<0.05$), however, as CM level was increased, FCR was also increased. Generally chicks fed CM diets showed higher utilizabilities of gross energy, dry matter, crude protein and crude fat. The best nutrients utilizability was obtained in CM Ⅰ-1 group, and the worst was found in the control group. During the finisher period, the utilizabilities of crude protein, crude ash and phosphorus were not affected by the dietary treatments. Amino acids utilizability was not significantly affected by the treatments except CM Ⅰ-5 group. In all amino acids tested, chicks did not show the big difference in utilizabilities. Only in the CM Ⅰ-5 group, amino acids utilizability was significantly lower than control group. However, among CM Ⅰ groups, the mean value of the amino acids utilizability was decreased as the level of CM inclusion in the diet was increased. During the finisher period, similar trend was found in amino acids utilizability.

**(Key Words**: Cell Mass, Lysine, Broilers, Performance, Protein Sources)

## INTRODUCTION

Feed accounts for about 50 to 70% of monogastric animal production cost, and protein sources are most expensive feed ingredients in feed production. The prices of high protein feed ingredients, regardless of the origin, are increasing continuously. And the production of some high protein ingredients, such as fish meal, is decreasing. Therefore, there is a need to find new protein sources. There have been a lot of researches to find out alternative protein sources in animal diets, such as yeast (Ringrose, 1949; Samuel and Zimmerman, 1977), single cell protein (Woodham and Deans, 1973; White and Balloun, 1977; D'Mello et al., 1976) and eprin and paprin (Han et al., 1995).

In modern feed production, synthetic amino acids, such as lysine, methionine etc, are widely used to reduce crude protein content in the feed (Chae et al., 1988; Han et al., 1978, 1991, 1995; Heo et al., 1995) and to get optimal amino acids balance in the diet. Lysine, which is regarded as the first limiting amino acid in monogastric animal and most commonly used synthetic amino acid, is produced by industry in large amounts using bacteria. A lysine producing bacteria is Corynebacterim which is short-rod type, Gram positive, aerobic and typical amino acid-producing bacteria. The bacterial cell mass from

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lysine fermentation is rich in amino acids, especially in lysine and methionine, thus has a great potential to be used as a high protein feed ingredient.

Thus this experiment was designed to evaluate CM as an alternative protein source in broiler diets. The availability of proximate nutrients, amino acids and gross energy was measured and the performance of broiler fed containing graded levels of CM was also examined.

## MATERIALS AND METHODS

### 1. Experimental design

This experiment consisted of 6 treatments. Corn-SBM-fish meal based diet was used as a control, and fish meal was replaced with CM Ⅰ at the level of 1% (CM Ⅰ-1), 3% (CM Ⅰ-3), 5% (CM Ⅰ-5), and with CM Ⅱ (3% of the diet), CM Ⅲ (3% of the diet), respectively. The cell mass was prepared by centrifugation and drying of fermentation broth. Three different batches of lysine fermentation were used to harvest bacteria cells by the degree of the intensity of centrifugation. CM Ⅰ was made by the high centrifugal intensity while CM Ⅱ and CM Ⅲ by medium and low intensity, respectively. It appeared that more cells could be collected as centrifugal intensity increased. Each treatment had 9 replicates consisted of 6 male arbor acre broiler chicks in each replicate.

### 2. Experimental animals, period and location

Male broiler chicks of arbor acre produced by Han Il breeding Farm (Korea) were used as experimental subjects. At one day of age, experimental animals were chosen to have similar initial body weight (49.06 g) and fed the experimental diets for six weeks. A randomized

**Table 1.** Formula and chemical composition of the experimental diets for starter period

| | Control | CM I-1 | CM I-3 | CM I-5 | CM II | CM III |
|---|---|---|---|---|---|---|
| Ingredients: | | | | | | |
| Corn | 59.22 | 59.52 | 59.89 | 59.87 | 60.01 | 59.39 |
| SBM | 27.84 | 27.20 | 26.91 | 27.22 | 27.22 | 27.22 |
| CGM | 4.51 | 5.00 | 5.00 | 4.75 | 5.60 | 5.23 |
| Fish Meal | 5.00 | 4.00 | 2.00 | 0.00 | 2.00 | 2.00 |
| Tallow | 1.02 | 0.73 | 0.35 | 0.00 | 0.30 | 0.29 |
| Limestone | 0.09 | 0.20 | 0.52 | 0.85 | 0.56 | 0.54 |
| TCP | 1.60 | 1.64 | 1.64 | 1.64 | 1.64 | 1.62 |
| Vit.-Min. Mix.[1] | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Salt | 0.22 | 0.22 | 0.22 | 0.22 | 0.23 | 0.22 |
| Methionine | 0.05 | 0.04 | 0.02 | 0.00 | 0.01 | 0.02 |
| Antibiotics | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Lysine | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| CM | 0.00 | 1.00 | 3.00 | 5.00 | 3.00 | 3.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Chemical composition: | | | | | | |
| GE (kcal/kg)[2] | 3,995.84 | 3,979.49 | 3,955.56 | 3,931.61 | 3,951.29 | 3,953.71 |
| CP (%)[2] | 23.92 | 23.66 | 23.17 | 23.97 | 23.30 | 22.20 |
| Lysine (%)[2] | 1.25 | 1.13 | 1.17 | 1.17 | 1.24 | 1.11 |
| Met + Cys (%)[2] | 0.64 | 0.60 | 0.59 | 0.59 | 0.61 | 0.63 |
| Ca (%)[3] | 1.00 | 1.00 | 1.00 | 1.00 | 1.01 | 1.00 |
| Phosphorus (%)[3] | 0.85 | 0.85 | 0.85 | 0.85 | 0.86 | 0.85 |

