Tecaliman
Center of expertise for a sustainable feed business

i'Tec_T13
June 2018

Keywords: Carry-over - elevator

Pilot study on micro-ingredient carry-over via a bucket elevator: Aggregate results

1. Focus

This study was designed to assess the part played by bucket elevators in generating carry-over.

2. Apparatus and methods

The pilot testing centre, the manufacture of the reference product and the experimental protocol are detailed in i'Tec_T12.

3. Results and discussion

Before presenting the results, it is important to note that the scores A, B and C refer to three repeatability tests, while the numbering 1 to 16 concerns experimental design tests that boost the effect of process factors, the results of which will be discussed in a later datasheet.

3.1. Batch concentrations after transiting through the elevator

The tracer batches were introduced at an initial concentration of 250 ppm, which decreased following transit in the bucket elevator. This decrease in initial tracer concentration varied from 17.1 to 62.2 ppm depending on the conditions. Post-test, the mean concentration of the tracer batches was 205.3 ppm, i.e. 82% of the initial concentration, while that of the collector batches was 19.9 ppm (Figure 2 and Figure 2).

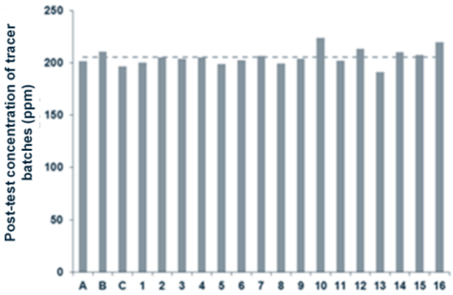


Figure 1: Tracer batch concentrations

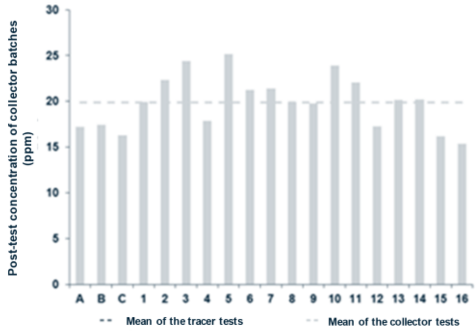


Figure 2: Collector batch concentrations

These values clearly illustrate the two distinct phases in the carry-over process, i.e. initial deposition of micro-ingredients during throughput of the tracer batch, followed by their partial recovery (≈ 45% on average on this basis) during throughput of the collector batch. Note also that the relative dispersion of the concentration profile is less marked in tracer batches than in collector batches. This indicates that the diverse controllable elevator settings impact primarily on the amount of tracer collected.

3.2. Product masses deposited in the elevator

The aggregate study of residual deposit masses in the testing centre after batch throughput reveals that deposition increases with the number of loads transferred (Figure 3). An increase of approx. 255g by weight was observed between the "tracer" and "tracer + collector" tests.

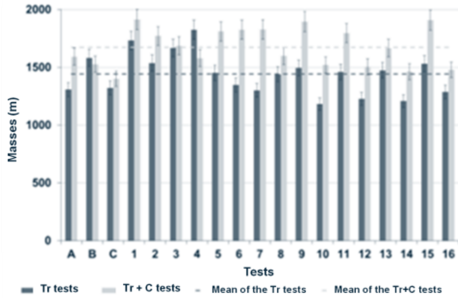


Figure 3: Total deposition masses in the elevator following the tests

This difference has been statistically validated by an analytical comparison of means (Table 1).

	Total mass
Difference (g)	254.65
Standardised difference	4.13
Critical value - 95% (Student's t-test table)	2.04
Probability of error	0.00
Significant difference	Yes

Table 1: Results of analytical testing of the comparison of means

While these total product deposition masses might seem rather low, on an industrial scale - involving batches of 3 to 5 tons - this additional deposition mass would actually represent 15 to 25 kg of feedstuff in an industrial elevator.

This increase can be explained by products accumulating in certain areas (i.e. by adhering to walls) with or without renewed deposition.

