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Salmonella in animal feed

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This i'Tec summarises a bibliographic review (i'Doc_S10) that was written for a programme with financial backing from SYPRAM funds, entitled "Maîtrise de la contamination par les Salmonelles, en aval du traitement thermique, dans les usines d'aliments du bétail" (Controlling Salmonella contamination in cattle feed plants, downstream of the heat treatment process). This summary:

- points out risk areas in the feed manufacture process,
- presents the advantages of the heat treatment schedule (press or other) designed to eliminate Salmonella, in order to make better use of it,
- proposes preventive measures to be implemented throughout the process.

1. The task ahead

The frequency with which Salmonella is identified in animal feeds varies from one country to another from 1.6% (according to a 1968 study by ZINDEL and BENNETT in Michigan in the United States) to 44% (according to a 1980 study by SMELTZER *et al.* in the United Kingdom). It should be stressed that the final level of contamination of a feedstuff depends on the type of treatment it has undergone. Therefore, animal feed meals are often contaminated (2.8 to 58%, depending on author and country), while pellets are more rarely affected by contamination (0 to 1.4%). Crumbs are subject to slightly more contamination than pellets (3%).

For industrials, it would be very useful to have access to a specific Salmonella indicator, which would save them time, reduce analysis costs and increase reliability. This has focused research efforts on flora that are taxonomically similar to Salmonella. The best candidate for a Salmonella risk indicator can be found in the group of **Enterobacteria**. This result was discussed in a paper by KONIG (1995). This was confirmed by the findings of a follow-up on ten animal feed plants carried out jointly by CNEVA and TECALIMAN, under the same contract, the results of which are pending publication.

Efforts to control the risk of Salmonella contamination in feedstuffs may involve setting up a HACCP procedure at the plant, which, in the first instance, would spotlight all **high-risk areas**; research by Davies and Wray (1997) and CNEVA and Tecaliman agree on the need to designate **receiving pits** and the **cooler** as the areas with the highest Salmonella detection rates.

The area **least affected by contamination** is the **press** (Davies & Wray, 1997 – Dipl, 1991). However, when the plant is closed over the weekend, the press gates and press outlet pipes also become an at-risk area (hot and humid), as shown by Boloh (1995), König (1995) and Israelsen *et al.* (1996b).

Lastly, one source of **recontamination** of the finished product can be found in **transport vehicles** (Dipl, 1991 - Riemann, 1995), as confirmed by current studies by Tecaliman and CNEVA's on delivery trucks.

2. Factors in Salmonella resistance

The fight against Salmonella requires greater insight into the resistance patterns and growth limiting factors (= multiplication) of this bacteria.

While the **optimal temperature for growth and development** of Salmonella in feedstuffs is between 35°C and 37°C (Beumer, 1992), these bacteria are capable of multiplying between 7°C and 46°C. könig (1995) demonstrated that "artificial" flora are not as heat resistant as "natural" flora. This would indicate that secondary contamination, carried by rats, is easier to eliminate than intrinsic contamination vehicled by one or more raw materials.

a_w (water activity) is an important contributing factor to bacterial growth. This value of between 0 and1 refers to the quantity of water (free + bound) contained in a product. The more a_w tends towards 1, the greater the growth in Salmonella (as from 0.92). In dryer products, Salmonella will survive, but will not develop. Note, however, that dehydration stress increases Salmonella heat resistance (as reported by Riemann, 1968 – Corry, 1974 - Durand *et al.*, 1990).

Salmonella do not grow in dry feeds, i.e. with a moisture content of less than 14%; in these cases,

the bacteria lie dormant, but can become viable again if the moisture content exceeds 25 to 30% (Beumer, 1992 - Israelsen *et al.*, 1994 – Vahl, 1995).
Bacterial resistance to these various factors (temperature, humidity, a_W) can be modified by the surrounding "matrix" (i.e. the structure that surrounds the bacteria). Solutes, such as sugars, "protect" Salmonella by increasing their heat resistance (CORRY, 1974).
The methods designed to control Salmonella are described below.

2.1. Pelleting press

Salmonella contamination is reduced during the industrial process by **pelleting**, which combines a hydrothermal and thermomechanical treatment. The trials carried out by Tecaliman and CNEVA in a pilot workshop (i'Doc S6, 1996) on products that had been naturally or artificially contaminated demonstrated that the minimum schedule of **85°C for 90 seconds** cuts the proportion of samples that tested positive for Salmonella from 100% to 0% at the pelleting press output (the sample had initially been infected with 1000 Salmonella/g). According to Hansen and Israelsen (1997), pelleting at 81°C with 10% moisture eliminates 99% of Salmonella bacteria, which is not enough to ensure total decontamination given the rate and frequency at which certain raw materials become infected.

