i'Tec_H6
October 2001

**Keywords**: Mix, mixing time, Homogenisation, Control, Quality.

# Investigating the effects of mixing time
# Tecaliman trials

## 1. Introduction

The theoretical variation in product distribution according to mixing time is a well-known fact (Figure 1). Heterogeneity decreases rapidly (Phase A), oscillates down to a minimum (Phase B) and finally levels off according to which mixer and mixed products are involved (Phase C).

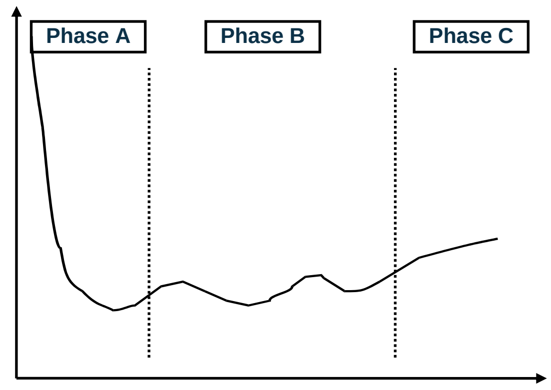


**Figure 1: Theoretical effect of mixing time on heterogeneity**

The respective durations of the 3 phases and the amplitudes in variation depend on which mixer and mixed products are used. This made it necessary to have data on specific mixer operating procedures.
Furthermore, data on mixing times are not readily exploitable unless beater speed is indicated. This datum is rarely included in the available literature. Recommended mixing times, therefore, often vary widely for a given type of mixer.
Under standard mixer operating conditions and for the products in question, the mixing time linked to product distribution should be the time between introducing the product into the mixer and full emptying of this mixer. However, there are practical difficulties in taking an accurate measurement of a properly applied mixing time that will have to be taken account of prior to making any assumptions on this topic:

If the traced product is introduced upstream of the mixer, it is difficult to determine the exact time of its introduction into the mixer that marks the theoretical start of its distribution

If the traced product is introduced at the start of the mixer filling operation, and if it takes a long time to fill the mixer with the remaining macro-ingredients to be dosed, the start point of the dispersion would also be difficult to identify.

If liquids are introduced into the mixer, there would be a succession of phases as opposed to one single mixing time. Mixing could therefore be considered to be either the time taken for all the phases, or the time taken for a dry mixing, or the time taken to mix following the introduction of liquids.

Mixing phase times may be measured using messages sent by the PLC. It should also be noted that there may be gaps between the actual situation and the messages received, and that the messages depend on the position of the sensors.

If the mixer is not fully open, a portion of the mix will continue to be mixed during the emptying phase, making it difficult to accurately determine the end of the mixing phase.

Several parameters would appear to act on the time needed for the mix to achieve the required quality (difference between the tracers, incorporation rate, rotary beater speed, location of tracer incorporation, etc.).
Increasing the mixing time often provides the most common form of corrective measure faced with changes in a given parameter. However, this cannot be considered a cure-all solution, and this increase may not have any effect, for instance, if the fill rates are too high or if too few particles of a product with a large particle size are distributed.

## 2. Pilot trials

Table 1 summarises the conditions for carrying out the pilot trials.

### 2.1. Mobile vertical mixer

Test No. 1 A study of the mixing process in a Hobart brand planetary mobile vertical mixer made it possible to track changes in the distribution of coloured iron particles (microtracer F) with diameter 300 µm after a mixing time of 1, 2.5, 5, 7.5 and 60 minutes respectively. This appeared to demonstrate that an oscillation followed by segregation occurs in this type of mixer over time (Figure 2), as even though the results in the lower part of the curve lay below the analysis resolution (blank plot point), the segregation appeared to be significant for a mixing time of one hour.

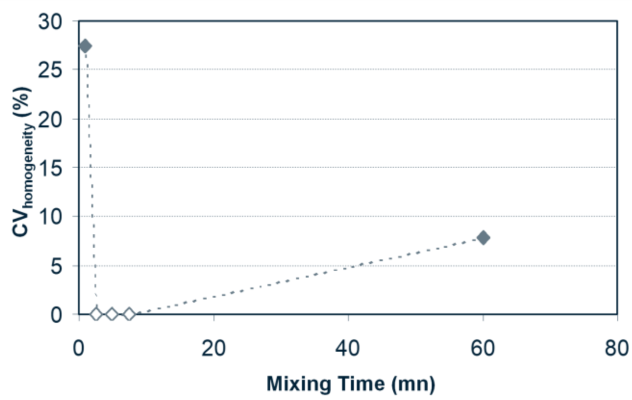


**Figure 2: Change in coefficients of variation for the distribution of microtracer F-red according to mixing time in a mobile vertical mixer – Test No. 1**

