

## Establishing decontamination scales via the pelleting of pig, laying hen, broiler and turkey feeds

European regulations 183/2005 of 12/01/05 and 2160/2003 of 17/11/03 are driving the animal feed sector to strengthen its control over the risk of salmonella infection. This legislation was incorporated into French law under the order of 23 April 2007, which focuses specifically on the treatment of feedstuffs destined for breeding laying hens. The requirements laid down in these regulations may eventually apply to other types of animal feed intended for other monogastric species (broiler, turkey, pig). A programme has been set up to help industrials meet these requirements by demonstrating and establishing the conditions for ensuring bacteriolysis during standard pelleting operations on these four feedstuffs. Phase 1 of this programme seeks to identify which pelleting parameters ensure the destruction of the enterobacterial flora found on a pilot press, i.e. which parameters can achieve a 3-log reduction in feed contamination and obtain feeds that contain less than 1000 enterobacteria per gram at the cooler output. In addition to providing a means for circulating these scales, this datasheet also explains the method used to establish them and how they can be of use to industrials.

### 1. Principle

The tests used to establish these scales consist in:

- pelletising batches of broiler, turkey, pig and laying hen feed at a constant rate and at five different temperatures at the conditioner output, using five different die thicknesses (i.e. 5 different residence times in varying dies).
- taking samples earmarked for pre-treatment microbiological analysis, post-steam injection and post-pelleting, at the pilot cooler output.
- sending the samples to the testing laboratory under controlled conditions.
- running the results through a statistical analysis in order to identify the minimum temperatures and die residence times that ensure a satisfactory level of decontamination.
- using the statistical results to construct a scale showing die residence time / required temperature at conditioner output for each feedstuff.

### 2. Equipment and apparatus

#### 2.1. Feedstuffs

The feedstuffs used for the tests were all produced at the same time. The broiler and turkey feeds consisted mainly of wheat. The laying hen feed mainly comprised maize with an 8.5% carbonate content in the form of meal. The pig feed mainly comprised wheat and barley.

The physical feedstuff measurements (Table 1) distinguished two main feed categories. Pig and laying hen, on the one hand, which have smaller particle sizes and flow less smoothly. Broiler and turkey, on the other hand, which have larger particle sizes and flow more easily.

	Pig	Laying hen	Broiler	Turkey
Median diameter ( $\mu\text{m}$ )	542.0	515.6	656.3	635.4
Bulk density (g/l)	628	685	629	607
Angle of repose (flow) ( $^\circ$ )	65.0	65.7	63.7	58.9

Table 1: Physical properties of the feedstuffs

In order to ensure a sufficient level of initial contamination, these feedstuffs were subjected to secondary contamination by incorporating waste from the mill scourer into the mix. This waste contained  $5.10^6$  enterobacteria per gram and was incorporated into the feedstuffs at a ratio of 1% in order to ensure a contamination level of  $5.10^4$ .

#### 2.2. Pelleting and cooling apparatus

The line used for these tests comprised:

- a hopper with feed screw flow control
- a 'standard' conditioner ' with length 80 cm and width 15 cm
- an 11-kW rotating ring die with 5 dies
- temperature probes fitted in the ambient environment, at the feed hopper output, at the conditioner, and at the press output for sampling pellets on an ad hoc basis.

A power sensor and a data acquisition card were used to track the various temperatures and power demands at the level of the press. The steam rate was also recorded.

7-L vertical pilot coolers were also used to dry the samples taken at the press output.

### 2.3. Sampling and packing apparatus

The samples were taken using disinfected metal shovels, and then placed in sterile bags and stored in a cold room at +4°C. The samples were then repacked using disinfected riffle splitters and sent to the testing lab in polystyrene boxes kept cold with frozen eutectic packs.

## 3. Method

### 3.1. Experiment plan

These tests studied the effect of 3 factors: the type of feedstuff, the compression rate and the setpoint temperature at the conditioner output. This was done by developing a "central composite design" specific to each feedstuff experiment plan (Figure 1).