Table 1 lists certain heat treatment schedules that correspond to either a reduction or an elimination of Salmonella, and are recommended by some authors.

	Schedule			Authors
	Time	Temperature	Moisture content	
To reduce Salmonella	few secs.	≥ 80 °C		Voeten & Van De Leest (1989)
		≥ 82 °C	18%	Cover, cited by himathongkham *et al.* (1996)
	90 sec.	93 °C	15%	himathongkham *et al.* (1996)
To destroy Salmonella	4.1 min	85.7 °C	14.5%	Mc Capes, cited by cantor (1990)
	4.41 min	89 °C	12%	
	4.41 min	83 °C	13%	
	2 min	80 °C		Vahl (1995)
		88 °C	15%	John (1990)
	2.5 to 3 min.	87.8 °C		Caroll & Ward (1967) cited by Crane *et al.* (1972)

Table 1: Pelleting press heat treatment schedules, recommended by various authors

For pelleting treatments using the **APC** system (Anaerobic Pasteurizing Conditioning System), it would appear that the optimal Salmonella elimination schedule is: 82.9°C +/- 2.1 applied for 4.3 min. +/- 0.4, with a moisture content of 16.3% +/- 0.3 (Mc Capes *et al.*, 1989).

2.2. Extrusion and expansion treatments

Also referred to as HTST (High Temperature Short Time) treatments, their very high operating temperatures (approx. 120 to 135 °C) and pressures (approx. 50 bars) provide an effective method of eliminating Salmonella (Israelsen *et al.*, 1996a - Nagaraja, 1989). According to these same authors, treatment at 90 °C enables a 5 log reduction in Salmonella bacteria (3100 to 0.02 bacteria/g).

2.3. Chemical treatment

Chemical processes such as acidification can provide an effective complementary decontamination effect to the heat treatments. The most effective organic acids are, in descending order of efficacy, formic acid, acetic acid, followed by propionic and lactic acids (Adams, 1991 – Langlois, 1993). Formic acid acts on protein stability (according to Franco, 1994). The acids block the metabolism of the bacterial cells, which first arrests their multiplication, and then eliminates them in the longer term.

The acid's efficacy depends on **their concentration**: at low doses (0.7% in mass/mass), Cherrington *et al.* (1991) demonstrated that the acids have an efficacy that is practically null. According to Adams (1991) it requires a dosage of 20 to 30 kg/t to effectively eliminate Salmonella; however, there are other issues to take into account such as inappetence, and corrosion of circuits.
In addition to its concentration, the decontaminant efficacy of an acid also depends on:

⇨ **temperature**: efficacy improves at 37 °C rather than at ambient temperature (Cherrington *et al.*, 1991).

⇨ **pH**: acids are more effective when they can diffuse in undissociated form inside bacterial cells, liberating protons and cations (Hinton, 1996). However, each acid has a characteristic dissociation pH and, at a given pH, an acid may already be mostly dissociated, and therefore less active.

⇨ **action time**: According to Beumer (1992) and GARLAND (1995), optimal efficacy is achieved after 24h. Hinton (1996) therefore suggests applying the treatment during the storage period.

⇨ **A_W**: according to Cherrington *et al.* (1991), acids become active as from an a_W of 0.93 .

Renggli (1996) suggests incorporating 6% propionic acid in raw materials for decontamination, and 1% propionic acid in finished products in order to prevent recontamination.
However, research by Cottin *et al.* (1995) involving efficacy trials on 12 acidifying agents revealed that none of these agents (i) acidified the product at the manufacturer's recommended doses and (ii) provided total elimination of Salmonella bacteria artificially introduced into the feedstuff at a dosage of 10^5 Salmonella/g.

3. Conclusion and recommendations

The practical recommendations that should be proposed to industrials have two main objectives: **decontamination of animal feed** and **prevention of recontamination** (Renggli, 1996). Effective control of Salmonella contamination depends on the implementation of an array of measures spanning the whole industrial process, from reception of raw materials up to loading of finished products (Garland, 1995).