Figure 4 shows the change in median diameter (a) and the ratio of fines (b) in the batches, before and after transit in the elevator. Figure 4a illustrates a clear increase in the batch's median diameter after elevator transit (an average increase of 25 µm). Figure 4b shows an average loss of 15.8% for particles between 125 and 200 µm, and 4.5% for particles below 125 µm. This indicates that the products being deposited in the elevator consist primarily of particles smaller than 200 µm.

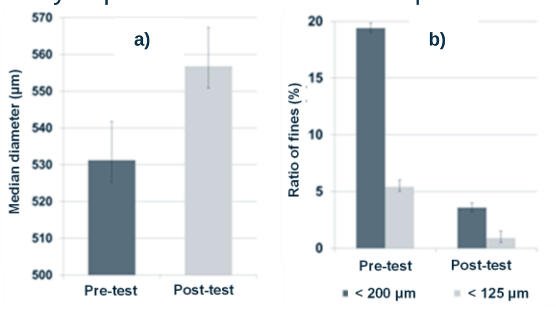
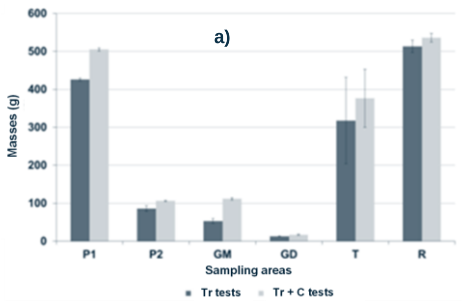


Figure 4: Change in median diameter (a) and ratio by weight of fine particulate matter (b) - mean values of the "tracer" tests

Figure 5 (mass (a) and % (b)) illustrates the distribution of product quantities deposited in each sampling area following throughput of "tracer" and "collector" batches.



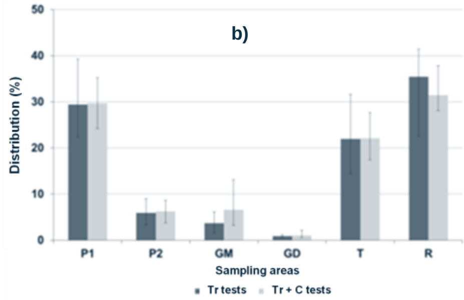


Figure 5: Relative distribution of deposition in the elevator

These results demonstrate the variation in areas of deposition during batch throughput. Certain areas, such as the bottom of the foot (P1) and the head of the elevator (T) are particularly favourable to deposition, with approximately 60% of the total mass of deposition occurring in these two areas.

Statistical analysis of the comparison of means (Table 2) confirms the significance of the increase in deposition masses following throughput of an extra batch for 4 areas, but not for the head (T) and the rest (R).

	Student t-test criterion	Critical value - 95% (Student's t-test table)	Probability of error	Significant difference
P1	5.37	2.04	< 0.0001	Yes
P2	2.13	2.04	0.04	Yes
GM	4.62	2.04	< 0.0001	Yes
GD	3.19	2.04	0.001	Yes
T	2.03	2.04	0.05	No
R	0.77	2.04	0.45	No

Table 2: Analysis of the comparison of means for deposition masses in each sampling area

There is a substantial degree of variability in locations (T) and (R). This can be explained by the vertical profile of these areas and by the large deposition masses. In these areas, the product accumulates until it reaches its critical avalanche angle, thus causing the deposit to slump. The collected quantity is therefore strongly dependent on the sampling time. The verticality of these areas also adds to the difficulty by preventing full collection of the deposit (some product may fall).

For the head (T), the Student t-test value (2.04) is only just above the value of the calculated criterion (2.03). This means that a higher probability threshold (P > 5%) would generate a significant difference. The behaviour of masses in this area therefore provides valuable insight.

3.3. Microtracer concentration in the deposits

Figure 6 illustrates that the average microtracer concentration in these deposits is approx. seven times higher than the initial concentration (250 ppm). This concentration remains four times higher than the initial concentration even after throughput of a collector batch.

