i'Tec_H9
May 2003

Keywords: Homogenisation, Additives, Segregating

Homogenisation of compound feeds: Definitions

Compared to a similar operation in other sectors, this operation has its own specific characteristics in terms of animal feed:

- it relates to a mixture of powders and a low percentage of liquid
- the powders are from organic or "chemical" sources and, therefore, have very different physical characteristics.
- it involves mixing powders, some of which are present in very small quantities, but which can be endowed with very high "biological "activity.

Therefore, controlling this operation is not easy. First and foremost it requires the use of a common vocabulary.

1. Concepts

1.1. Homogeneity and heterogeneity

The terms homogeneity and heterogeneity describe the status of the mix, they are defined by Gy (1988):

- **Homogeneity:** status of a batch of material in which all the component parts are (or rather would be) strictly identical to each other.
- **Heterogeneity:** status of a batch of material in which all the component parts are not strictly identical to each other.

These two extremely general notions apply to the "component parts of a batch of material". To be applicable in the animal feed sector, it is necessary to specify the nature of these component parts. This aspect is addressed by Danckwerts (1953), who states that the concept of mix quality must be defined in terms of a "level of scrutiny". In animal feed, this level equates to the daily feed intake for the particular animal. Consequently, the homogeneity of an animal feed can be defined as follows:

"The status of a batch of compound feed in which all the daily feed intakes for the animal for which the batch is intended, are identical to each other"

The "identical" nature of these daily feed intakes may be subject to tolerances.

1.2. Homogeneity and compliance

According to "Le petit Robert", "**compliance**" is the *nature of that which is of a similar form to that of a template or model*.
In our case, the template or model is the formula designed by the nutritionist and the similar nature is judged for the entire batch. However, the definition of compliance depends somewhat on the observer's interpretation. It may take account of the weighing operation (measuring), but also the unintended introduction of a product into the formula by means of cross-contamination.
Homogeneity and compliance are often confused. Figure 1 helps to clarify the significant difference between these two notions.

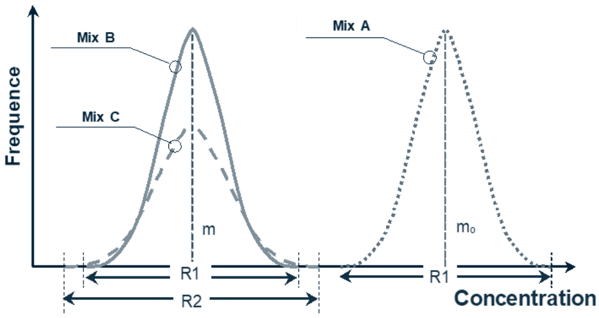

Figure 1: Homogeneity/Compliance comparison

If, for a given product, the desired feed should have an average m_0 and a distribution tolerance R1, mix A can be declared compliant and homogeneous. Mix B has the same distribution (R1), but the average is m instead of m_0. Therefore, it is homogeneous but not compliant. For mix C, the distribution is greater and the average is m instead of m_0. This mix is heterogeneous and non-compliant.

1.3. Mix and dissemination

Additives are liable to develop toxicity, either by their mere presence, or at a dose that is close to that at which they are used. This obliges livestock feed manufacturers to comply with a maximum of two requirements:

- additives must be distributed uniformly throughout the entire feed

- additives must only be present in the feed for the animals for which they are intended.

Moreover, animal feed involves mixtures of powders that have an almost natural tendency to separate. This is known as segregating.
The second notion makes reference to production by "successive loads", which almost all follow the same circuit. The products for a load can spread across the facility and be gathered by one or more other loads. There is therefore a source of **cross-contamination** between loads. Some authors, such as Beumer (1986), believe that these are the same phenomena that result in segregating and dissemination.
These two problems occur both in the case of macro-ingredients and of additives, but it is for the latter that they are the most acute.

1.4. Mixing and homogenisation

According to David (1985), **mixing** is *the operation resulting in the uniform and adequate mixing of the previously measured component parts of a formula*. The term mixing can also apply to the product resulting from the operation and this similarity can occasionally cause confusion. This is why, in terms of mixing, some people prefer to use **homogenisation**: ***an operation, the purpose or, otherwise, the effect of which is to make a batch of material homogeneous or less heterogeneous*** (Gy, 1988).
As a result, notions of quality play a part in the definition of mixing itself: " ... uniform and adequate ... ". These notions have been clarified even further by Jansen (1992) as, for this author, *the aim of the mixing operation is to homogenise different substances such that even the smallest quantities of the finished product contain quantities of products that comply with the composition of the mix*.

