

## Effects of Concentration and Size of Porous Calcium Silicate (PCS) in Broiler Feeds on Performances, Fly Generation and Malodorous Gas Emission

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### Porous Calcium Silicate (PCS)의 급여수준 및 PCS 입자 크기가 육계의 성장, 파리 및 악취 발생에 미치는 영향

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#### 요 약

PCS와 zeolite 첨가급여가 육계의 성장능력, 유해가스 및 파리발생에 미치는 영향을 구명하기 위하여 대조구, PCS구, zeolite구를 두었으며 처리구당 4반복, 반복당 브로일러 12수씩 총 144수를 완전임의배치하여 사양시험을 실시하였다. PCS 급여구는 증체, 사료섭취량이 대조구에 비해 유의적으로 적었으나, 사료효율은 현저하게 개선되었으며 ( $P<0.05$ ) zeolite와 증체 및 사료요구율은 통계적인 차이가 없었고, 사료섭취량은 감소하였다.

암모니아 가스의 농도는 PCS 급여구와 대조구 간에 유의적인 차이가 없었다. 그러나 PCS 처리구는 zeolite 급여구에 비해 2, 3주령에 현저하게 높은 결과를 보여주었지만 ( $P<0.05$ ) 5주령에는 유의적인 차이가 없었다.

PCS 첨가수준이 육계의 성장능력, 유해가스 감소 및 파리발생에 미치는 영향을 구명하기 위하여 대조구, PCS 1.5%구, PCS 3.0%구, PCS 4.5%구를 두었으며 각 처리당 4반복, 반복당 브로일러 12수씩 총 192수를 완전임의배치하여 사양시험을 실시하였다. 시험 결과 PCS 1.5% 급여구는 증체량, 사료섭취량은 대조구에 비하여 낮은 경향을 보였지만 통계적인 차이가 없었으며, 사료요구율은 PCS 3.0%에서 다른 처리구에 비하여 개선되었다. 영양소 소화율과 에너지 이용율은 PCS 처리구에서 대조구보다 높았으며, 3.0% 처리구에서 제일 높았다. 계분에서 발생하는 암모니아 농도는 5주령에 PCS 1.5와 3.0% 처리구에서 대조구에 비하여 현저하게 낮았으며 ( $P<0.05$ ), 황화수소는 PCS 처리구간에 일관성은 없었지만 1.5% 급여구에서 대조구에 비하여 현저하게 낮았다( $P<0.05$ ).

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2009년 8월 16일 투고, 2009년 8월 20일 심사완료, 2009년 8월 24일 게재확정

PCS 입자도별 급여가 브로일러의 능력, 유해가스 발생 농도 및 파리 발생에 미치는 영향을 구명하기 위하여 대조구, PCS 20, 50, 90 mesh구를 두었으며 증체 및 사료섭취량은 대조구에 비해 모든 PCS 입자도 (20, 50, 및 90 mesh) 급여구에서 유의적으로 감소하였다. 그러나 사료 요구율은 대조구와 처리구들 사이에 유의적인 차이를 나타내지 않았으나 PCS 20 mesh를 급여한 구에서 다소 개선되는 경향을 보였다.

이상의 실험 결과를 토대로 PCS 육계의 영양소 소화율은 대조구보다 개선되었고 암모니아 및 황화수소 농도를 낮추는 경향을 보였으나 이에 대한 더 많은 연구가 필요하다고 사료된다. (핵심단어 : PCS, 제올라이트, 육계, 파리, 암모니아, 황화수소)

## INTRODUCTION

Under normal conditions, the large cavities and entry channels of zeolites are filled with water molecules forming hydration spheres around the exchangeable cations. Some zeolites are capable of adsorbing up to about 30 % of a gas (Mumpton and Fishman, 1977). This report also indicated that 40 natural species have been recognized, and an equal number have been synthesized in laboratory. Zeolites are crystalline and hydrated aluminum silicate of alkali and alkaline earth cations. Zeolite was discovered in 1956 as well-formed crystals in cavities of basal rock by Baron Axel Fredrick Cronstedt, a Swedish mineralogist. They are further characterized by an ability to lose and gain water reversibly and to exchange constituent cations without a major change of structure.

Porous calcium silicate (PCS) is a construction material, and it was a name given to crystalline calcium silicate hydrate because silicate, lime and cement are basic materials mixed with water to make slurry. This slurry is promulgation treated and oven treated artificially. The outside of this material is porous. In Europe this material is called gas concrete, cellular concrete, light weight concrete, light silica concrete or light lime concrete (Ssangyoung Co. Ltd., 1992).

Poultry feeding operations are associated with aerial emissions of ammonia ( $\text{NH}_3$ ), volatile organic compounds (VOCs), and odor, and the magnitude of emissions is influenced by manure management practices (Moore, 2003). Ammonia is the most abundant gas emitted from poultry manure (Kristensen and Wathes, 2000), but VOCs and odor are also of concern.

A review of natural zeolite (clinoptilolite) reveals that both the ion-exchange and absorption properties of natural zeolites can be exploited to make more efficient use of feed nitrogen in animal nutrition, to reduce intestinal diseases prevalent in young livestock and poultry, to control moisture and ammonia content of animal manure, to purify recirculating hatchery waters in aquaculture, to provide oxygen-enriched air for fish breeding and transportation, and to reduce the nitrogen content of feedlot- and hatchery-runoff waters (Mumpton and Fishman, 1977). Recently Liang et al. (2005) also said that the properties and the abundance of low-cost zeolite-bearing deposits made it an attractive option for a variety of applications in the treatment of livestock and poultry wastes. And application directly to the manure seems to be more effective in reducing  $\text{NH}_3$  emissions.

Milne and Froseth (1982) reported that zeolite reduced growth rate. Son (1999) said 2

% of zeolite or bentonite did not act as a growth promotant. Nakaue et al. (1978) said that feed consumption was low when feeds for layers contained 5% and 10% of zeolite. Onagi et al. (1965) reported that  $\text{NH}_3$  gas production was low and fly numbers were lowered by 82.4% when the ratio of chick manure and zeolite was 3:1. Weaver (1990) mentioned that  $\text{NH}_3$  gas production from chick manure was higher when the moisture content was higher.

