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McIlroy S.G.

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S.G. McIlroy M.R.C.V.S.
John Thompson & Sons Ltd, 35-39 York Road, Belfast, Northern Ireland

SUMMARY – Human and animal salmonellosis is still causing high economic losses. In humans, the main infection vector is related to poultry product consumption. The US Agriculture Department has reported that animal feeds are the main source of infection in poultry production, and *Salmonella enteritidis* is the most frequently isolated serotype. It may be present in feeds at such low levels that it is difficult to detect, but nevertheless it proves to have a high colonization ability in poultry. In 1997, in the USA, it was found that 26% of raw protein materials of animal origin tested positive for some Salmonella types and raw materials of plant origin showed similar levels of contamination. Thus, 15% of feed samples analysed tested positive for some Salmonella serotypes. Recent studies showed that *S. enteritidis* is isolated in one out of every 3 mills. The dust in suspension also can be an important contamination vector of Salmonella, especially in chilling facilities. The control methods for Salmonella in animal feeds depend on the effectiveness of feed decontamination and the prevention of recontamination. Bactericide products and methods combining temperature and duration, etc., can be used, all of them complemented with biosecurity measures to make sure recontamination does not occur. Since raw materials are an important reservoir of Salmonella, it is of utmost importance to ensure a total decontamination of feeds, especially in poultry production.

Key words: Biosecurity, Salmonella.

RESUME – *"Programmes de biosécurité pour le contrôle de Salmonella". La salmonellose humaine et animale continue de causer de fortes pertes économiques. Chez les humains, le principal vecteur d'infection est lié à la consommation de produits de l'élevage de volailles. Le Ministère de l'Agriculture des Etats-Unis a reporté que les aliments pour l'élevage sont la principale source d'infection en production avicole, et* Salmonella enteritidis *est le sérotype le plus fréquemment isolé. Il peut se trouver présent dans les aliments pour animaux à des niveaux si faibles qu'il est difficile de le détecter, mais cependant il s'est avéré qu'il a une grande capacité de colonisation chez les volailles. En 1997, aux Etats-Unis, on a trouvé que 26% des matières premières protéiques d'origine animale se sont révélées positives pour certains types de Salmonella et les matières premières d'origine végétale ont montré des niveaux semblables de contamination. Ainsi, 15% des échantillons d'aliments analysés ont été positifs pour certains sérotypes de Salmonella. Des études récentes ont montré que* S. enteritidis *est isolée chez un fabricant sur trois. La poussière en suspension peut également être un vecteur important de contamination de Salmonella, spécialement dans les installations de réfrigération. Les méthodes de contrôle de Salmonella en alimentation animale dépendent de l'efficacité de la décontamination de ces aliments et de la prévention de la recontamination. On peut employer des produits bactéricides et des méthodes combinant la température et la durée, etc., tous complémentés par des mesures de biosécurité pour s'assurer qu'il n'y ait pas recontamination. Etant donné que les matières premières sont un réservoir important de Salmonella, il est de la plus grande importance d'assurer une décontamination totale des aliments, spécialement pour la production de volailles.*

Mots-clés : *Biosécurité, Salmonella.*

Human and animal disease caused by Salmonella probably costs billions of dollars each year. In the UK, it is conservatively estimated that human illness associated with Salmonella costs around 25M dollars per annum. Much of this is blamed, rightly or wrongly, on the consumption of poultry products.

Detailed investigations by the Ministry of Agriculture, Fisheries and Foods (MAFF) in the United Kingdom have indicated that feed can be the commonest source of Salmonella for poultry flocks. Furthermore, a recent House of Commons Agricultural Committee Report on Food Surveillance has recommended that government should provide the impetus to achieve Salmonella free feed in the future.

Compulsory monitoring of animal proteins under European Community Directives is carried out

across the EC. In addition, strict Codes of Practice for the manufacture, storage, transport and monitoring of poultry feed have been agreed with feed manufacturing industries in individual member states, and other non-EC countries, and have provided important information on the risk of Salmonella contamination in a wide range of both raw materials and finished feeds.

Several detailed investigations by MAFF in recent years have established that feed is a major source of Salmonella infection for poultry flocks. *S. enteritidis* is not the most common serotype to be isolated from feed. However, it may be present at low levels, which are difficult to detect. The difference between the level of contamination identifiable in feed and that subsequently recorded in poultry flocks is attributed to the ability of *S. enteritidis* to readily colonise poultry and be present at high levels in a flock. The *S. enteritidis* will also be present in the environment, and thus detectable by the established methods of monitoring. This is in contrast to many other non-pathogenic Salmonella serotypes, which can be isolated from feed at comparable levels to isolations from poultry flocks.

Contaminated animal proteins

Investigations carried out by MAFF in 1986 showed that 10% of locally produced animal proteins were contaminated with a Salmonella serotype. Ten per cent of the isolates were *S. enteritidis*. A further survey that year showed that up to 39% of imported animal proteins were contaminated with a Salmonella serotype. Again, a similar proportion of isolates were *S. enteritidis*.

