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Industrial trials aimed at assessing the homogeneity of muesli feeds using a pelleted tracer

1. Focus

Two in-plant trials were carried out (8 tests in all) to develop a technique for assessing the homogeneity of muesli[1] feeds.
The trials were designed to study a range of tracer incorporation rates and sampling points.

Researching these various conditions makes it possible to determine the best methods for assessing the homogeneity of muesli feeds.

2. Apparatus and methods

The general method for these trials is based on the technical rules described in **i’Tec H1**.
For these trials, 4 batches of muesli feed were produced successively at 2 industrial sites.

2.1. Tracer

Tecaliman designed the tracer used in these trials to meet the features specific to muesli feeds.

It comprises wheat, a beetroot co-product and a colouring agent. It takes the form of pellets with length 10 mm and diameter 4 mm. Its particle count is 7.8/g.

2.2. Muesli feeds

The muesli feeds produced during the trials comprise raw materials used routinely at both plants. The Plant 1 formula comprises 13 raw materials; that at Plant 2 comprises 7 raw materials. The raw material presentations are highly diverse.

To characterise the two feed formulas, the proportion of fines was measured using a sifter with diameter 3.2 mm. Durability was measured on the feed minus the fines using the Eurotest durability tester (20 s., sifter 3.2 m). Bulk density was measured using a Nilema litre (Table 1).

While the relevance of these analysis techniques, generally used to characterise feedstuffs, and pellets in particular, has not yet been demonstrated with muesli feeds, it does open up an avenue for investigating the physical characteristics of this type of feedstuff.

	Bulk density (g/l)	Proportion of fines (%)	Durability (%)
Muesli plant 1	667.1	19.3	67.7
Muesli plant 2	766.2	51.5	86.7

Table 1: Physical characteristics of the tested feedstuffs

Plant 2 feedstuffs present a higher bulk density, proportion of fines and durability.

2.3. Test procedures

These 2 plants were selected for the trials as they employ different production circuits for their muesli feeds. Table 2 illustrates the main components of the production flow chart.

Plant 1	Plant 2

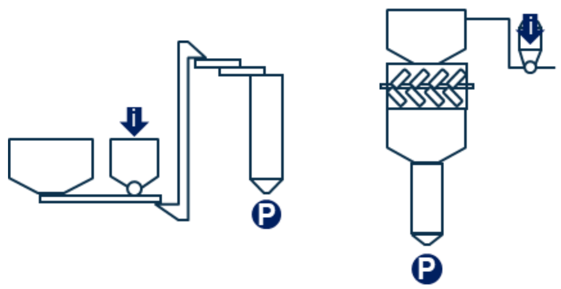

Table 2: Main components of the production flow chart at the 2 plants (i: Tracer incorporation – P: sampling)

The plant 1 circuit has no mixer, the main weighing bin is filled “**camembert**” style via the automated PLC that controls the formula’s raw materials according to their

[1] Muesli Feed: compound feed no pelletized, make up mixing of raw material visibly different, with size, form, density and appearance different (particles, coarse pieces, laminates, flaked, extruded, pellets,…), and which may contain complementary compound feed, definition written by the French organization in charge of the French livestock feed quality qualification, Oqualim.

density and the amount to be incorporated.
The two weighing bins are emptied simultaneously onto a conveyor belt. The product is then stored in a silo prior to filling the truck.

The plant 2 circuit is fairly short and contains a blade mixer. The production conditions used during the trials are representative of the practices at each plant.

2.4. Batch size

The sizes of the tested batches are representative of the sizes generally used at the plants. All the tested batches at each plant were identical in size: 5 tonnes at plant 1 and 2 tonnes at plant 2.

2.5. Tracer rates and incorporation locations

Three theoretical tracer incorporation rates were tested at each site: 2, 5 and 10 kg/t. The 5 kg/t incorporation rate test was performed in duplicate. It was decided not to test higher incorporation rates as the presence of large quantities of tracer could prevent the sale of the batches in question.

At plant 2, tracer quantities were prepared for 2.5 tonne batches. On the date of the tests, the batch size was reduced to 2 tonnes. Therefore, actual tracer incorporation rates (2.5, 6.2 and 12.5 kg/t) vary from the theoretical rates. To improve the readability of the results, the findings of this study were based on the theoretical incorporation rates.

At plant 1, the tracer was added to the weighing bin reserved for micro-ingredients. The incorporation rates tested during these trials were lower than the rates generally employed at this plant.

At plant 2, the tracer was added to the bag pourer. It was then incorporated in the mixer via pneumatic conveyance.

2.6. Sampling points

Note that it is advised to choose a sampling point located in a flow. In order to obtain a representative sample, it is strongly recommended to:

- Cut the flow in opposing directions from one sample to the next,
- Choose a sampling point with a moderate flow rate.

Each batch was sampled at 2 points at each plant.

At plant 1, samples were taken in the flow during loading. The flow rate was regulated manually by adjusting the size of the opening of the silo bin hatch. However, sampling was complicated overall by the large width of the flow.

