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Segregating feedstuffs at industrial sites

In 1999, tests were carried out to establish the range for coefficients of variation for the feedstuffs considered the most heterogeneous on the market: laying hen feeds (Special Report No. 40). Up till then, feed homogeneity had only been studied at the level of plant output. This had made it impossible to establish a relationship between coefficients of variation, feed properties and the characteristics of the apparatus and equipment used during the tests. This study seeks both to assess whether the animal meals produced at six different plants segregate during manufacture between the mixer output (MO) and the plant output (PO), and to identify the physical or industrial parameters that could explain why segregation occurs.

1. Apparatus and equipment

Table 1 lists the equipment found between the two sampling points at each plant.

Equipment	Plants					
	1	2	3	4	5	6
Chain conveyor				X		
Elevator	X	X	X	X	X	X
Chain conveyor					X	
Distribution box				X		
Revolver system	X	X	X	X	X	X
Chain conveyor		X	X		X	
Revolver system					X	
Chain conveyor		X				
Distribution box						X
Cell	X	X	X	X	X	X
Worm screw		X	X			X
Chain conveyor	X		X		X	

Table 1: List of equipment making up the circuits between the two sampling points at the 6 plants under study

Each plant used the RF-blue lake microtracer, which was incorporated into the mixes via premixes introduced at variable dosages (from 5 to 10 kg/t) depending on the plant, with a targeted end concentration of 250 ppm.
The properties of the feedstuffs used for these tests (Table 2) revealed that while only two species were involved, this did not prevent a certain variability, particularly in terms of particle size. On the other hand, there was only minor variation in densities or angles of repose.

Plants	1	2	3	4	5	6
Type	Pig	Pig	Duck	Duck	Pig	Duck
Liquids (%)	0.77	0.02	0.41	0.22	0.44	1.3
Quantity (t)	2.2	4.4	4.0	2.0	5.0	2.5
D50 (µm)	645	489	397	584	561	896
Standard geometric deviation	2.15	2.14	1.96	2.18	2.19	2.27
Bulk density (g/dm^3)	504.5	634.0	588.2	652.7	588.3	609.5
Angle of repose (°)	55.8	53.3	52.7	54.2	49.8	51.5
Elutriation ratio	187.1	151.9	147.0	172.9	178.4	188.6

Table 2: Physical properties of the tested feedstuffs

2. Method

The premixes containing tracer were incorporated into the feedstuff via the plant's usual circuit, except for plant 5 where it was introduced directly into the mixer.
The first sampling point was located as close as possible to the mixer: at the conveyor output under the mixer.
The second sampling point was located at the plant output, at the time of loading into a truck.
The flow was cut in directions that differed from one sample to the next. The target sample number is 30. However, this may vary at each plant and each sampling point.
In most of the lab tests, alternate samples were halved using a riffle splitter, after which each sub-sample was analysed. In plants 1 and 4, all the samples taken at plant output were analysed. Where many samples were taken, every third sample was analysed.
Following the protocol described in Technical Datasheet No. 46, microtracer analysis was performed on samples taken in-plant and on samples taken after the elutriation test.
The elutriation test was performed on an average feedstuff sample based on the protocol described in Technical Datasheet No. 41.
The results of the microtracer analyses at each location were processed using a random model

analysis of variance.

Segregation was expressed in terms of the variation in CV $_{homogeneity}$ between plant and mixer outputs: a positive variation indicated that segregation had occurred.

3. Results

Plants	Mixer output	Plant output	Variation
1	3.4	11.6	+ 8.2%
2	4.0	5.1	+ 1.0%
3	2.4	2.6	+ 0.2%
4	5.7	8.3	+ 2.6%
5	9.5	13.2	+ 3.7%
6	16.0	18.0	+ 2.1%

Table 3: Findings of the 6 tests in terms of CV homogeneity for the range of these coefficients of variation

The findings of these tests regarding changes in $CV_{homogeneity}$ between the two sampling locations revealed a systematic increase (Table 3).

In four of the six cases, however, this increase was minimal. The mean change equalled 3%, i.e. similar to that recorded over 20 years ago by the IFF (1982), relating to CV $_{total}$: + 2.0% Deleting the result of plant 1, which has a significant effect on the mean, gives a new mean of 1.9%.