Much research has been done on these zeolite materials and their actions. Studies of current research encouraged comparisons of PCS and silicate. These studies will show how much PCS can be used with poultry feed.

## MATERIALS AND METHODS

Three experiments were conducted at different time periods in the same house and under the same management procedures as described by Dorminey and Nakaue (1977). Approximately equal numbers of day-old, sexed Cobb  $\times$  Cobb male broiler chicks from the Hi-line Company, Seoul, Korea, were raised together in each pen.

When the experiment started, weights were maintained the same. Weight gain was measured at the end of each week. Feed consumption was measured from 09:00 through 09:00 of the next day by collecting feeds. Feed and feces were placed in an oven at 600 C for 3 days and then ground for chemical analysis. Nutrient digestibilities were measured with 23 day old Cobb chicks with absorbed nutrients and feces for 4 days in digestible box. Total collection method for nutrient digestibilities was used with 1 chick from 5 replicates for 4 days. Gas concentrations from manures were measured for 3 days which was

Friday of 2nd, 3rd and 5th week. About 500 g of fresh manure was placed in a 20L container with a cover having a 0.7 cm hole, and the average measurement for 3 days was used for the table values.  $\text{NH}_3$  was measured with a gas detector (New Cosmos Company, Ltd, Osaka, Japan).  $\text{H}_2\text{S}$  and  $\text{CO}_2$  were measured with an Anagas CD 95 detector (Geotechnical Instruments Co. Ltd., London, United Kingdom).

Fly numbers were measured after collecting 500 g of fresh broiler manure at the end of 2, 3, and 5 wks. Manure was spread on the floor of broiler houses at room temperature for 2 days to let flies grow. When flies hatched, a net was used to cover the manure for 20 days and then the flies were counted. For fly production moisture is important so 2 cm wood deep chips were moistened for fly production with a small water pump. AOAC (1985) methods were accepted for analytical methods, and an automatic bomb calorimeter (Parr) was used for nutrient energy values.

There were 144 broiler chicks in each pen (3.1 m  $\times$  4.3 m). Each bird was allowed 0.084 m<sup>2</sup> floor space. Clean rice hull litter was used in all pens at a depth of about 3 cm.

### 1. Experiment 1

In Experiment 1, PCS was compared with natural zeolite. There were 12 chicks in each treatment with each treatment having 4 replications. The treatments were the control (4 replicates), PCS (4 replicates), and natural zeolite (4 replicates). The control treatment had no PCS or natural zeolite in the feed. The experimental diets were starter and finisher diets (Table 1).

Table 1. Percentage composition of starter and finisher diets in Experiment 1

| Ingredient(%)         | Starter ( 0~21 days) |         |         | Finisher (22~49 days) |         |         |
|-----------------------|----------------------|---------|---------|-----------------------|---------|---------|
|                       | Control              | PCS     | Zeolite | Control               | PCS     | Zeolite |
| Corn                  | 55.00                | 55.00   | 55.00   | 62.70                 | 62.70   | 62.70   |
| Soybean Meal          | 26.19                | 26.19   | 26.19   | 23.17                 | 23.17   | 23.17   |
| Fish meal (CP 63%)    | 10.00                | 10.00   | 10.00   | 4.55                  | 4.55    | 4.55    |
| Corn gluten meal      | 1.76                 | 1.76    | 1.76    | 2.68                  | 2.68    | 2.68    |
| Tallow                | 5.00                 | 5.00    | 5.00    | 4.00                  | 4.00    | 4.00    |
| Salt                  | 0.30                 | 0.30    | 0.30    | 0.25                  | 0.25    | 0.25    |
| Limestone             | 0.20                 | 0.20    | 0.20    | 0.40                  | 0.40    | 0.40    |
| L-lysine              | 0.10                 | 0.10    | 0.10    | 0.10                  | 0.10    | 0.10    |
| D. L. Methionine (50) | 0.20                 | 0.20    | 0.20    | 0.20                  | 0.20    | 0.20    |
| Dicalcium-phosphate   | 0.70                 | 0.70    | 0.70    | 1.40                  | 1.40    | 1.40    |
| Vit.-min. mixture     | 0.55                 | 0.55    | 0.55    | 0.55                  | 0.55    | 0.55    |
| PCS                   |                      | 3.00    |         |                       | 3.00    |         |
| Zeolite               |                      |         | 3.00    |                       |         | 3.00    |
| Chemical Analysis     |                      |         |         |                       |         |         |
| ME (Kcal/kg)          | 3181.67              | 3089.00 | 3089.00 | 3191.18               | 3098.23 | 3098.23 |
| Crude protein (%)     | 23.20                | 22.53   | 22.53   | 19.37                 | 18.80   | 18.80   |
| Lime (%)              | 1.52                 | 1.47    | 1.47    | 1.14                  | 1.11    | 1.11    |
| Methionine (%)        | 0.55                 | 0.53    | 0.53    | 0.43                  | 0.42    | 0.42    |
| Calcium (%)           | 1.02                 | 1.59    | 1.49    | 0.92                  | 1.49    | 0.89    |
| Phosphate (%)         | 0.80                 | 0.78    | 0.71    | 0.73                  | 0.71    | 0.71    |

<sup>1</sup> Vit.-min. mixture provided the following per kg: Vitamin A, 1,600,000 IU; Vitamin D<sub>3</sub>, 300,000 IU; Vitamin E, 800 IU; Vitamin K<sub>3</sub>, 132 mg; Vitamin B<sub>2</sub>, 1,000 mg; Vitamin B<sub>12</sub>, 1,200 mcg; Zn, 9,000 mg; Fe, 4,000 mg; Cu, 500 mg; Pyridoxine, 200 mg; Choline chloride, 35,000 mg; Niacin, 2,000 mg; Calcium pantothenate, 800mg; Folic acid, 60 mg; B.H.T., 6,000 mg; Mn, 12,000 mg; I, 250 mg; Co, 100 mg.

## 2. Experiment 2

The object of this experiment was to show the influences of the different amounts of PCS in broiler feed. There were 12 chicks in each treatment with each treatment having 4

replicates. Treatments were the control, 1.50% PCS, 3.00 % PCS, and 4.50 % PCS. The control treatment had no PCS. The experimental diets were starter and finisher diets (Table 2).