[1] Vit.-Min. mixture contains following in 1 kg of the diet: vitamin A, 10,000 IU; vitamin $D_3$, 1,500 IU; vitamin $K_3$, 5 mg; vitamin E, 15 mg; vitamin $B_2$, 8 mg, vitamin $B_{12}$, 0.008 mg; Ca-d-pantothenate, 8 mg; niacin, 25 mg; folic acid, 0.4 mg; biotin, 0.2 mg; choline, 500 mg; pyridoxine, 1 mg; B.H.T. 125 mg; Co, 0.85 mg; I, 1.29 mg; Zn, 100 mg; Mg, 110 mg; Cu, 8.75 mg; Se, 0.15 mg; Fe, 35 mg.

[2] Analyzed Value.

[3] Calculated Value.

complete design was employed in assigning chicks to treatments, in which a total of 324 chicks were used. All feeding trial, metabolic trial, chemical analysis and statistical analysis were conducted in the Animal Nutrition Laboratory, Department of Animal Science and Technology, College of Agriculture and Life Science, Seoul National University located in Suweon, Korea. Feeding trial initiated on April 10, 1996 and terminated on May 23, 1996.

**3. Experimental diets**

A Corn-soybean meal based experimental diets were formulated to meet the NRC (1994) requirements for the starter period (table 1) and the finisher period (table 2). For starter period, the diet was formulated to 23% crude protein, 1.21% lysine, and 0.5% methionine, while for finisher period, the diet was formulated to 20% crude protein, 1.07% lysine and 0.40% methionine. The amino acids composition of CM is presented in table 3.

**4. Methods of experiments**

**1) Feeding trial**

All the chicks were raised in battery cages made of steel wire and housed in a room with a constant light and air ventilation. Before the feeding trial began, the chicks were fed a commercial diet for one day. Experimental diets and drinking water were provided *ad libitum* during the entire experimental period of six weeks. Body weight and feed intake were recorded weekly on replication basis to calculate the weight gain and feed conversion ratio.

**2) Metabolic trial**

To measure the nutrient utilizability of the experimental diets, the metabolizability coefficient was

**Table 2.** Formula and chemical composition of the experimental diets for finisher period

| | Control | CM I-1 | CM I-3 | CM I-5 | CM II | CM III |
|---|---|---|---|---|---|---|
| Ingredients: | | | | | | |
| Corn | 67.82 | 68.43 | 67.82 | 67.35 | 68.94 | 68.24 |
| SBM | 20.40 | 20.02 | 21.63 | 21.30 | 17.99 | 18.92 |
| CGM | 3.78 | 3.97 | 2.95 | 3.27 | 5.39 | 5.14 |
| Fish Meal | 5.00 | 4.00 | 2.00 | 0.00 | 2.00 | 2.00 |
| Tallow | 0.68 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 |
| Limestone | 0.42 | 0.44 | 0.75 | 1.21 | 0.76 | 0.76 |
| TCP | 1.21 | 1.21 | 1.21 | 1.23 | 1.21 | 1.21 |
| Vit.-Min. Mix.[1] | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Salt | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.19 |
| Antibiotics | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Lysine | 0.05 | 0.05 | 0.00 | 0.00 | 0.06 | 0.09 |
| CM | 0.00 | 1.00 | 3.00 | 5.00 | 3.00 | 3.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Chemical composition: | | | | | | |
| GE (kcal/kg)[2] | 4,011.37 | 3,992.83 | 3,972.81 | 3,958.11 | 3,974.74 | 3,976.27 |
| CP (%)[2] | 21.09 | 21.39 | 20.94 | 20.89 | 19.17 | 21.15 |
| Lysine (%)[2] | 1.03 | 1.08 | 1.13 | 1.00 | 1.08 | 1.01 |
| Met + Cys (%)[2] | 0.57 | 0.60 | 0.54 | 0.49 | 0.53 | 0.55 |
| Ca (%)[3] | 0.92 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Phosphorus (%)[3] | 0.73 | 0.73 | 0.73 | 0.73 | 0.74 | 0.73 |

