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Electrostatic charging of animal feeds

The electrostatic charging of powders can initiate a range of behaviours of varying complexity and detectability, which can even sometimes appear rather unexpected.
In the animal feed sector, electrostatic charging may to some extent explain various undesirable phenomena:

- Carry-over
- Electrical charging of facilities
- Explosions

The tests carried out jointly by Tecaliman and Poitiers University (M. TOUCHARD) between 1995 and 1997 established a basis for taking account of these phenomena by setting up procedures designed to measure three properties in both laboratories and the industrial environment.

1. Definitions

1.1. Conductivity

The conductivity of a material is defined as its ability to transmit an electrical current when placed in an electric field. The higher a material's conductivity the greater its ability as a **conductor**. Conversely, the lower the conductivity and the greater the material's ability as an **insulator**, such as dry air. Conductivity values are very low when expressed in conventional terms as Siemens per metre: S/m. Thus, a body with a conductivity of 10^{-5} S/m is a better conductor than a material with a conductivity of 10^{-10} S/m.

1.2. Chargeability

This parameter represents a product's "electrostatic" capacity. On being handled, some products generate a substantial electrical load; this corresponds to a high chargeability in terms of absolute value (non-null). Other products, though, generate hardly any electrical load when being carried, stirred, etc. This corresponds to a low chargeability in terms of absolute value (close to zero). Chargeability is expressed in NanoCoulombs per gram: NanoC/g.

There are positive and negative chargeabilities. This sign depends on the bodies in contact and not the product alone. During pneumatic conveyance in a conductive metal pipe for instance:

- a positive sign indicates that the product is donating electrons
- a negative sign indicates that the product is receiving electrons
- carbonate: and flax press cake: high, but opposite, chargeability

1.3. Static charge build-up in an electric field

When an electric field is applied to a body using two electrodes, the body becomes charged. These charges may be generated by charge injection at the electrodes or, conversely, by electrodes "attracting" charges from the surrounding environment. Generally speaking, it follows that the material contains an overall quantity of non-neutral electric charges. This charge quantity may then dissipate once the field is no longer applied. This property is used to measure and record a product's ability to build up charges, thus fulfilling its role as a charge reservoir. Thus, the larger the number, the greater the product's ability to build up charge. Charge dissipation is expressed in Picocoulombs per gram: PicoC/g. The values for this capacity are fairly low, being of the order of 10^{-10} to 10^{-15}. A product with a charge build-up value of 10^{-10} PicoC/g can store more charge than a product with a value of 10^{-15} PicoC/g.

1.4. Conclusion

Products with a detectable electrostatic risk are characterised by weak conductivity, high chargeability in terms of absolute value (negative or positive) and a strong tendency to build up charges. Such a product may generate differences in electrical charge while providing little means of eliminating them.
A lower risk product would be one with strong conductivity and low chargeability. Its capacity to generate differences in electrical charge (chargeability) when being handled is not taken into account as these charge differences can be rapidly eliminated.

2. Laboratory tests

2.1. Measurements

2.1.1. Electrical conductivity and static charge build-up in an electric field

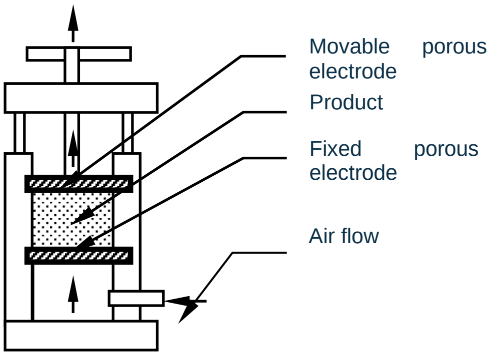

Figure 1: Electrical conductivity measuring cell and static charge build-up in an electric field

Both these measurement methods use the same system consisting in a cell, as illustrated in Figure 1. The product is placed between two porous electrodes that allow throughflow of an air current with a controlled moisture content that standardises the measurement environment. The top electrode is movable and enables the placement of a weight that compresses the product layer continuously.

It is only the changes to the protocols and the surrounding electrical devices that can explain the differences in the two measurements:

- electrical conductivity: A voltage difference relative to earth is applied using a stabilised power supply on the bottom electrode. This voltage difference induces a current in the powder sample. The current is measured with a picoamperemetre placed between the top electrode and the earth.
- build-up of charges: A voltage difference is applied between the two electrodes. This voltage difference is maintained for 30 seconds, time during which the charges build up in the powder. Next, the electrodes are short-circuited via the discharge system and the change in voltage recorded by the data acquisition system. The whole current flowing through the circuit corresponds to the cell's total charge (free + bias). The bias charge is then subtracted, giving the sum of the free charges "injected" during the charge build-up phase.

2.1.2. Charging by friction

The powder is introduced into the input hopper. An air flow of 1170 l/h is routed through the whole pipe set-up from the feed hopper and the adjustable pressurisation system. This air escapes via the porous cover of the receiving hopper.

Once the air flow is stabilised, the powder is incorporated into the flow. As the valve gradually starts to open, the hopper starts to vibrate in order to ensure a smooth, even flow of powder.