Table 2. Percentage composition of starter and finisher diets in Experiment 2

| Ingredient(%)                  | Starter ( 0~21 days) |          |          |          | Finisher (22~49 days) |          |          |          |
|--------------------------------|----------------------|----------|----------|----------|-----------------------|----------|----------|----------|
|                                | Control              | 1.5% PCS | 3.0% PCS | 4.5% PCS | Control               | 1.5% PCS | 3.0% PCS | 4.5% PCS |
| Corn                           | 55.00                | 55.00    | 55.00    | 55.00    | 62.70                 | 62.70    | 62.70    | 62.70    |
| Soybean Meal                   | 26.19                | 26.19    | 26.19    | 26.19    | 23.17                 | 23.17    | 23.17    | 23.17    |
| Fish meal (CP 63%)             | 10.00                | 10.00    | 10.00    | 10.00    | 4.55                  | 4.55     | 4.55     | 4.55     |
| Corn gluten meal               | 1.76                 | 1.76     | 1.76     | 1.76     | 2.68                  | 2.68     | 2.68     | 2.68     |
| Tallow                         | 5.00                 | 5.00     | 5.00     | 5.00     | 4.00                  | 4.00     | 4.00     | 4.00     |
| Salt                           | 0.30                 | 0.30     | 0.30     | 0.30     | 0.25                  | 0.25     | 0.25     | 0.25     |
| Limestone                      | 0.20                 | 0.20     | 0.20     | 0.20     | 0.40                  | 0.40     | 0.40     | 0.40     |
| L-lysine                       | 0.10                 | 0.10     | 0.10     | 0.10     | 0.10                  | 0.10     | 0.10     | 0.10     |
| D. L. Methionine (50)          | 0.20                 | 0.20     | 0.20     | 0.20     | 0.20                  | 0.20     | 0.20     | 0.20     |
| Dicalcium-phosphate            | 0.70                 | 0.70     | 0.70     | 0.70     | 1.40                  | 1.40     | 1.40     | 1.40     |
| Vit.-min. mixture <sup>1</sup> | 0.55                 | 0.55     | 0.55     | 0.55     | 0.55                  | 0.55     | 0.55     | 0.55     |
| Silicate supplemented          |                      | 1.5      | 3.0      | 4.5      |                       | 1.5      | 3.0      | 4.5      |
| Chemical Analysis              |                      |          |          |          |                       |          |          |          |
| ME (Kcal/kg)                   | 3181.67              | 3134.65  | 3089.00  | 3044.66  | 3191.18               | 3144.02  | 3098.23  | 3053.76  |
| Crude protein (%)              | 23.20                | 22.86    | 22.53    | 22.20    | 19.37                 | 19.09    | 18.80    | 18.53    |
| Lime (%)                       | 1.52                 | 1.50     | 1.47     | 1.45     | 1.44                  | 1.12     | 1.11     | 1.09     |
| Methionine (%)                 | 0.55                 | 0.54     | 0.53     | 0.52     | 0.43                  | 0.47     | 0.42     | 0.41     |
| Calcium (%)                    | 1.02                 | 1.31     | 1.59     | 1.86     | 0.92                  | 1.21     | 1.49     | 1.77     |
| Phosphate (%)                  | 0.80                 | 0.79     | 0.78     | 0.77     | 0.73                  | 0.72     | 0.71     | 0.7      |

<sup>1</sup> Vit.-min. mixture provided the following per kg: Vitamin A, 1,600,000 IU; Vitamin D<sub>3</sub>, 300,000 IU; Vitamin E, 800 IU; Vitamin K<sub>3</sub>, 132 mg; Vitamin B<sub>2</sub>, 1,000 mg; Vitamin B<sub>12</sub>, 1,200 mcg; Zn, 9,000 mg; Fe, 4,000 mg; Cu, 500 mg; Pyridoxine, 200 mg; Choline chloride, 35,000 mg; Niacin, 2,000 mg; Calcium pantothenate, 800mg; Folic acid, 60 mg; B.H.T., 6,000 mg; Mn, 12,000 mg; I, 250 mg; Co, 100 mg.

### 3. Experiment 3

The object of this part of the research was to show the influences of particle size(mesh size) of PCS in broiler feed. There were 12 chicks in each treatment with each treatment

having 4 replicates. Treatments were the control, 20 mesh 3 % PCS, 50 mesh 3 % PCS, and 90 mesh 3 % PCS. The control treatment had no PCS. The experimental diets were starter and finisher diets (Table 3).