[1] Vit.-Min. mixture contains following in 1 kg of the diet: vitamin A, 10,000 IU; vitamin $D_3$, 1,500 IU; vitamin $K_3$, 5 mg; vitamin E, 15 mg; vitamin $B_2$, 8 mg, vitamin $B_{12}$, 0.008 mg; Ca-d-pantothenate, 8 mg; niacin, 25 mg; folic acid, 0.4 mg; biotin, 0.2 mg; choline, 500 mg; pyridoxine, 1 mg; B.H.T. 125 mg; Co, 0.85 mg; I, 1.29 mg; Zn, 100 mg; Mg, 110 mg; Cu, 8.75 mg; Se, 0.15 mg; Fe, 35 mg.

[2] Analyzed Value.

[3] Calculated Value.

**Table 3.** Nutrient composition of SBM, FM and CMs[1]

| | SBM | FM | CM I | CM II | CM III |
|---|---|---|---|---|---|
| Proximate composition: | | | | | |
| Moisture (%) | 9.11 | 6.35 | 8.20 | 11.40 | 8.40 |
| C. Fat (%) | 3.14 | 4.50 | 4.90 | 5.90 | 7.30 |
| C. Ash (%) | 6.03 | 16.40 | 1.80 | 1.90 | 2.80 |
| C. Protein (%) | 42.03 | 56.79 | 69.00 | 66.80 | 58.60 |
| Gross energy (kcal/kg): | 3,843.14 | 4,132.80 | 4,397.54 | 4,383.28 | 4,483.55 |
| Amino acids: | | | | | |
| ASP | 4.02 | 4.36 | 5.56 | 5.26 | 5.01 |
| THR | 1.38 | 1.91 | 2.60 | 2.65 | 2.29 |
| SER | 1.81 | 2.20 | 2.14 | 2.27 | 1.89 |
| GLU | 8.19 | 7.40 | 8.11 | 8.17 | 7.42 |
| PRO | 1.60 | 3.04 | 1.80 | 1.37 | 1.73 |
| GLY | 1.40 | 5.26 | 2.55 | 2.46 | 2.25 |
| ALA | 1.88 | 4.29 | 5.64 | 5.66 | 5.00 |
| VAL | 1.66 | 2.50 | 3.41 | 3.46 | 2.98 |
| MET | 0.51 | 1.19 | 3.14 | 3.21 | 2.77 |
| ILE | 1.79 | 1.88 | 2.37 | 2.26 | 1.97 |
| LEU | 2.83 | 4.25 | 3.80 | 3.51 | 3.40 |
| TYR | 1.29 | 1.96 | 2.12 | 1.35 | 2.28 |
| PHE | 2.13 | 2.02 | 1.95 | 1.64 | 1.99 |
| HIS | 1.10 | 1.62 | 1.50 | 1.45 | 1.39 |
| LYS | 2.21 | 3.13 | 5.72 | 6.10 | 4.69 |
| ARG | 3.15 | 3.24 | 3.58 | 3.13 | 2.42 |
| Total | 37.00 | 50.26 | 56.00 | 53.95 | 49.47 |
| Fatty acids: | | | | | |
| lauric acid | 0.00 | 5.31 | 1.78 | 1.67 | 1.22 |
| palmaitic acid | 20.39 | 27.34 | 48.76 | 45.71 | 44.91 |
| palmitoleic acid | 0.00 | 1.92 | 0.00 | 0.00 | 0.00 |
| stearic acid | 4.61 | 8.49 | 2.64 | 2.88 | 2.79 |
| oleic acid | 14.28 | 35.06 | 41.44 | 43.78 | 45.99 |
| linoleic acid | 60.73 | 24.89 | 0.00 | 0.00 | 0.00 |
| linolenic acid | 0.00 | 1.52 | 0.00 | 0.00 | 0.00 |
| arachidic acid | 0.00 | 0.78 | 0.00 | 0.00 | 0.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Trace elements: | | | | | |
| P | 0.60 | 2.74 | 0.09 | 0.06 | 0.13 |
| Ca | 0.18 | 3.70 | 0.03 | 0.03 | 0.00 |
| Na | 0.02 | 0.91 | 0.03 | 0.03 | 0.02 |
| Fe | 0.03 | 0.02 | 0.10 | 0.10 | 0.10 |
| K | 2.32 | 0.74 | 0.39 | 0.43 | 0.21 |
| Mg | 0.35 | 0.28 | 0.04 | 0.04 | 0.02 |

[1] Analyzed Value.
SBM: soybean meal; FM: fish meal.

calculated by total excreta collection method during seven days at the end of the starter period and finisher period, respectively. Six and four chicks per treatment for the starter period and finisher period, respectively, were chosen and caged in the metabolic cage in pair for the starter period, and individually for the finisher period. Experimental diets and water were fed to satiation. After four days of adaptation, total excreta were collected four times a day for the three consecutive days to avoid the contamination of foreign materials such as feed, feathers and scales. Collected excreta were pooled and dried in an air-forced drying oven at 60℃ for 72 hours to gain constant dry weight and ground with 1 mm Wiley mill for further chemical analysis.

