The salmonella challenge – part one

By Dr Peter Spring, Professor, Swiss College of Agriculture

Despite the many changes in legislation and farming practises in the last 20 years, salmonella infection in humans from contaminated meat and eggs continues to be a problem for the industry.

The majority of infections from S. enteritidis and S. typhimurium reported in humans are still considered to be derived from consumption of contaminated eggs and poultry meat. It is known that S. enteritidis is commonly found in the reproductive organs of hens, and is particularly difficult to eradicate, due to its tenacious colonisation of this part of the body.

Hence any hen that has been in contact with Salmonella spp is likely to be a carrier and produce eggs that are contaminated to some degree.

Salmonella outbreaks

To put the levels of infection in the human population into context, health statistics from 2009 showed that there were 108,614 verified cases of salmonella infections in the EU population of 500 million people (EFSA, 2009). If this is extrapolated globally, this translates to between 1 and 15 million human salmonella cases every year.

Studies from EU farms have reported a wide range of infection rates in flocks, with between 0 and 79% of the flocks being tested positive. In some countries, levels of salmonella positive birds can be very low, for example, the stringent measures taken in Denmark to control infection in flocks reduced the number of positives in each flock from 13% down to less than 1% in the period between 1998 and 2006. Other notably low salmonella infected flocks are found in the UK, Scandinavia and New Zealand. This is due to a stringent regime of prevention measures and the use of specialised dietary ingredients that negate or control the ability of salmonella to infect and establish viable colonies within the bird.

In order to control salmonella infections within flocks of poultry, certain management strategies must be applied. The first is based on preventing infection initially, by removing exposure to salmonella for the birds.

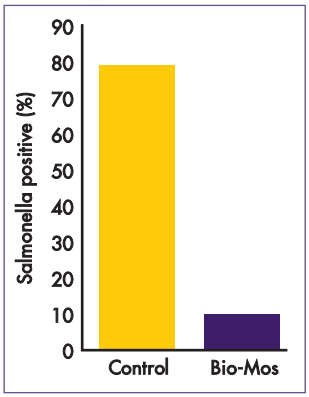

Fig. 1. Impact of feeding diets supplemented with Bio-Mos on faecal salmonella shedding from contam-

This includes effective disinfection of houses and equipment between flocks, biosecurity on farm, control of disease in the breeder flock to guarantee that only salmonella-free day old chicks or point-of-lay pullets are brought onto the farm and ensuring that all feed used is heat processed and contains proven pronutrient ingredients.

An important part of control of salmonella in feed is to control rodents and wild bird access, as these animals can be a zoonoses of infection, causing contamination of previously 'clean' feed. Finally, strict hygiene measures at slaughter are critical to reduce cross-contamination.

Even in a well managed poultry farm, feed can become contaminated with salmonella by various means which are difficult to control. Heat processing assists by destroying bacteria present within the feed.

However, great care must be taken not to damage the nutrients or their digestibility characteristics within feed by overheating it purely to remove potential bacterial contamination, as this will compromise performance. Organic acids are commonly added to feed to assist in the control of bacteria, and certain other pronutrients, such as mannan-oligosaccharides (MOS), can be used in synergy with acids. Competitive exclusion products (probiotics) are another example of a feed pronutrient that can be used to control any bacteria that do make it past the control measures into the digestive tract, and, once again, MOS can help facilitate their mode of action.

How pronutrients work

Commercial MOS products, such as Bio-Mos (Alltech), have been extensively researched, and are known to bind bacteria such as salmonella by attachment to lectins on the cell surface. These lectins are used by the bacterial cell to facilitate binding to the gut wall – which is an essential step in allowing colonisation and proliferation within the gut.

By acting as a decoy and causing the bacteria to bind to Bio-Mos instead, colonisation and infection is prevented, with the bound microbes being flushed from the gut.

The reason for the synergy between Bio-Mos and other pronutrient ingredients, such as acids and probiotics, is because it has a completely different mode of action, effectively mopping up any bacteria that have not been destroyed by the acid, and creating a less competitive environment, allowing the probiotics to colonise the gut.

Trials conducted in Hungary on 73,000 commercial broiler chickens, kept on a farm with a known high contamination rate of salmonella, examined the impact of feeding diets containing Bio-Mos on productive performance and levels of salmonella infection in the flocks.

