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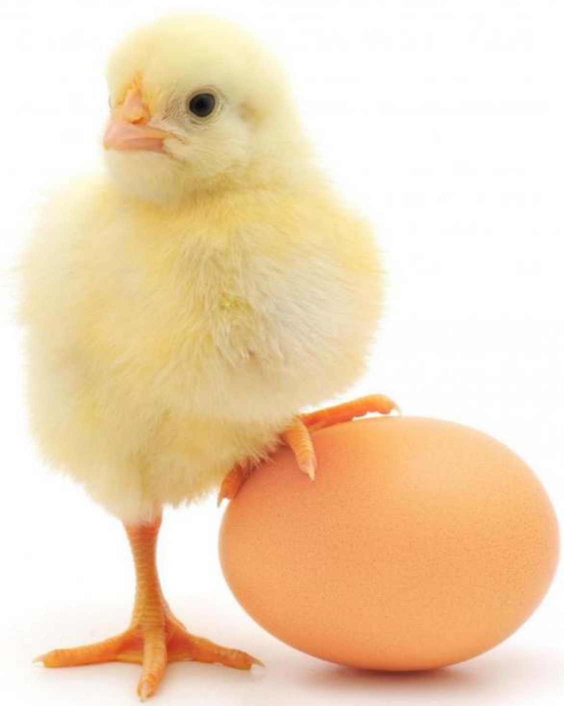

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Mixing Performance of a Novel Flat-Bottom Vertical Feed Mixer

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Abstract: The objective of the present study was to test mixing performance of a flat-bottom vertical mixer. The mixer has a capacity of 250 liter with 430 mm height and 900 mm diameter. A diet was formulated to contain 69.5% corn, 27.5% soybean meal, 0.9% limestone, 0.8% dicalcium phosphate, 0.5% vitamin-mineral premix, 0.45% salt and 0.4% chromic oxide. The mixing performance of the mixer was tested with 80 kg batch in triplicate for 30, 180, 300 and 420 sec. At the end of each mixing, 100 g of samples were collected from the initial 5, 30, 60 and 95% of feed discharged from the spout end of the mixer. The 4 samples from each mixing time were analyzed for the concentrations of crude protein. The coefficients of variation of crude protein among the samples from each mixing of 30, 180, 300 and 420 sec were 14.8, 7.4, 6.7 and 6.0%, respectively. A broken-line analysis was conducted to estimate the minimum mixing time. The result indicated that the most suitable mixing time was 202 sec (R^2 = 0.99; p = 0.077). In conclusion, at least 200 sec of mixing is required for optimum mixing performance of the novel feed mixer.

Key words: Coefficient of variation, crude protein, feedstuff, mixing efficiency

INTRODUCTION

The production performance of poultry and livestock is affected by many factors including nutrition, genetics and environment. A uniform and precise mixing of diets is very critical for providing energy and nutrients to meet the requirements for animals (Traylor *et al*., 1994). Poor mixing of feedstuffs may cause over supply or under supply of nutrients to animals, resulting in economic loss, poor performance, or both. Detrimental effects of insufficient mixing time on average daily gain and gain to feed ratio have been reported (Groesbeck *et al*., 2007). Uniform mixing of diets is also very important in animal nutrition studies as insufficient diet mixing process can critically affect the results of nutrition experiments (Cromwell *et al*., 2003).

Horizontal and vertical feed mixers are widely used for mixing the animal feeds at feed mills. These types of feed mixers have been tested for the degree of uniformity in diet mixing (Cromwell *et al*., 2003; McCoy, 2005). Cone-bottom type vertical mixers have been tested for mixing performance (Cromwell *et al*., 2003; Groesbeck *et al*., 2007). However, a flat-bottom vertical mixer has not been tested for mixing performance. Therefore, the objective of this study was to determine the optimum mixing time of the flat-bottom vertical mixer for uniform diet mixing.

MATERIALS AND METHODS

A flat-bottom mixer: The mixer used in the current study was a vertical flat-bottom mixer (DKM-350SBF; Daegwang Construction Mechanic Inc., Seoul, Republic of Korea) with 40 revolutions per minute, 250 liter capacity, 460 mm height and 900 mm diameter (Fig. 1).

Experimental diet: A diet mainly based on corn and soybean meal was formulated (Table 1). Vitamins and minerals were included and 0.4% chromic oxide was included to confirm the uniformity of mixing diet with the unaided eye.

Mixing performance test and chemical analysis: The mixing time periods tested were 30, 180, 300 and 420 sec in triplicate. At the end of each mixing time, samples were collected from the initial 5, 30, 60 and 95% of feed discharged from the spout end of the mixer. Samples were analyzed for crude protein (CP; method 990.03; AOAC, 2005) as the criterion of the degree of the uniformity in the mixed diet.

Statistical analysis: To determine the uniformity of mixing, standard deviation and coefficient of variation (CV) of CP concentrations were calculated. The optimal mixing time was estimated by regression analysis between the mixing time and CV of CP concentrations using NLIN procedure of SAS. The optimal mixing time was determined by one slope broken-line analysis (Robbins *et al*., 2006) and the significance of the model was accepted at an alpha level of 0.10.

