ANALYSIS OF FEED MIXER EFFICIENCIES OF COMMERCIAL FEED MANUFACTURERS IN THE PHILIPPINES FROM 2012 TO 2016

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ABSTRACT

The study was done to determine the efficiency of feed mixers with different batch sizes, mixing time and diet types using data gathered from commercial feed manufacturers in the Philippines. Mixing efficiency was evaluated by calculating the coefficient of variation (CV) using color-coded tracer homogeneity test and was described as excellent (CV $\leq$ 10%), good (CV=10-15%), fair (CV=15-20%) and poor (CV $\geq$ 20%). Results from 2012 to 2016 were grouped according to mixer type, batch size, mixing time and feed type, and were subjected to descriptive statistics. Of the 985 feed samples mixed using the horizontal-type, only 24% yielded excellent mixing efficiency while only 14% for vertical-type mixer (n=85). The highest percentage of excellent mixing efficiencies of different mixer capacity, mixing time using horizontal mixer, mixing time using vertical mixer, and feed types were at 500-kg (31.54%), <4 minutes (30.58%), 15 minutes (26.09%), and sow feeds (34.12%), respectively. These factors can significantly alter the homogeneity of the mixed rations. Recognition of these factors and regularly checking the quality of mix can help maintain the acceptable CV to deliver nutritionally uniform feeds to the animals.

Keywords: feeds, homogeneity test, mixing efficiency

INTRODUCTION

Nutrition and feed science belong to the critical factors of livestock and poultry production that aim to provide adequate and balanced nutrients (Kersten *et al*., 2005). The fundamental assumption of all nutritionists when formulating diets is that each part of the feed is balanced according to the nutrient requirement of the animals to support maintenance, growth, production, and reproduction (Behnke, 2006). With the demand of the addition of micro-ingredients such as amino acids, vitamins, minerals and other feed additives, efficient feed mixing operation becomes even more necessary (Marczuk *et al*., 2017).

Mixing is one of the most critical processes in feed manufacturing. The principal objective in feed mixing operation is to produce rations in which nutrients and medication are evenly distributed (Herrman and Behnke, 1994). Mixing efficiency, another term for feed homogeneity, determines how thoroughly a batch of feed is mixed (Goodband,

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1990). Conversely, the concept of feed homogeneity is significant that if feed ingredients, particularly low-inclusion ingredients are not properly incorporated, animal performance is affected negatively (McCoy *et al*., 1994; Traylor *et al*., 1994). Some animals could intake the right amount of these additives while others might be deficient or in excess. This excess could possibly induce toxicity (Behnke, 2006) and could bring economic losses to animal producers and may amplify the incidence of drug residues (Djuragic *et al*., 2009). Furthermore, feed costs account to 65 to 75% of the cost of production for swine and poultry operations (Goodband, 1990.; Marczuk *et al*., 2017); therefore, feed utilization is a crucial factor in determining profitability. Lastly, the Bureau of Animal Industry Current Good Manufacturing Practices (cGMP) under the inter-agency committee on food safety require that feed produced in a given cycle of manufacture be uniform in character and quality (Administrative Order No. 153 Series 2004).

To ensure the quality of feeds, routine mixer testing should be a part of the quality assurance program (Chin, 2006). The test involves obtaining at least 10 samples from a single batch of feed and analyzing each sample for salt content (Goodband, 1990). Salt is used as mixer test markers because it is a common component of most livestock and poultry rations (Chin, 2006), and is relatively easy and inexpensive to test (Goodband, 1990). Another method is the use of color-coded tracers wherein sufficient amount of iron filings, colored with a water-soluble die is added to the mix and demagnetized from the collected samples (Chin, 2006; Djuragic *et al*., 2009).

Coefficient of variation (CV) is commonly used in the determination of mixer efficiency. According to Groesbeck *et al*. (2004), a CV of <10% for mixer efficiency is an indicator of excellent mixing, a CV of 10 to 15% is considered good, a CV of 15 to 20% is fair, and a CV of 20% or greater means insufficient mixing and needs consultation. A number of factors such as mixer equipment, ingredient or feed characteristics and mixing time may affect mixing efficiency. There are a number of researches about mixing efficiency, however, a review on the performance of feed mixers in the Philippines is limited. Therefore, the study was conducted to determine the efficiency of feed mixers with different batch sizes, mixing time and diet types using data gathered from feed manufacturers in the Philippines.

