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FEED MILL HACCP AND PATHOGEN REDUCTION STRATEGIES

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Introduction

It has long been recognized that the production and delivery of quality feeds is vital to the success of any animal production operation. It has also long been recognized infectious agents are most effectively spread in commercial production situations via either contaminated birds or contaminated feed (i.e. "breed or feed").

While a number of researchers have examined the spread of contamination via hatcheries, few have examined the spread of contamination via feed. Therefore, it seems prudent to examine this area.

Basic in Control of Contamination in Feeds and Feed Mills

Blackman *et al.* (1993) and Jones and Ricke (1994) have published detailed information on control of contamination in feeds and feed manufacturing facilities. Control of contamination in feeds and feed mills involves procedures to:

1. Exclude contamination from the feed,
2. Prevent multiplication of the organism in the feed and
3. Kill organisms within the feed and prevent recontamination.

Higher numbers of organisms in feeds require harsher treatments for destruction than lower numbers. Harsher treatments cause nutritional damage to the feed in addition to the fact that they cost more. Thus, in reality, each of these control procedures are interdependent and must be pursued simultaneously (Jones and Richardson, 1996).

Flow Charts for Coordinating Control Strategies

The first step in developing contamination control plans is to develop a flow diagram which outlines the flow of ingredients and feeds through each feed manufacturing facility. A generalized example of a flow diagram is shown in Figure 1. It is important to realize that flow diagrams will be unique for each facility. In addition, flow diagrams that do not represent the actual flow of ingredients or feed in your facility are worthless! However, developing an accurate flow chart will assist in visualizing and addressing situations in each facility that promote or encourage contamination.

Steps to Exclude Contamination from Feeds

It appears rather obvious that if vermin are not controlled around a feed manufacturing facility, it is foolish to expect to control feed contamination. The presence of pathogens in rodent feces is well documented. In addition, my own limited sampling of wild bird feces collected around feed manufacturing facilities has revealed that *Salmonella* may be isolated from as much as 25% of these samples. Can we logically expect to curb *Salmonella* and other pathogens in feed if vermin such as these are not controlled?

Sampling is an often over-looked area when gathering information about pathogens in the feed mill environment. Certainly, the collection of adequate samples that represent the batch being sampled is important. However, a more basic question must be addressed. Are we certain that the contamination detected in the feed came from the sample or from the hands of person collecting the sample? The data in Table 1 illustrate this point. At one feed mill, facility personnel were instructed to collect samples and researchers collected samples from many of the same locations. A total of 43.75% of the samples collected by mill personnel were positive, while only 7.32% of samples collected by researchers were positive. These data suggest that adequate sample collection is a must if one wants to have a true assessment of contamination. While a variety of methods exist for dealing with the issue of cross contamination, perhaps one of the simplest is one developed by Jim Andrews of Holly Farms (now Tyson). I call this method the "Dixie Cup" method. Paper cups ("Dixie Cups") are purchased in a plastic bag from the grocery. Mill employees are instructed not to touch samples, and keep cups tightly closed within the plastic bag when not in use. Samples are collected only in new paper cups. Cups are used once and discarded. Samples are placed in sterile plastic bags following collection for transport to the laboratory. Although simple, this method is quite effective at preventing cross contamination.

Feed ingredients are a major source (if not **the** major source) of contamination in finished feeds. The data in Table 2 involve a small number of samples and are not representative of industry contamination levels. However, the data illustrate the point that pathogens can be isolated from virtually any organic feed ingredient. It would appear, therefore, that if one expects to control pathogens in feeds, one must first address control of pathogens in feed ingredients. Several simple and direct questions appear in order here. Do the specifications from which we order feed ingredients state that products will be free of pathogens?

Factors Influencing Microbial Growth in Feed

Prior to launching into a specific discussion, some familiar basic principles should be briefly established. Dust, moisture and feed age will have a major bearing on the degree to which a given lot of feed will be contaminated. Time and space preclude a full presentation of background data. However, the principles illustrated by the data presented generally apply to each classification of microorganism as well as to feed and ingredients.