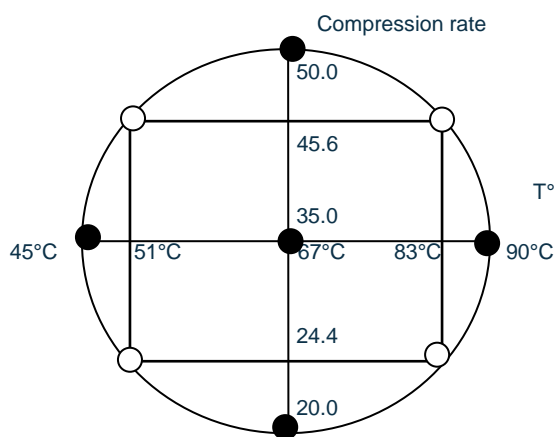


Figure 1: Applied central composite design

This involved a factorial design (white points) to which were added five experimental points (black) that swept the whole of the defined experimental area. The central point was repeated several times in order to take account of how outlying parameters impact on the results (repeatability test). This design minimised the number of tests that needed to be performed on the defined area.

### 3.2. Establishing the parameter settings

The flow rate applied during the tests (280 kg/h) was selected to match up the residence time obtained with the 4-35mm die (central point) with the plant-estimated median residence time of 4 s. (Table 2). Given that the residence time depends on the weight and flow rate of the feedstuff in the die at time  $t$  (residence time = weight of the pellets in the die in grams / flow rate in grams per second) and that the weight of the feedstuff in the die is a known quantity, the flow rate can be calculated.

Temperature Conditioner output (°C)	Die thickness (mm)	Flow rate (kg/h)	Die residence time(s)
45	20	280	2.3
51	24.4	280	2.8
67	35	280	4.0
83	45.6	280	5.3
90	50	280	5.8

Table 2: Pelleting parameters

### 3.3. Test set-up

The first sample to undergo microbiological analysis was taken from each pre-treatment feedstuff batch at the hopper intake. The press was then switched on and operated with native feedstuff until the pelleting settings had stabilised. The various batches were then pelleted at the planned settings. Over the course of a 15-minute sampling phase in each test run during the pelleting operation, three 150g samples were taken at the conditioner output, placed in sterile bags, and then cooled in a cool-box in contact with eutectic packs at +4°C. Three 1-kg samples were also taken at the press output and placed in a pilot cooler. Once dry, an average sample was taken in the cooler in the form of quartered sub-samples. The samples were then packed into sterile containers and sent to the testing laboratory under cold conditions. The lab identified the enterobacterial flora according to standard NF V08 054 at 37°C.

## 4. Results

### 4.1. Broiler and turkey feeds

The microbiological results underwent multiple linear regression statistics processing in order to identify models that could be used to predict the enterobacterial decontamination rate (ET-SR) for each feedstuff, and the final enterobacterial contamination rate according to the temperature at the conditioner output and the thickness of the pilot die, which correlates directly with residence time in the die. The models were shown as isoresponse curves.

The first step in establishing the scales involved deciding which of the 2 models to use. For these two feedstuffs, the predictive decontamination model (ET-SR) was selected as it provided the most stringent conditions. The next step was to define which isoresponse curve to follow in order to achieve the fixed objectives. An initial scale, with no margin, was developed using the 3-log curve. This scale, referred to as the scale with no margin, is generally sufficient to obtain adequate decontamination.

In order to take account of the variability of test results, and to ensure that the feeds achieved a 3-log decontamination rate 95% of the time, a second scale was established based on an isoresponse curve whose confidence intervals indicated that the objectives were reached 95% of the time. In this scale, referred to as a scale with margin, broiler feed corresponds to the 4.5-log  $\sphericalangle$  curve, and turkey feed to the 4-log  $\sphericalangle$  curve.

Before these scales can be used at industrial animal feed plants, the residence times corresponding to the various pilot die thicknesses have to be established. These residence times were determined following the programme's phase 1 tests, revealing a straight-line correlation between residence times and die thickness (Figure 2).