Table 3. Percentage composition of starter and finisher diets in Experiment 3

| Ingredient(%)                  | Starter (0~21 days) |         |         |         | Finisher (22~49 days) |         |         |         |
|--------------------------------|---------------------|---------|---------|---------|-----------------------|---------|---------|---------|
|                                | Control             | 20 Mesh | 50 Mesh | 90 Mesh | Control               | 20 Mesh | 50 Mesh | 90 mesh |
| Corn                           | 55.00               | 55.00   | 55.00   | 55.00   | 62.70                 | 62.70   | 62.70   | 62.70   |
| Corn meal, dehulled            | 26.19               | 26.19   | 26.19   | 26.19   | 23.17                 | 23.17   | 23.17   | 23.17   |
| Fish meal (CP 63%)             | 10.00               | 10.00   | 10.00   | 10.00   | 4.55                  | 4.55    | 4.55    | 4.55    |
| Corn gluten meal               | 1.76                | 1.76    | 1.76    | 1.76    | 2.68                  | 2.68    | 2.68    | 2.68    |
| Tallow                         | 5.00                | 5.00    | 5.00    | 5.00    | 4.00                  | 4.00    | 4.00    | 4.00    |
| Salt                           | 0.30                | 0.30    | 0.30    | 0.30    | 0.25                  | 0.25    | 0.25    | 0.25    |
| Limestone                      | 0.20                | 0.20    | 0.20    | 0.20    | 0.40                  | 0.40    | 0.40    | 0.40    |
| L-lysine, HCl                  | 0.10                | 0.10    | 0.10    | 0.10    | 0.10                  | 0.10    | 0.10    | 0.10    |
| D. L. Methionine               | 0.20                | 0.20    | 0.20    | 0.20    | 0.20                  | 0.20    | 0.20    | 0.20    |
| Dicalcium-phosphate            | 0.70                | 0.70    | 0.70    | 0.70    | 1.40                  | 1.40    | 1.40    | 1.40    |
| Vit.-min. mixture <sup>1</sup> | 0.55                | 0.55    | 0.55    | 0.55    | 0.55                  | 0.55    | 0.55    | 0.55    |
| Silicate supplemented          |                     | 3.0     | 3.0     | 3.0     |                       | 3.0     | 3.0     | 3.0     |
| Chemical Analysis              |                     |         |         |         |                       |         |         |         |
| ME (Kcal/kg)                   | 3181.67             | 3098.00 | 3098.00 | 3089.00 | 3191.18               | 3098.23 | 3098.23 | 3098.23 |
| Crude protein (%)              | 23.20               | 22.86   | 22.86   | 22.86   | 19.37                 | 18.80   | 18.80   | 18.80   |
| Lysine (%)                     | 1.52                | 1.47    | 1.47    | 1.47    | 1.14                  | 1.11    | 1.11    | 1.11    |
| Methionine (%)                 | 0.55                | 0.53    | 0.53    | 0.53    | 0.43                  | 0.42    | 0.42    | 0.42    |
| Calcium (%)                    | 1.02                | 1.59    | 1.59    | 1.59    | 0.92                  | 1.49    | 1.49    | 1.49    |
| Phosphate (%)                  | 0.80                | 0.78    | 0.78    | 0.78    | 0.73                  | 0.71    | 0.71    | 0.71    |

<sup>1</sup> Vit-min. mixture provided the following per kg: Vitamin A, 1,600,000 IU; Vitamin D<sub>3</sub>, 300,000 IU; Vitamin E, 800 IU; Vitamin K<sub>3</sub>, 132 mg; Vitamin B<sub>2</sub>, 1,000 mg; Vitamin B<sub>12</sub>, 1,200 mcg; Zn, 9,000 mg; Fe, 4,000 mg; Cu, 500 mg; Pyridoxine, 200 mg; Choline chloride, 35,000 mg; Niacin, 2,000 mg; Calcium pantothenate, 800 mg; Folic acid, 60 mg; B.H.T., 6,000 mg; Mn, 12,000 mg; I, 250 mg; Co, 100 mg.

## RESULTS

### 1. Experiment I

Weight gain, feed intake, and feed conversion are shown in Table 4-A (T4-A). The weight gain of the control group was higher ( $P \leq 0.05$ ) than the PCS and natural

zeolite group from 0 to 21 days, but the tendency was the same from 21~49 days. Results in the overall period concerning weight gain showed that the control group was higher ( $P \leq 0.05$ ) than PCS group, but same as the natural zeolite group. During all periods, feed intake was higher ( $P \leq 0.05$ ) in the control than PCS and natural zeolite group. The

natural zeolite was second ( $P \leq 0.05$ ) and PCS group was third from 0 to 21 ( $P \leq 0.05$ ) and 21-49 days. Feed conversion of the zeolite group was higher (better) ( $P \leq 0.05$ ) than PCS groups for 0 to 21 days and lower (worse) ( $P \leq 0.05$ ) in the PCS group for 21 to 49 days and the overall periods.

As shown in Table 4-B (T4-B) nutrient digestibilities were not significantly different among the PCS, zeolite and control groups. The PCS groups tended to be higher than the control and natural zeolite groups (T4-B).

Noxious gas emissions from broiler manure including  $\text{NH}_3$ ,  $\text{H}_2\text{S}$ , and  $\text{CO}_2$  are shown in Table 4-C (T4-C).  $\text{NH}_3$  emissions were lowest

( $P \leq 0.05$ ) in the zeolite group during the 2nd and 3rd periods than the control and PCS groups.  $\text{NH}_3$  emissions from the zeolite group during the 5th period were lower than the PCS and control groups although they were not significantly different.  $\text{H}_2\text{S}$  production tended to be the same as  $\text{NH}_3$  production. The zeolite group had the lowest production of  $\text{H}_2\text{S}$  during the 5th period, and the 2nd and 3rd periods ( $P \leq 0.05$ ) and the PCS group had the highest ( $P \leq 0.05$ ) production of  $\text{H}_2\text{S}$  during the 2nd and 3rd periods. The amount of  $\text{CO}_2$  production is not significantly different.

Table 4-D (T4-D) shows fly populations. Control values were higher ( $P \leq 0.05$ ) than the PCS

Table 4 (T4). Experiment 1

A. Effects of feeding PCS and zeolite on broiler performances

| Treatment       | 0 to 21 days        | 21 to 49 days        | Overall               |
|-----------------|---------------------|----------------------|-----------------------|
| Weight gain (g) |                     |                      |                       |
| Control         | 633.42 <sup>a</sup> | 1751.04              | 2384.46 <sup>a</sup>  |
| PCS             | 479.82 <sup>c</sup> | 1729.17              | 2235.27 <sup>b</sup>  |
| Zeolite         | 567.75 <sup>b</sup> | 1719.79              | 2287.54 <sup>ab</sup> |
| Feed intake (g) |                     |                      |                       |
| Control         | 936.90 <sup>a</sup> | 3630.25 <sup>a</sup> | 4567.15 <sup>a</sup>  |
| PCS             | 785.27 <sup>b</sup> | 3235.11 <sup>b</sup> | 4020.38 <sup>c</sup>  |
| Zeolite         | 882.67 <sup>a</sup> | 3395.75 <sup>b</sup> | 4287.42 <sup>b</sup>  |
| Feed Conversion |                     |                      |                       |
| Control         | 1.48 <sup>b</sup>   | 2.07 <sup>a</sup>    | 1.91 <sup>a</sup>     |
| PCS             | 1.65 <sup>a</sup>   | 1.87 <sup>c</sup>    | 1.82 <sup>b</sup>     |
| Zeolite         | 1.56 <sup>ab</sup>  | 1.98 <sup>b</sup>    | 1.87 <sup>ab</sup>    |