Perhaps some of the earliest published data linking dust to microbial contamination is that of Nape (1968), which is shown in Figure 2. More recent data are shown in Figure 3. It is obvious to all of us that moisture encourages microbial growth in feeds. It may not, however, be quite as obvious that feeds are in equilibrium with the moisture in their surroundings. This means that, given time, feeds will either absorb or give up moisture to the surrounding air. Headley (1969) demonstrated (Figure 4) the positive correlation between feed moisture and relative humidity. In addition, there is a negative correlation between temperature and moisture (Figure 5). In short, cool areas tend to retain moisture longer than do warm areas.

Mycotoxins (such as aflatoxin) are toxic compounds that are produced when molds grow. Therefore, the presence of mycotoxins in feeds is evidence of mold growth in either the feed or the feed ingredients. The data in Figure 6 demonstrate a positive association between aflatoxin concentration and feed age. A similar association with feed age is likely true for microbial counts.

Any point within the feed manufacturing process that is either dusty, adds moisture (including relative humidity), adds heat to feed or allows feed to remain for an extended period of time should be examined as a possible sanitation control point. Some possible points to examine would be the boots of elevator legs, ground grain bins and basements.

Specific Problem Areas in the Mill

Bucket elevators (commonly known as elevator legs) are the most efficient means of raising materials to overhead binds. It is likely that every feed manufactured anywhere in the world has been conveyed through at least one elevator leg. As shown in Figure 7, elevator legs are comprised of three general sections: the head, the trunk and the boot. Product (feed or feed ingredients) are loaded in the boot section, elevated in the trunk section and discharged in the head section. Elevator legs generally aerosolize sizable amounts of dust. In addition, heat is generated, particularly around the pulleys in the head and boot sections. The boot section of the elevator tends to collect feed and each subsequent batch of feed that passes through the leg is then exposed to this collected material. After one or two batches of feed have passed through the leg, the boot section is full and little else collects. However, if the materials collected in the boot are contaminated, the potential for cross contamination is great. In addition, if feed sits in the boot area for extended periods of time, the heat generated can cause moisture to concentrate in cooler areas of the boot resulting in an increased potential for contamination.

Figure 8 illustrates a typical hammer mill system for grinding grain. As grain particles are fed into the system and reach the hammers, they are accelerated from near 0 to over 200 miles per hour (MPH) in a matter of seconds. This acceleration has two outcomes: particle size reduction and heat. The temperature of ground grains can rise 10 to 15°F during grinding and only a small part of this temperature increase is lost during transport to the ground grain bin. Once in the ground grain bin, moisture will tend to accumulate in cooler areas increasing the potential for microbial growth. The degree to which moisture accumulates in ground grain bins depends upon how long grains remain in the bin. Therefore, the time ground grains remain in storage bins should be kept to an absolute minimum. The data in Table 3 illustrate what can happen when ground grain tanks are not properly managed. The hatchability of eggs from flocks fed these feeds was 1 to 5% lower than that obtained from flocks fed normal feed.

Basements can be the most damp and dusty part of the mill. Moisture can collect in poorly sealed basements and feed will tend to accumulate here. In addition, many mills will house the cooler in the basement. This can lead to designs similar to the one shown

in Figure 9. Please note the close proximity of raw product conveyors to coolers, which draw tremendous volumes of air to cool pellets. Covers on raw conveyors were often left ajar or completely off for easy access. Furthermore, the windows were often left open because it was stuffy. These open windows allowed insects and occasionally a bird access to this area. In general, I believe it is best to avoid designing mills with basements. However, basements are a reality in many older mills. Nevertheless, if at all possible avoid locating coolers in basements.

The data in Figure 10 illustrate the difficulties with basements. The data demonstrate that highest counts are generally always obtained from the mixer while lowest counts were obtained from the pellet mill. While counts obtained at the mixer were similar for all the mills examined, at all other locations counts obtained from mill 1 were higher than those obtained from the other two mills examined. Neither mill 2 nor mill 3 had a basement and coolers were located on the second floor. The basement arrangement outlined in Figure 9 was located in mill 1.

