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Study of the persistence of carry-over at feed plants

In 2009, a European directive (directive 2009/8/CE) laid down limits on the levels of coccidiostats present in animal feeds, corresponding to carry-over levels of 1% to 3% of maximum permissible values.
In France, feed plants only perform a single carry-over (CO) test with at least 2 collector batches, and there is no guarantee that this type of test clearly identifies the number of batches required to cross, one by one, the "discharging" levels of the bans on producing such or such feedstuff.
This original study aims to explore how carry-over levels change beyond the 2 standard collector batches, and to determine whether a "law" of evolution can be inferred from this data. To do this, 2 batches of feedstuffs containing a tracer were produced successively at 3 different plants. Next, 5 batches initially free of tracer were produced on the same circuit and sampled at mixer output and at the entrance to the silo bin upstream of the press, in order to assess carry-over levels at these two sampling stations, thereby examining how these levels change from one batch to another.

1. Equipment and apparatus

1.1. Premix

The premixes were produced using maïzarine incorporated at a rate of 5 kg/t. **RF blue lake microtracer** was used at a concentration of **500 ppm**, in order to increase the sensitivity of low-concentration analyses (a previous study demonstrated that carry-over levels were not affected by increased tracer concentration: i'Tec T11). Equivalent weights of premix media (minus tracer) were injected into the same station (bag emptier) in each of the 5 collector batches.

1.2. Matrices

Plant	1	2	3
Feedstuff	Repro turkey	Finishing duck	Grain blend
Batch size (s)	5	2.5	2.5
Median diameter (µm)	555	438	502
Geometric standard deviation	2.23	2.15	1.93
Bulk density (g/l)	591	627	552
Angle of repose (°)	68.8	59.6	69.0

Plant 1 feed is fatty with poor flow, but has a particle size centred around a relatively standard value. Plant 2 feed is finer and slightly less fatty, but with better flow. Lastly, while the particle size of the grain blend used at plant 3 is centred around a standard value of 500 µm, it has a poor flow.

1.3. Plants

These **3 plants** were selected due to the **significant** size of their reported **carry-over levels**. While they do not reflect the levels found in French feed plants, they are similar in terms of their use of conventional manufacturing processes. The circuits are also very different (see table below).

Plant 1	Plant 2	Plant 3
Incorporation of premix in bag-emptiers		
Premixer (+ minerals)	Screw	Chain conveyor
Chain conveyor	Premixer	Chain conveyor
Elevator	Hopper below the premixer	Elevator
Hopper above the mixer	Chain conveyor	Hopper above the mixer
Mixer	Elevator	**Mixer**
Hopper below the mixer	Chain conveyor	Hopper below the mixer
Chain conveyor	Hopper above the mixer	Chain conveyor
Distribution box 2	**Mixer**	
	Hopper below the mixer	
	Chain conveyor	
	Distribution box 3	
Sampling at mixer output (MO)		
Elevator	Elevator	Distribution box 2
	Revolver distributor	Revolver distributor
	Distribution box 2	Elevator
		Revolver distributor
Sample taking at the entrance to the silo bin upstream of the press (ES)		

The 3 tested circuits include **relatively long sections upstream of the mixer** with premixes being conveyed via the macro-ingredient circuit. **Two plants have premixers** (plants 1 and 2). Conversely, downstream circuits are often fairly short.

2. Method

The **methodology conforms to the technical rules that apply within France** (i'Tec T 2). The differences involve:

- **sampling** technique, performed at 2 locations: at **mixer output** (MO) and at the **entrance to the silo bin upstream of the press** (ES).
- concentration of the 2 tracer batches (T1 and T2) targeted at **500 ppm**
- performance of all **analyses in duplicate** on each sample, and use of the average of the 2 analyses.