In addition, the position of the person tasked with taking the samples over the truck can be hazardous.
At plant 2, the samples were taken above the truck compartments after loading. In this case, the sampling method deviates from the technical rules as the samples were not taken in the feed flow.
Moreover, the person tasked with taking the samples has to get down into the truck compartment to take the samples, which can also be hazardous.

At both sites, the second sampling point is taken on unloading the truck. In this case, it is theoretically possible to regulate the emptying rate and control sampling frequency.
However, this requires expertise in adjusting the truck emptying rate.

This sampling point meets the recommendations set out in **i'Tec H1** and corresponds to the product delivered to the breeder.

2.7. Sample number and size

The testing targeted 20 samples. Given the physical characteristics of the muesli feed, which contains large particles and rations for target animals, sample size is greater than for the samples generally taken for homogeneity tests on compound animal feeds.

To ensure that the samples were representative, sample size was therefore between 1 and 2 kg.

2.7.1. Plant 1

Prior to the trials, sampling frequencies were calculated according to standard batch throughput times at the sampling points, i.e. 2 minutes at loading and 4 minutes 30 at unloading.

Table 3 shows the actual throughput times measured and the number of samples obtained.

Batches	Loading	Unloading
1	2 minutes 15 (24)	3 minutes 39 (16)
2	2 minutes 00 (24)	3 minutes 21 (21)
3	2 minutes 33 (24)	3 minutes 24 (20)
4	2 minutes 35 (24)	3 minutes 21 (21)

Table 3: Plant 1 - Batch throughput times (number of samples)

A difference between the theoretical and actual throughput times for the various batches was recorded at the time of unloading.

This difference meant that no samples were taken during the last 15 seconds of batch throughput. For each test, 24 sampling pots were prepared to collect 20 samples.

On unloading, batch 1 emptied faster than planned. This resulted in only 16 samples being taken. Following this test, sampling frequency was reduced to obtain the desired number of samples.

2.7.2. Plant 2

Samples were taken at the surface, directly in the truck compartment. This was done by identifying 10 areas, identical from one test to the next, used to take the 10 samples.

On exiting the truck, sampling frequency was calculated according to the theoretical batch throughput time, i.e. 2 minutes 30. Table 4 shows the actual throughput times measured and the number of samples obtained.

Batches	Unloading
1	3 minutes 20 (24)
2	2 minutes 50 (23)
3	1 minute 30 (11)
4	2 minutes 40 (24)

Table 4: Plant 2 - Batch throughput times (number of samples)

A difference was recorded between the theoretical and actual throughput time.

In the 1st batch, this difference meant that no samples were taken in the last 25 seconds of unloading. In the 3rd batch, emptying was shorter than planned.

After this 3rd test, sampling frequency was speeded up for the following batch so as to obtain the desired number of samples. Despite this adjustment, in the last test, the batch continued to empty for one minute after completing the sampling procedure.

It was not possible to clearly identify the reason for the variations in flow rate between the various batches.

2.8. Processing the samples

For each test, 10 samples were taken from all the samples collected so as to be representative of the batch as a whole. Tracer dosage was analysed on each selected sample.

3. Results

3.1. Tracer recovery rates

Firstly, the tracer recovery rate (% TR) was determined by calculating the average (m) of all the analyses and identifying the expected concentration (C) according to the weighing operations:

$$TR = 100 . \frac{m}{C}$$

This rate should lie between the acceptability limits set by the RCNA (70 to 110%).

2 out of the 16 tests performed were considered nonconform in terms of tracer recovery rates (Figure 1, Table 5).

Tracer incorp. rate (kg/t)	Plant 1		Plant 2	
	Loading	Unloading	Truck compartment	Unloading
2 kg/t	77.5	81.1	78.7	73.3
5 kg/t	62.9	71.5	64.9	86.0
5 kg/t	84.9	82.7	90.6	74.8
10 kg/t	109.5	89.0	73.0	74.3

Table 5: Recovery rate (%) according to sampling point (Nonconform – Conform)

The first nonconform test corresponds to a test at plant 1 performed when loading the truck at an incorporation rate of 5 kg/t. The second corresponds to a test at plant 2 performed in the truck compartment at an incorporation rate of 5 kg/t.

The recovery rate for the plant 1 test on loading at 10 kg/t is close to the acceptability limit. The recovery rates obtained for the 8 tests using samples taken during truck unloading all lie within the acceptability limits.

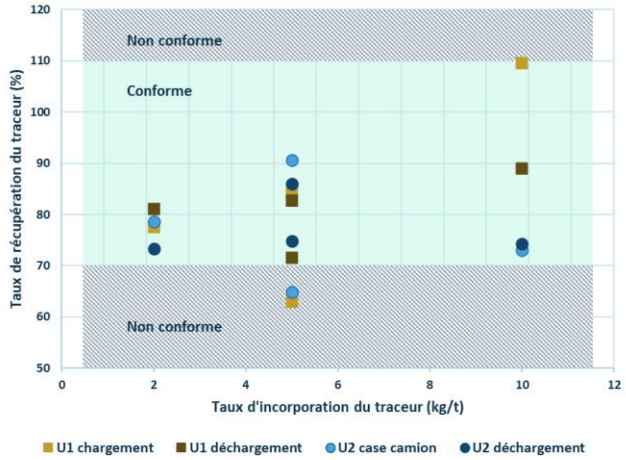

Figure 1: Recovery rate (%) according to theoretical tracer incorporation rates

The sampling methods used during these trials gave samples that were representative overall.

