Decontamination effect of a pilot pelleting process on broiler feed

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In human food, contamination by salmonellae is one of the primary causes of food poisoning. Politicians are highly vigilant with regard to this public health problem which has an impact on businesses (Beumer, 1992). Authors such as König (1995) maintain that salmonellae serotypes are transmitted by animal feed to animals and then to humans. In order to reinforce management of the salmonellae risk in animal feed, regulation EC 2160 edited in 2003 stipulates that feed for monogastrics, first in line being feed for broilers must be taken into account here.
The traditional animal feed pelleting process (David et Lefumeux, 1972) consists of mixing the feed into meal under steam in a conditionner, before transferring the mixture to a pelleting press. When it is removed from the conditioner, the mixture is added to the pressing chamber where it passes through the rotary die pierced with three radian cylindrical ducts, and from where it is pushed outside by rollers. A knife cuts the pellets to length at the periphery of the die as it rotates. Further to shaping, the pellets are cooled.
This is therefore a thermomechanical process which combines the effect of steam with that of shearing on all of the components making up the feed. Microorganisms, such as salmonellae for example, may be present, often rarely, in this meal and processing may have a depressive action on the flora. This decontaminant effect is presumed as the prevalence of salmonellae in the pellets is lower than that revealed in meal (Veldman *et al*., 1995). Davies *et al*. (1992) show that out of almost 450 meal samples, 8% are contaminated by salmonellae compared to 3.4% for the 1,060 pellet samples tested. A study led by Prio *et al*. (2000), shows that the percentage of contamination of raw materials by salmonellae has a clear influence on contamination of meal feed. This relationship does not exist for pelleted feed and final contamination of the pellets would appear to result from recontamination in the cooler, truck or silo.
Salmonellae detection is nevertheless difficult due to the heterogeneity of their distribution in feed (Hansen and Israelsen, 1997). Microbiologists therefore took an interest in the use of indicators to detect the probability of presence of salmonellae. According to Veldman *et al*. (1995), Enterobacteriaceae are an effective salmonellae contamination marker. In order to study the effect of thermal treatment on salmonellae, a number of studies were conducted on the effects of these treatments on Enterobacteriaceae. Veldman *et al*. (1995) thus show that an increase in pelleting temperature from 60°C to 80°C reduces the number of Enterobacteria after treatment from 3.4 to 1.1 log/g. Even if other studies (Cox *et al*., 1986, Beumer, 1992, Riemann *et al*., 1995) show that pelleting leads to a reduction in Enterobacteria of 2 to 7 log, none propose tables indicating Enterobacteria decontamination achieved according to the gradual increase in treatment constraints. In the same way, few studies take the type of feed or the time during which the feed is subject to shearing, namely retention time in the die, as parameters that may have an influence.
This study was conducted in the aim of helping manufacturers to obtain a certain level of decontamination in feed in manufacturing processes, without having to invest in more costly treatment processes, and this in application of French law targeting feed for laying hens for breeding flocks. The decontamination objective was therefore defined by the French legislator. The treatment applied must demonstrate its ability to reduce Enterobacteria contamination by 3 log and the possibility of obtaining a final population of less than 1,000 Enterobacteria/g feed after cooling. The final objective of this study was therefore to define treatment scales combining retention time in the die and pelleting process temperature to achieve such Enterobacteria decontamination levels in broilers feed.

Materials and method

The principle of these tests is to study, at pilot level, the effect of pelleting conditions on Enterobacteria contamination in feed. The two parameters studied were meal steam treatment temperature before entry in the press and the thickness of the die plate compacting the meal into