3. Results

3.1. Conformity

Plant	1		2		3	
Stations	**MO**	**ES**	**MO**	**ES**	**MO**	**ES**
R1 (ppm)	477.9	464.5	460.9	425.1	419.4	393.4
R2 (ppm)	469.1	478.6	437.5	438.4	437.5	425.3
R1 (% *)	**96.1**	**93.4**	**91.9**	**84.7**	**84.0**	**78.8**
R2 (% *)	**94.6**	**96.5**	**87.2**	**87.3**	**87.7**	**85.4**

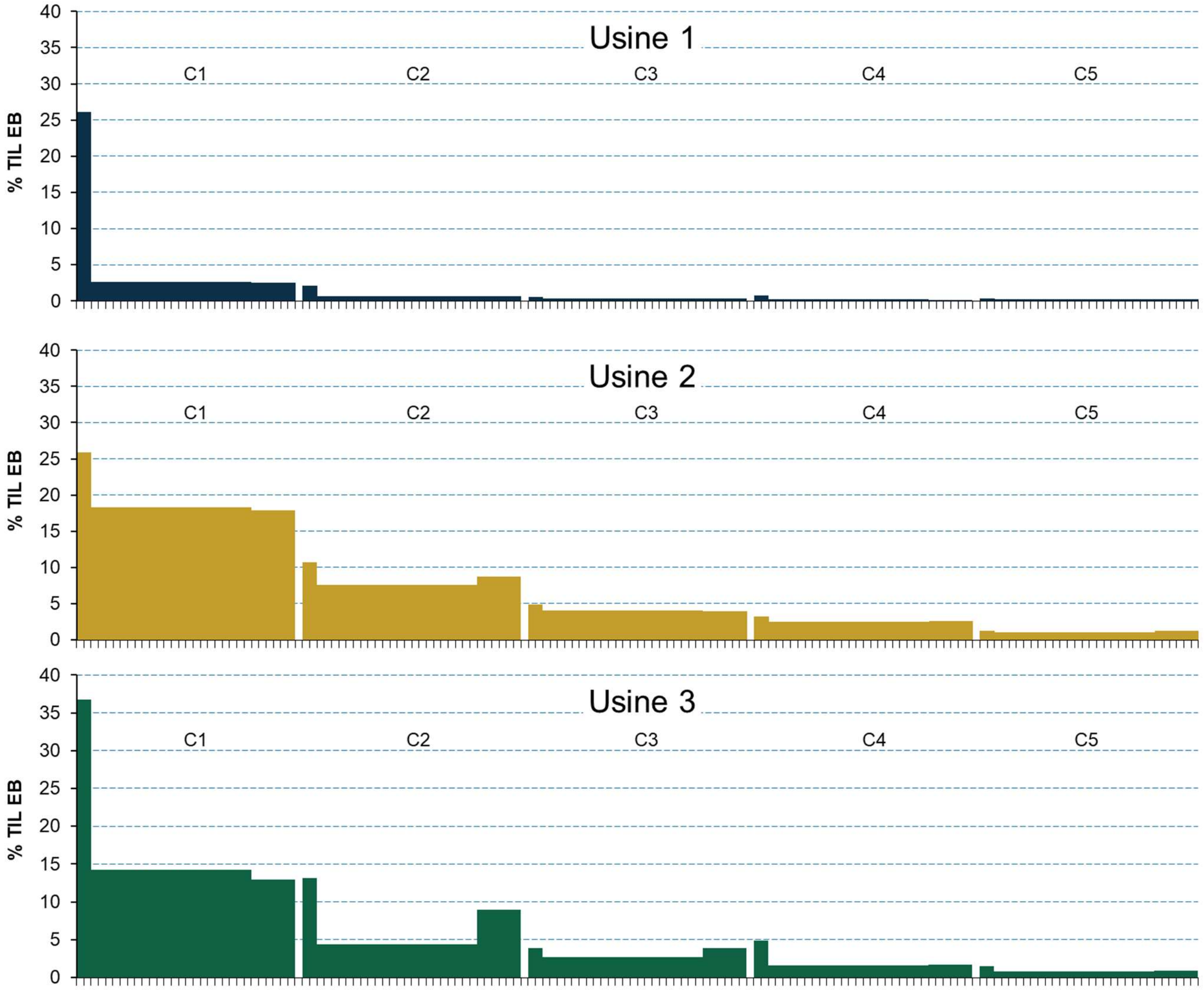
* Recovery rates / expected rates

The recovery rates obtained at the 3 plants were all acceptable. An increase in concentrations between the two tracer batches and between stations was not systematically observed. Logically, Plants 2 and 3 should have lower recovery rates and higher carry-over levels.