3.1. Relationship between physical and behavioural properties

The identification of elutriation ratios exposed the relationship between this ratio and the particle size properties of the tested matrices. Consistent with current insight into the behaviour of powders, it would appear that the coarser the matrix and the broader the particle size spectrum, the greater the dissociation of the microtracer (Figure 1).

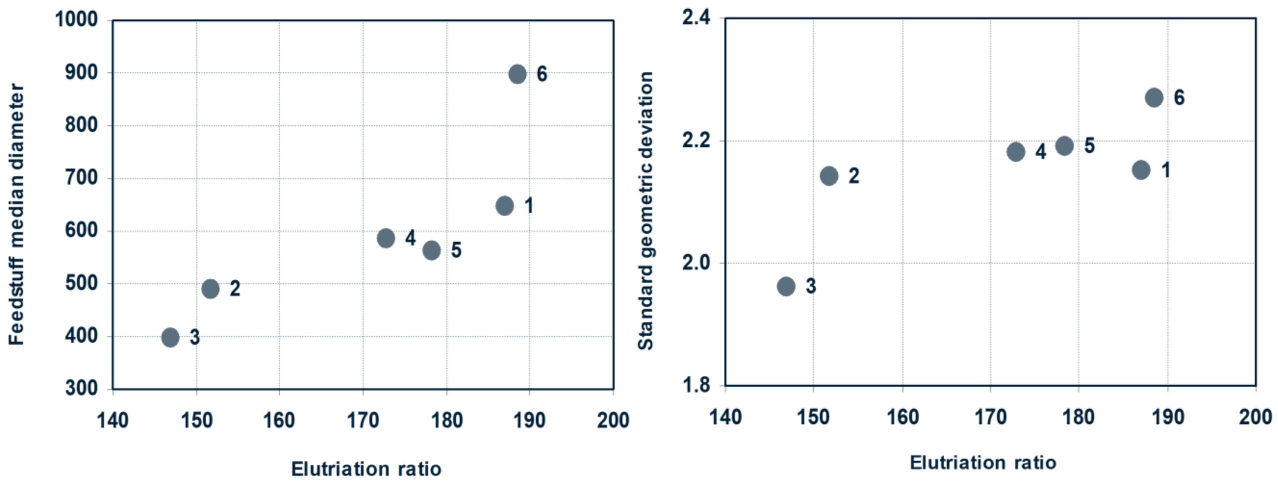

Figure 1: Relationship between the elutriation ratio for the RF-blue lake microtracer and the feedstuff median diameter (left) or feedstuff standard geometric deviation (right)

3.2. Homogeneity at mixer output

No relationship was identified between this industrial datum and the feedstuff's angle of repose or bulk density. A trend was observed, however, in the feedstuff's median diameter, confirmed to a certain degree by other, previously reported, industrial results (Figure 2). This suggests that a feedstuff with a small particle size could facilitate homogeneity during the mixing process. This would make sense as reducing the feedstuff's particle size would bring it closer to that of the additives incorporated into it.

A much clearer relationship, largely confirmed by other industrial tests, can be seen with the geometric standard deviation, which depicts the range of the particle size spectrum (Figure 3). Only 4 test results out of 12 diverge from the pattern whereby the homogeneity of the matrix size spectrum (small standard deviation) would help to improve final mix homogeneity.

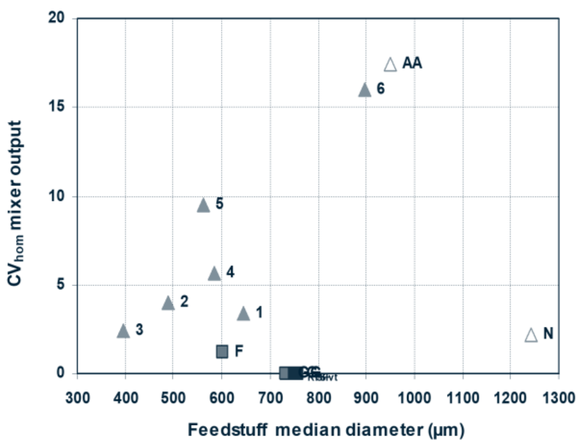

Figure 2: Relationship between CV $_{homogeneity}$ at mixer output and feedstuff median diameter