The electric current is then measured on the measurement section that was insulated from the rest of the line and integrated according to time. The integral corresponds to the total charge received for a given powder sample. This charge is then converted into Coulombs per gram.

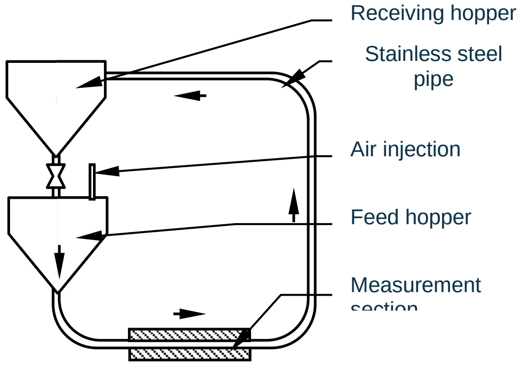

Figure 2: Measurement circuit for charging by friction

2.1.3. Conclusion

These methods have demonstrated outstanding intrinsic properties in terms of sensitivity, accuracy and reproducibility. They are simple to take, but not often used due to a gap in the market for this type of measuring apparatus. Given their clear benefits, it is to be hoped that this situation will develop favourably in the future.

2.2. Comparison with other physical properties

Out of all the comparative trials conducted by Tecaliman, no more than a tenuous relationship between electrical conductivity and bulk density (Figure 3) or particulate matter (Figure 4) has been observed. These relationships can generally be explained by the presence of oligo-elements (I), which are often dense and highly conductive.

Most organic products (Antibiotics A, Coccidiostats D, Vitamins H, etc.) have fairly low conductivities.

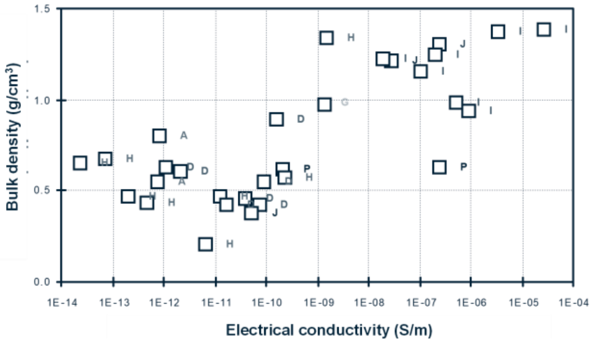

Figure 3: Relationship between electrical conductivity and bulk density

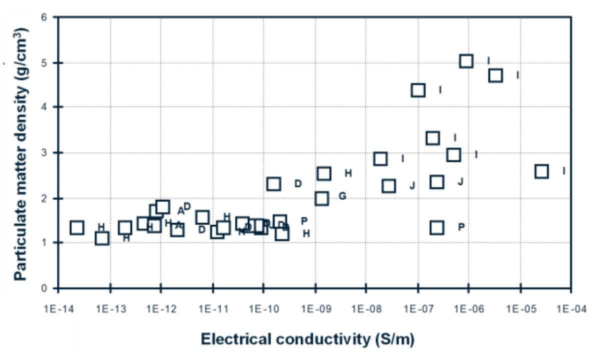

Figure 4: Relationship between electrical conductivity and particulate matter density

2.3. Results for the 30 products

Measurements were made on 30 additives that are routinely used in animal feeds and considered to be benchmark products in this domain.

Of these thirty products, only two vitamins (H) showed a potential for electrostatic sensitivity due to their high chargeability during flow and their moderate electrical conductivity (Figure 5).

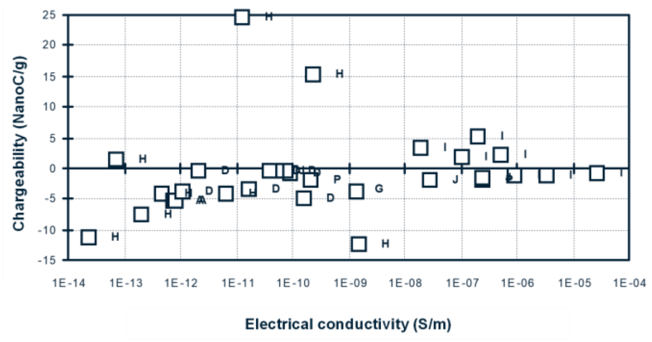

Figure 5: Relationship between electrical conductivity and chargeability

These thirty products form a "representative" population whose distribution in relation to the three electrostatic measurements is described in Table 1. Electrical conductivity evolves over a wide measurement range spanning 2.3 10^{-14} and 3 10^{-5} S/m, i.e. 9 powers of 10. The products' median chargeability in relation to a steel pipe was negative, which would suggest that most of these products (over 75%) pick up electrons.

Electrostatic build-up evolves over a narrower range than that of conductivity - between 86 and 12800 PicoC/g, i.e. 2 powers of 10.