3.2. Carry-over (CO)

While **an increase in CO levels between the 2 stations** was observed (see table below) in nearly every case excluding batch C5 at Plant 1, these values nevertheless remain close to the detection threshold (the second figure after the comma is given for information only).

Plant	1		2		3	
Stations	**MO**	**ES**	**MO**	**ES**	**MO**	**ES**
%CO C1	2.41	4.10	16.55	18.68	18.31	15.46
%CO C2	0.65	0.75	7.46	7.96	4.77	5.85
%CO C3	0.23	0.40	3.91	4.12	2.91	2.94
%CO C4	0.18	0.23	2.42	2.56	1.27	1.71
%CO C5	0.16	0.15	1.10	1.18	0.75	0.83

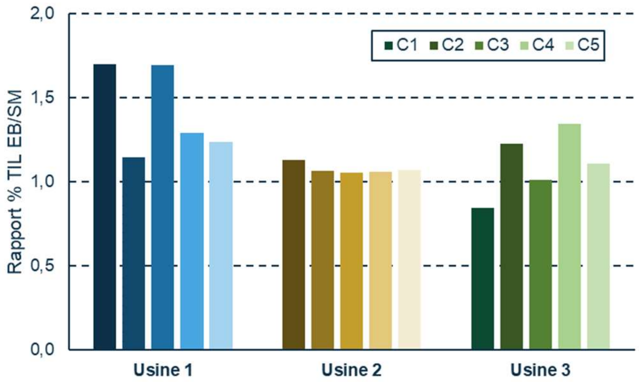


The 3 plants tested were found to have markedly different **carry-over profiles and levels** at the entrance to the silo bin upstream of the press (see figure above), indicating a variety of sources. At Plant 1, the carry-over profile is characterised by a strong peak at the start of the batch, which then descends to a fairly low overall level. This profile is found on all the collector batches. The premixer appears to be quickly rinsed by the mineral fraction introduced with the premix. The peak reported at the beginning of the carry-over profile (difference with the MO column) is caused by the elevator downstream of the mixer.

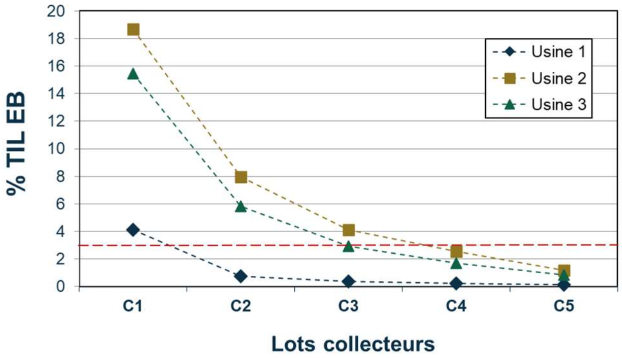
Conversely, at Plant 2, the early peak is low compared with the overall level. However, the level then rises sharply, and is already observed at mixer output with each collector batch. The combination of a screw and a premixer in the premix conveyor circuit upstream of the main mixer would appear to offer the best explanation of the high carry-over levels observed (close to MO column values).

Lastly, Plant 3 appears to combine elements of the first two plants, with a strong peak early on in the profile, followed by a high overall level. In certain collector batches, the profile increases erratically at the end of batch throughput. Circuit length both upstream and downstream of the mixer appears to be the best assumption to explain the high carry-over levels observed. The variety of sources could explain the batch-to-batch variation in profiles observed at this plant.

The ratio of carry-over levels between the two stations (ES/MO – see figure below) can be used to assess the increase in CO between the two stations. These ratios, calculated for each collector batch at each of the 3 plants, are fairly constant. The ratios at Plants 2 and 3 are especially constant. Only at Plant 1 does the ratio vary by twice as much. This suggests that all the successive collector batches respond to identical demands in the circuits downstream of the mixer at all 3 plants. However, ratios close to 1 could demonstrate that **most carry-over occurs upstream of the mixer** (MO) at these 3 plants, despite the apparent differences in the circuits.