MATERIALS AND METHODS

Feed homogeneity test was conducted using Microtracer™ Rotary Detector in self-mix and commercial feed manufacturers across the Philippines. A total of 1,070 samples collected from 2012 to 2016 came from 83 feed manufacturers in North Luzon, 75 in South Luzon, 9 in Visayas and 30 in Mindanao. Mixing efficiency was calculated using coefficient of variation (CV) and was described as excellent (CV≤ 10%), good (CV=10-15%), fair (CV=15-20%) and poor (CV≥20%). The results from 2012 to 2016 were grouped according to mixer type (horizontal or vertical mixer), mixer capacity (500, 1,000, 1,500, 2,000, 3,000-kg), mixing time using horizontal mixer (<4, 4, 5, 6, >7 minutes), mixing time using vertical mixer (10, 15, 20, >25 minutes), and feed types (fattener, sow, broiler, layer feeds). Average and standard deviation for the different factors were computed using MS Excel. Results were presented as pie graphs and stacked bar graphs in order to determine the efficiency of feed mixers using different factors.

RESULTS

Majority of the feed manufacturers are using horizontal-type mixers, while vertical type is still common in on-farm feed manufacturing operations. Of the 985 samples mixed using the horizontal-type, only 24% yielded excellent feed uniformity while 39% resulted in good mixing (Figure 1). Additionally, 19% were between 15 to 20% CV, and 18% had CVs greater than 20%. For vertical-type (n=85), only 14% showed excellent mixing (Figure 2). Fifty one percent were between 10 to 15% CV, 21% were between 15 to 20% CV, and 14% had CVs greater than 20%.

The mixing efficiency with different mixer capacity showed that 31.54% of the samples blended at 500-kg batch size yielded excellent feed uniformity with an average CV of 8.28 ± 1.45% (Figure 3). Moreover, 52.24% of the samples mixed using 1500-kg batch size resulted in good mixing (average CV: 12.86 ± 1.34%). The 2000-kg mixer capacity showed 25.76% fair mixing (average CV: 17.30 ± 1.23%) while 3000-kg batch size yielded 43.18% poor mixing (average CV: 39.05 ± 13.63%).

More than 30% of the feed samples mixed using horizontal-type were blended for 5 minutes. The mixing efficiency with different mixing time using horizontal mixers showed that 30.58% of the samples mixed below 4 minutes yielded excellent mixing with an average CV of 8.45 ± 1.24% (Figure 4). Moreover, 41.75% of the samples mixed at >7 minutes resulted in good mixing (average CV: 12.45 ± 1.43%). At 4 minutes mixing time, 23.18% of the samples showed fair mixing (average CV: 17.13 ± 1.55%) while at 6 minutes, 20.36% of the samples resulted in poor mixing (average CV: 33.47 ± 11.49%).

The mixing efficiency with different mixing time using vertical mixer showed 26.09% of the samples mixed for 15 minutes yielded excellent mixing with an average CV of 8.13 ± 1.42% (Figure 5). Additionally, 66.67% of the samples mixed for 10 minutes

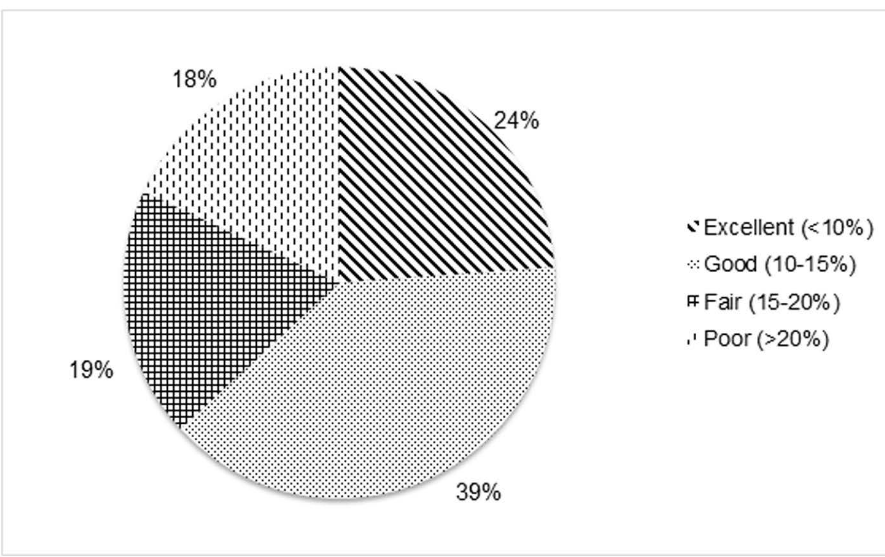


Figure 1. Relative distribution of mixing efficiency of horizontal mixers of feed manufacturers in the Philippines.