Notably, stringent production procedures have reduced the incidence of Salmonella contamination in locally produced Meat & Bone Meal and Fishmeal from a figure of 10% recorded in 1986 to a level of between 2% and 3% each year from 1992 to 1997. However, monitoring has also demonstrated that the level of contamination can frequently double between manufacture and delivery to the feed mill, clearly indicating the highly important role of transport in the re-contamination of raw materials.

Contamination rates in imported animal proteins have also decreased from a peak of 39% in 1989 to a level of between 9% and 12% seen in the three years of 1995, 1996 and 1997. Imported fishmeal is now categorised with regard to the level of risk dependent on the source and the previous testing history. This has substantially reduced the number of positive shipments being imported into the UK.

A 1997 survey in the USA of 262 rendering plants found on average 26% of samples tested positive for a Salmonella serotype. The levels of contamination varied from 14% in NRA members to 67% in plants that were described as protein blenders.

Monitoring of processed animal proteins and fish meals in GB has also identified an important epidemiological observation with regards to the level of re-contamination which can occur during transport. Consistently from year-to-year, the percentage of Salmonella positive isolates in locally produced animal proteins and fish meals arriving at feed mills is approximately double the level of Salmonella positives found at the local manufacturing premises. In 1998 the prevalence at each location was 4.4% and 1.7% respectively. This re-contamination during transport can be a very important epidemiological factor for both raw materials and finished feeds.

Contaminated vegetable raw materials

Vegetable sources of raw materials are not monitored under EC Directives but individual Governments of some member states have comprehensive monitoring schemes operating under industry Codes of Practice. This monitoring has shown that vegetable raw materials have similar levels of Salmonella contamination to animal sources. The most common vegetable raw material found to be contaminated is oil seed proteins such as sunflower, rape and soya.

Monitoring of oilseed proteins in 1997 found 5.6% positive for Salmonella serotypes with rapeseed Meal from one crushing plant consistently showing positive results of a particular serotype. Notably, this source of rapeseed Meal had a higher level of Salmonella contamination to both locally produced and imported animal proteins in 1997.

A survey in Great Britain in 1990 showed that, on average, 7% of vegetable raw materials

contained a Salmonella serotype. Both *S. enteritidis* and *S. typhimurium* have been found in soya, sunflower and wheat.

Annual surveys in Great Britain through 1996, 1997 and 1998 have shown that 11.8%, 10.0% and 6.4% of all vegetable raw materials tested by MAFF were positive for a Salmonella serotype, including pathogenic serotypes such as *S. typhimurium* and *S. enteritidis*. Historically, processed animal proteins and fish meals have been associated with contamination with pathogenic Salmonella serotypes such as *S. enteritidis* and *S. typhimurium*. However, in recent years isolation rates of these serotypes have been higher in vegetable raw materials. Approximately 50% of the *S. typhimurium* isolates from finished feeds and raw materials by MAFF in GB in 1997 and 1998 were found in vegetable raw materials, whilst in 1996 over 80% of the *S. enteritidis* isolates were found in vegetable raw materials. Pressure from European consumers and retailers, in particular British retailers, has promoted the use of vegetable only animal feeds and with this an increase in the nutritional reliance from vegetable proteins. This change will not necessarily reduce the risk of Salmonella contamination of finished feeds, as demonstrated by the levels identified in oilseed proteins in recent years.

Contaminated finished feeds

Approximately 44,000 samples of finished feed are tested each year by MAFF. Approximately 2000 samples are usually positive giving an annual prevalence of 4%. Since 1991 the number of *S. enteritidis* isolates, whilst relatively small, has fallen from 28 to 6 in 1997, while the prevalence of *S. typhimurium* has been maintained at a low but consistent level of approximately 40 positives per year. Notably, a recent survey carried out in the USA in 1995 found that on average finished feed samples had approximately 15% positive for Salmonella serotypes.

A recent feed mill survey carried out by MAFF demonstrated that *S. enteritidis* could be isolated from the intake pit in 1 out of 3 mills. In addition, the survey clearly demonstrated the same serotypes are present in both the intake raw material area of the feed mill and the cooler area. Salmonella can be carried throughout a feed mill environment on particles of dust and these will frequently move from the raw material end of the feed mill to the finished feed area. The cooler, in particular, will draw very large volumes of air some of it containing dust particles contaminated with Salmonella, and the cooler can be a frequent and effective method of recontamination of finished feed.

Compilation of Salmonella isolate information from European Government sources and individual poultry integrations has clearly demonstrated a good correlation between the incidence of Salmonella serotypes in finished feed and in poultry flocks. For many Salmonella isolates this link is also reflected in the prevalence of isolation, as frequently the same serotypes are seen in the top 5 isolates from finished feeds and the top 5 isolates from poultry flocks over a similar time period. As previously discussed, this may not always be evident for *S. enteritidis* due to the much higher prevalence of isolations from poultry, compared to feed, based on the particular highly invasive and infectious nature of this serotype. Some *S. typhimurium* phage types also exhibit a similar epidemiological feature, especially where trans-ovarian, vertical transmission, causes rapid dissemination of the Salmonella infection throughout an integrated poultry organisation.