### 3) Chemical analysis

Analysis of proximate nutrients composition of experimental diets and excreta was conducted according to the methods of AOAC (1990), and amino acids composition was measured using an automatic amino acid analyzer (LKB, Model 4150-alpha, UK). Phosphorus content was measured using the UV-visible spectrophotometer (Hitachi, U-1000, Japan) and gross energy content was measured using the Adiabatic Bomb Calorimeter (Model 1241, Parr Instrument Co., USA).

### 4) Statistical analysis

Statistical analysis for the present data was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) procedure of SAS (1985) package program.

## RESULTS AND DISCUSSION

### 1) Chemical composition of CM products

Analyzed nutrient composition of three CMs is presented in table 3. CM products are all high in crude protein content and especially high in lysine and methionine contents. Generally, single cell protein is low in methionine contents (Woodham and Deans, 1973), but CM in this study was found to be high in methionine. Gross energy contents of CM products were comparable to that of fish meal. Crude ash contents of CM products were extremely low. So were Ca and P contents. CM products were very low in essential fatty acids. Palmitic acid and oleic acid accounted for almost 90% of the fatty acids in CM products. It should be noted that the chemical composition of CM could be different among the batches. Therefore, centrifugation intensity can be a important factor to determine the nutritional value of CM products.

### 2) Growth performance

Table 4 summarized the growth performance of broilers fed the experimental diets containing CM. For the starter period, all CM groups showed better weight gain, chicks fed CM Ⅰ-1 diets were especially high in weight gain ($p < 0.05$). The same trends were found in feed intake in all CM groups. CM groups consumed 14.4 to 18.0% more feed than chicks fed control diet ($p < 0.05$). The reason for the higher feed intake of chicks fed the experimental diets containing CMs was not clearly understood in this study. Since the analyzed gross energy value for CMs was much higher than the value for FM, the experimental diets were formulated to be isocaloric by changing the inclusion level of tallow (table 1 and 2). Thus, it is likely that the experimental diets might not be isocaloric in terms of ME.

The crude protein portion provided from FM plus CMs of experimental diets were calculated to be 3.25%, 3.26%, 3.27%, 3.29%, 3.22% and 3.03% for control, CM Ⅰ-1, CM Ⅰ-3, CM Ⅰ-5, CMⅡ and CMⅢ, respectively. Thus, it does not seem that crude protein from CM or FM influences the growth performance of chicks fed the experimental diets.

The best feed conversion ratio (FCR) was found in CM Ⅰ-1 groups ($p < 0.05$), but as CM level was increased, FCR was also increased. However, still no significant differences were found among the treatments in FCR except for CM Ⅰ-1 groups. White and Balloun (1977) examined the nutritional value of SCP (methanol-derived single cell protein) and found that the chicks fed lower level (2% of the diet) of SCP showed better growth performance while at higher level (4 or 6 % of the diet) the growth rate was diminished. Han et al. (1995) also reported the worse growth performance of pigs when SCP fed more than 4% of the diet when they examined the nutritional value of eprin and paprin.

During the finisher period, weight gain was similar among treatments. Control group appeared to catch up with CM groups in weight gain. However, all CM groups consumed significantly more feed, which resulted in worse FCR than control group ($p < 0.05$). The worst FCR was found in CM Ⅰ-5 groups. Waldroup and Payne (1974) suggested that the reduction in growth rate when fed bacterial cell protein could be largely overcome by pelleting the diets, and the similar results were reported by Wayne and Balloun (1977). Therefore, for the CM,