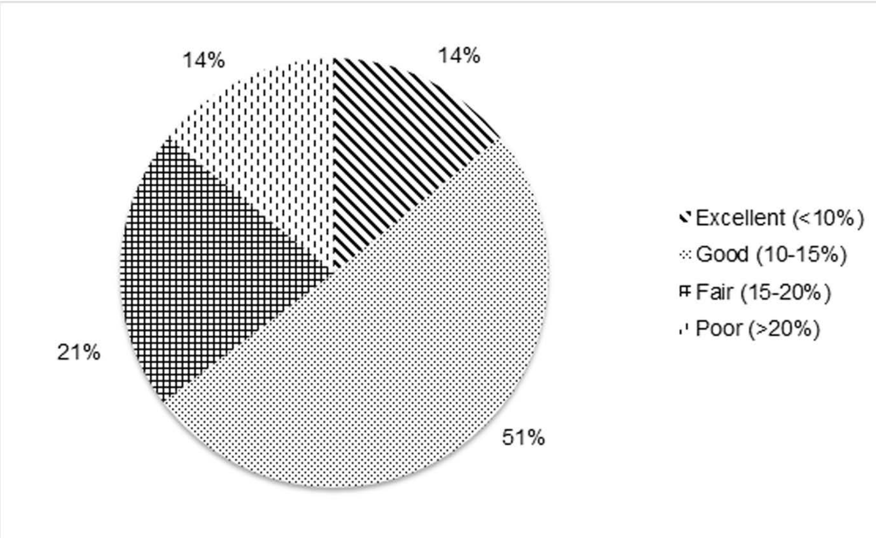
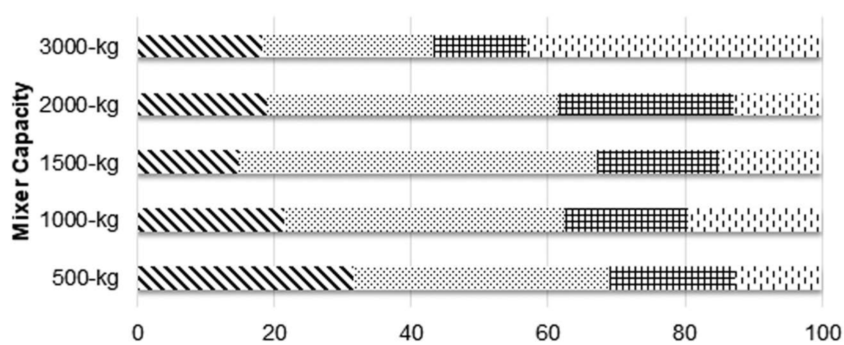


Figure 2. Relative distribution of mixing efficiency of vertical mixers of feed manufacturers in the Philippines.

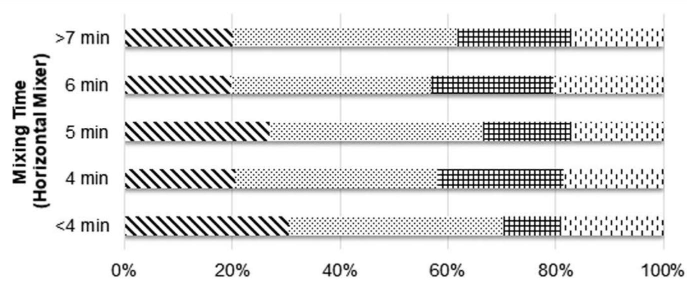


	500-kg	1000-kg	1500-kg	2000-kg	3000-kg
Excellent	31.54	21.52	14.93	18.94	18.18
Good	37.31	40.74	52.24	42.42	25.00
Fair	18.46	18.17	17.90	25.76	13.64
Poor	12.69	19.57	14.93	12.88	43.18

Figure 3. Relative distribution of mixing efficiency of different mixer size of feed manufacturers in the Philippines.