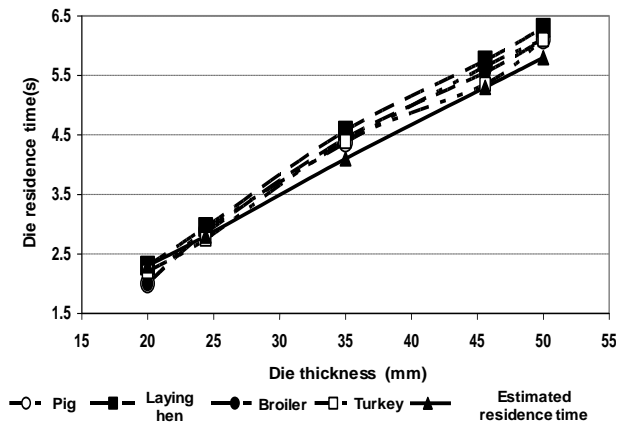


Figure 2 : Relationship between pilot die thickness and residence time

Pilot die thickness (mm)	Die residence time(s)	Scale with margin ( $\sphericalangle$ 4.5 log)	Scale with no margin ( $\sphericalangle$ 3 log)
		Temperature at conditioner output (°C)	
20.0	2.0	87.0	77.5
22.5	2.5	88.0	
25.0	2.9	88.5	79.0
27.5	3.3	89.0	
30.0	3.7	89.0	79.5
32.5	4.1	88.0	
35.0	4.4	87.5	78.0
37.5	4.7	86.0	
40.0	5.0	84.5	74.0
42.5	5.2	82.5	71.0
45.0	5.5	80.0	67.5
47.5	5.8	77.0	61.0
50.0	6.1	72.5	T° minimum de 45°C

Table 3: Broiler feed decontamination scale

Once both scales had been established, three zones could be seen on

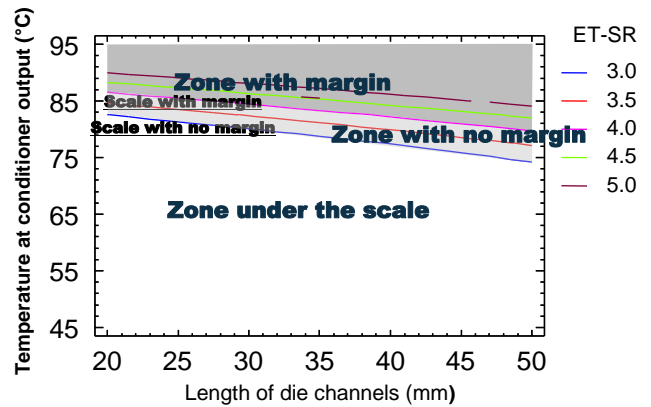


Figure 4 and Figure 3. If the pelleting conditions match up with the zone-with-margin, there would be a strong chance of achieving the required decontamination targets. The zone with no margin corresponds to application of the conditions between the two scales.

Figure 3 : Turkey feed decontamination zones

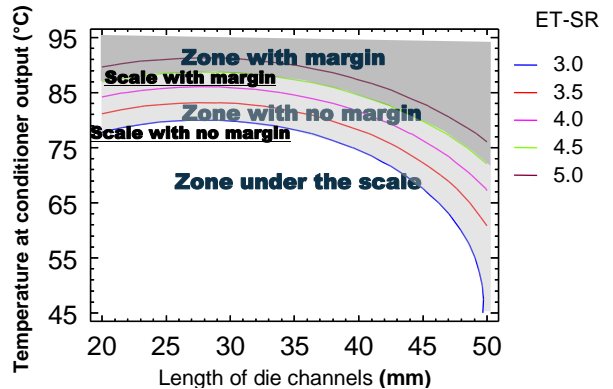


Figure 4 : : Broiler feed decontamination zones

Pilot die thickness (mm)	Die residence time(s)	Scale with margin ( $\sphericalangle$ 4 log)	Scale with no margin ( $\sphericalangle$ 3 log)
		Temperature at conditioner output (°C)	
20.0	2.2	86.5	82.5
22.5	2.5	86.0	
25.0	2.8	85.5	81.0
27.5	3.2	85.0	
30.0	3.6	84.5	80.0
32.5	4.0	84.0	
35.0	4.4	83.5	79.0
37.5	4.6	83.0	
40.0	4.8	82.5	77.0
42.5	5.1	81.5	
45.0	5.3	81.0	75.5
47.5	5.7	80.5	
50.0	6.1	80.0	74.0

Table 4: Turkey feed decontamination scale

While it is possible to achieve the decontamination targets, there is nevertheless a residual risk. The last zone (the under scale zone) corresponds to application of parameter settings that fall short of the

recommendations. In this case, there is little chance of achieving the decontamination targets. Table 3 and Table 4 illustrate these curves and zone limits in the form of scales.