pellets. At a constant flow rate, the thickness of the die plate governs retention time of the feed in the die for compacting into pellets.
The feed used for these trials is for broilers. The apparus used are a mixing material, a pelleting line, sampling material and sample packaging material. The feed formula of the broiler feed is wheat-based and contains 3 % soya oil (656 µm).
To ensure a minimum level of contamination in feed prior to treatment, 1% mill waste contaminated by 5.10^6 Enterobacteria/g was added to the feed. The feed/waste was mixed in a 224 litres double ribbon mixer.
The pelleting line used in these tests comprises four main elements. The feed hopper, upstream of the line, is where the feed is transferred to the press. A worm, of which the speed is adjustable, is located at the bottom of the hopper and feeds the press at an adjustable flow rate. The conditioner is a cylindrical compartment which ensures meal-steam mixing for 6 second periods. The steam is injected at the inlet at a pressure of 2 bars. Within the conditioner, blades tilted at 15° and attached to a rotating axis stir the feed and ensure that the mixture is homogeneous. A sensor placed at the outlet measures the temperature acquired by the feed. The sensor is the first element of a regulation loop which commands a valve, in turn regulating the steam flow rate according to the final expected temperature. The feed is shaped into pellets in the rotary ring die, which is under the conditioner. It comprises a ring die with ducts, and two rollers placed and attached at the centre of the die, which exert friction on the plate. The meal is compacted between the rollers and the die. Plastic deformation takes place turing the meal into a continuous rod. Knives at the periphery of the system cut the rods to length as one-centimetre pellets. The Meccanica press used in this study has a pelleting capacity of 50 to 800 kg/h. The die plates used in these tests have 624 ducts, 4 mm in diameter, of which the length, corresponding to the thickness of the die plate, is between 20 and 50 mm according to the retention time desired.
Line instrumentation includes T-type thermocouple temperature sensors installed outside the conditioner (regulation loop temperature setting), in the hopper (temperature of the feed prior to pelleting) and outside the line (ambient temperature). A power sensor is installed on the motor and a flow metre on the steam incorporation circuit. A computer connected to the acquisition system makes it possible to monitor and record the granulation conditions continuously. In order to measure the press flow rate and the temperature of the pellets when they come off the press, a stop watch, scales, isotherm vessels and three manual temperature sensors are used. The pellet samples are cooled and dried on individual coolers against a seven litre counter-flow when they come out of the press. Metal shovels are used to take samples before and after treatment. The shovels and coolers are disinfected using an agrifeed disinfectant (sorbic acid and ethyl alcohol mixture) and a scourer blowing hot air at 440°C. The samples taken are placed in sterile bags and refrigerated at +4°C. Test samples are prepared from the samples taken using riffle samplers.

Table 1: Values of the parameters studied in the test

Die plate thickness (mm)	Conditioning temperature (°C)
20	67
35	45
35	67
35	90
50	67
24	51
24	83
45	51
45	83

The experiment design selected for these tests was established on the basis of a composite central design with repetition of the central point (Goupy J., 2006). The test area (temperature 45 to 90°C and die plate thickness 20 to 50 mm) initially defined is traced and the number of tests reduced (14 tests per feed). Repetitions of the central point, over the whole test period, make it possible to test any potential day effect as the tests tooks place over six weeks. Table 1 indicates the pelleting parameters tested. At an identical flow rate, retention time of the feed in the die