**Table 4.** Effects of CM on the growing performance of broiler chicks

| Treatment | Initial body weight (g) | Final body weight (g) | Weight gain (g) | Feed intake (g) | F/G |
|---|---|---|---|---|---|
| Starter | | | | | |
| Control | 49.20 | $615.37^{c}$ | $566.17^{c}$ | $933.21^{b}$ | $1.65^{ab}$ |
| CM I (1%) | 49.05 | $764.43^{a}$ | $715.37^{a}$ | $1,093.44^{a}$ | $1.53^{c}$ |
| CM I (3%) | 49.00 | $723.59^{b}$ | $674.59^{b}$ | $1,101.43^{a}$ | $1.64^{ab}$ |
| CM I (5%) | 48.90 | $689.17^{b}$ | $640.27^{b}$ | $1,067.76^{a}$ | $1.67^{a}$ |
| CM II (3%) | 49.02 | $726.59^{ab}$ | $677.58^{ab}$ | $1,081.73^{a}$ | $1.60^{ab}$ |
| CM III (3%) | 49.19 | $721.74^{b}$ | $672.55^{b}$ | $1,070.42^{a}$ | $1.59^{b}$ |
| PSE[1] | 0.05 | 8.36 | 8.36 | 10.45 | 0.01 |
| Finisher | | | | | |
| Control | $615.37^{c}$ | $1,930.53^{c}$ | $1,315.16^{a}$ | $2,507.86^{b}$ | $1.91^{c}$ |
| CM I (1%) | $764.43^{a}$ | $2,101.33^{a}$ | $1,336.91^{a}$ | $2,743.09^{a}$ | $2.05^{b}$ |
| CM I (3%) | $723.59^{b}$ | $2,047.96^{ab}$ | $1,324.37^{a}$ | $2,846.81^{a}$ | $2.15^{a}$ |
| CM I (5%) | $689.17^{b}$ | $1,995.27^{bc}$ | $1,306.11^{a}$ | $2,876.92^{a}$ | $2.20^{a}$ |
| CM II (3%) | $726.59^{ab}$ | $2,060.52^{ab}$ | $1,333.93^{a}$ | $2,868.40^{a}$ | $2.15^{a}$ |
| CM III (3%) | $721.74^{b}$ | $2,013.80^{b}$ | $1,292.05^{a}$ | $2,784.19^{a}$ | $2.16^{a}$ |
| PSE[1] | 8.36 | 12.35 | 8.32 | 24.12 | 0.02 |
| Overall | | | | | |
| Control | 49.20 | $1,930.53^{c}$ | $1,881.33^{c}$ | $3,441.06^{b}$ | $1.83^{c}$ |
| CM I (1%) | 49.05 | $2,101.33^{a}$ | $2,052.28^{a}$ | $3,836.52^{a}$ | $1.87^{c}$ |
| CM I (3%) | 49.00 | $2,047.96^{ab}$ | $1,998.96^{ab}$ | $3,948.24^{a}$ | $1.98^{b}$ |
| CM I (5%) | 48.90 | $1,995.27^{bc}$ | $1,946.38^{bc}$ | $3,944.67^{a}$ | $2.03^{a}$ |
| CM II (3%) | 49.02 | $2,060.52^{ab}$ | $2,011.50^{ab}$ | $3,950.13^{a}$ | $1.96^{b}$ |
| CM III (3%) | 49.19 | $2,013.80^{b}$ | $1,964.61^{b}$ | $3,854.61^{a}$ | $1.96^{b}$ |
| PSE[1] | 0.05 | 12.36 | 12.36 | 31.21 | 0.01 |

| Contrast | Final body weight (g) | Weight gain (g) | Feed intake (g) | F/G |
|---|---|---|---|---|
| Starter | | | | |
| Con vs CM | 0.0001 | 0.0001 | 0.0001 | 0.0585 |
| Con vs CM3% | 0.0001 | 0.0001 | 0.0001 | 0.1024 |
| Finisher | | | | |
| Con vs CM | 0.0001 | 0.8765 | 0.0001 | 0.0001 |
| Con vs CM3% | 0.0004 | 0.9453 | 0.0001 | 0.0001 |
| Overall | | | | |
| Con vs CM | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Con vs CM3% | 0.0004 | 0.0004 | 0.0001 | 0.0001 |

[1] Pooled standard error.

[a,b,c] :Values with different superscripts within the same column are significantly different ($p < 0.05$).

some feed processing need to be tested for the better growth performance of the animal.

Through whole experimental period, weight gain and feed intake were significantly higher in all CM groups except for CM I -5 group than control group ($p < 0.05$) and FCR of CM I -1 group was comparable to that of control group, largely due to the superior performance obtained in starter period. But as CM level was increased, FCR was also increased. Orthogonal contrast clearly showed that chicks fed CM containing diets gained more and consumed more feed than the chicks fed control diet during the starter period and overall period.

### 3) Nutrient utilizability

Nutrient utilizabilities of chicks fed CM are presented in table 5. For the starter period, chicks fed CM diets showed higher utilizabilities of gross energy, dry matter, crude protein and crude fat. CM I -1 groups showed higher utilizability in every nutrients except for phosphorus than control group ($p < 0.05$). Among CM I groups, nutrients utilizability appeared to be decreasing as CM level was increased. The best nutrients utilizability was obtained in CM I -1 group, and the worst was found in the control group. Especially, gross energy utilizability was significantly lower in chicks fed control diets. The experimental diets were formulated on the basis of gross energy since the metabolizable energy value for CM was not determined. It is assumed that this big differences in gross energy utilizability between control diet and other treatments influenced growth performance of chicks fed the experimental diets. Collectively, it appeared that higher nutrients utilizability supported better growth performance in starter period.