B. Effects of feeding PCS and zeolite on nutrient digestibility and energy values

| Treatments | Dry Matter | Crude Protein | Ether extract | NFE   | Energy |
|------------|------------|---------------|---------------|-------|--------|
| Control    | 76.41      | 67.36         | 82.39         | 81.34 | 78.57  |
| PCS        | 77.14      | 69.41         | 81.88         | 82.28 | 79.51  |
| Zeolite    | 72.33      | 65.48         | 85.42         | 78.23 | 75.82  |

## C. Effects of feeding PCS and zeolite on noxious gas from broiler manure

| Treatments             | Weeks               |                    |          |
|------------------------|---------------------|--------------------|----------|
|                        | 2nd                 | 3rd                | 5th      |
| NH <sub>3</sub> (ppm)  |                     |                    |          |
| Control                | 43.67 <sup>ab</sup> | 56.94 <sup>a</sup> | 37.76    |
| PCS                    | 47.07 <sup>a</sup>  | 60.64 <sup>a</sup> | 33.41    |
| Zeolite                | 35.45 <sup>b</sup>  | 48.14 <sup>b</sup> | 31.80    |
| H <sub>2</sub> S (ppm) |                     |                    |          |
| Control                | 1.42 <sup>ab</sup>  | 7.67 <sup>ab</sup> | 4.84     |
| PCS                    | 1.83 <sup>a</sup>   | 9.00 <sup>a</sup>  | 5.00     |
| Zeolite                | 1.25 <sup>b</sup>   | 5.50 <sup>b</sup>  | 3.92     |
| CO <sub>2</sub> (ppm)  |                     |                    |          |
| Control                | 10744.17            | 10345.00           | 13594.17 |
| PCS                    | 10873.33            | 10750.84           | 12758.83 |
| Zeolite                | 11978.33            | 12195.84           | 13567.50 |

## D. Effects of feeding PCS and zeolite on fly populations

| Treatments | Weeks               |                    |       |
|------------|---------------------|--------------------|-------|
|            | 2nd                 | 3rd                | 5th   |
| Control    | 64.00 <sup>a</sup>  | 93.25 <sup>a</sup> | 93.75 |
| PCS        | 50.00 <sup>ab</sup> | 72.00 <sup>b</sup> | 51.25 |
| Zeolite    | 12.75 <sup>b</sup>  | 38.25 <sup>c</sup> | 81.00 |

<sup>a,b,c</sup> Values with different superscripts within the same column are significantly different ( $P < 0.05$ )

\* NFE: Nitrogen Free Extract.

group and natural zeolite group during the 2nd and 3rd periods, and zeolite values were lowest ( $P \leq 0.05$ ) among the three groups during the 2nd and 3rd periods. They were not significantly different during the 5th period.

## 2. Experiment 2

Weight gain, feed intake, and feed conversion are shown in T5-A. The control group and 1.5% PCS were higher ( $P \leq 0.05$ ) than the 3.0% PCS and 4.5% PCS groups from 0 to 21 days, 21 to 49 days and the

overall periods in weight gain. In feed intake, the control and 1.5% PCS were higher ( $P \leq 0.05$ ) than the 3.0 and 4.5% PCS group during all periods of time. The order of feed intake was control > 1.5% PCS > 3.0 % PCS > 4.5% PCS, although the control and 1.5% PCS were not significantly different from each other during all periods of time. Feed conversion values showed that the 3.0% PCS group was best ( $P \leq 0.05$ ) in the overall period. Nutrient digestibilities and energy values were not different among treatments (T5-B).



Table 5 (T5). Experiment 2

A. Effects of dietary level of PCS on broiler performances

| Treatment       | 0 to 21 days        | 21 to 49 days         | Overall              |
|-----------------|---------------------|-----------------------|----------------------|
| Weight gain (g) |                     |                       |                      |
| Control         | 616.33 <sup>a</sup> | 1769.79 <sup>a</sup>  | 2386.13 <sup>a</sup> |
| PCS 1.5         | 595.25 <sup>a</sup> | 1761.46 <sup>a</sup>  | 2356.71 <sup>a</sup> |
| PCS 3.0         | 510.11 <sup>b</sup> | 1717.71 <sup>ab</sup> | 2227.81 <sup>b</sup> |
| PCS 4.5         | 426.90 <sup>c</sup> | 1631.25 <sup>b</sup>  | 2058.15 <sup>c</sup> |
| Feed intake (g) |                     |                       |                      |
| Control         | 906.83 <sup>a</sup> | 3603.19 <sup>a</sup>  | 4510.02 <sup>a</sup> |
| PCS 1.5         | 904.37 <sup>a</sup> | 3642.35 <sup>a</sup>  | 4546.73 <sup>a</sup> |
| PCS 3.0         | 769.19 <sup>b</sup> | 3312.11 <sup>b</sup>  | 4081.29 <sup>b</sup> |
| PCS 4.5         | 696.92 <sup>c</sup> | 3222.40 <sup>b</sup>  | 3919.31 <sup>c</sup> |
| Feed Conversion |                     |                       |                      |
| Control         | 1.48                | 2.04                  | 1.89 <sup>ab</sup>   |
| PCS 1.5         | 1.52                | 2.07                  | 1.90 <sup>a</sup>    |
| PCS 3.0         | 1.52                | 1.94                  | 1.83 <sup>b</sup>    |
| PCS 4.5         | 1.64                | 1.98                  | 1.91 <sup>ab</sup>   |

B. Effects of dietary level of PCS on nutrient digestibility and energy values

| Treatments | Dry Matter | Crude Protein | Ether extract | NFE   | Energy |
|------------|------------|---------------|---------------|-------|--------|
| Control    | 74.4       | 65.48         | 79.76         | 80.45 | 76.55  |
| PCS 1.5    | 75.19      | 66.11         | 82.44         | 80.31 | 77.52  |
| PCS 3.0    | 77.47      | 70.26         | 82.51         | 83.02 | 80.03  |
| PCS 4.5    | 74.26      | 66.44         | 82.79         | 80.78 | 77.33  |

Noxious gas production from broiler manure is shown in T5-C. NH<sub>3</sub> gas production was significantly lower ( $P \leq 0.05$ ) in the 1.5% PCS and 3.0% PCS groups during the 2nd and 5th week period. They did not show any significant differences among them during the 3rd week period. H<sub>2</sub>S gas production from the 1.5% PCS and control groups were lower ( $P \leq 0.05$ ) than the 3.0% PCS and 4.5% PCS

groups during the 2nd, 3rd, and 5th week periods. CO<sub>2</sub> gas production was not significantly different among treatments in all period.