Parameters		Percentage of the population						
		Minimum			Median			Maximum
		10%	15%	25%	25%	15%	10%	
Electrical conductivity	S/m	2.3 10^{-14}	4.6 10^{-13}	3.2 10^{-12}	1.0 10^{-10}	9.0 10^{-8}	6.0 10^{-7}	3.0 10^{-5}
Chargeability	NanoC/g	-12.4	-5.6	-4.1	-1.5	-0.2	3.6	24.6
Static charge build-up in an electric field	PicoC/g	86	105.9	499.5	998.5	2875	4711	12800

Table 1: Electrostatic properties of the range of thirty benchmark additives

3. Industrial trials

3.1. Measurements

The measurements were made on five benchmark products selected from among the family of thirty "representative" products.

The measurements focused on electrostatic charging during homogenisation (plough share mixer) of a 1-ton premix containing either 0.2% or 20% of additive in pure carbonate, and electrostatic charging during pneumatic conveyance in the dense, pure additive phase.

The measurement apparatus were made specially for these trials by Poitiers University. The chargeability measurement section on the pneumatic circuit was 1 m in length and located at the end of the conveyor belt.

3.2. Results and comparison with laboratory measurements

For mixes with an additive content of 0.2%, charging by friction was mainly driven by the carbonate.

For mixes with an additive content of 20%, the additive may play a role up to the 20% mark. This means that, if the pure carbonate generates a charge Cs and the pure additive a charge Ca, then a mix consisting of 80% medium and 20% additive should generate a charge of 0.8Cs+0.2Ca. This rather simplistic reasoning only fits with a 'first approximation though; specifically, it takes no account of either mix homogeneity or the effects of reaction and dissipation between the two components. Nevertheless, this first approximation does appear to correctly describe the experimental results.

The principal results reveal that charge build-up in a mix with a 20% additive content (Figure 6) or during transport of a pure product on the pneumatic conveyor (Figure 7) could be predicted by a chargeability measurement made in the laboratory.

This last result is hardly surprising as this involves identical charge build-up processes. Note that a difference in the values was recorded however, with the laboratory piping giving a result that was nearly 3.6 times bigger.

Chargeability during flow along a pneumatic conveyor is an interface, or contact, phenomenon that occurs between the flowing powdered medium and the pipe walls.

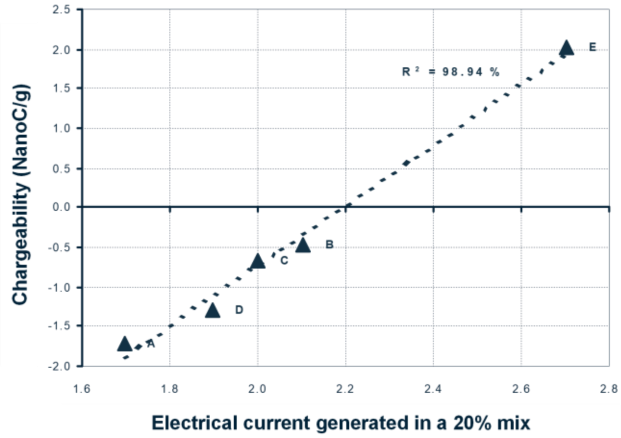

Figure 6: Change in the current generated with a 20% mix in carbonate in relation to the chargeability value measured in the lab

For pipes with a small cross-section, it may be safely assumed that the total quantity of product would come into contact (by being beaten or rubbed) with the metal wall; conversely, for pipes with a large cross-section (industrial), only part of the product would come into contact with the wall, while the central area would be hardly active in the chargeability process.

The above results suggest that in the industrial facility, no more than about 30% of the section of flowing product would actually come into contact with the wall.

The results revealed another possible relationship between chargeability and product distribution during the mixing process. This relationship was not confirmed, however, by additional tests performed on a pilot facility.

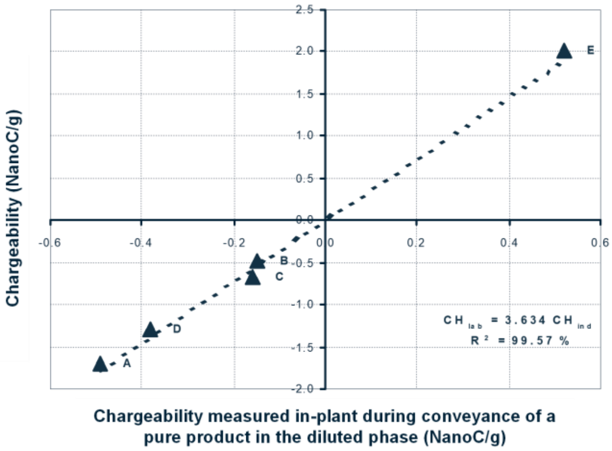

Figure 7: Change in chargeability measured at the industrial site in relation to the chargeability value measured in the lab

4. General conclusion

The laboratory measurements developed by the team led by M. Touchard can be used to predict electrostatic charging in an industrial setting during mixing and pneumatique conveyance.

Out of the thirty benchmark products, only two appeared to be capable of generating electrostatic risks.

On completing these tests, M. Touchard declared that he would like to carry out further investigations on this topic.

5. Bibliography

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