During the finisher period, the utilizabilities of crude protein, crude ash and phosphorus were not affected by the dietary treatments. The chicks fed control diets showed the best nutrients utilizability. This also matches well with the growth performance.

**Table 5.** Effects of CM on nutrient utilizability of broiler chicks (%)

| Treatment | DM | C. Protein | C. Fat | C. Ash | Phosphous | GE |
|---|---|---|---|---|---|---|
| (1~3 weeks) | | | | | | |
| Control | $71.17^{c}$ | $52.69^{d}$ | $78.48^{b}$ | $36.65^{d}$ | $47.01^{c}$ | $75.40^{c}$ |
| CM I (1%) | $74.72^{a}$ | $59.10^{ab}$ | $90.44^{a}$ | $43.06^{bc}$ | $49.59^{bc}$ | $79.12^{a}$ |
| CM I (3%) | $73.17^{abc}$ | $56.74^{bc}$ | $89.87^{a}$ | $41.28^{c}$ | $50.23^{bc}$ | $78.44^{a}$ |
| CM I (5%) | $71.20^{c}$ | $53.73^{cd}$ | $86.14^{a}$ | $43.79^{abc}$ | $52.11^{bc}$ | $76.13^{bc}$ |
| CM II (3%) | $73.97^{ab}$ | $60.87^{a}$ | $86.68^{a}$ | $48.18^{a}$ | $58.27^{a}$ | $79.48^{a}$ |
| CM III (3%) | $72.11^{bc}$ | $53.69^{d}$ | $77.85^{b}$ | $46.14^{ab}$ | $54.73^{ab}$ | $77.64^{ab}$ |
| PSE[1] | 0.40 | 0.83 | 1.46 | 1.02 | 1.05 | 0.42 |
| (4~6 weeks) | | | | | | |
| Control | $76.51^{a}$ | 59.42 | $80.67^{a}$ | 40.44 | 40.23 | $82.02^{a}$ |
| CM I (1%) | $76.47^{a}$ | 60.62 | $78.22^{a}$ | 40.63 | 40.38 | $81.23^{ab}$ |
| CM I (3%) | $75.07^{ab}$ | 56.44 | $77.93^{ab}$ | 35.94 | 37.34 | $79.19^{bc}$ |
| CM I (5%) | $72.65^{b}$ | 55.12 | $76.83^{abc}$ | 34.83 | 36.21 | $78.08^{c}$ |
| CM II (3%) | $75.71^{a}$ | 58.06 | $73.18^{c}$ | 35.18 | 40.81 | $81.09^{ab}$ |
| CM III (3%) | $75.17^{ab}$ | 58.93 | $73.61^{bc}$ | 31.69 | 40.31 | $80.53^{ab}$ |
| PSE[1] | 0.44 | 1.10 | 0.75 | 1.29 | 1.18 | 0.38 |

| Contrast | DM | C. Protein | C. Fat | C. Ash | Phosphous | GE |
|---|---|---|---|---|---|---|
| (1~3 weeks) | | | | | | |
| Con vs CM | 0.0258 | 0.0046 | 0.0115 | 0.0004 | 0.0057 | 0.0014 |
| Con vs CM3% | 0.0291 | 0.0043 | 0.0391 | 0.0003 | 0.0019 | 0.0008 |
| (4~6 weeks) | | | | | | |
| Con vs CM | 0.0857 | 0.3515 | 0.0072 | 0.1178 | 0.6647 | 0.0208 |
| Con vs CM3% | 0.1267 | 0.2561 | 0.0025 | 0.0529 | 0.7443 | 0.0492 |

[1] Pooled standard error.
[a,b,c,d] : Values with different superscripts within the same column are significantly differ ($p < 0.05$).