### 2.2. Plough share mixer

Four distribution patterns were tracked according to time in a Lödige brand pilot plough share mixer (              ). In terms of the production of mixes similar to mineral-based premixes (Figure 3), the results demonstrated that, under test conditions, a minimum mixing time of 10 minutes was required to achieve stable homogenisation levels. These fairly long times were unexpected and could be explained by an excessively long filling time and the high beater speed that might have centrifuged the product mass, thereby limiting mixing efficacy.
It should be noted that the position of curve limits relates to particle size and tracer incorporation rate, which would tend to highlight the probable effect of particle number without ignoring the effect of the corresponding matrices.

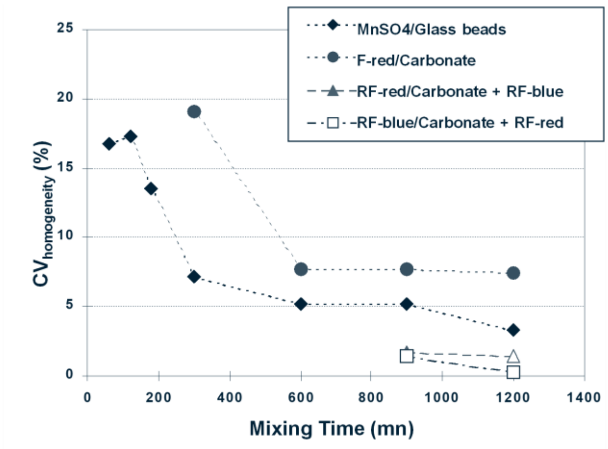


**Figure 3: Change in $CV_{homogeneity}$ of tracer distribution in various matrices according to mixing time in a plough share mixer –**

| | Test No. 1 | Test No. 2 | Test No. 3 |
|---|---|---|---|
| **Mixer type** | Hobart mixer<br>27.5 litres | Lödige plough share mixer<br>50 litres | Gondard ribbon mixer<br>224 litres |
| **Matrices** | Pigfeed<br>(400 µm) | Glass beads (260 µm) or carbonate (140 µm) | 2 beef cattle feeds F and G<br>(280 µm – 460 µm) |
| **Type of tracer, particle size and incorporation rate** | Microtracer F-red<br>(300 µm- 1000 ppm) | Manganese sulphate (65 µm – 37 ppm) – microtracers F (306 µm – 1000 ppm) or Rf (90 µm – 1000 ppm) | Microtracer RF-blue<br>(90 µm- 250 ppm) |

**Table 1: Conditions for the pilot trials**

### 2.3. Ribbon mixer

In part 1 of **Test No. 3**, a different mix (5 in all) was produced for each mixing time and the products sampled after emptying the mixer. In part 2 (using the beef cattle feed with the largest particle size), the samples were taken above the mixer; The sampled quantity was replaced by a similar mass of an identical mix that had been homogenised previously for 5 minutes.

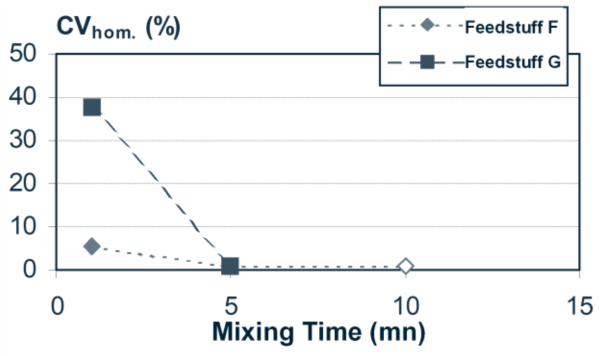


**Figure 4: Changes in $CV_{homogeneity}$ according to the mixing time for two beef cattle feeds with different particle sizes ( )**

