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Comparison of different indicators for the evaluation of feed mixing efficiency

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ABSTRACT

The mixing process is essential for manufacturing animal feed, and due to the increased use of low-inclusion ingredients, its efficiency becomes even more important, as well as the methods to evaluate this efficiency. This study aimed to compare different internal and external indicators of feed mixing efficiency. Using an experimental horizontal paddle mixer, we evaluated dry mix cycle with DL-methionine 99%, L-lysine HCl 99%, L-threonine 98%, inorganic minerals (NaCl, $CuCl_2$, $MnSO_4$ and $ZnSO_4$), vitamin B_2 80%, and MicroTracer® (external indicator), and the wet mix cycle with DL-HMTBA (liquid analogue of methionine) 88% and liquid L-lysine 50%. The time required to achieve a homogeneous mix was also evaluated based on the coefficient of variation (CV) of such indicators every 15 s between 20 and 155 s of mixing. The mixing CV was below 5% for most of the tested indicators, except for vitamin B_2 (21%) and $CuCl_2$ (15%), whereas L-threonine showed the best mixing CV (3%). Powder and liquid sources of methionine and lysine had similar mixing efficiency at the end of the mixing cycles. The study indicated that the usage of powder and/or liquid industrial amino acids as internal indicators is suitable for evaluating the mixing efficiency as well as time required for achieving homogeneous mixes of feed mixers.

1. Introduction

Proper mixing process is essential for manufacturing commercial animal feed, as particles of each feed ingredient are randomly dispersed throughout the feed and systematically reorganised (Cooke et al., 1976). When different ingredients are combined to supply a complete animal feed, manufacturers must be able to guarantee that each animal receives the same amount of nutrients and additives in adequate concentrations to meet growth, production, and health requirements (McCoy et al., 1994). With the increased use of low-inclusion ingredients, such as vitamins, micro-minerals, amino acids and other feed additives in animal nutrition, efficient mixing processes become even more necessary (Groesbeck et al., 2007).

Abbreviations: L, litres; cm, centimetres; s, seconds; rpm, rotations per minute; mm, millimetres; g, gram; kg, kilogram; GMD, geometric mean diameter; GSD, geometric standard deviation; HW, hectolitre weight; LLP, L-lysine HCl 99%; DLM, DL-methionine; LT, L-threonine; MFR, MicroTracers® F-Red; MnS, manganese sulphate; CuCl, cuprous chloride; ZnS, zinc sulphate; VB2, vitamin B2; NaCl, sodium chloride; DL-HMTBA, 2-hydroxy-4-methylthiobutanoic acid (liquid analogue of methionine); LLL, liquid L-lysine 50%; μm, micrometres; MJ, mega joule; t, ton; PPG, particles per gram; CV, coefficient of variation.

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In a theoretical perfect mixture, every aliquot taken from the mixture, regardless of the sampled amount, would have exactly the same percent composition (Williams, 1976). Because this essentially never occurs in practice, the use of quality control methods becomes necessary to evaluate the efficiency of the particle dispersion by the industrial processing. This efficiency is expressed as the variation that exists in the composition of different aliquots compared probabilistically with that obtained from a perfect mixture (Barbour, 1998). The most commonly used index is the Pearson's coefficient of variation (CV), which is a dimensionless measure of relative dispersion widely used to compare different distributions. This measure is expressed as the ratio of the standard deviation to the arithmetic mean (Kaps and Lamberson, 2009).

The quality control methods employed in industrial practices to determine the efficiency of mixing processes aim to evaluate the homogeneity of particle dispersion within the same mixing cycle, as well as the uniformity of dispersion between successive cycles (Nagata, 1975). Efficient processes are characterised as having a minimum CV in each cycle (homogeneous) and a maximally similar CV among different cycles (uniform) for all mixed ingredients, regardless of the model and/or parameterisation of the mixer (Cholette and Cloutier, 1959).