**Table 6.** Apparent fecal digestibilities of amino acids in experimental diets (%, 1～3wks)

| | Control | CM I (1%) | CM I (3%) | CM I (5%) | CM II (3%) | CM III (3%) | PSE |
|---|---|---|---|---|---|---|---|
| EAA (%) | | | | | | | |
| THR | $81.13^{ab}$ | $83.93^{a}$ | $82.64^{ab}$ | $78.74^{b}$ | $84.65^{a}$ | $81.72^{ab}$ | 0.65 |
| VAL | $82.31^{ab}$ | $83.94^{a}$ | $82.29^{ab}$ | $78.39^{b}$ | $85.28^{a}$ | $81.95^{ab}$ | 0.66 |
| CYS | $82.97^{b}$ | $85.84^{ab}$ | $86.20^{ab}$ | $85.06^{ab}$ | $88.90^{a}$ | $86.51^{ab}$ | 0.60 |
| MET | $87.46^{bc}$ | $89.59^{ab}$ | $89.04^{ab}$ | $85.37^{c}$ | $90.99^{a}$ | $90.05^{ab}$ | 0.56 |
| ILU | $86.58^{a}$ | $87.28^{a}$ | $85.66^{a}$ | $81.56^{b}$ | $88.44^{a}$ | $85.37^{a}$ | 0.67 |
| LEU | $88.30^{ab}$ | $89.72^{a}$ | $88.62^{ab}$ | $85.59^{b}$ | $91.18^{a}$ | $89.02^{ab}$ | 0.55 |
| PHE | $88.29^{ab}$ | $88.82^{a}$ | $87.96^{ab}$ | $85.15^{b}$ | $90.96^{a}$ | $88.10^{ab}$ | 0.56 |
| LYS | $88.24^{a}$ | $88.11^{a}$ | $87.37^{ab}$ | $84.62^{b}$ | $89.71^{a}$ | $86.75^{ab}$ | 0.50 |
| HIS | $87.07^{ab}$ | $87.97^{ab}$ | $87.78^{ab}$ | $84.92^{b}$ | $90.07^{a}$ | $87.55^{ab}$ | 0.51 |
| ARG | $92.32^{a}$ | $91.54^{ab}$ | $91.07^{ab}$ | $89.49^{b}$ | $92.92^{a}$ | $90.88^{ab}$ | 0.36 |
| Sub-mean | $86.47^{ab}$ | $87.67^{a}$ | $86.86^{ab}$ | $83.89^{b}$ | $89.31^{a}$ | $86.79^{ab}$ | 0.52 |
| NEAA (%) | | | | | | | |
| ASP | $85.40^{ab}$ | $86.07^{a}$ | $85.35^{ab}$ | $82.13^{b}$ | $87.21^{a}$ | $84.14^{ab}$ | 0.54 |
| SER | $84.89^{ab}$ | $86.36^{a}$ | $85.03^{ab}$ | $81.92^{b}$ | $87.86^{a}$ | $84.98^{ab}$ | 0.59 |
| GLU | $90.56^{a}$ | $90.74^{a}$ | $89.02^{a}$ | $86.08^{b}$ | $90.99^{a}$ | $88.79^{ab}$ | 0.51 |
| PRO | $84.76^{b}$ | $87.22^{ab}$ | $86.79^{ab}$ | $84.66^{b}$ | $88.77^{a}$ | $85.96^{ab}$ | 0.50 |
| GLY | $71.97^{ab}$ | $74.88^{ab}$ | $72.47^{ab}$ | $69.44^{b}$ | $75.83^{a}$ | $71.15^{ab}$ | 0.77 |
| ALA | $85.11^{a}$ | $86.00^{a}$ | $82.57^{a}$ | $77.29^{b}$ | $85.72^{a}$ | $83.58^{a}$ | 0.81 |
| TYR | $88.81^{a}$ | $89.06^{a}$ | $88.41^{ab}$ | $85.70^{b}$ | $90.95^{a}$ | $89.10^{a}$ | 0.49 |
| Sub-mean | $84.50^{a}$ | $85.76^{a}$ | $84.23^{ab}$ | $81.03^{b}$ | $86.76^{a}$ | $83.95^{ab}$ | 0.56 |
| Average (%) | $86.61^{a}$ | $87.59^{a}$ | $86.32^{ab}$ | $83.22^{b}$ | $88.72^{a}$ | $86.14^{ab}$ | 0.53 |

$^{a,b,c}$ : Values with different superscripts within the same row are significantly differ ($p < 0.05$).

It was found that the nutrient utilizabilities were high in CM groups for the starter period, while high in the control group for the finisher period. The reason for this change was not clearly identified in this study.

#### 4) Amino acids utilizability

For the starter period, amino acids utilizability was not significantly affected by the treatments except for CM I -5 group. In all amino acids tested, chicks did not show the big difference in utilizabilities. Only in the CM I -5 group, amino acids utilizability was significantly lower than control group ($p < 0.05$). However, among CM I groups, the mean value of the amino acids utilizability was decreased as the level of CM inclusion in the diet was increased. During the finisher period, similar trend was found in amino acids utilizability.

## IMPLICATIONS

Based on the results obtained from this study, Lysine Bacteria Protein (CM) appeared to be an excellent alternative high protein ingredients for the broiler chicks, especially for the starter period. However, when fed at higher inclusion level, CM didn't improve the growth performance of the chicks. Thus, some feed processing may be needed to include CM at higher level in the broiler diet. And for the use of CM in the swine diet, more study is needed to test the nutritional value of CM with pigs.