Fly populations were significantly lower ( $P \leq 0.05$ ) in the 1.5% PCS group during the 5th week period than the control, 3.0% PCS, and 4.5% PCS groups. All treatments were not significantly different during the 2nd and 3rd week periods (T5-D).

## C. Effects of dietary level of PCS on noxious gas from broiler manure

| Treatments             | Weeks               |                     |                    |
|------------------------|---------------------|---------------------|--------------------|
|                        | 2nd                 | 3rd                 | 5th                |
| NH <sub>3</sub> (ppm)  |                     |                     |                    |
| Control                | 57.49 <sup>ab</sup> | 70.64               | 44.02 <sup>a</sup> |
| PCS 1.5                | 41.15 <sup>a</sup>  | 56.12               | 34.67 <sup>b</sup> |
| PCS 3.0                | 58.69 <sup>ab</sup> | 53.29               | 33.82 <sup>b</sup> |
| PCS 4.5                | 70.65 <sup>b</sup>  | 71.98               | 41.90 <sup>a</sup> |
| H <sub>2</sub> S (ppm) |                     |                     |                    |
| Control                | 1.67 <sup>c</sup>   | 7.83 <sup>b</sup>   | 4.25 <sup>a</sup>  |
| PCS 1.5                | 1.59 <sup>c</sup>   | 7.00 <sup>b</sup>   | 3.08 <sup>b</sup>  |
| PCS 3.0                | 3.67 <sup>b</sup>   | 11.59 <sup>ab</sup> | 4.00 <sup>ab</sup> |
| PCS 4.5                | 5.83 <sup>a</sup>   | 14.58 <sup>a</sup>  | 5.08 <sup>a</sup>  |
| CO <sub>2</sub> (ppm)  |                     |                     |                    |
| Control                | 9915.17             | 10940.83            | 13866.67           |
| PCS 1.5                | 10355.83            | 12226.67            | 13135.83           |
| PCS 3.0                | 10440.00            | 11287.50            | 13677.50           |
| PCS 4.5                | 9725.83             | 11711.67            | 12045.00           |

## D. Effects of dietary level of PCS on fly populations

| Treatments | Weeks |       |                     |
|------------|-------|-------|---------------------|
|            | 2nd   | 3rd   | 5th                 |
| Control    | 25.25 | 33.00 | 82.00 <sup>bc</sup> |
| PCS 1.5    | 29.50 | 24.50 | 38.75 <sup>c</sup>  |
| PCS 3.0    | 33.00 | 41.25 | 148.50 <sup>a</sup> |
| PCS 4.5    | 25.00 | 53.75 | 98.75 <sup>b</sup>  |

<sup>a,b,c</sup> Values with different superscripts within the same column are significantly different ( $P < 0.05$ )

\* NFE: Nitrogen Free Extract.

## 3. Experiment 3

The results of the effects of PCS mesh size are shown in T6-A, B, C, and D. T6-A showed broiler performances. Weight gain in the control group was higher ( $P \leq 0.05$ ) than 20 mesh PCS, 50 mesh PCS and 90 mesh PCS groups during 0 to 21 days and the

overall period. The control group had higher feed intake ( $P \leq 0.05$ ) than the 20 mesh, 50 mesh, and 90 mesh PCS during the 0 to 21 days, 21 to 49 days, and overall periods. However, feed intake of the 20 and 50 mesh PCS were the same during 0 to 21 days, 21 to 49 days and the overall periods, while the 90 mesh PCS was lower ( $P \leq 0.05$ ) than 20

Table 6 (T6). Experiment 3

A. Effects of PCS particle size on broiler performances

| Treatment       | 0 to 21 days        | 21 to 49 days         | Overall               |
|-----------------|---------------------|-----------------------|-----------------------|
| Weight gain (g) |                     |                       |                       |
| Control         | 642.23 <sup>a</sup> | 1815.63               | 2457.86 <sup>a</sup>  |
| PCS 20          | 486.65 <sup>b</sup> | 1822.92               | 2309.56 <sup>b</sup>  |
| PCS 50          | 464.56 <sup>b</sup> | 1764.58               | 2229.15 <sup>b</sup>  |
| PCS 90          | 476.33 <sup>b</sup> | 1744.79               | 2221.13 <sup>b</sup>  |
| Feed intake (g) |                     |                       |                       |
| Control         | 953.77 <sup>a</sup> | 3644.61 <sup>a</sup>  | 4598.38 <sup>a</sup>  |
| PCS 20          | 793.94 <sup>b</sup> | 3430.96 <sup>ab</sup> | 4234.90 <sup>bc</sup> |
| PCS 50          | 806.25 <sup>b</sup> | 3497.65 <sup>ab</sup> | 4303.90 <sup>b</sup>  |
| PCS 90          | 793.73 <sup>b</sup> | 3301.85 <sup>b</sup>  | 4095.58 <sup>c</sup>  |
| Feed Conversion |                     |                       |                       |
| Control         | 1.49 <sup>b</sup>   | 2.01 <sup>a</sup>     | 1.87                  |
| PCS 20          | 1.63 <sup>a</sup>   | 1.89 <sup>b</sup>     | 1.83                  |
| PCS 50          | 1.74 <sup>a</sup>   | 1.98 <sup>ab</sup>    | 1.93                  |
| PCS 90          | 1.67 <sup>a</sup>   | 1.89 <sup>b</sup>     | 1.84                  |

B. Effects of PCS particle size on nutrient digestibility and energy values

| Treatments | Dry Matter | Crude Protein | Ether extract | NFE   | Energy |
|------------|------------|---------------|---------------|-------|--------|
| Control    | 75.62      | 66.45         | 81.24         | 82.39 | 77.61  |
| PCS 20     | 74.51      | 69.36         | 83.87         | 80.48 | 77.23  |
| PCS 50     | 75.71      | 68.42         | 82.01         | 81.46 | 78.34  |
| PCS 90     | 74.6       | 67.20         | 84.12         | 80.54 | 77.51  |

mesh size and 50 mesh size during the 21 to 49 days and overall periods. Feed conversion of the control was better ( $P \leq 0.05$ ) than 20, 50, and 90 mesh PCS groups during the 0 to 21 days period. However the 20, 50, and 90 mesh PCS group were better ( $P \leq 0.05$ ) than the control during 21 to 49 days period, although they did not show any difference during overall period. Nutrient digestibilities and energy values (T6-B) were not different among treatments.