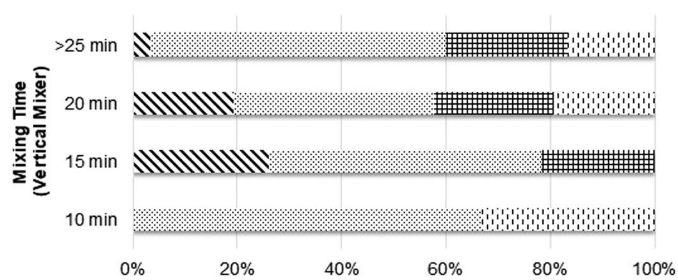
resulted in good mixing (average CV: 13.35 ± 1.71%). Mixing time at >25 minutes showed 23.33% fair mixing (17.15 ± 1.52%), and at 10 minutes mixing resulted in 33.33% poor mixing (average CV: 25.62 ± 2.81%).

Lastly, the mixing efficiency for varied diet types showed that 34.12% of the sow feeds yielded excellent mixing with average CV of 8.38 ± 1.11% (Figure 6). While 41.67% of the broiler feeds resulted in good mixing (average CV: 12.35 ±1.39%). Furthermore, 20.21% of the fattener feeds yielded fair mixing (average CV: 17.34 ± 1.42%) while 22.55% of the layer feeds resulted in poor mixing (average CV: 30.89 ± 12.33%).



	<4 min	4 min	5 min	6 min	>7 min
Excellent	30.58	20.53	26.99	19.76	20.10
Good	39.67	37.75	39.49	37.13	41.75
Fair	10.74	23.18	16.48	22.75	21.13
Poor	19.01	18.54	17.04	20.36	17.02

Figure 4. Relative distribution of mixing efficiency at different mixing time of feed manufacturers in the Philippines (horizontal mixers).

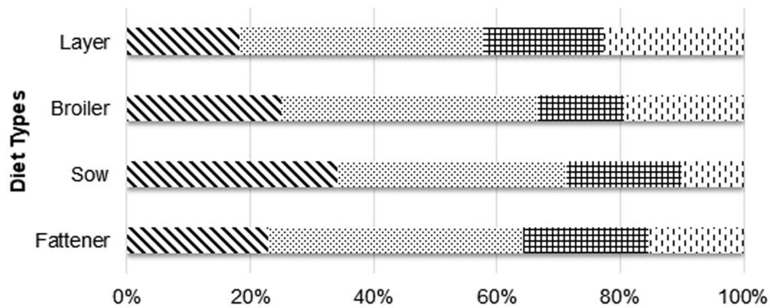


	10 min	15 min	20 min	>25 min
Excellent	0.00	26.09	19.23	3.33
Good	66.67	52.17	38.46	56.67
Fair	0.00	21.74	23.08	23.33
Poor	33.33	0.00	19.23	16.67

Figure 5. Relative distribution of mixing efficiency at different mixing time of feed manufacturers in the Philippines (vertical mixers).

DISCUSSION

There are factors that can affect the homogeneity of the mixed feeds. These include the equipment type, mixing time and feed/ingredient characteristics (Behnke, 2006; Chin, 2006). The horizontal mixer is by far the most common type of feed mixing equipment used, and the vertical mixer is sometimes found in smaller feed mill operations (Behnke, 2006). The results on mixer efficiency of different mixer types showed that horizontal-type had a higher percentage of CVs below 10% than vertical-type. This could be due to mixing against the force of gravity such that dense materials like limestone and phosphates are difficult to elevate because of sliding and have the tendency to go to the bottom because of the height factor.



	Fattener	Sow	Broiler	Layer
Excellent	22.87	34.12	25.00	18.22
Good	41.49	37.06	41.67	39.81
Fair	20.21	18.82	13.89	19.42
Poor	15.43	10.00	19.44	22.55

Figure 6. Relative distribution of mixing efficiency of varying diet types of feed manufacturers in the Philippines.