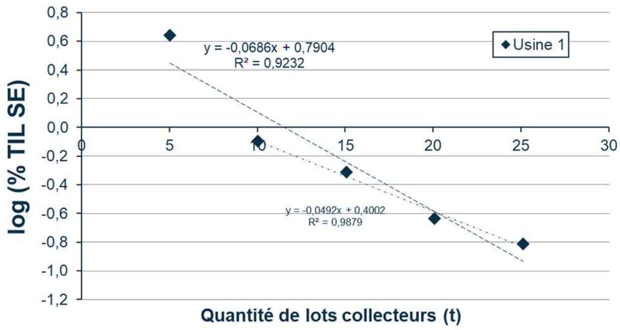


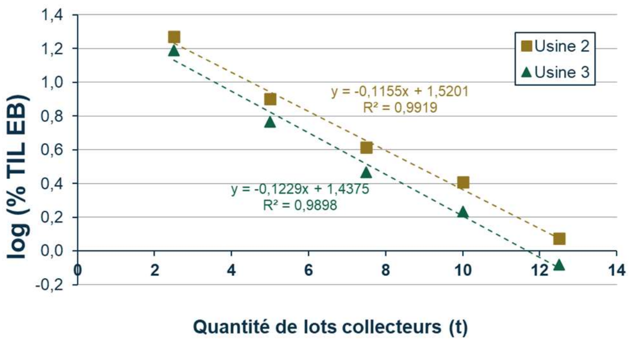
At all 3 plants, carry-over levels therefore decrease from one batch to the next at the entrance to the silo bin upstream of the press. The three plants can therefore be ranked in descending order of carry-over level at the entrance to the silo bin upstream of the press: Plant 2 > Plant 3 >> Plant 1. This means that if a CO level below 3% is sought (red threshold), it would be observed at Plant 1 as of the second collector batch, while at Plant 3, it would be necessary to wait for the third batch, and at Plant 2, the fourth batch.



At all three plants, **carry-over levels decrease in an asymptotic rather than a linear fashion**, getting progressively closer to zero.

It would be useful to identify the law governing this asymptotic decrease. As shown in the following figures, converting carry-over data into a decimal logarithm based on the number of tonnes produced would seem to provide an answer.





While the linear regression is not fully meaningful for Plant 1, despite having a coefficient of determination above 0.92, the coefficients of determination for the regressions at the other two plants are above 0.98. At Plant 1, the regression seems to be leaning towards the first point. Removing this point would improve regression quality (0.99).

The assumption of a logarithmic decrease is therefore generally viable. Similar patterns of decrease, despite the differences in conveyancing circuits at the 3 plants tested, would appear to suggest fairly general behaviour that can be attributed to carry-over sources at the plants being mainly upstream of the mixer.

This logarithmic regression model is reminiscent of the model for dust cloud emissions in relation to carry-over levels recorded at a premix plant (i'Tec T3).

4. Conclusion

These three tests were performed under very different feed and circuit conditions. They demonstrate that, at all 3 plants, **residues** of the first tracer batches **do carry over from one collector batch to the next and persist in the circuit for up to at least 5 collector batches**. Even if not repeated at all plants, all the sites appear to show a **general model for the logarithmic decrease** of carry-over levels. This would appear to be **independent of the circuits** and is possibly related to **dust emission by the identical tracer** used here. Given the variability recorded at Plant 1, it would appear that at least 3 collector batches are required to obtain a reliable estimate of the decrease slope at the entrance to the silo bin upstream of the press, even if a preliminary estimate could be attempted using 2 batches at each site.

This **slope differs** at each plant, possibly indicating a different ratio for each process in terms of tracer dust emission. Calculating this slope would make it possible to identify the number of collector batches required to cross a given level, and also to make **inter-plant comparisons based on the rate at which they "clean" their circuits**.

This type of slope would provide an alternative perspective on carry-over results, and therefore on their sources and the persistence of residues within industrial feed manufacture circuits.