Securing feed from salmonel

Animal feeding plays an essential role in salmonella control because it might be a potential carrier and infection source. Effective measures can be applied to control the transmission.

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Microbiological screening of all raw materials is impractical, expensive and time consuming. Therefore, it is wise to assume that salmonella may potentially contaminate all raw materials.

Salmonellosis is the most common zoonotic disease in developed countries. The average number of reported cases in Europe is 73 per 100.000 inhabitants with important variations among countries depending on diagnostic methods, data communication and also cooking habits. These data probably underestimate the real incidence of the disease because minor infections go unrecorded. Most cases results in gastroenteritis with fever but in some patients (5%) septicaemia ('blood poisoning') may arise and even cause death (0.1% of total cases).

Real incidence of the disease in the European Union is estimated at 450 cases each year, per 100,000 inhabitants with three deaths per million inhabitants. These estimations correspond to USA data where between 400 and 800 people die each year due to salmonellosis.

Other than the tremendous importance from a food safety standpoint, salmonella control is also important from a trading standpoint. Health status can be used to create trade barriers between countries. Also, food safety issues can become marketing tools to sell in demanding and competitive markets.

An improvement in food safety standards represents a product differentiation while the other members of the sector do not adopt the attribute as a mandatory requirement. This temporary advantage may result in an increase of market share. A good example of this approach is the salmonella control programme implemented since 1993 in Denmark, a net exporter country. On the other hand, the programme in Sweden (since 1961) is the basis for demanding additional requirements to meat imported from other members of the EU. Last but not least, salmonella plays an important role in animal health status. Salmonellosis produces a diarrheic process with high fever in for example finishing pigs. In acute forms of the disease, sudden death may occur. The net result is an increase of mortality, higher medication costs, slower daily gain, more weight variation and higher production costs. Outbreak costs can vary from e2 to e3 per pig in severe cases.

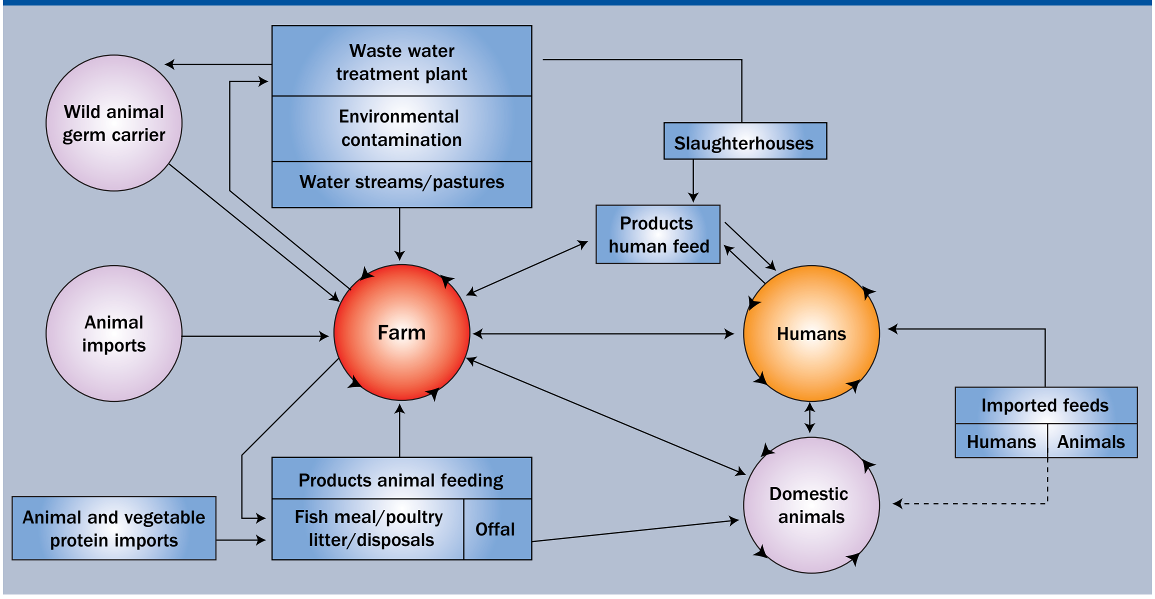
Table 1 - Reduction in microorganism's number after expander processing of different feeds (Revised by: Beumer and Van der Poel, 1997)

			Nº de micro-organisms / g of feed				
Type	**Tª (ºC)**	**Pressure (bar)**	**Aerobic**	**Entero-**	**E. Coli**	**Moulds**	**Salmonella**
Broilers	Meal		63.000	10	<10	1.400	-
	125	10	900	<10	<10	<10	-
	135	20	870	<10	<10		-
Layers	Meal		8 x 105	103		1.400	+
	125		39.000	<10	<10	<10	-
Pigs	Meal		7 x 107	105	103	300	-
	120		3 x 105	<10	<10	<10	-
Turkeys	Meal		6 x 105	104	10	120	+
	90	10	3 x 104	<10	<10	<10	-
	110	20	2 x 104	<10	<10	<10	-
	120	30	1 x 104	<10	<10	<10	-

Bacteria properties

Salmonella is a genus of Gram-negative, oxidase negative bacteria that belong to the family *Enterobacteriaceae.* Salmonellas are able to survive la

Figure 1 - Introduction of and recontamination with salmonella on a pig farm (WHO, 1988)



and, under certain conditions, even multiply in the external environment and water. They resist freezing temperatures and dryness. On the other hand; heat, light and common disinfectants (phenols, chlorines and iodophores) inactivate the bacteria. Also, its concentration declines in an acid environment.