Faecal shedding of bacteria was monitored at the end of each production cycle to assess infection status.

Fig. 1 shows the reduction in salmonella shedding for the birds receiving the feed supplemented with Bio-Mos, which decreased from 80% of the birds from each flock being tested positive, down to 10%.

This trial demonstrated that, even in a highly contaminated rearing environment, the use of Bio-Mos can effectively bind bacteria, preventing gut and organ colonisation.

The performance data from this trial allowed the determination of the impact that bacterial loading had on bird performance.

Weight gain and feed intake were monitored throughout the trial, allowing the calculation of the feed conversion ratio for both the control and the treatment (Bio-Mos) groups of birds.

The impact of feeding the treatment diet improved FCR by 3%. These results also showed that birds fed Bio-Mos consumed 62g less feed than their control counterparts for each kilogram of weight gained.

In terms of feed consumption for this particular farm, this equates to a saving of over 60 tons of feed annually.

Despite the high contamination rate for this facility, the mortality for the farm was only in the region of 7%. However, when mortality rates for the control and the treatment fed birds were compared, this was reduced to just over 4%, which again would equate to further cost benefits to the producer. When all benefits in terms of production factors and mortality were taken into account, the final European Production Efficiency Factor (EPEF) value was 33 points higher (283 versus 249) compared to the control.

In summary, even with new strategies in place to help prevent salmonella contamination on poultry farms, the risk of contamination still remains.

Specialist pronutrients and a combined holistic approach are needed to reduce such risks to a minimum. ■

The salmonella challenge – part two

By Dr Peter Spring, Professor, Swiss College of Agriculture

Salmonella infections continue to be a major issue in the poultry industry, due to their association with human disease. However, certain feed ingredients can be used to prevent colonisation by salmonella, effectively removing it from the internal environment of the bird and preventing the contamination of meat and poultry products. In order to best understand how these benefits can be obtained, it is essential to focus on how these feed ingredients work and what they can achieve in vivo via assessments, both at a research and a commercial level.

Bio-Mos (Alltech Inc, USA) is commonly used as a feed ingredient to help protect the avian digestive tract from colonisation by pathogens. In the 20th Century, it was industry practice to use antibiotics in poultry feed to control pathogens in the gut, however concerns regarding the promotion of antibiotic resistance in the human population by such feeding practices resulted in a Europe-wide ban on their prophylactic use in feed.

Prior to the ban, the yeast-derived mannan-oligosaccharide (MOS) that forms the basis of the product Bio-Mos was already being studied and exploited for its properties in maintaining gut health in agricultural species, including poultry. This work included understanding the mode of action of Bio-Mos and how it brings about the changes required in the gut microflora profile, not only by inhibiting the colonisation of pathogenic bacteria but also by promoting beneficial gut bacterial profiles.

In the mid-1990s work by Spring established the essential binding capacity of Bio-Mos on pathogenic bacteria. This research established that the thread-like surface fimbrae, that pathogens such as salmonella employ to attach to the gut wall (Fig. 1), can be blocked by preferential attachment to Bio-Mos.

These fimbrae could otherwise attach to the surface lectins on the gut wall, allowing the bacterium to be stabilised within the gut environment and reproduce to form colonies that can then cause disease.

Attachment to Bio-Mos causes blocking of the receptor sites on the ends of the fimbrae, hence they cannot attach to the gut wall and colonise the gut. The benefits of this are many:

- The bacteria are excreted harmlessly from the gut in the flow of digesta.
- The animal is protected from disease causing organisms without resorting to pharmaceutical products, which can also destroy beneficial microbes as well as pathogens.
- The desirable bacteria within the gut are not affected by competition from pathogens, allowing them to flourish and maintain a correct bacterial balance, optimising the digestive environment.

Such benefits are known to directly contribute to productive performance as well as disease control – and many trials have shown that Bio-Mos activity in feed and the gut maintains performance to levels previously seen with antibiotic supplemented diets.

