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Summary

Liquid addition systems are often designed to add liquid ingredients with the shortest application time in order to increase the batching capacity and efficiency of the mixing process. The quantity of liquid that is added into the mixer affects batch cycle time, particularly when there is a programmed “wet mix” time, or mixing time after liquid application has completed. Shorter application time of liquids typically produces a larger droplet size, which may lead to greater clumping tendencies in the feed and less uniformity of liquid incorporation. Two experiments were conducted to determine the effect of liquid application time and wet mix time on the uniformity of mix in different mixers. In both experiments, treatments were arranged in a 2×3 factorial. Experiment 1 used a double ribbon mixer with 2 liquid application times (20 vs. 30 s) and 3 wet mix times (15, 30, and 45 s). Experiment 2 used a single shaft paddle mixer with 2 liquid addition times (15 vs. 30 s) and 3 wet mix times (15, 30 and 45 s). Ten samples were collected, and coefficient of variation (% CV) determined within those samples. Each treatment had 10 separate replicates. Experiment 1 indicated that wet mix time ($P < 0.0001$), but not application time ($P = 0.653$) or the interaction ($P = 0.638$), impacted % CV in the double ribbon mixer. As wet mix time increased, % CV decreased in a quadratic manner ($P = 0.02$; 37.2, 18.6, and 10.8% for 15, 30, and 45 s wet mix time, respectively). In Experiment 2, both wet mix time ($P = 0.030$) and application time ($P = 0.001$) impacted % CV, but not their interaction ($P = 0.290$). A longer application time led to a better uniformity of mix ($P < 0.05$; 13.5 vs. 9.8% CV for 15 vs. 30 s liquid application time), as did a longer wet mix time ($P < 0.05$; 17.0, 9.8, and 8.2% CV for 10, 20, and 30 s wet mix time, respectively). These results suggest that extending liquid application times may be beneficial in some mixers, and underscore the importance of a sufficient wet mix time to maximize the uniformity of liquid incorporation.

Key words: liquid addition, wet mix, uniformity of mix

Introduction

The number and quantity of liquid ingredients added to the mixer has increased during the last 10 years. The total quantity of liquids added to a mixer may affect batch cycle

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time, particularly if a constant wet mix time is utilized. The liquid application time varies based on the quantity of liquid applied and type of application system. Shorter application times typically produce a larger droplet size. When dry particles come in contact with a large droplet size, they have a greater propensity to clump, which may reduce the uniformity of the total mix. While some clumps were reduced by the shear force generated by the turning shaft of the mixer, this is dependent upon other factors, such as mixer type and wet mix time. Tekchandaney (2013)³ concluded that a relationship exists between the shear degree and the mixer type, namely that double-paddle mixers have a slightly higher degree of shear, single-paddle and ribbon mixers have an average degree of shear, and the tumbling mixers have a low degree of shear. However, no data exist to evaluate the role of liquid application time or wet mix time in different types of mixers. The objective of these experiments was to determine the effect of liquid application time, and wet mix time on the uniformity of mix in two different types of mixers.

Procedures

Materials and Method

Experiment 1

Treatments were arranged in a 2×3 factorial of liquid application time (20 and 30 sec) and wet mix time (15, 30 and 45 s). Dry ingredients of a swine grower diet were mixed in a 2-ft³ double ribbon mixer (model HP2SSS-0106, Fort Worth, Texas) for 15 s, followed by the addition of 18.4 oz of saline solution (2.27% per 60 lb batch) to the dry mixture in the mixer via hand-held sprayer (model 26329, Orscheln Farm & Home LLC) with 2 different application times by using different nozzles (TP11015 and TP11006, TeeJet Technologies). Feed was then mixed for 15, 30 and 45 s wet mix time after liquid application was complete. A total of 10 samples were obtained from 10 different locations throughout the mixer. There were 3 replicates per treatment.

Experiment 2

Treatments were arranged in a 2×3 factorial of liquid application time (15 and 30 sec) and wet mix time (15, 30, and 45 s). Dry ingredients of a swine grower diet were mixed in a 6-ft³ paddle mixer (model 2014197-SS-S1, Bonner Springs, Kansas) for 15 s, followed by the addition of 61.3 oz of saline solution (2.27% per 200 lb batch) to the dry mixture with 2 different application times (15 and 30 sec) by using 2 and 4 hand-held sprayers (model 26329, Orscheln Farm & Home LLC) with a nozzle (model TP11020, TeeJet Technologies), respectively. Feed was then mixed for 15, 30 and 45 s wet mix time after liquid application was complete. A total of 10 samples were obtained from 10 different locations throughout the mixer. There were 3 replicates per treatment.