3.1. Select raw materials carefully:

This involves avoiding heavily contaminated raw materials such as animal meal and press cakes (Israelsen, 1996b - Cantor , 1990 – Renggli, 1996) and, in particular, selecting raw material suppliers and sources that have already integrated Salmonella control measures into their business (Jones & Richardson, 1996). Lastly, it is also vital to inspect ingredients visually prior to unloading (Jones & Richardson, 1996).

3.2. Control the heat treatment process:

This item was discussed in detail above. Effective control of the heat treatment process requires appropriate press settings (time-temperature), which should not be solely dependent on achieving certain technological features, combined with a reliable measurement system that ensures real control over these two parameters.

3.3. Keep equipment and facilities hot and dry:

condensation points should be identified in order to ensure their control. According to Israelsen *et al.* (1996a) and Vahl (1995), these points are located in the preheating chamber upstream of the press and the cooler, as well as inside the cooler, at the top where the air flow is slow. These same authors (in addition to Garland, 1995) recommend heat-insulating condensation zones, fitting fans, or even preheating the facilities.

3.4. Prevent deposition:

By making sure there are no dead spots and corners in the production facilities (Vahl, 1995). According to Vahl (1995) et John (1990), it is necessary to carry out regular inspections via the access hatches in order to remove any deposits. Garland (1995) suggests running a cleaning mix comprising cereals and organic acids through the system.

3.5. Control cooling - drying air:

It is recommended to sample the air in a clean, calm area (Garland, 1995 – Vahl, 1995) or even to filter it (Garland, 1995 – Boloh, 1995 – Jones, 1996). The study currently in process, led by Tecaliman and CNEVA, has made it possible to confirm that there is a greater risk of recontaminating a product when air is sampled in the workshop as opposed to outside the plant and in a clean area (unpublished results).

Location	Procedure	Frequency	Author
Receiving dock	Clean after each delivery to ensure no food is left around for rats	after each delivery day	Jones (1996)
	Cover the pit	after each delivery day	
	Drain the pit correctly		
Delivery trucks	Clean the trucks	On arrival	Jones (1996)
	Disinfect by spraying	Prior to loading	Montoya (1996)
Silos	Disinfect the silos with formol	Weekly	Boloh (1995)
Walls of the conditioner + pipe after the conditioner	Scrape clean	Daily	Montoya (1996)
Storage cells	Empty and scrape clean	every 2 months	Montoya (1996) Garland (1995)
Conveyor zones	Clean	On a regular basis according to inspection	Garland (1995)
Dead space at the bottom of the base of the elevator	Plan for a self-cleaning system and a hatch for disposing of tailings		Garland (1995)
Conditioner, cooler	Disinfect with hot air by preheating to 85°C, 15 min.	Weekly	Montoya (1996)
Heat treatment tower	Disinfect by thermofogging	Twice a month	Montoya (1996)
Machinery	Disinfect using formol	Weekly	Boloh (1995)

Table 2: Recommendations on plant cleaning procedures and frequencies

3.6. Clean and disinfect equipment:

Table 2 summarises the cleaning frequencies for each plant area, based on the recommendations of various authors.

3.7. Follow general hygiene measures:

↗ products:

- Keep "raw material" and "finished product" circuits separate (JOHN, 1990, VAHL, 1995),
- Separate treated products from non-treated products (RENGGLI, 1996),
- Use organic acids to control recontamination (CANTOR, 1990); note, however, that the doses required to ensure effective decontamination make the feedstuffs unappetising.
- Do not put tailings in finished product silos (VAHL, 1995),
- Make sure that all "suspect" feedstuffs are returned to the decontamination area (prior to pelleting or before sterilising animal meals) (VAHL, 1995).

↗ staff:

- Ensure staff have the relevant health and hygiene training (RENGGLI, 1996),
- Provide footwear disinfection trays for staff coming from the raw materials area and going to the finished products area (JOHN, 1990),
- Make sure staff observe sanitary hygiene requirements (VAHL, 1995).

↗ equipment and facilities:

- Do not bring wet equipment into the plant (Jones, 1996),
- Make sure that each area is properly equipped with the necessary dustpans, brushes and specific tools (John, 1990),
- Lock production facilities (Renggli, 1996).

↗ transport:

- Transport feedstuffs in trucks that are clean, dry and properly closed and locked (JOHN, 1990),
- Equip trucks so they are specialised in the transport and delivery of heat treated products (Tecaliman).

4. Bibliographic references

These can be seen in **i'Doc_S10**.