Depending on antigenic characteristics, 2,213 different serotypes have been described. From these, more than 200 have been isolated in infected persons. Currently, *S. typhimurium*, *S. enteritidis*, *S. infantis, S. cholerasuis* and *S. heidelberg* are some of the serotypes most often isolated in man and animals. However, many others are important from an epidemiological standpoint depending on the host and geographical location.

Introduction of *salmonella* into a farm can be a complex process as shown in *Figure 1.* Attention is focused on the control of feed and animals inputs, but the importance of other carriers should not be underestimated.

Control in feed production

Salmonella control in feed manufacturing embraces the following procedures:

- Prevent or minimise the introduction of salmonella: control of contamination of raw materials.
- Implement decontamination steps: chemical and / or thermal treatments.
- Prevent recontamination: microbiological hygiene of equipment and facilities in feed mill and transportation.
- An integrated approach is needed to implement a HACCP system (hazard analysis and critical control points) at the different stages of the process: incoming raw materials, feed manufacturing and transportation.

Contamination of raw materials

Non-introduction of salmonella into the feed manufacturing plant cannot be assured for several reasons. Microbiological screening of all raw materials is impractical since analyses are very expensive and time-consuming. Even when a sample coming from a certified supplier tests negative, the load could be contaminated because of the uneven distribution of bacteria in feedstuffs. Moreover, contamination can occur by different carriers: mice, insects, birds and humans. Therefore, it is wise to assume that salmonella may potentially contaminate all raw materials.

Nevertheless, some raw materials have a higher risk of contamination than others. Animal proteins have always been identified as critical ingredients with variable degrees of contamination (from < 1% to 50%) depending on the process hygiene, facilities and transportation. Also, oilseed products can be contaminated if the bacteria are present in the industrial process. Different surveys indicate potential contamination rates of 6% in rapeseed meal or 10% in soybean and sunflower meals.

These results are in agreement with data published by Defra, the agriculture department of the UK where between five and 10% of vegetal proteins were con-

Table 2 - Minimum inhibitory concentration of different acids (g/kg diet) on bacteria and moulds (Singh-Verma, 1973; Strauss and Hayler, 2001)

Bacteria	Formic	Propionic	Lactic	
Salmonella typhimurium	1,0	1,5	3,0	
Pseudomonas aeroginosa	1,0	2,0	3,0	
Escherichia coli	1,5	2,0	4,0	
Staphylococcus aureus	1,5	2,5	4,0	
Listeria monocytogenes	1,0	2,0	2,5	
Campylobacter jejuni	1,0	2,0	3,0	
Clostridium botulinum	1,5	2,5	3,0	
Clostridium perfringens	1,0	2,5	3,0	
Mould	**Formic**	**Acetic**	**Propionic**	**Sorbic**
Aspergillus Níger	5,0	5,0	2,5	5,0
Penicillium expansum	1,0	2,5	1,3	0,5
Fusarium nivale	2,5	5,0	1,3	0,5
Cladosporium sp.	1,0	2,5	2,5	2,5

taminated. On the other hand, cereal grains are raw materials with the least salmonella contamination (<1,5%), whereas cereal by-products such as wheat middlings can show high contamination rates depending on the suppliers (from zero to 30%). Even if the contamination rate is very low, all raw materials share the same incoming pit at the feed plant; and thus, cross contamination is highly probable. A recent study conducted by the Defra isolated *Salmonella enteritidis* in the incoming pit of more than 30% of feed plants.

However, the serotypes isolated in raw materials and feeds are frequently not those found most commonly in animal populations or human cases. The serotypes S. *tennesse, S. mbandaka, S. cubana, S. livingstone, S. anatum* are some of the most frequently isolated in raw materials and feeds. However, the frequency of *S. enteritidis* in poultry feed is very low. Conversely, *S. typhimurium* is rarely found in the feed survey of the Danish salmonella control programme. Therefore, salmonella presence at the farm is not related so much to salmonella presence in the feed as it is to feed characteristics that influence intestinal health of the animal. This does not mean that salmonella presence in the feed can be disregarded because hazardous serotypes can vary temporally and geographically and thus, potential new risky serotypes could be introduced through incoming raw materials.