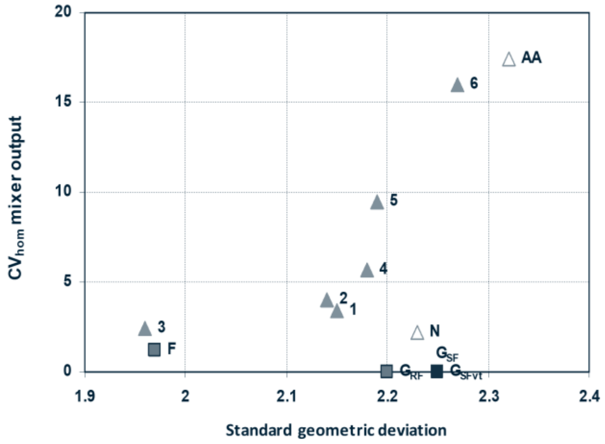

Figure 3: Relationship between CV homogeneity at mixer output and feedstuff standard geometric deviation

A linear trend was observed based on 5 points out of 6 between the elutriation ratio and CVhomogeneity at mixer output (Figure 4). Given the relationship between the elutriation ratio and matrix particle size data (see **Figure 1**), this is a logical result. It is not clear whether the elutriation-driven separation is responsible for this homogeneity defect on mix completion, nor to what extent it affects matrix particle size distribution. However, the elutriation behaviour measurement is not unrelated to possible segregation in the mixer due to a trajectory effect (see Technical Datasheet No. 4).

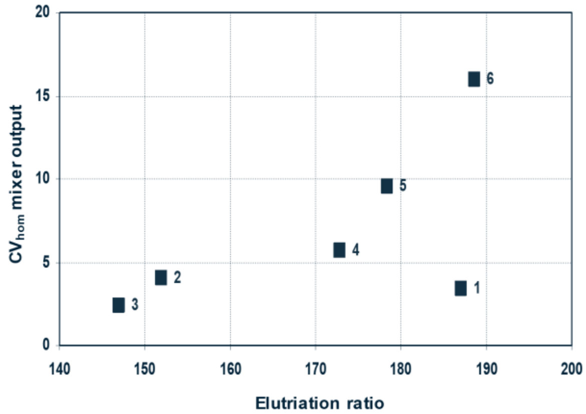

Figure 4: Relationship between CV homogeneity at mixer output and feedstuff elutriation ratio

3.3. Segregation

No relationship was identified with bulk density, illustrating that the differing densities of the microtracer and the feedstuff cannot explain microtracer behaviour on dispersion.

A relationship was identified, however, between the variation in CVhomogeneity and feedstuff median diameter. Figure 5 demonstrates that as the median diameter increases, so does the level of segregation. The only result that deviated from this apparent relationship was that of plant 6, which used a feedstuff that contained wheat incorporated in its "crude" state.

As with the mixer, a relationship was sought with the spread of the particle size spectrum assessed by the size of the geometric standard deviation, but the related graph did not show any evidence for such a relationship.

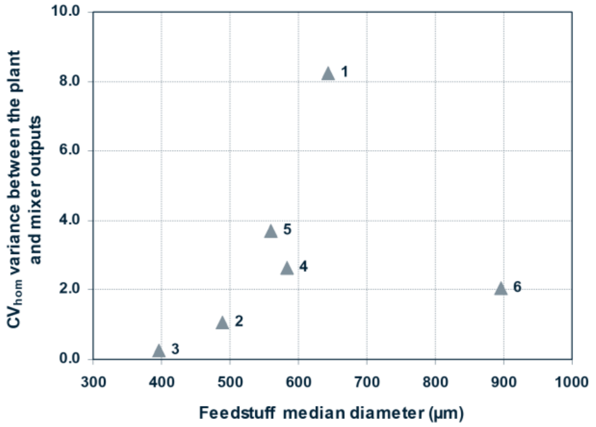

Figure 5: Relationships between feedstuff median diameter and CVhomogeneity variance over the 6 tests

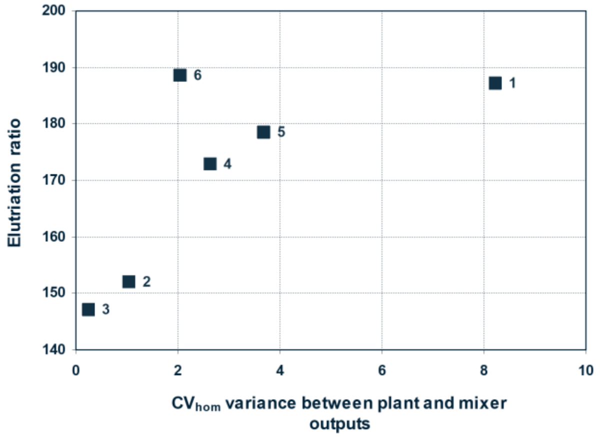

Figure 6: Relationship between elutriation ratio and CVhomogeneity variance over the 6 tests

There was evidence, however, of a relationship between the elutriation assessment in the lab and the change in CV homogeneity at the plants (Figure 6).