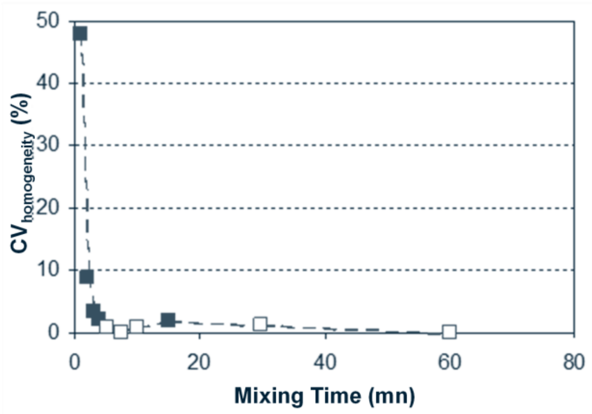


**Figure 5: Changes in $CV_{homogeneity}$ according to the mixing time for beef cattle feed G**

Initial results (Figure 4) highlighted a greater speed of dispersion in the feed with the smaller particle size, which would appear to contradict the theory that postulates slower mixing times in cohesive mixes. This result would need to be checked by other trials, even though a similar result was obtained by Amornthewaphat *et al* (1998).
The second set of results demonstrates the change in the coefficient of variation with a sharp fall in the first two minutes (Figure 5), followed by stagnation and a very slight oscillation at the limit of the assessment method's detection capabilities. No significant segregation was reported after one hour under these test conditions. Other trials of the same type would also be needed to confirm this result, which is inconsistent with the general theory that states that segregation occurs over time.

## 3. Industrial trials

Table 2 sets out the conditions for the industrial trials

### 3.1. Trough-shaped ribbon mixer

One single test was carried out on an industrial trough-shaped ribbon mixer. In Test No. 4, the mixes involved 3-ton batches of piglet feed containing the three tracers; each assessment was made independently of the others.

| | Test No. 4 | Test No. 5 | Test No. 6 |
|---|---|---|---|
| **Mixer type** | Trough-shaped ribbon mixer 12000 litres | Drum-shaped ribbon mixer - 18000 litres | Drum-shaped ribbon mixer - 12000 litres |
| **Rotation speed** | 17 tr/min | 15 tr/min | 15 tr/min |
| **Matrices** | Piglet feed (600 g/l - 500 µm) | Piglet feed (610 g/l - 560 µm) | Soya rate - Rapeseed rate (590 g/l - 660 µm) |
| **Tracer type Particle size and Incorporation rate** | Copper sulphate (330 µm - 600 ppm) Microtracer F (300 µm - 500 ppm) Dimetridazole (360 µm - 1000 ppm) | Sodium chloride (466 µm - 4000 ppm) | Microtracer RF-blue (90 µm- 125 ppm) |

**Table 2: Data for the industrial trials protocol**

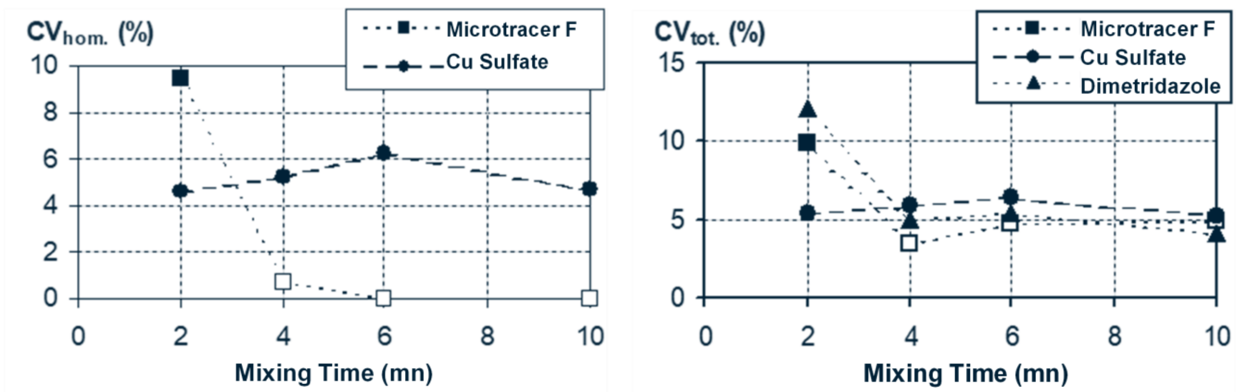


**Figure 6: Change in $CV_{homogeneity}$ (left) and $CV_{total}$ (right) according to mixing time in a 12000-litre industrial trough-shaped mixer in Test No. 4**

The results (Figure 6) obtained with two of the three tracers (DMZ and microtracer) agreed at the beginning of the descending phase after a 4-minute mixing time, i.e. 68 beater rotations.
$CV_{total}$ values were close to 5%. The change in the distribution of copper sulphate would appear to differ from that of the other 2 tracers. It is possible that the descending phase in the coefficient of variation was shorter for this tracer and that it occurred prior to the 2-minute mark. For microtracer F, $CV_{homogeneity}$ was below 1% after 4 minutes and the assessment method was, and remained, below its detection threshold.