Decontamination of feedstuffs

It is essential to apply processes to eliminate salmonella and to assure that the feed is not a carrier of the bacteria into the farm. Decontamination systems may combine chemical treatments and technological processes. Chemical treatments are based on the negative effect of acid pH on salmonella growth. Technological processes are based on the heat sensitivity of salmonella and combine temperature, moisture and time. Different processes are used in experimental and industrial conditions:

- Pasteurisation or sterilisation of the meal
- Long conditioning time
- APC systems – anaerobic pasteurisation conditions
- Double pelleting
- BOA Compactor – Compacting by agglomeration
- Conditioning and expander treatment with or without pelleting
- Extrusion and other high temperature short time (HTST) processes

Expander processing, although not primarily designed for improving hygienic quality of feeds, has been proven to be one of the more effective options for elimination of salmonella and other pathogenic organisms from feedstuffs (*Table 1).*

As in other technological treatments, efficacy of decontamination depends on temperature, treatment time and moisture content. The higher the temperature, the shorter the needed treatment time. Assuming that heat distribution is not uniform in all feed, a safety margin is needed to assure that the treatment affects all parts of the product from the start-up to the end of the batch.

At the same treatment and energy input, higher moisture content leads to a greater reduction in the number of microorganisms. As expected, at the same moisture content, higher temperatures increase the extent of reduction. At the German IFF institute it was demonstrated that, by combining different moistures, temperatures and energy inputs, expander could reduce the number of microorganisms per gram of feed by a factor of up 10^6 and 10^7. In that study, the energy input was extremely high (37 to 57 kWh/tonne) probably because it was conducted in an experimental facility, however similar temperatures can be achieved in industrial conditions with lower energy inputs (eight to 20 kWh/ton) and the right steam addition.

Better to expand *and* pellet

Israelsen and his co-workers found that when feed was expanded and pelleted, salmonella was basically not detected at 88, 100 and 112˚C (reductions of 10^5). However, when feed was expanded but not pelleted, only the highest temperature was effective, whereas the decontamination was totally ineffective at 88˚C with reductions of 10^2. Therefore, although the temperature was theoretically high enough, the 88˚C treatment was not effective due to the short retention time.

From this research it was recommend that, when processing with the expander alone without pelleting, higher temperatures (>105˚C) may be required for reduction of salmonella than when expansion is combined with pelleting. However, when feed is expanded and pelleted, pelleting results in a longer retention time at high temperatures. In high-production lines, there is also less retention time and thus, it is recommended to increase working temperature as well. In all instances, moisture content should be higher than 14% for maximum efficiency. Other than the temperature effect, the drop in pressure that occurs when the feed leaves the expander produces fatal changes in the internal cell pressure of the bacteria. In conclusion, use of expander and pelleting is an effective technology to eliminate salmonella, if used properly.

Expanding combined with pelleting is an effective technical means to eliminate salmonella

Recontamination

Hygienic feed should not share routes with non-hygienic feed. Salmonella rapidly grows under moist conditions. Moreover, the bacteria can be in the dust particles coming from external environment. The cooler is a potential recontamination focus because of the operating conditions: temperature, air movement and moisture. Implementation of a HACCP system must include a periodic monitoring of salmonella presence in the cooler. Frequency of inspection and cleaning should be higher in horizontal than in vertical coolers. Cooling air should not come from the raw materials incoming area.

Other critical points are the bins in the plant because of potential condensations and recontaminations by birds or rodents. The same problems can occur in the feed bins at the farm, especially when the lids are left open or when cleaning between batches is insufficient. It is recommended to implement good management practices such as periodic hygienic treatment, rodent control, hermetic storage and transportation, and use of additives that inhibit bacteria growth.

A salmonella control programme at the feed mill should include the control and monitoring of the critical points of the facility. Samples from the plant spots where salmonella growth is more likely should be analysed periodically, such as unloading pit for raw materials, dust in aspiration filters, top of pellet cooler, bottom of elevators and conveyors, top of finished feed bins.

Negative tests of samples and the application of corrective actions provide assurance of the hygiene of feed exiting the plant. Implementation of good practices during transportation, such as proper cleaning of trucks especially if raw materials have been shipped, will provide assurance of the microbiological hygiene of feed delivered to the farm.

Organic acids work well

Equilibrium of gastrointestinal microflora is essential to control salmonella prevalence in swine farms. The lower prevalence of salmonella is associated to a larger population of lactic acid bacteria, lower coliform numbers and no changes in yeast concentration. This equilibrium results in larger productions of lactic, acetic, propionic and butyric acids that cause a pH drop, which limits salmonella growth.

Similar profiles of microbial flora and acid production can be achieved by supplementation with organic acids. The antimicrobial properties are based on two effects. The first effect is a depression of the feed pH. Secondly, but more important, the undissociated form can freely diffuse through the microorganism membrane. Once inside the cell, the acid dissociates and suppresses cell enzymes and nutrient transport systems. Bacteria gram negative are more sensible to acids than gram positive (*Table* 2). Organic acids may have synergies with essential oils and plant extracts.

Animal feeding, as part of the production chain, plays an important role on the pathogen control. Feed can be a potential carrier of the pathogen. Therefore, microbial hygiene of the feed is needed to prevent salmonella transmission. Moreover, specific feeding strategies are very effective to reduce salmonella prevalence due to the positive effects on the equilibrium of gastrointestinal microbial ecology. ●