(Retention time = pellet mass in die / pelleting rate) increased according to the quantity of feed present in the die and therefore according to the length of the ducts. All tests applied a pellet yield of 280 kg/h (+/-5 kg/h). At this rate, retention time of the feed in the die is estimated at 2.3 s. for the 20 mm die plate and 5.8 s. for the 50 mm die plate.
For each test, a mixture of 170 kg of feed and 1% mill waste was prepared one week before pelleting. Contamination of at least 10^4 Enterobacteria per gram of feed was thus expected. The samples for microbiological testing and moisture content measurements were taken on the morning of the tests from various parts of each mixture. The sampling material is disinfected between each batch of feed.
The pelleting tests are organised so that one die is tested per day. One day of pelleting therefore involves evaluation of various conditioning temperatures for the same die. The press flow rate is checked at regular intervals by weighing the mass of pellets produced in one minute, and is readjusted where required. Finally, the temperature of the pellets leaving the press is measured several times by sampling one kilogram of pellets in an isotherm vessel in which a T-type thermocouple is placed. When the same temperature is read on several samples, pellet heating in the die is considered to be stable. Following stabilisation of the pelleting conditions, three 1.5 kg samples of pellets are taken from the press at regular intervals, over a 15-minute period. After each, 130g of meal is sampled from the conditioner in order to determine the Enterobacteria load after steam treatment alone. The sampling material is disinfected between each trial. Pellet temperature is measured between the three series of samples and the flow rate is checked midway through this phase. The samples taken from the conditioner are cooled immediately at +4°C and the samples taken from the press are placed on pre-disinfected coolers. Four pellet samples are taken from the cooler and are placed into sterile bags fifteen minutes at least after the end of the test. A sample is also taken in order to determine final pellet moisture content. The remainder of the pellets is set aside for durability measurements. The samples for microbiological testing and moisture content measurements are stored at +4°C after the end of the test.
The conditioning temperature is readjusted where required and a new stabilisation phase is implemented before carrying out the next test.
The samples are reconditioned for sending to the laboratory. The samples are grouped and divided in order to have one sample per feed per day prior to treatment and one sample from the conditioner and the cooler per test. Reconditioning carries a risk of recontamination of feed. The material is therefore disinfected between each grouped series and sample separation. The samples are stored at +4°C ready for sending to the test laboratory in their isotherm packing. An indicator placed in the parcel controls the absence of a rise in temperature of the products during transport. Finally, the tests carried out by the laboratory include Enterobacteria count according to standard NF V08 054 with incubation at 37°C on 20 g of meal or pellets.
Statistical processing of the results by multilinear regression using the statgraphics software, was applied in order to generate two types of models for predicting, firstly, final Enterobacteria contamination in pellets following treatment and cold-drying and secondly, Enterobacteria decontamination of feed by the pelleting process (difference in contamination in log before and after treatment) according to the pelleting conditions. The latter are the temperature upon exit from the conditioner (TC) and the thickness of the compacting die plate (D), directly related to retention time in the die.

Results

Two types of results were generated by these tests: Effective pelleting conditions and bacteriological results generated by these conditions.
Table 2 gives, for each type of test (average for the central point), the output pelleting rate measured, initially estimated pellet retention time in the die, then that measured from the actual pelleting flow rate and the density of the pellets. It would appear that the output rate varies between 275.9 and 283.5 kg/h. These values are similar to those expected and are, for the main part, included in the range initially set (+/-5kg/h). Retention times are slightly higher than those estimated, due to a difference between actual density and that expected.

Table 2: Pellet flow rate from the press and related retention time

Die	Temperature setting (°C)	Output Pelleting rate (kg/h)	Retention time measured	Estimated retention time
20	67	277.3	2.3	2.3
24	51	277.2	3.0	2.8
24	83	277.4	2.9	2.8
35	45	283.5	4.8	4.1
35	67	281.4	4.6	4.1
35	90	283.5	4.3	4.1
45	51	277.1	5.8	5.3
45	83	275.9	5.7	5.3
50	67	281.8	6.3	5.8

The temperatures measured upon exit from the conditioner are shown in table 3. The average temperature setting appears to be very similar to the recommended temperature setting (0.1 to 0.3°C). The regulation loop ensures a steam flow rate for reaching the temperature setting and stability of the conditioning temperature during the test.

Table 3: Steam regulation and steam flow rate measured

Temperature setting (°C)	Conditioning temperature (°C)	Steam flow rate (kg/h)
45	44.9	5.8
51	50.8	7.7
67	66.8	11.7
83	82.9	17.6
90	89.7	19.3

In order to understand the behaviour of the feed in the die, the temperature of the pellets upon exit from the die and durability are two determining criteria. The feed durability of the broiler feed is 54.2 % durability with the 35 mm die at 67°C (Corresponding to 92.7 PDI in USA). In addition to the nature of the feed, the compressive thickness of the dies and temperature setting are essential criteria when it comes to changes in heating in the die and durability. Where little steam is added to the meal (low temperature setting), shearing forces are higher and the feed reaches a high temperature in the die. In the same way, the difference in temperature between the pellets and the conditioner increases with compression. Durability increases as conditioning temperature increases.

The results of the microbiological tests are summarized in figure 1. The abscissa on the graphs show the pelleting conditions, namely die plate thickness (mm) and conditioning temperature (°C). The ordinate axis shows contamination by Enterobacteria of the samples taken at the start of processing (black), from the conditioner after addition of steam (grey) and from the cooler after pelleting (white), in log CFU per gram of feed.