## 3.2. Drum-shaped ribbon mixer

Two trials (Test No. 5 and Test No. 6) were carried out on two drum-shaped industrial mixers of differing capacities.

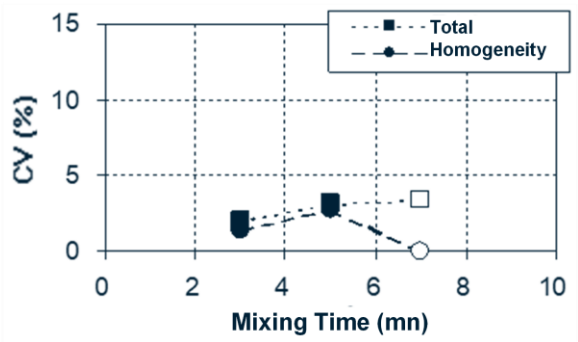


**Figure 7: Change in $CV_{homogeneity}$ and $CV_{total}$ (bottom) according to mixing time in the 18000-litre industrial drum-shaped industrial mixer in Test No. 5**

In Test No. 5, the chloride analysis suggested that low coefficients could be obtained with mixing times of 3 to 7 minutes (Figure 7). $CV_{homogeneity}$ increased slightly over 5 minutes, but still remained well below the 10% mark. These results would seem to prove the efficacy of this type of mixer for a 3-minute mixing time.

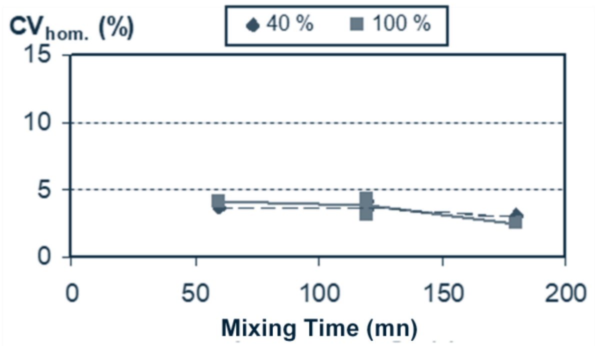


**Figure 8: Change in $CV_{homogeneity}$ according to mixing time in the 12000-litre industrial drum-shaped industrial mixer in Test No. 6**

Test No. 6 on the 12000-litre mixer focused on much shorter mixing times (1 to 3 minutes) and on both fill rates (40% and 100%). 3 repetitions were made for each fill rate, with a 2-minute mixing time. The coefficients of variation recorded during the repetitions were very similar (Figure 8). $CV_{homogeneity}$ for both fill rates were approx. 3 to 4%, and showed a very slight decrease. These results confirmed that coefficients of under 5% can be obtained rapidly with this type of mixer, irrespective of fill rate.

# 4. Conclusions

For the trough-shaped mixer, the results of the industrial trial agree with the commonly suggested data of a 4-minute mixing time, which corresponds to an rpm of approx. 70 (after the addition of liquids). However, a good result may have already been achieved with a 3-minute mixing time. While this assessment was not carried out in an industrial environment, the pilot data are nevertheless encouraging. The industrial data also demonstrate that the choice of tracer is important, as this shapes the viewpoint on mixer performance.
Drum-shaped mixers would appear to be more effective, as they would enable faster production of homogenous mixes: approx. 1 minute.
While it would be hazardous to extrapolate from such a low number of useable results, it is possible that the times actually required for homogenisation are under 4 minutes or 60 turns of the beaters for some mixers. It should be stressed that the phase of descending homogeneity was observed in very few tests, which makes it impossible to identify its actual status.
This highlights the difficulty of identifying minimum mixing times. The primary objective of the mixer is to optimise mix quality using a tracer and a matrix rather than produce an identical level of homogeneity in all products.
Lastly, doubts remain over whether mixing times are faster in finer-grained matrices and whether segregation is absent over too long a time, meaning that other tests will have to be carried out.

# 5. Bibliography


**Amornthewaphat N., Behnke K.C., Hancock J.D., 1998.** Effects of particle size and mixing time on uniformity and segregation in pig diets. Kansas state university swine day report, 261-263.