## 4.2. Pig and laying hen feeds

These two feedstuffs do not react to the die in the same way as the broiler and turkey feeds, meaning that the procedure used for the two previous feeds cannot be used to establish reliable scales. In this case, another procedure has to be followed that takes account of the strong heating of pig and laying hen feeds in the dies. This consists in:

- predicting the pellet temperature that has to be reached at the die output in order to ensure adequate decontamination.
- using a second model to predict the conditioner output temperature to be applied to a given die thickness in order to reach the desired die output temperature.

### 4.2.1. Pig feed

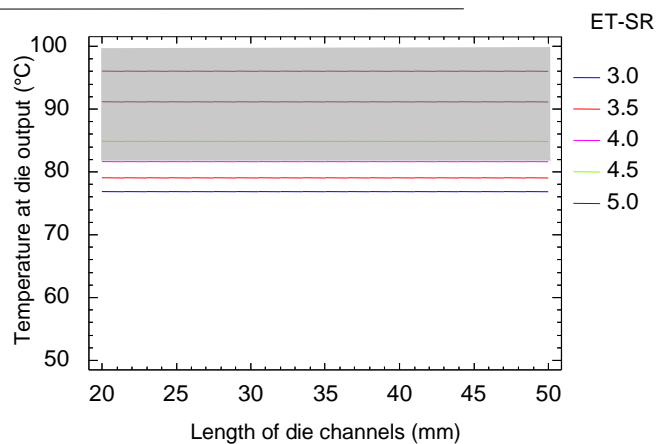
Two models were developed for the pig feed in order to determine the pellet temperature that needs to be reached at the die output in order to meet the two-fold objective concerning enterobacterial flora. The first step involved re-establishing which model to choose. The first model (ET-SR), which is most stringent, was selected.

**The scale with no margin was established based on the 3-log  $\alpha$  isoresponse curve (bottom curve,**

Figure 5). The model revealed that, generally speaking, a pellet temperature of 77°C ensures adequate decontamination.

**Note that it is problematic to recommend a given pellet temperature as this often varies in industrial settings. This led to the development of a second model used to predict the temperature at die output according to the stimulated parameters (**

Figure 5).

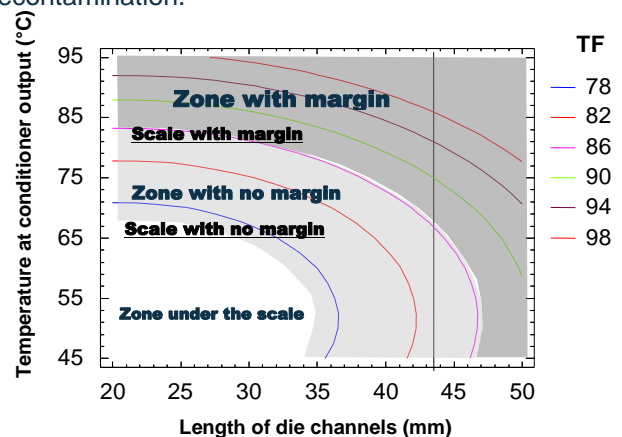


**Figure 5 : Temperature at die output required to ensure the destruction of enterobacterial flora in pig feed**

The "77°C" curve, shown by the shaded limit marked "scale with no margin" on

Figure 6, was used to determine which pelleting conditions would ensure a temperature of 77°C at the die output. This established the scale with no margin (Table 5).

Two margins were applied in order to fix the second scale. The first margin indicates that, in 95% of cases, the pellet temperature allows adequate decontamination.



**Figure 6 : Zones de décontamination de l'aliment porc**

Thickness of the related pilot die (mm)	Die residence time(s)	Scale with margin (≈4-log ⇒ 86°C at die output)	Scale with no margin (≈3-log ⇒ 77°C at die output)
		Temperature at conditioner output (°C)	
20.0	2.0	83.5	
22.5	2.5	83.0	68.0
25.0	3.0	83.0	
27.5	3.3	82.0	
30.0	3.7	81.0	64.0
32.5	4.0	80.0	
35.0	4.4	78.5	52.0
37.5	4.7	75.5	
40.0	5.0	72.5	
42.5	5.3	69.0	
45.0	5.6	61.0	T° minimum of 45°C
47.0	5.8	53.5	
> 47.0	> 5.8	T° minimum of 45°C	

Table 5 : Pig feed decontamination scale

This first margin corresponds to the 4-log ≈ decontamination curve which requires a die output temperature of 82°C (shaded limit in

Figure 5). The second margin is applied to this temperature in order to identify which conditioner output temperature is sufficient to achieve a 95% decontamination rate on a given pilot die. This second margin corresponds to the 86°C curve in

Figure 6 (scale with margin). Taken together, these margins were used to establish the scale with margin shown in Table 5.