**Table 7.** Apparent fecal digestibilities of amino acids in experimental diets (%, 4~6wks)

| | Control | CM I (1%) | CM I (3%) | CM I (5%) | CM II (3%) | CM III (3%) | PSE |
|---|---|---|---|---|---|---|---|
| EAA (%) | | | | | | | |
| THR | 84.62 | 83.56 | 83.79 | 81.31 | 85.85 | 86.03 | 0.65 |
| VAL | 85.24$^{a}$ | 85.29$^{a}$ | 83.44$^{ab}$ | 80.07$^{b}$ | 85.71$^{a}$ | 85.99$^{a}$ | 0.63 |
| CYS | 92.42 | 91.71 | 91.81 | 92.66 | 92.35 | 93.43 | 0.41 |
| MET | 90.77$^{a}$ | 90.84$^{a}$ | 88.64$^{ab}$ | 87.03$^{b}$ | 90.36$^{a}$ | 90.93$^{a}$ | 0.44 |
| ILU | 87.41$^{a}$ | 87.37$^{a}$ | 86.17$^{a}$ | 82.32$^{b}$ | 87.56$^{a}$ | 87.22$^{a}$ | 0.57 |
| LEU | 91.35$^{a}$ | 90.97$^{a}$ | 89.33$^{ab}$ | 87.95$^{b}$ | 90.82$^{a}$ | 91.50$^{a}$ | 0.41 |
| PHE | 89.93$^{a}$ | 89.85$^{a}$ | 88.66$^{a}$ | 85.24$^{b}$ | 89.63$^{a}$ | 89.85$^{a}$ | 0.46 |
| LYS | 88.35$^{a}$ | 88.09$^{a}$ | 87.72$^{a}$ | 84.51$^{b}$ | 88.52$^{a}$ | 87.83$^{a}$ | 0.45 |
| HIS | 89.73$^{a}$ | 90.04$^{a}$ | 89.43$^{a}$ | 86.41$^{b}$ | 89.78$^{a}$ | 90.60$^{a}$ | 0.43 |
| ARG | 93.36$^{ab}$ | 93.91$^{a}$ | 92.28$^{b}$ | 88.88$^{b}$ | 92.99$^{ab}$ | 92.90$^{ab}$ | 0.38 |
| Sub-mean | 89.32$^{a}$ | 89.16$^{a}$ | 88.13$^{ab}$ | 85.64$^{b}$ | 89.36$^{a}$ | 89.62$^{a}$ | 0.44 |
| NEAA (%) | | | | | | | |
| ASP | 87.57$^{a}$ | 86.40$^{ab}$ | 86.81$^{ab}$ | 82.52$^{b}$ | 87.19$^{a}$ | 86.85$^{ab}$ | 0.62 |
| SER | 89.61$^{a}$ | 89.42$^{a}$ | 88.45$^{a}$ | 83.40$^{b}$ | 87.76$^{a}$ | 89.53$^{a}$ | 0.59 |
| GLU | 91.90$^{a}$ | 90.53$^{a}$ | 89.58$^{a}$ | 86.07$^{b}$ | 90.00$^{a}$ | 90.21$^{a}$ | 0.51 |
| PRO | 88.07$^{ab}$ | 88.58$^{a}$ | 86.87$^{ab}$ | 84.94$^{b}$ | 87.68$^{ab}$ | 89.10$^{a}$ | 0.45 |
| GLY | 71.07$^{a}$ | 73.42$^{a}$ | 70.83$^{a}$ | 60.76$^{b}$ | 72.99$^{a}$ | 72.57$^{a}$ | 1.05 |
| ALA | 87.71$^{a}$ | 86.30$^{ab}$ | 82.63$^{b}$ | 78.71$^{c}$ | 84.67$^{ab}$ | 85.44$^{ab}$ | 0.76 |
| TYR | 91.62$^{a}$ | 90.00$^{a}$ | 88.90$^{ab}$ | 86.63$^{b}$ | 89.29$^{ab}$ | 90.73$^{a}$ | 0.46 |
| Sub-mean | 83.84$^{ab}$ | 86.38$^{a}$ | 84.75$^{a}$ | 80.43$^{b}$ | 85.65$^{a}$ | 84.57$^{a}$ | 0.64 |
| Average (%) | 87.68$^{a}$ | 88.32$^{a}$ | 87.08$^{a}$ | 83.67$^{b}$ | 88.06$^{a}$ | 87.21$^{a}$ | 0.49 |

$^{a,b,c}$ : Values with different superscripts within the same row are significantly differ ($p < 0.05$).

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