NH<sub>3</sub> gas production was not significantly

different among treatments (T6-C). H<sub>2</sub>S gas production in the control group was lower ( $P \leq 0.05$ ) than any mesh size of PCS (20, 50, and 90 mesh size PCS) during the 2nd period. CO<sub>2</sub> gas production tended to similar way of H<sub>2</sub>S, which was higher ( $P \leq 0.05$ ) in the control group and lower ( $P \leq 0.05$ ) in 90 mesh size PCS during 5th period.

Fly populations (T6-D) did not show any differences among treatments during the 2nd, 3rd, and 5th weeks.

## C. Effects of PCS particle size on noxious gas from broiler manure

| Treatments             | Weeks              |          |                        |
|------------------------|--------------------|----------|------------------------|
|                        | 2nd                | 3rd      | 5th                    |
| NH <sub>3</sub> (ppm)  |                    |          |                        |
| Control                | 73.15              | 74.45    | 40.92                  |
| PCS 20                 | 75.24              | 65.96    | 33.12                  |
| PCS 50                 | 66.29              | 69.75    | 39.15                  |
| PCS 90                 | 76.43              | 72.18    | 47.17                  |
| H <sub>2</sub> S (ppm) |                    |          |                        |
| Control                | 2.17 <sup>b</sup>  | 11.58    | 4.00                   |
| PCS 20                 | 3.42 <sup>ab</sup> | 8.58     | 3.83                   |
| PCS 50                 | 4.75 <sup>ab</sup> | 9.00     | 3.25                   |
| PCS 90                 | 5.67 <sup>a</sup>  | 11.34    | 4.42                   |
| CO <sub>2</sub> (ppm)  |                    |          |                        |
| Control                | 10780.84           | 10013.33 | 14272.50 <sup>a</sup>  |
| PCS 20                 | 11947.50           | 10903.33 | 13122.50 <sup>ab</sup> |
| PCS 50                 | 11958.34           | 10289.17 | 13292.50 <sup>ab</sup> |
| PCS 90                 | 10068.33           | 9622.5   | 12257.50 <sup>b</sup>  |

## D. Effects of PCS particle size on fly populations

| Treatments | Weeks |       |       |
|------------|-------|-------|-------|
|            | 2nd   | 3rd   | 5th   |
| Control    | 31.00 | 38.50 | 79.75 |
| PCS 20     | 29.75 | 32.00 | 86.25 |
| PCS 50     | 43.50 | 58.00 | 49.25 |
| PCS 90     | 41.50 | 58.50 | 85.25 |

<sup>a,b,c</sup> Values with different superscripts within the same column are significantly different ( $P < 0.05$ ).

\* NFE: Nitrogen Free Extract.

## DISCUSSION

The present study dealt with the utilization of PCS and the effects of its size in broiler feeding. Comparisons were made among PCS and naturalzeolite, the amount of PCS added, and the mesh size of the PCS for their effects on broiler performances, nutrient digestibilities, noxious gas production from broiler manure, and relative fly populations.

## 1. Production performance and nutrient digestibilities

Weight gain for the overall period in the control group was higher ( $P \leq 0.05$ ) in experiments 1, 2, and 3. Feed intake for all values was higher ( $P \leq 0.05$ ) in the control groups in experiment 1, 2, and 3 than other treatments, although in experiment 2 all of values were not significantly different between the 1.5% PCS and control groups. These results are somewhat consistent with other scientists

(Donaldson etc. 1956; Sunde, 1956; Jacson, 1982) because energy level, protein level, lysine level, methionine level and phosphorus level are higher in the control group than any other treatments. In this study, higher calcium content in PCS supplemented feed resulted in lower weight gain ( $P \leq 0.05$ ) in experiment 1 than natural zeolite, which has a lower calcium content. Latshaw and Turner(1991) said that the addition of Shell-Developer had no positive effects at any time on any of the characteristics measured. However, Hulan et al.(1987) said that high contents of calcium in feed can grow heavier broilers than lower contents of calcium in broiler feed. PCS supplemented feed, 3.0 % PCS and 20 mesh size PCS were lower (better) ( $P \leq 0.05$ ) in feed conversion than the control group in experiment 1, 2, and 3 during 21 to 49 days and overall periods although the control group was lower in experiments 1, 2, and 3 during 0 to 21 days. This research showed that PCS supplemented feed, the amount of PCS in feed, and any mesh size of feed may influence the speed of gastrointestinal tract (GIT) passage as the chick ages (Min et al., 1988). Tuckey et al.(1958) reported that the addition of fat or cellulose in feed did not influence GIT passage of chicken feed.

The addition of PCS or zeolite, and the amount of PCS and PCS mesh size may not influence in nutrient digestibilities and energy values. Willis et al.(1982) reported that the effect of the addition of big size particle zeolite was significantly lower than smaller size particle zeolite on nutrient digestibilities.