Aside from mixer type, mixing time also affects mixer efficiency. The vertical-type is generally slower than a comparably sized horizontal-type. Horizontal mixer requires shorter mixing time and higher percentages of liquid may be added to the feed compared to vertical mixer (Behnke, 2006). Moreover, horizontal mixers with either paddles or ribbons typically require about 5 to 10 minutes mixing time to get a coefficient of variation below 10% while vertical mixers require approximately 15 minutes for optimum feed homogeneity (Goodband, 1990). According to Chin (2006), the mixing time necessary to produce a uniformly mixed diet should be measured for each mixer. It is a function of mixer design and the rotational speed of the ribbon or paddle. For optimum ingredient distribution, each mixer should be adjusted to its proper revolutions per minute (RPM). Different types of raw materials may have a different flow pattern within a mixer at similar RPMs. Generally, the higher the RPM the more efficient the pattern of dispersion. However, optimum RPM can change based on the type of mixer and its condition resulting from normal wear, structure basis or ingredient buildup. These factors may increase the time required to completely mix a batch of feed (Djuragic *et al*., 2009). Additionally, Herrman and Behnke (1994) suggested that at less than 10% CV, no corrective action should be taken, and at 10 to 15% CV, mixing time should be increased by 25 to 30%. At 15 to 20% CV, mixing time should be increased by 50% and be checked for worn equipment, overfilling or sequence of ingredient addition. And, at greater than 20% CV, possible combination of all of the suggested corrective action and consultation of extension personal or feed equipment manufacturer should be done.

Lastly, the physical properties of raw materials can also affect mixing efficiency. Some of these factors include particle size, density, hygroscopicity and liquid addition. According to Herrman and Behnke (1994), the uniformity of size of various feedstuffs can directly impact final ingredient segregation. Large and small particles do not mix well, and ingredients tend to separate. When the particle sizes between ingredients are more uniform, the shorter the mixing time and the lower the CV; even after mixing, the batch is more resistant to segregation (AFIA, n.d.). A typical sow feed has the highest percentage of fillers which particle size almost uniform with the micro ingredients. And, poultry feeds are composed of varying particles sizes of ingredients as they prefer coarsely grind grains for a more developed gizzard (Amerah *et al*., 2007). Additionally, layer feed has the highest percentage of limestone this could explain why it had the lowest percentage of excellent mixing efficiency. Another factor is density wherein ingredients with different particle densities also tends to be dispersed. The denser particles such as minerals go to the bottom through the lighter particles (Axe, 1995). According to New (1987), the common raw materials and their corresponding bulk density are as follows: whole wheat (0.72-0.83 mt/m^3), ground wheat (0.60-0.62 mt/m^3), wheat bran (0.17-0.25 mt/m^3), rice bran (0.32-0.33 mt/m^3), ground corn (0.60-0.64 mt/m^3), soybean meal extruded (0.57-0.64 mt/m^3), fish meal (0.48-0.64 mt/m^3), molasses (1.33 mt/m^3), limestone (1.08-1.14 mt/m^3), and fine salt (1.12-1.28 mt/m^3). Among the feed types, a typical fattener feed has the highest percentage of molasses and fillers in the formulation while layer feeds have the highest inclusion of limestone. Additionally, a hygroscopic material, such as salt and choline chloride, may absorb moisture that will cause lumping of mixed feeds resulting in poor mixing efficiency (Behnke, 2006). Moreover, the incorporation of liquid ingredients such as fats, oils, and molasses are being done today. Grower-finisher and sow feeds are commonly formulated with molasses and this usually builds up on the interior of the mixer and can seriously reduce mixer efficiency. As the number of ingredients and variations increases, a greater appreciation of the complexity of the mixing operation is formed (Behnke, 2006).

The present study described that the horizontal-type mixer had the highest percentage of excellent mixing efficiency compared to the vertical-type mixer. In terms of mixer capacity, 500-kg batch size had the highest percentage of excellent mixing. With different mixing time using horizontal-type and vertical-type mixers, feed uniformity was excellent at <4 minutes and 15 minutes, respectively. Lastly, mixing efficiency with different feed types was excellent at sow feeds. Each mixer analysis will be different due to equipment type and capacity, mixing time and feed/ingredient characteristics. Recognition of these factors and regularly checking the quality of mix can help maintain the acceptable mix CV to deliver nutritionally uniform feeds to the animals.

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