The increased demand for efficiency and the trends towards rationalisation and mechanisation of the mixing processes have led to the development of scientific criteria for the evaluation and comparison of quality standards of (or even between) feed mixers (Lindley, 1991). However, because it is not feasible to quantify the total number of particles of each ingredient of feed in aliquots, certain ingredients or even chemical components of the feed are analysed or quantified and used as indicators of the efficiency of the mixing process.

According to Eisenberg (2004), the mixing process can be practically assessed by adding one or more micro-ingredients into the feed (internal indicators) at inclusion levels of up to 100 g/t. The analytical results for these internal indicators can be extrapolated to all others ingredients to determine the overall efficiency of the mixing process. Some researchers even argued that measuring chemical component levels (nutrients or otherwise) in different aliquots would be enough to evaluate the efficiency of the mixing process (Li and Toor, 1986).

The use of indicators (whether internal or external) to evaluate mixing efficiency should follow a criteria that ensures homoscedastic behaviour (statistical homogeneity of variances among different dispersions) for all ingredients in the mixture and that consider differences in physical characteristics among the products (Barbour, 1998). According to Clark et al. (2007), certain indicator characteristics, such as the accuracy of relevant laboratory analysis, the analytical viability, cost and safety of the indicator (in the case of an external indicator), the presence of the indicator in a single ingredient (in the case of chemical components), and its physical similarity to the feed ingredients, must be previously verified.

With this background, the aim of this study was to evaluate the use of different internal and external indicators to assess feed mixing efficiency, using a horizontal paddle mixer with single axis.

2. Materials and methods

2.1. Evaluations and indicators

Two types of evaluations were performed: the mixing efficiency test and the comparison of mixing indicators. For the dry mixing efficiency test, the powder industrial amino acids L-lysine HCl 99% (LLP), DL-methionine (DLM), and L-threonine (LT) were used as indicators. For the dry mixing indicator comparison test, besides those three powder industrial amino acids were used: MicroTracer F Red #3 (MFR) (Micro-Tracers Inc., San Francisco, CA, USA), manganese sulphate (MnS), copper chloride (CuCl), zinc sulphate (ZnS), vitamin B_2 (VB2), and sodium chloride (NaCl). For the wet mixing efficiency test, liquid analogue of methionine (DL-HMTBA) (2-hydroxy-4-methylthiobutanoic acid) was used as an indicator. For the wet mixing indicator comparison test, DL-HMTBA and liquid L-lysine 50% (LLL) were used.

The LLP indicator was passed through a set of 595 μm and 297 μm sieves on a bottom pan, and only the portion retained in the 297 μm sieve (GMD of 420 μm) was used in the feed production process. NaCl was passed through a set of 420 μm and 297 μm sieves on a bottom pan, and only the portion retained in the 297 μm sieve (GMD of 353 μm, calculated with Granucalc) was used in the indicator comparison test.

The MnS, CuCl, ZnS, and VB2 were included in the vitamin mineral premix at a proportion of 1.9 kg premix per ton of feed; this proportion corresponded to the inclusion levels of 165.4 g of MnS, 23.6 g of CuCl, 244.3 g of ZnS and 8.6 g of VB2 per ton of feed. Mn, Cu, Zn and VB2 concentrations of 51.3 mg/kg, 13.7 mg/kg, 85.5 mg/kg and 6.8 mg/kg, respectively, were measured in the feed.

2.2. Equipment

A horizontal paddle mixer (model MHI-002 P, Clam Ind. Com. Ltda., Faxinal dos Guedes, Santa Catarina, Brazil) with a single 50.26 L capacity, 40 cm diameter and length shaft and an output de-rating of 35 rpm was used (Fig. 1). A scale with a 25 kg capacity (5 g precision) was used to weigh the macro-ingredients, and a scale with a 0.32 kg capacity (0.001 g precision) was used to weigh the micro-ingredients.