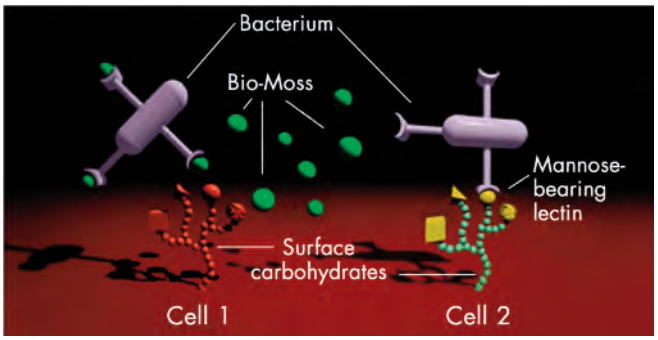

Fig. 1. Attachment of fimbrae-bearing bacteria to the gut wall and/ or Bio-Mos.

In addition, research by the Rowett Institute has shown that the attachment capacities of Bio-Mos in the gut can help stimulate appropriate immune reactions via the gut-associated lymphatic tissue. This is highly useful in assisting the recognition of pathogens in the gut, through presentation of the bacteria when it is bound to Bio-Mos, to certain cells within the gut wall.

This promotes the birds' own natural recognition of pathogens, which is essential for launching an efficient response when any unbound pathogens, including salmonella, are encountered.

Without this 'early response' mechanism, any delay in immune response could lead to colonisation and some disease problems before the animals own defence systems come to the fore in specifically negating the pathogen.

In practical cases, the reduction of salmonella in broiler flocks has been demonstrated repeatedly in the last decade or more.

Sisak (1994) showed that birds infected with a wild-type salmonella strain had 70% colonisation in the caeca, but that this was reduced to less than 20% when fed Bio-Mos.

Yamaguchi (2000) demonstrated a 90-99% reduction in S. enteritidis infections in broilers fed Bio-Mos supplemented diets in their trials that monitored levels of colonisation in the caeca, liver and spleen.

Under practical conditions, in many countries broiler flocks must be tested negative for salmonella before the flock can be released for slaughter and processing. Such reductions and control of this pathogen in broiler flocks, by applying a product such as Bio-Mos in feed, is a simple and effective way of preventing the disease in broilers as well as controlling its entry into the human food chain. When commercial flocks were tested, and the levels of salmonella in the caeca and organs were determined, a clear impact of control by Bio-Mos in both the gut and organs, as well as on the external carcase was clearly seen.

Any programme of salmonella control must be sure to include all the major pathogenic strains of the bacterial species. In terms of the efficacy of Bio-Mos against different types of salmonella infections, research has demonstrated that many commonly encountered strains are mannose sensitive, and will therefore be bound in the presence of MOS.

Work in the 2000s on the use of Bio-Mos in feed, has evaluated several newly emerged strains of salmonella associated with poultry production. For example, S. dublin and S. java have both been identified as strains that are subject to agglutination (binding) by MOS. These benefits were evaluated from commercial slaughter house samples. Trials in Thailand (2002) further demonstrated the high binding capacity of Bio-Mos for S. enteriditis compared to other yeast isolates.

The specific mode of action of Bio-Mos has been clearly demonstrated in both research and commercial trials, with respect to its ability to bind pathogens and effectively remove them from the gut environment.

This is reflected in the lower levels of infected birds, and even the ability to 'clear' a flock that would otherwise be positive for salmonella.

For the poultry industry, being able to control gastric infections such as these, whilst maintaining an antiobiotic-free status, is highly relevant.

Using Bio-Mos as part of a practical control programme is a simple solution. ■

The salmonella challenge – part three

By Dr Peter Spring, Professor, Swiss College of Agriculture

Salmonella infection in poultry is a major concern to food processors and consumers alike. The limitation of its entry into the food chain continues to be a focal point within the poultry industry, for both meat and egg producers. This has been of particular importance since the public health scares in the 1980s and the ban on prophylactic antibiotics within the European poultry industry in the late 1990s.

Since that time, several alternatives have been proposed as in-feed solutions to control this and other enteric pathogens.

One such product that has been used with particular success is Bio-Mos (Alltech Inc, USA). Over more than a 20 year period it has been shown to be effective, not only in preventing colonisation of the avian gut by pathogenic organism, but also in the balancing of the gut microflora, allowing better bird performance.

However, the main issue remaining is consumer confidence in the safety of the meat and eggs they purchase, as well as the ongoing welfare of farmed poultry, i.e. the use of safe, natural feed ingredients.

In the previous article, the mode of action of Bio-Mos was discussed in detail; showing how its use can drastically reduce the levels of salmonella in the gut, as well as it efficacy for binding different strains of the pathogen.