The microbiological results reveal a true variation in final contamination of feed from the cooler according to the pelleting conditions tested. With the least compressive die plate of a thickness of 20 mm, the feed for broiler still shows final contamination of 4.1 log CFU/g. But high temperatures in the conditioner (90°C) and the 35 mm die make it possible to fully remove Enterobacteria contamination from the feed. The experimental design tested in these trials therefore makes it possible to study this variation zone and to then determine the minimal conditions required for satisfactory decontamination.

The variations in decontamination observed may be related to processing temperature and to compressive thickness, and therefore to retention time of the feed in the die. Broiler feed is therefore fully decontaminated with a little compressive die (24 mm) at a high treatment temperature (83°C). The low temperature rise of the die (4°C) and low contamination upon exit from the conditioner (1 log CFU/g) indicates the preponderent role of the temperature acquired by the feed in the conditioner with respect to decontamination. The sample taken from the conditioner however is still highly contaminated and it would appear that clearly decontamination occurs in the die.

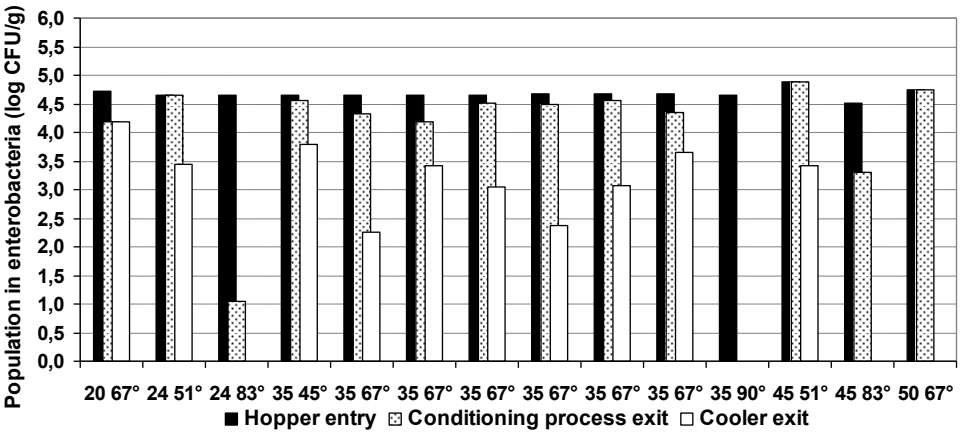

Figure 1: Bacteriological results - broiler feed

The repetition of the central point of the experiment design (35 mm die at a temperature of 67°C) also makes it possible to demonstrate that the broilers feed shows a variation in contamination after pelleting of 2.3 to 3.7 log CFU/g. Result variability due to the external environment is nevertheless taken into account in statistical processing and justifies the experiment design selected for these tests.

These results were then used to establish decontamination scales. These scales aimed to propose combinations: Die retention time / conditioning temperature combined with satisfactory Enterobacteria decontamination. Two models were pre-determined for the broiler feed. The first, illustrated by the iso-response curves in figure 2.

The aims is to predict final Enterobacteria contamination from the cooler according to conditioning temperature (ordinate) and the thickness of the pilot die plate (abscissa). The second (Figure 3), using the same variables, predicts decontamination, that is to say the variation in contamination during processing. On these figures it would appear that the conditions required for decontaminating feed by 3 log (shaded area, figure 3) are stricter than those required for obtaining final contamination of under 3 log in the treated feed. Therefore, in order to attain both objectives, the second model is selected in order to establish the recommended decontamination scale.