Prevention

Monitoring of raw materials can give useful epidemiological information and facilitate the supply of material from the most appropriate sources. However, due to the limitations on effectively sampling large volumes of material on a regular basis and the practical implications of operating a test and release strategy, all raw materials should be considered as possibly contaminated with a Salmonella serotype.

Compulsory Government monitoring of targeted raw materials, such as animal proteins in the European Community, can have an influence on the level of contamination recorded in such material over a period of time. In addition, Hazard Analysis Critical Control Point (HACCP) procedures within both the raw materials supply chain and the compound feed mill environment can also substantially reduce the level of Salmonella contamination, both in material entering the mill and the finished product being produced. In addition, engineering procedures, which minimise the flow of dust particles

across a mill and facilitate a "clean" air supply to coolers, will also impact on the level of contamination in the finished feed product. Several MAFF surveys of feed mills have clearly demonstrated the same serotypes present in both the intake raw material area of the feed mill and the cooler area.

Control

Consistent and effective control of Salmonella contamination in finished poultry feed, is dependent on the ability to effectively de-contaminate the feed and prevent re-contamination.

Several commercial products containing organic acids, commonly propionic and formic acids, and their salts have been successfully used to reduce Salmonella contamination of feed. However, some of the products can be corrosive to the mill equipment. The organic acid products may also help in preventing re-contamination, both in the feed mill and during storage and transport. In addition, the products have been claimed to improve animal performance, in particular broiler flock performance.

Enhanced organic acid products are also available commercially. These contain aldehydes, natural terpenes and surfactant, in addition to the organic acids. The combination of these ingredients has a synergistic effect on the bacteriocidal activity of the commercial product. In addition, the products are effective against both gram negative (*Salmonella* and *E. coli*) and gram positive (*Clostridia*, *Staphylococcus* and *Streptococcus*) bacteria. Furthermore, they can have a role in preventing re-contamination. Similarly, it is claimed that these products enhance animal performance.

Traditionally, Salmonella control in finished feeds, such as poultry breeder feed, has been attained by heating the feed through a manufacturing process such as pelleting. However, at standard pelleting temperatures (65-70°C) total de-contamination is highly unlikely and subsequent multiplication of any residual Salmonella can occur. Furthermore, re-contamination, especially through the cooling system, may occur.

For effective heat de-contamination, a defined combination of a set temperature for a set period of time, at a set relative humidity must be consistently applied to the finished feed. In addition, the de-contaminated feed must be protected post the heating process to prevent re-contamination and this should be extended through to the poultry flock.

In Northern Ireland, John Thompson & Sons Ltd, the largest feed manufacturing mill facility within the United Kingdom or the island of Ireland, have established technology to effectively decontaminate poultry feed. This technology has been developed in conjunction with Moy Park, Ireland's leading poultry integrator and major food processor, and Ross Breeders Ltd. A specialised biosecure manufacturing facility has been built to ensure that all of the poultry feed supplied to the Moy Park poultry integration, and some other producers in Northern Ireland, is free from Salmonella. This unique commercial facility has been specifically designed to destroy pathogenic bacteria, such as *Salmonella* and *E. coli*, by subjecting every batch of feed to a predetermined time, temperature and humidity, using the latest technology. The heat decontamination parameters have been verified by independent accredited Research Laboratories to give a total kill of *S. senftenberg* at 10_6 cfu's (colony forming units). *S. senftenberg* has a relatively high D-value which is greater than most other Salmonella serotypes including *S. enteritidis* and *S. typhimurium* and 10_6 cfu's is the level which could be present in infected rodent or wild bird faecal material. Only effectively decontaminated feed can pass into the Biosecure facility, due to a unique "hold" facility which will only positively release feed which has attained the necessary de-contamination parameters.

Recontamination of the decontaminated feed is prevented by enclosing the entire manufacturing process within a complete hygiene barrier. This includes the controlled access of both personnel and equipment using procedures to ensure that contamination is not introduced into the hygiene barrier. All of the air supply to the biosecure milling facility is filtered through a comprehensive ventilation system, down to 5 microns, to remove any dust particles which could be potentially contaminated. Positive air pressure is maintained throughout the manufacturing facility. The biosecure milling facility is capable of producing in excess of 250,000 tonnes of Salmonella-free feed per year which is delivered to poultry flocks throughout Northern Ireland by a totally dedicated transport fleet, to ensure that recontamination does not occur between the biosecure mill and the farms.

Conclusion

Raw materials and untreated finished feed constitute a significant reservoir of Salmonella contamination for poultry flocks. In Europe, during the late 1980s and early 1990s, animal proteins were the most important source of contamination but vegetable raw materials are now considered to be equally important. *S. enteritidis* and *S. typhimurium* are found at low levels in raw materials but this nidus constitutes a significant primary source of contamination for animal production systems, such as poultry integrations. Commercial organic acids and enhanced chemical products have an important role in the control of contamination of finished feeds. Heat de-contamination can be fully effective but re-contamination must be prevented, especially in post heat manufacturing areas such as the cooler environment. Total protection of the de-contaminated feed must be extended to the delivery of the feed to the farm.