How process operations affect cross contamination in animal feed industry.

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ABSTRACT
Cross contamination (carry-over of additives) is a common issue in feed industry. Currently cross contamination rates of a production line can be accurately defined but the causes are not identified yet because of a misunderstanding of the phenomenon. The main objective of this study is to understand how process operations affect cross contamination. Handling equipments in feed industry are in metal and accessibility is reduced so that observations and studies in situ are impossible all the more during running. So a test bench has been designed and built where several studies on determining the locations of contaminating (dust) particles deposits in the system and their potential impact on cross contamination have been carried out. Feed products are compared with a “standard product” in terms of deposits mass, mass and concentration of tracer in these deposits. On the other side, global contamination of batches is analysed for all tested products. Moreover working on a test bench allows us to have a different point of view of contamination between batches. Indeed not only global contamination but also product’s “deposit capacity” (capacity for a tracer batch to leave microtracer in the elevator) and “collecting capacity” (capacity for a collector batch to “clean” the elevator) have been considered. Finally, behaviour of different parts of the system is analyzed regarding its tendency to accumulate or not dust deposits and/or tracer.

Keywords: cross-contamination; feed industry; dust deposits; powder handling

INTRODUCTION
Since recent food crisis feed industry has been really concerned by cross-contamination between feed batches during production. The most important form of cross contamination is carry-over of additives from previous batches into the following feed batch. Some studies have been carried out on this issue by observing and measuring the impact of production line diagram and feed recipes on cross contamination due to additives [1] [2] and many efforts have been made by industrialists to reduce these rates. For example the new directive 08/09/EU determines maximal contamination rates for some additives (coccidiostats) used in feed in order to prevent their presence in all animal derived products from non-target animals (meat, eggs, milk…). Implementing these modifications contamination rates of production lines decrease significantly but slug since several years [3]. Thus looking closer on handling equipment is the condition to understand the behaviour during handling so as to pare again this phenomenon. A field study conducted by Tecaliman [4] [5] showed that the bucket elevator placed just after the mixer is responsible for a significant increase of cross contamination in industrial feed production lines. This bucket elevator transfers meal of crushed products just after additive introduction.

The main objective of this experimental study is to understand the behaviour of contaminating particles in this bucket elevator during handling and their relation with dust generation and dust deposits. The first part, exposed in this article was the creation of a standard product which behaves as most of feeds. In the same time a protocol has been elaborated in order to determine interesting output data to mark out the locations of contaminating particles deposits in the system, their behaviour throughout batches passing and their potential impact on cross contamination.

MATERIALS & METHODS
Test Bench
A test bench has been designed and built to carry out studies and observations. Its dimensions and spaces have been defined with a geometrical scale. The pulleys diameters and buckets dimensions have been chosen in order to access the three discharges profiles on the elevator head described in literature : centrifugal, mixed and gravitational discharges [6] [7].Then, the main parts of this test bench are in antistatic polycarbonate to make observations possible during handling (Figure 1 (b)). Besides foot of this elevator is optimised in order to make the buckets passing the nearest of the foot wall. It corresponds to at least 80% of post mixer elevators’ foot in French production lines.
This system enables activating a maximum of process parameters:

- Parameters which can be modified directly by control operator (belt velocity, feeding flow rate and angle of the discharge spout)
- Parameters which can be modified on an existing elevator (number of buckets per meter, space between buckets and wall)
- Parameters which have to be modified during conception (feeding ways - down leg or up leg feeding-, position of the connection between legs, position of decompression socks)

As shown on Figure 1, the product is introduced in the feeding hopper and transferred until the bucket elevator with a screw. Then it is unloaded on the elevator head in a second hopper or outside the system. Thereby, the system can run in closed loop or not.

**Figure 1 : Test bench photos (left) and scheme (right)**

**Standard Product**

Feed recipes evolve during the year and from one production plant to another so in order to keep a constant product during the study and to control its physico-chemical characteristics a “standard product” has been created from a mix of different size corn cob granules to be a reference for feed products. Its physical characteristics (Table 1) correspond to an average of feed (based on Tecaliman data base). The first experimentations showed that standard product only composed by corn cob granules do not behave like a classical feed, especially in terms of deposits mass and fines particles liberation. So that, sunflower oil has been incorporated (incorporation rate: 1.5 %) in the recipe. Three different feeds (Table 1) have been chosen for validating experimentations.