1.5. Segregating

During or after homogenisation, the mix may be subject to the influence of various factors that can increase its heterogeneity. This is known as **segregating**, but some authors use the term **segregation,** which Fischer (1960) defines as the *separation of mixed ingredients, during transfer, transport, mixing or the process*. Segregating is intrinsically linked to mixing and the factors that contribute to one work to the disadvantage of the other, and vice versa.
Six phenomena resulting in segregating have been identified. Three have been described by Bruxelmane (1978). "**Percolation**" equates to the falling of the finest particles through the "sieve" formed by the coarsest particles (Figure 2). "**Vibration**" relates to the rising of coarse particles under the effect of shaking to which the powder bed is subjected.
These two phenomena relate to formed powder beds (storage, meal being transported in a truck, etc.). Their main difference is the initial mixing stage: more coarse particles than fine ones for percolation, and vice versa for vibration, but both result in the presence of coarse particles on the top of heaps.

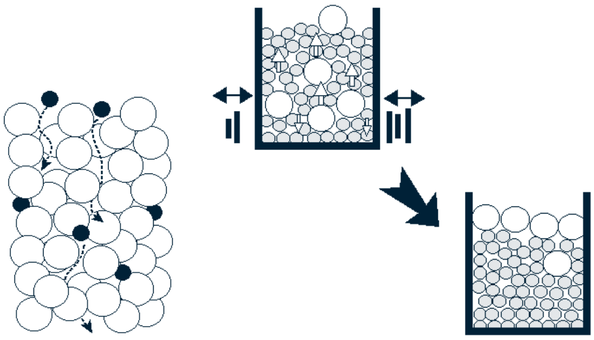

Figure 2: Segregating by percolation and vibration

The **angle of repose** phenomenon occurs as the powder falls to create a heap (Figure 3).

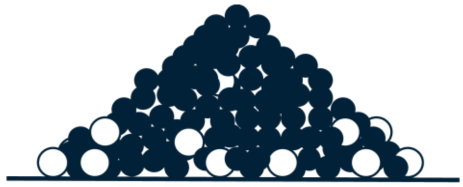

Figure 3: Segregating by the angle of repose

When a heap of powder forms, it must be borne in mind that its surface quickly becomes a kind of sieve through which small particles pass more easily than large ones. As a result, large particles will have more difficulties passing through a housing or settling, which is why many of them are found at the foot of the heap. This phenomenon occurs when products are loaded into a hopper or a truck (Kolher, 1987).
There are three other phenomena that, like the angle of repose, are caused by movements affecting the mix.
The trajectory effect occurs *when a particle is projected into a fluid at a certain initial horizontal speed, the coarsest and most dense particles fly further in a horizontal direction* (Williams, 1976). This phenomenon is illustrated by Axe and Behnke (1995) when it takes place at the end of a conveyor (Figure 4), but it can also occur in mixers with mobile linear speeds that are too fast. Consequently, any horizontal acceleration in the air and the range of differences in the air penetration of particles will increase the occurrence of this phenomenon.

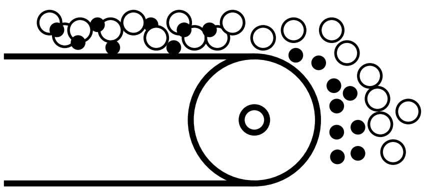

Figure 4: Segregating caused by the trajectory effect

"**elutriation**" is equivalent to the trajectory phenomenon but is vertical. Therefore, it occurs when a mix falls/drops. In this case, the particles will have different speeds, which will vary depending on their density, air resistance, etc., (Figure 5). Their arrival at different times creates segregating. It mainly occurs when mixes fall/drop in elevators, pipes, silos, etc.

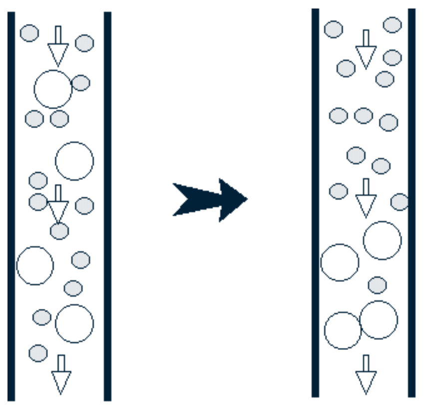

Figure 5: Segregating caused by elutriation

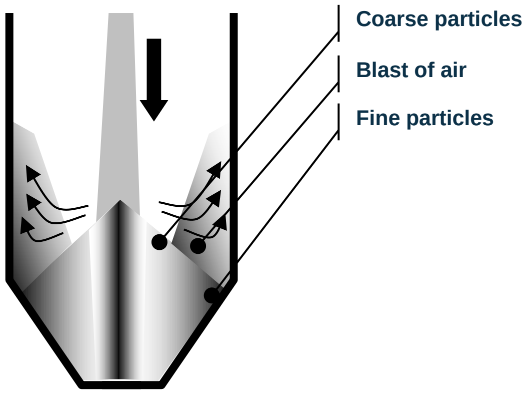

Figure 6: Segregating caused by an air blast wave

The air blast wave phenomenon is more complex and occurs when filling silos (Figure 6): *The falling flow of particles causes a downward flow of air, which bends round outside the main flow, runs along the walls and approaches the surface of the product introduced into the silo. The speed of this air flow decreases, from the centre, and fractions of fine powder, formed from particles of less than 100 µm, pushed by the air along the walls, drop down because of the loss of speed. According to this mechanism, fine particles gather along or close to the silo walls and coarse particles gather close to the centre*. (Enstad *et al*, 1993).