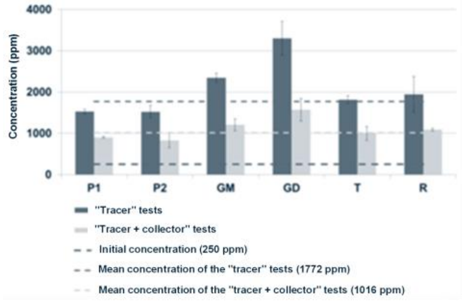


Figure 6: Mean deposition concentrations obtained during the repeatability tests and the experimental design tests

This trend is seen at every sampling area, thus confirming the bucket elevator's concentrator effect, as identified by Jansen et al (1982).

The deposits on the upwards (GM) and downwards (GD) casings show the highest concentrations (2000 and 3000 ppm respectively), but the lowest deposition masses (Figure 5a).

Conversely, the concentration at the foot (P1) is one of the lowest (~ 1500 ppm), but with one of the highest quantities of tracer. This is due to the large amount of deposition in this area (approx. 30% of total deposition mass).

These concentrations also highlight the differing behaviours of fines in the sampling areas (Figure 7).

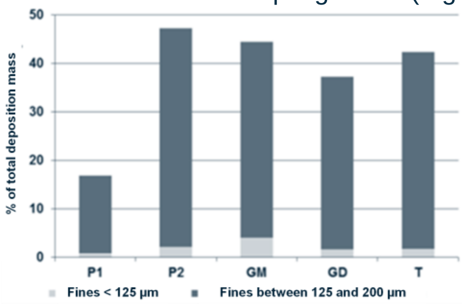


Figure 7: Percentage of fines according to their diameter at each sampling area

Comparing Figure 6 and Figure 7 reveals three areas:

- **"Residual" (P1):** These deposits are generated by both a pre-existing product fraction and product flow-back in the downwards strand. They show the lowest tracer concentration.
- **"Inclined (P2):** These deposits contain a large percentage of fines (47.3%) produced by airborne suspension when filling buckets and emptying the "overflow" pipe. Consequently, this area contains only a small amount of very fine particles, leading to lower measured concentrations.
- **"Vertical" (GM, GD and T):** These deposits generally comprise fine particles, with a fairly large quantity of particles of around 100 µm, particularly in the upwards casing (GM). This fraction generates high tracer concentrations.

In terms of carry-over studies, these results demonstrate the benefits of focusing on the masses of microtracer deposited and transferred rather than on the microtracer concentrations in these deposits.

3.4. Mass of microtracer deposition in the elevator

Figure 8 illustrates deposition renewal during throughput of collector batches, also referred to as "rinsing" or "sweeping".

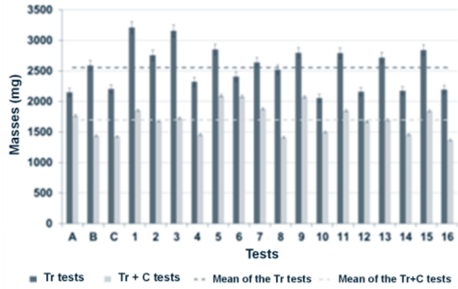


Figure 8: Total masses of microtracer deposition

A large decrease in microtracer deposition mass was observed between the "tracer" and "tracer + collector" tests (over 850 mg on average).

Figure 9 (mass (a) and % (b)) illustrates the distribution of microtracer deposition in the elevator. It demonstrates that running a collector batch through the elevator effectively sweeps the micro-ingredients through the system at every sampling area.

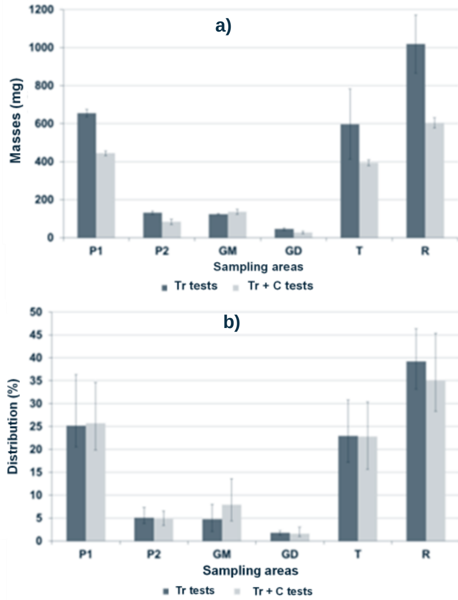


Figure 9: Distribution of microtracer deposition

This distribution is similar to that observed in Figure 5. This indicates an uneven distribution of microtracer in the fines that escape from the product matrix during its travel through the bucket elevator.