Consumer issues

This final article in the series will focus on consumer issues and the safety of the end product, be it meat or eggs. It will also look at how in-feed strategies can be used in an economically viable manner to maintain food safety and quality standards.

The challenge remains for poultry producers to be able to produce high quality, safe meat and eggs at a competitive cost.

Broiler producers in the USA have shown that using Bio-Mos in their flocks improved flock uniformity in male broilers by 2% overall, taking the coefficient of variation within body weight down from 8% to just under 6%.

This represents a clear economic benefit when marketing poultry carcases within a tight range for supermarkets.

Many other trials have shown that broilers and layers perform better and more efficiently on Bio-Mos, especially where antibiotics are no longer permitted in feed.

The benefits also include lower mortality. Indeed, when broiler trials were analysed in the USA, a cost saving of 4 cents per bird was realised when feeding Bio-Mos versus an unsupplemented diet.

Hence, from an economic perspective, using Bio-Mos is beneficial for producers. But where does that leave the issue of meat and egg safety for consumers?

In terms of eggs, it is known that on-farm conditions make a difference to egg contamination, with bacterial levels of between 10^3 to 10^5 in well managed flocks; rising to 10^8 in poorly managed facilities.

The higher the contamination level of an egg, the more likely a person utilising that egg in cooking will become infected themselves.

Likewise for hatching eggs, the chick will stand a higher chance of gaining an enteric infection due to exposure to pathogens on the shell.

Challenge plus diet	% positive in flock for S. enteritidis
Control plus hen caecal contents	87
Bio-Mos plus hen caecal contents	33

Table 1. Comparison of the effects of a challenge with Salmonella enteritidis in day old chicks.

This was demonstrated by a study comparing the effects of a challenge with 10^4 S. enteriditis in day old chicks exposed to hen caecal contents, both with and without Bio-Mos (Table 1).

The trial data showed that, even though all the chicks were exposed to the salmonella challenge as well as caecal contents (akin to faecal matter on eggs), the chicks fed Bio-Mos had significantly less positive swabs.

Treatment	Mucosa (g/kg body weight)	Muscularis (g/kg bodyweight)
Control	0.55^{ab}	1.49^{a}
Antibiotic (Virginiamycin)	0.46^{a}	1.33^{b}
Bio-Mos	0.58^{b}	1.60^{a}

Means not sharing a letter differ significantly P<0.05

Table 2. Broilers fed Bio-Mos have been shown to have thicker gut mucosa and more robust gut muscle compared to unsupplemented flocks.

When many trials were compared, in general a log 2 reduction in gut content bacterial numbers has been found when Bio-Mos is included in the diet of growing chickens and laying hens. If feeding Bio-Mos is coupled with improved management practises on farm and better biosecurity, the 10^3 levels of pathogens found on feathers and eggs may be reduced to an almost negligible level.

Carcase contamination with pathogenic bacteria is known to be directly related to the levels of infection in the flock during its growing cycle.

Non-diseased flocks have cleaner carcases, leading to better meat safety at slaughter. This is related to the fact that if broilers have well balanced, optimised digestive tracts, they are more robust organs during evisceration.

This leads to fewer tears during processing, which radically reduces the number of downgrades at the processing plant (via gut content spillages).

Broilers fed Bio-Mos have been shown to have thicker gut mucosa and more robust gut muscle (Table 2) compared to unsupplemented flocks and even those birds fed an antibiotic growth promoter.

Commercial trials carried out in the Netherlands showed that Bio-Mos was effective in binding the pathogen S. java found on the breast skin and feathers of broilers at the slaughterhouse. This is again valuable in negating contamination of meat at the end user level.

Twofold control strategy

Essentially, the key issue for controlling salmonella in poultry production is twofold – firstly by ensuring that flocks have minimal exposure to infection and secondly, that the end products that are marketed for human consumption are free from infection.

This ensures that the pathogen does not enter the food chain and cause further disease.

Bio-Mos can certainly play a role in both these areas, as it has been demonstrated to not only limit on-farm contamination of flocks, thereby improving production parameters and economics and it also makes the bird more internally robust to withstand infection and to reduce downgrades at slaughter due to spilt gut contents.

Using Bio-Mos in feed, alongside improvements in management practises and biosecurity, are the key to establishing the salmonella free status of poultry meat and eggs. ■