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th>Standard product</th>
<th>Pig feed</th>
<th>Rabbit feed</th>
<th>Poultry feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density (g/L)</td>
<td>485</td>
<td>643</td>
<td>514</td>
<td>571</td>
</tr>
<tr>
<td>Hausner ratio</td>
<td>1,1</td>
<td>1,1</td>
<td>1,1</td>
<td>1,3</td>
</tr>
<tr>
<td>Angle of repose (degree)</td>
<td>53,9</td>
<td>54,3</td>
<td>62,8</td>
<td>62,4</td>
</tr>
<tr>
<td>Mass equivalent diameter (µm)</td>
<td>531,2</td>
<td>592,6</td>
<td>716,6</td>
<td>510,8</td>
</tr>
<tr>
<td>% of fines &lt; 200µm</td>
<td>5,4</td>
<td>13,4</td>
<td>7,6</td>
<td>0,4</td>
</tr>
<tr>
<td>Added fat rate (%)</td>
<td>1,5</td>
<td>0</td>
<td>0,5</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 1 : Physical characteristics of standard product and tested feeds**

**Methods**

In feed industry, the method to assess cross-contamination rate of a production line consists on [4]

1. selecting a tracer
2. producing mixes containing the uniformly distributed tracer (tracer batch)
3. producing mixes using the same circuit without tracer (collector batch)
4. drawing samples from the batches (sequential sampling) in different points of the production line
5. processing the samples
6. determining the tracer quantity in the samples by dosing
The test bench is a closed system so sequential sampling is not representative of contamination. Only global sampling on the different batches is realised as well as deposits sampling. Global sampling is obtained by 6 successive divisions of batches after exit from the bench. Deposit sampling is realised by opening some parts of the bench and recovering all dust settled on the wall.

The elaborated method on the test bench consists on:

1. **Tracer test (Tr)**
   a. 3 loops of the tracer batch
   b. global sampling
   c. drawing deposits samples (Figure 2)
   d. cleaning the bench

2. **Tracer + collector test (Tr+C)**
   a. 3 loops of a second tracer batch
   b. 1 loop of the collector batch
   c. global sampling
   d. drawing deposits samples
   e. cleaning the bench

3. **Processing the samples**
4. **Determining the tracer quantity** in the samples by dosing

![Figure 2: Sampling points on the bucket elevator](image)

The batches weigh 50kg and tracer batches are concentrated at 250 ppm of microtracer RF blue Lake [4]. This tracer is composed by iron particles (less than 100 µm diameter) coated with a blue colouring agent (gum arabic). The particles are extracted magnetically and the corresponding colouring agent quantity is analysed by colorimetry.

**RESULTS & DISCUSSION**

**Repeatability**

In order to validate standard product and experimental protocol a measurement run has been realised. The first experimentation results with standard product showed a good repeatability in terms of mass, tracer mass, tracer concentrations and contamination rate. The observed variations are around 10% for global samples. Concerning local deposit samples, a more important variation (up to 30%) can be noticed in vertical or inclined sampling points (connection between legs, legs and buckets). It is explained because these sampling points are vertical or very inclined so that deposits accumulate and fall after reaching a certain quantity (depending on angle of repose). Therefore the collected mass depends on sampling moment.

**Global behaviour**

Tracer and collector batches concentrations after passing are considered as well as the contamination rate (Figure 3 (a) and (b)) which expresses the level of concentration of the collector batch with respect to tracer batch concentration expressed in percent. It is an indicator of the collector batch capacity to collect tracer let by tracer batch in the system. This rate is used to determine contamination of industrial production lines.

\[ C_r = \frac{C_{\text{tracer}}}{C_{\text{collector}}} \times 100 \]  \hspace{1cm} (1)

\( C_{\text{tracer}} \) : tracer batch concentration
\( C_{\text{collector}} \) : collector batch concentration

Batches concentrations for all tested products are in the same order of magnitude except for poultry feed collector batch (Figure 3 (a)). Thus contamination rates are closed together except poultry one which is a bit lower (Figure 3 (b)). This peculiar behaviour may be owed to its important cohesivity due to higher fat rate. Total deposit mass and total tracer mass in deposits (Figure 3 (c) and (d)) show similarities in global behaviour of the tested products. Standard product and poultry feed show a 5 to 20% increase of total deposit mass between tracer test and tracer+collector test and a nearly constant total tracer mass in deposits. In opposition, pig and rabbit feed show a constant total deposit mass and a 45% decrease of total tracer mass in deposits. These differences of behaviour can be explained by the difference of fat rate which is directly linked with product cohesivity. Indeed deposits of very cohesive products (poultry feed) tend to accumulate so that fines particle (including tracer) cannot be drained out of the system. On the contrary, deposits of less
cohesive products are continuously renewed and tracer particles are replaced by non contaminating ones and evacuated from elevator

![Graphs showing concentration and contamination rate](image)