## 2. Noxious gas production and fly population

The zeolite group had improved  $\text{NH}_3$  and  $\text{H}_2\text{S}$  ( $P \leq 0.05$ ) production than the control and

PCS group during the 2nd and 3rd periods although they did not show any difference during the 5th period. The current research results in experiment 1 are similar to the results of Kithome et al.(1998) who reported that data indicated the potential use of the tested natural zeolite as an  $\text{NH}_4^+$  adsorbent and a controlled-released  $\text{NH}_4^+$  fertilizer. Another review revealed that both the ion-exchange and adsorption properties of natural zeolite can be exploited to make more efficient use of nitrogen in animal nutrition (Mumpton and Fishman, 1977). However, Nakaue et al.(1978) reported no consistent lowering trend of fecal ammonia evolution rate was noticed between the fecal samples from layers fed 0 and 10% zeolite. 1.5% or 3.0% PCS in feed resulted in more improved  $\text{NH}_3$  and  $\text{H}_2\text{S}$  values ( $P \leq 0.05$ ) than the 4.5% PCS during 2nd and 3rd weeks in experiment 2 although 5th weeks of  $\text{NH}_3$  in experiment 2 showed significantly different ( $P \leq 0.05$ ) between control group or 4.5% groups and 1.5% or 3% PCS. Volatile organic compounds (VOCs), and odor were consistently controlled, with the reduction rate being proportional to the zeolite application rate in poultry manure storage (Cai et al. 2006). Experiment 3 proved the similar hypothesis of  $\text{NH}_3$  and  $\text{H}_2\text{S}$  production as experiment 2.  $\text{CO}_2$  gas production in experiments 1, 2, and 3 was not significantly different among treatments although in the 5th week of experiment 3 there was a difference ( $P \leq 0.05$ ) among the treatments. More than 90 mesh size PCS was better ( $P \leq 0.05$ ) in controlling  $\text{CO}_2$  in the 5th week than the 20 mesh size or 50 mesh size, and control groups (Experiment 3).

The control and PCS had higher fly production ( $P \leq 0.05$ ) due to moisture during the 2nd and 3rd periods than zeolite in experiment 1. Seltzer et al.(1969) reported that the moisture

content in livestock feces is important to reproduce flies. And Onagi (1965) reported that a ratio of poultry feces : zeolite = 3 : 1 was the best conditions to reduce fly production, which was 82.4% lower than the control groups. In experiment 2, 3.0% or 4.5% PCS in broiler feed resulted in higher fly populations than 1.5% PCS and control group, especially during the 5th week ( $P \leq 0.05$ ). In experiment 3, bigger mesh size (more than 90 mesh size of PCS) of PCS may have resulted in higher moisture than smaller mesh size of PCS. 90 PCS mesh size in broiler feed resulted in higher fly production than the 20, 50 PCS mesh size and the control groups.

## CONCLUSIONS

In order to develop porous calcium silicate (PCS) as a mineral additive for the reduction of fecal odor and fly production a series of experiments were conducted. In the first experiment PCS powder prepared by using a 50 mesh sieve was spread on top of chick droppings to investigate the odor from the manure. Zeolite was used as a comparative purpose. Reduction in ammonia production from chick droppings shortly after the PCS and zeolite application was evident ( $P < 0.05$ ), but there were no difference among treatments afterwards. Hydrogen sulfide level was significantly lowered by both PCS and zeolite treatment ( $P < 0.05$ ).

Effects of PCS particle size on chicks performance, fecal odor, and fly production were studied in the second feeding trial with 212 Cobb chicks. Regardless of the particle size, feeding PCS reduced weight gain and feed intake without affecting feed efficiency. Among PCS treatments the particle size prepared using a 20 mesh sieve showed the

best weight gain and feed efficiency, but the differences were not statistically significant. Ammonia and hydrogen sulfide level of chick manure, and fly production from chick manure were all not effected by PCS particle size.

Effects of different dietary levels of PCS supplementation on chick performance, fecal odor, and fly production were studied in the third feeding trial. Two hundred and twelve Cobb chicks were divided into four groups and fed diets containing 0, 1.5, 3.0, or 4.5% PCS. Feeding PCS at the 1.5% level did not affect chick weight gain and intake but feeding at the higher levels, 3.0 and 4.5%, reduced weight gain and feed intake ( $P < 0.05$ ). Feeding 3.0% level of PCS improved feed efficiency ( $P < 0.05$ ). Ammonia and hydrogen sulfide level in chick manure appeared to be raised in proportion to the dietary level of PCS but there were no consistent differences among treatments. Fly population was minimized by feeding PCS at the 1.5% level at the 3rd week ( $P < 0.05$ ), but there were no consistent trend of differences among treatments.

Effects of feeding PCS and zeolite on chick performance, fecal odor and fly production were studied in the fourth feeding trial using 159 Cobb chicks. PCS reduced weight gain and feed intake, but improved feed efficiency ( $P < 0.05$ ). Ammonia and hydrogen sulfide levels were lowered by zeolite when compared to PCS ( $P < 0.05$ ), but there were no differences among treatments in the 5th week. Fly production was minimized by feeding PCS at the 3rd week and zeolite at the 2nd week, but there seemed to be no consistent trend in all treatments.

In conclusion, it can be said that the effects of PCS manufactured in this study on chick performance, fecal odor and fly production from the manure are inconclusive, but the PCS

showed a good possibility of minimizing fecal odor and fly production from chick manure without harmful effects on chick performance, if used properly. Further studies regarding the quality control of PCS during manufacturing and the method evaluating the value of PCS manufactured appear to be necessary.

## SUMMARY

Three experiments on the addition of Porous Calcium Silicate (PCS) to broiler feed were conducted at different time periods in the same house. Each treatment had 4 replicates with 12 chicks in each treatment. Weight gain and feed intake were higher ( $P \leq 0.05$ ) in the control groups. Feed conversions were better ( $P \leq 0.05$ ) in the PCS group, 3.0% PCS and 20 mesh size of PCS than the control group from 21 to 49 days, and for the overall period.  $\text{NH}_3$  and  $\text{H}_2\text{S}$  gas production were decreased ( $P \leq 0.05$ ) when zeolite was added in broiler feeds. 1.5% or 3.0% PCS in broiler feed was better ( $P \leq 0.05$ ) than the 4% PCS. More than 90 mesh size PCS was better ( $P \leq 0.05$ ) in controlling  $\text{CO}_2$  production in the 5th period than the 20 or 50 mesh size or control groups. The control and PCS groups produced more flies ( $P \leq 0.05$ ) than zeolite group during the 2nd and 3rd weeks. The 3.0% or 4.5% PCS or 50 or 90 mesh size of PCS in broiler feed produced more flies than the 20 mesh size or control groups although 50 or 90 mesh size of PCS during 5th week tended to have lower fly production than the 20 mesh size of PCS and control group.

**(Key words :** Porous Calcium Silicate, Zeolite, Broiler, Fly,  $\text{NH}_3$ ,  $\text{H}_2\text{S}$ )

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