3.2. Coefficient of variation

The coefficient of variation (CV_{total}) is derived from the analysis results for all samples by calculating the total variance (V_{tot}) and the average (m). This coefficient of variation is referred to as "total" as it takes all sources of variation into account.

$$CV_{tot} = 100 . \frac{\sqrt{V_{tot}}}{m}$$

Concerning muesli feeds, the RCNA considers CV_{total} to be conform when it is below 20%, acceptable between 20 and 30%, and nonconform over 30%.

In terms of homogenisation performance with respect to the RCNA, the CV_{total} demonstrate that 8 tests had a nonconform mix quality.
3 tests were considered acceptable and in 5 tests the quality was conform (Table 6).

Tracer incorp. rate (kg/t)	Plant 1		Plant 2	
	Loading	Unloading	Truck compartment	Unloading
2 kg/t	122.9	39.8	20.9	17.1
5 kg/t	40.7	31.8	18.4	15.0
5 kg/t	38.4	32.2	24.8	18.7
10 kg/t	48.8	23.1	33.3	15.8

Table 6: CV_{total} (%) according to sampling points (Nonconform – Acceptable – Conform)

As with the recovery rates, sampling point results were better for the samples taken when unloading the truck. Sampling biaises are not as pronounced and the results of better quality.

At plant 1, the increased rate of tracer incorporation improves batch homogeneity, particularly during unloading. Note that the incorporation rates used during these tests are below the rates generally employed at this site.

This phenomen is not apparent at plant 2. During unloading, the CV_{total} was conform for all tested batches, whatever the tracer incorporation rate (Figure 2).

The results demonstrate that the tracer incorporation rate has little or no effect on CV_{total}. At plant 2, optimal homogenisation appears to be reached irrespective of the number of particles incorporated.

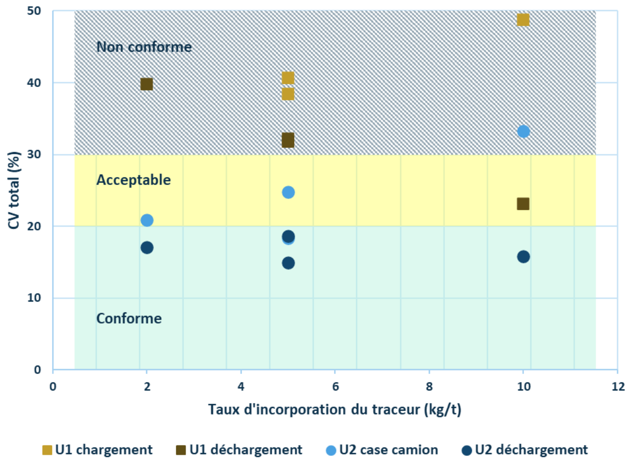

Figure 2: CV_{total} (%) according to theoretical tracer incorporation rates

A comparison of the 2 industrial circuits clearly demonstrates the benefits of a mixing phase, even of short duration.

Moreover, the low number of samples may also be significant in the event of batch heterogeneity.
If a larger number of samples had been analysed, it is likely that the recovery rates and CV for plant 2 would have been similar to the results obtained.

Given the plant's performance, the number of samples analysed is sufficient to achieve a reliable result.

At plant 1, the reliability of the results would be improved by analysing a larger number of samples.

For all the tests, and even more so when there is a large probable heterogeneity, the limited number of samples (10) and the number of tracer particles in each sample are likely to have an impact.

4. Conclusions

The tracer developed by Tecaliman, used during these trials, makes it possible to obtain results that conform to the requirements of **i'Tec H1** for incorporation rates of between 2 to 10 kg/t.

The incorporation rate should be chosen according to the plant's practices, up to a technical limit of an incorporation rate of 10 kg/t. Incorporating too great a quantity of tracer could prevent the sale of the batches produced, in particular due to an excessive nutritional impact.

Better results are obtained when the production line includes a mixer.

Recommendations concerning sampling method and location are conform to the recommendations set out in **i'Tec H1**, i.e.:

- Ensure that samples can be taken safely,
- Obtain samples that are representative of the batch,
- Choose a sampling location with a moderate flow rate.

At both tested plants, the sampling point at the truck outlet was the most favourable, which has the added advantage of corresponding to the delivered feedstuff.

To obtain the desired number of samples, batch emptying time needs to be controlled according to their position within the truck compartments.

More work needs to be carried out on physical characterisation of muesli feeds, as this could be useful in interpretating the results.

5. Bibliography

i'Tec H1: Technical rules for assessing mixer homogenisation performance per load
'i'Tec G7: Pellet durability measurements
RCNA : Certification Referential of Animal Nutrition, written by the French organization in charge of the French livestock feed quality qualification, Oqualim