2. Products

2.1. Additives and micro-ingredients

McEllhiney (1994) defines **an additive** as being an *ingredient or a combination of ingredients added to a basic feed mix or a fraction of the latter, with the aim of meeting a specific requirement. They are conventionally used in micro-quantities and require a careful transfer of the mix.* ***Micro-ingredients*** *equate, for this same author, to vitamins, minerals, antibiotics, medicines and other products usually incorporated and weighed in small quantities*.
As a result, the definition of an additive is based on the notion of function, while that of a micro-ingredient is based on the notion of quantity (up to a maximum of 1 %).
According to Directive 96/51/EC, Additives are substances *or preparations that are used in animal feed in order to:*

- favourably influence the characteristics of raw materials for animal feeds or compound animal feeds or animal products, or
- satisfy the nutritional requirements of animals or improve animal production, specifically by influencing gastro-intestinal flora or the digestibility of animal feeds, or
- provide favourable component parts, in the feed, to achieve specific nutritional objectives, or satisfy the specific temporary nutritional requirements of animals, or
- prevent or reduce the nuisance caused by animal manure or improve the environment for animals.

2.2. Premixtures and premixes

The term **Premixture** is legally defined (Decree of 31/08/89) as being: *mixtures of additives with each other or mixtures of one or more additives with carrier substances, which are intended for the production of animal feed*.
These premixtures must be legally incorporated at a ratio of 0.2 % or above. This percentage can be reduced to 0.05 % for certain processes.
In reality, it is possible to regard the additives used by premixture manufacturers as already being premixtures or concentrates, according to Melcion and Janet (1992), of one or more active substances, with a **carrier** or **excipient** and, possibly, one or more binders. In this case, it is possible to talk about a **preparation** or concentrate, even though the use of these terms is in no way official.
To eliminate any confusion between substances or preparations containing substances, Rosen (1996) recommends that the term substance is *limited to active ingredients* and that the term preparation is used *for a product placed on the market in a diluted form to facilitate uniform mixing*.
The term **Premix** is also used. Premix derives from an English word and has no legal meaning. Fischer (1960) defines it as *a mixture of a key ingredient (the ingredient whose proper dispersal is essential for the mixture to be successful) with a fraction of another product, prepared in advance of subsequent mixing stages, with a higher quantity of this other product*. This particular definition is closer to that of a preparation. McEllhiney (1994)

considers that a premix is *a uniform mixture of one or more micro-ingredients with a diluent and/or a carrier. Premixes are used to facilitate the homogeneous dispersal of micro-ingredients in a larger mix*.
As regards operations, the term Premixture has been used to qualify the premixing manufacturing operation defined by David (1985) as being, not the product, but *the step enabling trace elements and micro-ingredients to be introduced to a carrier, which will be added to the final mix in accordance with the mixing rules*.

2.3. Other products

To assess the homogeneity of a mix, use is made of a component of the mix known as a **tracer,** for which the concentration in animal feeds is determined (McCoy, 1994). There are two types of these:

- **internal tracers**: a component of the formula
- **external tracers**: an external agent added to the formula

These tracers form the basis for assessing the homogeneity of a mix. They are introduced alone or in a premixture.
A preparation or premixture uses a "neutral" product in which the active substance is diluted. If no link is created between the two, this product is only an **excipient** or **diluent**. However, if the active substance is attached to this product, the term **carrier** is preferred (Larrabee, 1976).
This difference will have consequences as regards mixing behaviour because, when the active agent is *scattered as a solution in a carrier, the carrier can be viewed as the active agent. However, if the active agent is dry mixed with an excipient, it must be viewed differently and should be identified in the diluent* (Bloom and Livesey, 1953).

To distinguish the active substance (attached to a carrier or not) from everything around it, it is possible to use the notions of **environment** or **matrix**, which equates to everything that is not the active substance (which acts as a tracer or not) in the remainder of the formula. Like Lucke *et al* (1994), it is possible to assess the distribution of a target product in a set of products, which is then considered as being a single product.

3. Conclusion

The notion of mixing and the related definitions must be understood, in order to limit confusion and errors:

- mixing and premixture/premixing can be products or operations (homogenisation)
- homogeneity is not compliance with an expected concentration, even though a lack of compliance has a consequence when measuring homogeneity.
- a tracer is only an "active" substance: the copper in copper sulphate, for example.

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