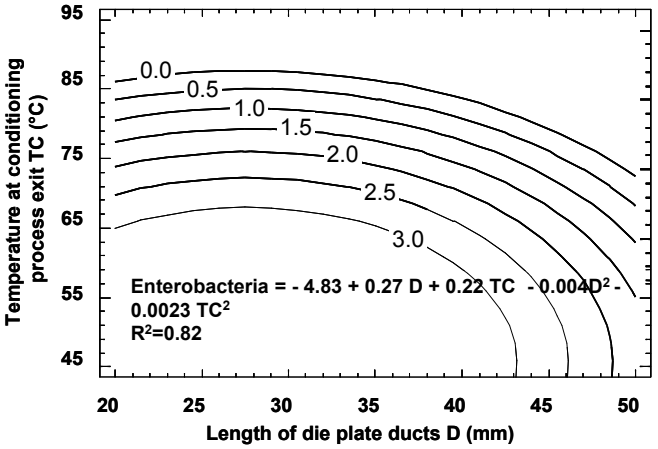

Figure 2: Response curves obtained from the statistical model predicting Enterobacteria contamination at the cooler exit for broiler feed

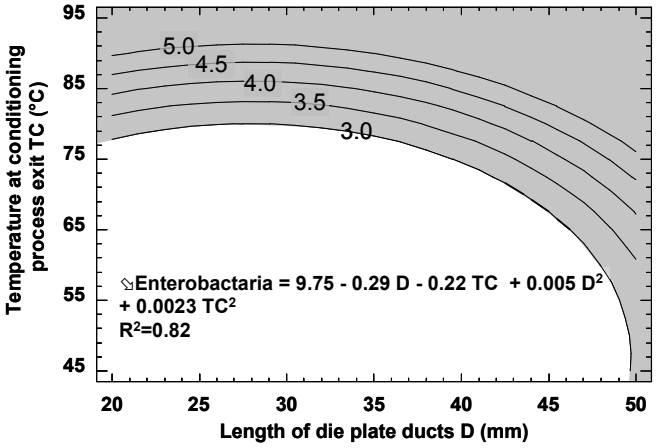

Figure 3: Response curves obtained from the statistical model predicting Enterobacteria decontamination via the broiler feed pelleting process

Discussion and conclusion

The results generated during this study show that the temperature acquired by the feed in the conditioner has an influence on enterobacteria decontamination of the meal despite the short retention time. Steam-treatment reduces flora by 0.3 log at 67°C. These figures are consistent with

this obtained by Cox *et al*. (1986) and Voeten and Van de Leest (1988) as at 72°C, the chicken feed studied saw a more significant drop in enterobacteria contamination, by 0.3 and 1 log respectively. At 82 or 83°C, the counts show that the flora reduces by 4 log acording to Voeten and Van de Leest (1988) and 1.8 log according to Cox *et al*. (1986). The results of our study are intermediate as at 83°C, the chicken feed shows a reduction in contamination of 2.4 log. These differences may be due to initial contamination or different retention time in the conditioner.
After mixing the meal with steam, the feed is pushed through the ducts of the die and comes out in pellet shape. This creates friction forces which lead to a higher feed temperature and therefore decontamination. According to the results observed by Cox *et al*. (1986), Voeten and Van de Leest (1988) and according to this study, enterobacteria flora reduces by 0 to 3.5 log between the conditioner exit and the press exit. In the way to compare the results of various publications, it would appear that the flora drops significantly at intermediate conditioning temperatures. Between 57 and 70°C, enterobacteria levels fall by 1.7 log (Cox *et al*., 1986) to 3.5 log (Voeten and Van de Leest, 1988). Lower or higher temperatures come with a variation in contamination after conditioning and reduced pelleting (reduction of 0.8 and 0 log for temperatures of 45 and 90°C, in our study). This observation may be explained by decontamination taking place in the conditioner where meal treatment temperatures are high and where the temperature acquired in the die is insufficient when conditioning temperatures are low.
The effect of heating the feed in the die on decontamination is also demonstrated by the relationship between the enterobacteria population in the pellets and die temperature. According to Veldman *et al*. (1995), the increase in final feed temperature from 60 to 80°C leads to a drop in enterobacteria levels from 3.3 to 1 log per gram of pelleted feed. The results of our study show the same phenomenon with a drop in flora from 4.2 to 0 log per gram of chicken feed (die temperature increased from 65 to 90°C).
In conclusion, it is clearly show it is possible to assure a good enterobacteria decontamination of broiler feed by pelleting process if the right conditions (Conditionning temperature, residence time thus input rate, die compression) are applied.

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