Excluding deposition in the upwards casing (GM), recorded masses varied widely between the "tracer" and "tracer + collector" tests (Table 3). While fines were seen to accumulate on this vertical wall (increase in product deposition mass), no rinsing phenomenon was observed (no notable variation in the mass of tracer).

	Student t-test criterion	Critical value - 95% (Student's t-test table)	Probability of error	Significant difference
Total mass	8.13	2.04	< 0.0001	Yes
P1	8.45	2.04	< 0.0001	Yes
P2	5.84	2.04	< 0.0001	Yes
GM	0.67	2.04	0.51	No
GD	7.60	2.04	< 0.0001	Yes
T	3.65	2.04	0.001	Yes
R	7.40	2.04	< 0.0001	Yes

Table 3: Analysis of the comparison of means for microtracer deposition masses

It is vital to study and analyse product and microtracer masses in order to gain insight into and understand the carry-over process. Two variables have been established: deposition capacity and collecting capacity, which provide for interconnecting the testing centre and industrial production lines.

3.5. Deposition and collecting capacities

These values facilitate comparisons between the pilot testing centre and industrial production sites. The deposition capacity is the ratio of the mass of deposited microtracer against the mass of the initial tracer quantity, expressed as a %. The collecting capacity is the ratio of the mass of collected microtracer against the mass of deposited tracer. Figure 10 and Figure 11 illustrate respectively the deposition and collection capacities for each test.

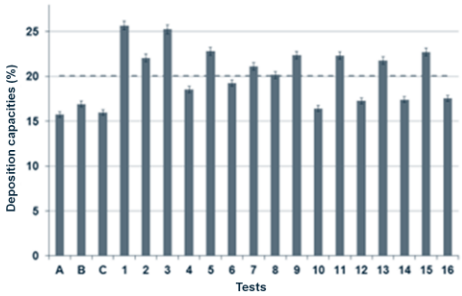


Figure 10: Deposition capacities (%)

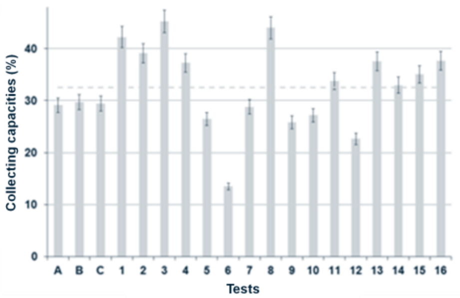


Figure 11: Collecting capacities (%)

As regards the deposition capacity, product transit through the bucket elevator generates an average loss of just under 20% of the initial tracer quantity. For the testing centre, this value represents 2.5 g, while for an industrial production line (5 tons at 250 ppm), this would correspond to a loss of 250g of micro-ingredient in the final feedstuff (50 ppm). Note also that the tests carried out under the reference conditions (tests A, B and C) recorded the lowest deposition capacities. This would suggest that industrial practices could be improved in terms of carry-over.

As regards the collecting capacity, the quantities of tracer recorded in the deposits during the two subtests suggest that collector batches rinse, on average, 32% of the mass of tracer deposited in the elevator. Note that test No. 6 recorded a far lower collecting capacity than the other tests, although there was no clear explanation for this difference.

Lastly, these tests, performed under different configurations at the testing centre, recorded similar deposition capacities. Despite this, these same tests may correspond to different collecting capacities, and vice versa. In other words, **the process factors acting on the deposition capacity are not the same as those acting on the collecting capacity.**

4. Conclusion

As described in the literature, the bucket elevator is a product handling device that retains a large proportion of the airborne particles generated during conveyance of a powdered product.

All the results obtained during tests at the experimental testing station demonstrate an accumulation of residues during batch throughput, in addition to the renewal of this deposition and the high concentration of fines. This last point demonstrates the benefit of breaking the carry-over process down into two separate processes: deposition during throughput of a tracer batch, and collection during throughput of a collector batch.

5. Bibliography

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