The deviation of feedstuff 6 from the general model derived from the other results appeared meaningful. This model indicates that the elutriation measurement taken on feedstuff 6 would predict a risk of segregation. In view of the above comment on the presence of crude wheat grains, the test portion was put through a 2-mm sieve in order to remove this particle size, after which the elutriation test was repeated on the smaller-sized test portion.

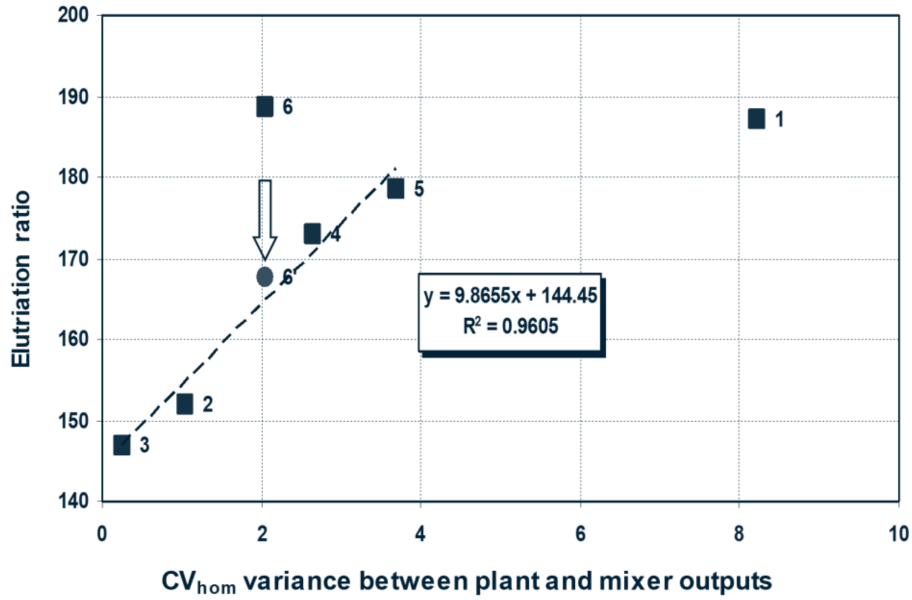

Figure 7: Relationship between the feedstuff elutriation ratio and $CV_{homogeneity}$ variance over the 6 tests following sieving and follow-up measurement of the elutriation ratio for feedstuff 6

After this operation, the plot point for feedstuff 6 migrated (Figure 7), directly aligning it with the relationship previously established by the other feedstuffs. This suggests an excellent linear relationship (R^2 = 0.9605) between the elutriation ratio (below 180 for the RF-blue lake microtracer) and the variance in $CV_{homogeneity}$. The line then bends around the 200 limit obtained with the method.

4. Conclusion

These industrial tests revealed that segregation does indeed occur between the mixer output and the loading area at all sites. In 5 out of 6 cases, this segregation can be considered reasonable. The mean increase in the coefficient of variation is 3%, and 1.9% if site 1 is considered unacceptable. This mean is comparable to that of the +2.0% observed by the IFF (1982) at over 150 plants, based on the CV_{total} determined using the methyl violet method.
While no industrial parameter could explain this segregation, it would appear that homogeneity is already affected by the feedstuff size spectrum at mixer output. This effect also acts on the increase in the coefficient of variation during segregation.
It is possible that an association between a low elevator rate and a coarse particle size spectrum helps to promote segregation, which would support previous observations made by Jansen et Friedrich (1982); however, having been based on a single plant, this observation can only provide limited insight pending other test results.

The effect of particle size and distribution is also evidenced through the elutriation ratio which, following these tests, proved to be a good candidate for predicting a product's segregation behaviour in an industrial setting.

5. Bibliography

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