Chloride concentration in the collected samples from each experiment was determined via the Quantab® chloride titrator method (McCoy 2005).⁴ A 10 g sample was weighed into a cup, and 90 g of hot distilled water (60°C) was added to the cup. The mixture was stirred for 30 s, allowed to rest for 60 s, and stirred for another 30 s. A folded filter paper was placed into the cup, and the Quantab® strip was inserted into the liquid at the

³ Tekchandaney, J. K. 2013. Selection of solid blending equipment. Powder and Bulk Solids Exhibition & Conference, p. 1-5.

⁴ McCoy, R. A. 2005. Chapter Appendix D: Mixer Testing. In Feed manufacturing technology V, 620-622. ed. E. K. Schofield and American Feed Industry Association, Arlington, VA: American Feed Industry Association.

bottom of the filter paper. The coefficient of variation (% CV) was calculated for each batch of feed. A lower CV was indicative of a greater uniformity of mix.

Data were analyzed using the GLIMMIX procedure of SAS. Means were separated by least squares means adjustment for Bonferroni's multiple comparisons. Results were considered significant if $P \leq 0.05$.

Results and Discussion

Experiment 1 indicated that wet mix time ($P < 0.0001$) impacted % CV in the double ribbon mixer, but not application time ($P = 0.653$; 22.7 vs. 21.8% CV for 20 vs. 30 s application time, respectively) or their interaction ($P = 0.638$). As wet mix time increased, % CV decreased in a quadratic manner ($P = 0.02$; Table 1). In Experiment 2, both application time ($P = 0.030$) and wet mix time ($P = 0.001$) impacted % CV, but not their interaction ($P = 0.290$). A longer application time led to a better uniformity of mix ($P < 0.05$; 13.5 vs. 9.8% CV for 15 vs. 30 s liquid application time), as did a longer wet mix time in a linear manner ($P = 0.0004$; Table 2).

The results of these experiments indicate the importance of testing mixers at the time of installation, as specified by Current Good Manufacturing Practice requirements for medicated feed (FDA, 21 CFR part 225.30 (a), 2015).⁵ The % CV of feed mixed with a ribbon mixer did not change when the liquid application time was decreased, while the % CV of the feed mixed with a paddle mixer increased when decreasing the liquid application time. The results demonstrated that mixer types and sizes may impact % CV. The results of these experiments also demonstrated that dry mix, liquid addition time, and wet mix time cannot be generically applied to mixers based on size and type.

In summary, the results of these experiments demonstrate that application time and wet mix time must be determined for each mixer type and size. In addition, while extended liquid application times may be beneficial, there must be a minimum fixed wet mix time after all of the liquids have been applied to the mixer.

⁵ U.S. Food and Drug Administration. 2015. Part 225 Current Good Manufacturing Practice For Medicated Feeds. U.S. Department of Health & Human Services.

Table 1. Treatment main effect for wet mix time on the coefficient of variation (% CV) of feed mixed and sprayed with a 2.27% of saline solution in a 2-ft³ double ribbon mixer (Experiment 1)

Item	Wet mix time, sec			SEM	Probability, <i>P</i> =		
	15	30	45		Main effect	Linear	Quadratic
CV, %	37.21 ^a	18.63 ^b	10.79 ^c	1.70	<0.0001	<0.0001	0.0241

^{a-c} Means with different superscripts are significantly different ($P \leq 0.05$).

Table 2. Treatment main effect for wet mix time on the coefficient of variation (% CV) of feed mixed and sprayed with a 2.27% of saline solution in a 2-ft³ paddle mixer (Experiment 2)

Item	Wet mix time, sec			SEM	Probability, <i>P</i> =		
	10	20	30		Main effect	Linear	Quadratic
CV, %	17.00 ^a	9.81 ^b	8.23 ^b	1.29	0.0009	0.0004	0.1004

^{a-b} Means with different superscripts are significantly different ($P \leq 0.05$).