### 4.3. Laying hen feed

Laying hen feed was processed in a similar way to the pig feed. This procedure, however, used a predictive feed decontamination model that was more stringent on dies with lower compressive power, in contrast to the predictive feed

decontamination model at cooler output, which was more stringent on dies with the highest compressive power.

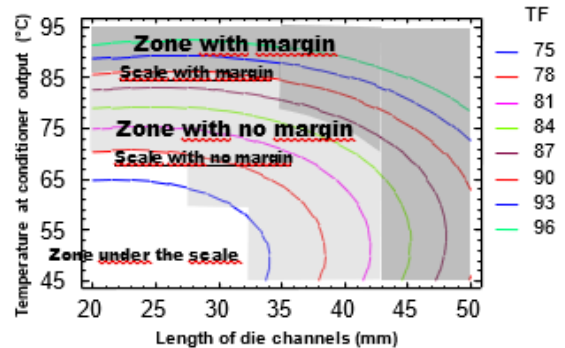


Figure 7 : Laying hen feed decontamination zones

Thickness of the pilot die (mm)	Die residence time(s)	Scale with margin	Scale with no margin
		Temperature at conditioner output (°C)	
20.0	2.3	85.0	70.0
22.5	2.7	85.0	
25.0	3.0	84.0	69.0
27.5	3.4	84.0	
30.0	3.8	83.0	61.0
32.5	4.2	83.0	
35.0	4.6	79.0	
37.5	4.9	77.0	
40.0	5.1	75.0	
42.5	5.4	71.0	T° minimum of 45°C
> 42.5	> 5.4	T° minimum of 45°C	

Table 6 : Laying hen feed decontamination scale

Both models were therefore selected according to the type of die used: the first model was used for dies with thickness between 20 and 43 mm, and the second model for thicker dies. To establish the scale with no margin, the 3-log ≈ isoresponse curve taken from the ET-SR model, and then the 3-log curve from the SR model, were followed in order to identify the target pellet temperatures for each die. The predictive pellet temperature model was then applied (Figure 7). To establish the scale with margin, the 4-log ≈ curves taken from the predictive decontamination model and the 2-log from the predictive contamination model at cooler output were selected. These precautionary measures were supplemented by the margin allowed for the predictive temperature model, from which was developed the scale with margin illustrated by the lower limit of the zone with margin (Figure 7). Table 6 shows the final scale for laying hen feeds.

It is important to note, however, that the heating of this feedstuff in the die is mainly due to the formula's calcium carbonate content in the form of meal. This

scale should therefore be selected for feedstuffs that share the same characteristic. Otherwise, it is recommended to use the broiler feed scale.

## 5. Applying these scales to industrial production lines

It is essential to establish feed residence times in the press die in order to be able to adapt these scales for use on an industrial line. This requires the collection of certain data:

- Number of die channels
- Compressive die thickness
- Weight of 1 cm of pellets
- Instantaneous pelleting rate, i.e. the quantity of feed that actually passes through the die per unit of time

In this case, the residence time corresponds to the ratio between the weight of the pellets in the die and the instantaneous flow rate (see Technical Datasheet No. 67). Once the scale has been selected and the residence time established, the temperature required at the conditioner output can be read off the scale.

## 6. Conclusion

These scales have undergone 84 validation tests at various industrial sites. These tests demonstrated that the scale with no margin is often sufficient for both broiler, turkey, pig and laying hen feeds. For broiler feeds, a test performed using the scale with no margin suggests recommending a minimum packing temperature of 68°C, irrespective of the die residence time.

Care should be taken with laying hen feeds, as industrial sites are not used to pelleting this type of feedstuff and the pelleting conditions applied during the tests were not fully optimised.

Pelleting rates for pig and laying hen feeds were lower than for broiler feeds, which explains the fairly long die residence times. Industrials do not, therefore, have to make any major changes in order to apply the scales, and the results tend to demonstrate the effectiveness of the scale with no margin due to strong heating in the dies.

These industrial on-site validations offer a positive indication, but are not 100% significant. Each industrial will therefore have to adapt these scales for use with their own lines, and confirm their effectiveness under the chosen pelleting conditions.