RESULTS

The CV of CP among the samples from each mixing for 30, 180, 300 and 420 sec were 14.8, 7.4, 6.7 and 6.0%, respectively (Table 2). Although the CP concentration among the diets in each mixing time is similar, the CV of CP concentration representing the variability among the sampling spots decreased with mixing time. Based

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Fig. 1: Pictures of a flat-bottom vertical mixer with a capacity of 250 liter, 460 mm height and 900 mm diameter

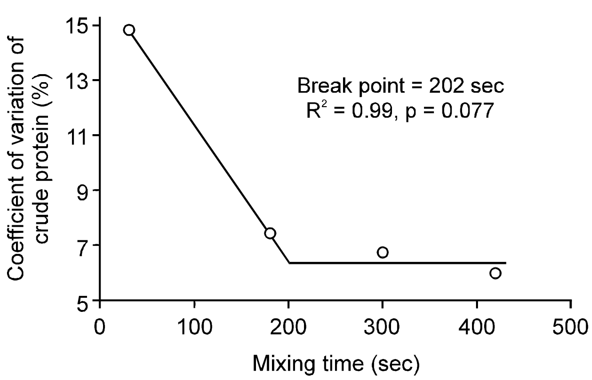

Fig. 2: Minimum mixing time based on the crude protein concentrations. Three batches were used in the mixing performance test and 4 samples from each batch were collected at initial 5, 30, 60 and 95% of feed discharge. Coefficient of variation represents the variability among the 4 samples at different sampling positions

on the broken-line analysis, the minimum mixing time was estimated at 202 sec (R^2 = 0.99, p = 0.077, Fig. 1).

DISCUSSION

The objective of mixing efficiency test was to determine the optimum mixing time for homogeneous mixing of feed ingredients. Homogenous mixing of diets has been shown to improve production performance (Traylor *et al.*, 1994; Groesbeck *et al.*, 2007). Therefore, the confirmation of mixing efficiency of a mixer is very important before using the mixer for animal feed production. To our knowledge, mixing performance of a vertical type flat-bottom mixer is first tested in the present study.

Table 1: Ingredient of composition of the diet (as-is basis)

Ingredient (%)	
Ground corn	69.5
Soybean meal, 48% crude protein	27.5
Ground limestone	0.9
Dicalcium phosphate	0.8
Vitamin-mineral premix[1]	0.5
Salt	0.4
Chromic oxide	0.4

[1]Provided the following quantities per kg of complete diet: vitamin A, 25,000 IU; vitamin D_3, 4,000 IU; vitamin E, 50 IU; vitamin K, 5.0 mg; thiamin, 4.9 mg; riboflavin, 10.0 mg; pyridoxine, 4.9 mg; vitamin B_{12}, 0.06 mg; pantothenic acid, 37.5 mg; folic acid, 1.10 mg; niacin, 62 mg; biotin, 0.06 mg; Cu, 25 mg as copper sulfate; Fe, 268 mg as iron sulfate; I, 5.0 mg as potassium iodate; Mn, 125 mg as manganese sulfate; Se, 0.38 mg as sodium selenite; Zn, 313 mg as zinc oxide and butylate dihydroxytoluene, 50 mg

Table 2: Analyzed values for crude protein concentrations (%) and the variability in feed samples by varying mixing time

	----------- Mixing time, sec -----------			
Item[1]	30	180	300	420
Mean	18.5	18.2	18.9	18.3
Standard deviation	2.8	1.4	1.3	1.1
Coefficient of variation (%)	14.8	7.4	6.7	6.0

[1]Three batches were used in the mixing performance test and 4 samples from each batch were collected at initial 5, 30, 60 and 95% of feed discharge. Standard deviation represents the variability among the 4 samples at different sampling positions

The uniformity of mixing diet is affected many factors including particle size, ingredient density, sequence of ingredient addition, amount of ingredients mixed, mixer design, mixing time and cleanliness of the mixer (McCoy, 2005). Because the mixing time is one of the most influential factors, the present experiment was designed to investigate the effects of mixing time on uniformity of mixed diet.

The CP concentration of samples was used to determine the degree of the uniformity in diet mixing. As CP concentrations of corn and SBM generally range from 7 to 8% and from 43 to 48%, respectively, showing relatively large deviation between corn and soybean meal, the CP concentration of the sample can be used as the criterion for uniformity of diet mixing.

In the present study, although the CP concentrations among the diets for each mixing time were similar, the CV of CP concentration of samples for mixing time period decreased with increasing mixing time which indicates that the longer mixing time of the flat-bottom feed mixer improves the uniformity of diet mixing. The CV was less than 10% with mixing time longer than 180 sec. Generally, less than 10% of CV is acceptable for determining the uniformity of mixing diets (McCoy *et al.*, 1994; Groesbeck *et al.*, 2007).

The minimum mixing time of 202 sec based on the broken-line analysis indicates that at least 200 sec of mixing time is required for homogenous mixing. The present data at least partially agree with the data in the literature. Groesbeck *et al.* (2007) reported quadratic improvements of feed uniformity and growth performance of pigs with increasing mixing time of 0, 30, 60, 120, 210, 330, 480 and 630 sec.

The capacity of the mixer tested in this study is 250 liter which is rather small for commercial usage, but is very useful for preparation of experimental diets for poultry and swine nutrition studies (Kil *et al.*, 2013; Kong and Adeola, 2014; Son *et al.*, 2013).

Conclusion: In conclusion, at least 200 sec of mixing is required for optimum mixing performance in the novel feed mixer based on protein concentration analyzed. Further research is needed to test mixing performance of a flat-bottom vertical mixer based on the variability in mineral contents.

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