**Figure 3: Global behaviour results – batches concentration after passing (a), contamination rate (b), total deposit mass (c) and total tracer mass in deposits (d)**

These results incite to classify products with their propensity to let tracer (and fines particles) on the process walls during tracer batch passing (deposit capacity) and the collector batch propensity to collect tracer settled on the handling equipment (collecting capacity).

\[
C_{\text{collecting}} = \frac{m_f}{m_i} \times 100 \quad \text{(2)}
\]

\[
C_{\text{deposit}} = \frac{m_f - m_C}{m_f} \times 100 \quad \text{(3)}
\]

**Figure 4: Evolution of contamination rate with collecting and deposit capacities**
These capacities can only be interpreted as a comparison between different products in this test bench. However 4 different behaviours can be identified regarding at the same time contamination rate, collecting and deposit capacities (Figure 4). This result highlights that it is essential not to settle for contamination rates but to distinguish the product ability to leave contaminating particles in the system and its capacity to collect settled particles during handling. These results may be directly used in feed industry to ordinate batches in the same production line. For example a feed batch with high collecting capacity should not be produced just after a batch of high deposit capacity containing a contraindicated additive.

**Local behaviour**

Local behaviour of a product gives information on its deposit and collecting capacities for each part of the elevator. Results exposed in Figure 5 (a) and (b) highlight two different kinds of areas:

- Areas characterized by an increase of deposit mass between tracer and tracer+collector test. Therefore deposits accumulate and mass of tracer do not evolve.
- Areas characterized by a non variation of deposit mass. In these areas, deposit is constantly renewed and settled particles are driven out and replaced. Thus tracer mass decrease with collector batch passing.

Moreover, observations during tests show that vertical or very incline sampling points with a quite important deposit mass on a rather small surface (especially head and connection) accumulate deposits until a certain quantity. When the deposit mass is over, it falls and the accumulation begins again. Thus the collected quantity depends on the moment when sampling is done. Then it has to be note that the more cohesive the product is, the less uniform the deposits are. Therby deposits in case of poultry feed are particle heaps in some parts of sampling points whereas pig feed deposits are layers of fines uniformly spread on deposits points.

**Figure 5:** Local behaviour results - deposits mass (a), tracer mass in deposits (b), deposit mass repartition (c) and tracer mass repartition (% of the total collected mass) (d) and deposits concentration (ppm) (e)
Observed deposits concentrations (Figure 5 (e)) are over the initial concentration (250 ppm) until 5 times. These results confirm the hypothesis formulated by Jansen and Friedrich [8] that elevator post mixer concentrates additives. Nevertheless even if concentrations are often used to express cross contamination, it is important to note that with regards to local behaviour contamination can easily be overestimated. Indeed a little deposit mass with high concentration does not have any impact on contamination because very little mass of tracer is concerned. Thereby the most representative factor of local contamination is tracer mass in deposits.

The foot of the elevator contains from 40 to 80 % of the total collected deposit mass and from 45 to 80 % of the total collected tracer mass (Figure 5 (c) and (d)). It represents from 2 to 5 % of the initial tracer mass (12.5g). Except for poultry feed, after tracer batch passing, foot is concentrated at least 3 times more than the initial concentration (250 ppm). This concentration decreases with collector batch but stay over initial concentration (Figure 5 (e)). Granulometric analysis shows that elevator foot selects finer particles. Indeed mass equivalent diameter of foot sample is about 50 to 65 % less than initial diameter; except for poultry feed which increase about 20 %. This is the consequence of down legging of very fine particles at the end of discharge phase and evacuation of overflow of product in the buckets at the beginning of ascension phase. Because of its high cohesivity poultry feed is less subject to these phenomena. Cleaning the foot after passing of a feed batch containing contaminant additives (for following batches) can be a rather easy way to reduce significantly the potential carry-over due to elevator.

CONCLUSION
This test bench enables observations of feed behaviour in a new way. It opens possibility to analyse deposits in almost all the system and to distinguish every parameters at stake in cross contamination phenomenon (deposit and collecting capacities), which is unthinkable in feed production lines. The first experimentations on this test bench highlight many interesting things which deserve to be studied closer. Standard product globally behave like tested feeds. Thus these results allow validating standard product as well as test bench and experimental protocol.

By the way, investigations are currently carried out and an experimental design has been created to active different process parameters and to highlight their role on cross contamination (in terms of deposits mass, tracer mass in deposits and deposits concentration on tracer), on cross contamination between batches (regarding contamination rate of tracer batch and contamination level of collector batch) and on deposit and collecting capacities. The results will be compared with another part of this study consisting on analysing the effects of process parameters on air motion and particles movements in the system [9].

REFERENCES