Pelleting for Contamination Control

The data in Figure 10 also illustrate the transient nature of the pelleting process on microbial contamination. While microbial counts were indeed reduced by the heat of the pelleting process, numbers quickly rebounded. Although many feed manufacturers rely on the pelleting process for microbial disinfection, few published studies have examined the process under field conditions. The data in Figure 11 show the *Salmonella* isolation rates at the various pelleting temperatures. These data were, at best, confusing. A greater percentage of samples that were pelleted at 190°F contained *Salmonella* than those samples pelleted at 140° or 170°F. While these data may reflect differences in rations and/or initial contamination level, a much more important point emerged from this study. Figure 12 contains the data collected from the three mills examined arranged as to pelleting temperatures. No *Salmonella* were isolated from mill 2 at the pellet mill at any temperature. Temperatures of 170° effectively eliminated *Salmonella* from feeds collected in mill 1, but in mill 3 *Salmonella* were isolated from feeds pelleted at 180° and 190° F. The most likely explanation for these data involves contamination at the exit to the pelleting chamber. A large amount of dust and debris was present on and over the pellet mill in mill 3, while virtually no dust or debris was observed in the same area of mill 2. The dust and debris in mill 3 were often observed falling into the pellet stream and into the cooler. Apparently this dust rapidly recontaminated feeds following pelleting. Hence, the temperature to which pellets were subjected in mill 3 did not matter because they were rapidly recontaminated.

Feeds can also be easily contaminated in poorly designed or managed coolers. In fact, several studies have noted that *Salmonella* contamination of feed can increase within coolers (Davies and Wray, 1997; Israelsen *et al.*, 1996). While feeds could be contaminated at numerous points between the cooler and the farm, a discussion of these points will be omitted at this time.

Control of Microbial Growth on Farm

Microbial growth in feeds does not stop upon delivery to the farm. In fact, conditions on farms can either enhance or discourage microbial growth. The data in Table 4 depict the productivity differences between broiler farms. Even though growers in each productivity class were within the same area, received the similar chicks and apparently identical feed, some growers got better results from birds than others. The reasons for these differences are myriad. However, microbial growth was, in this case, apparently correlated with productivity (Table 5).

The same principals that govern microbial growth and contamination at the feed mill also operate on the farm. When pelleted feeds are delivered to poultry farms, only a portion of the feed delivered actually remains as pellets. Materials that are not pellets in such feeds are generally called fines. The data in Table 6 demonstrate that fines contain more microbial activity than pellets. Fines can be extremely dusty since they are pellets that were crushed or ground by the feed handling system. Feeder systems on-farm can promote the generation of fines (Figure 13). Fines have two difficulties on farm. Their small particle size and extra surface area makes them more efficient than pellets at absorbing moisture. In addition, birds prefer to eat pellets rather than fines, so fine tend to be eaten last.

Summary

In summary, although most microbial contamination is likely traceable to feed ingredients, countless locations within the feed manufacturing and delivery system can spread or increase contamination levels. In general, areas which are associated with elevated moisture levels, increased heat or are dusty should be closely examined as possible sanitation control points.

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Table 1. Sampling for *Salmonella* at Feed Manufacturing Facilities.

Sample Type	Mill Personnel Collected			Researcher Collected		
	No. Run	No. Pos.	% Pos	No. Run	No. Pos.	% Pos.
Mash	14	4	28.57	5	1	20.00
Cooler	14	2	14.28	6	0	0.00
Load Out	14	5	35.71	19	0	0.00
Meat Meal	14	12	85.71	2	2	100.00
Fish Meal	8	4	50.00	2	0	0.00
Corn/Wheat	8	1	12.50	1	0	0.00
Liquid Fat	8	7	87.50	6	0	0.00
All Samples	80	35	43.75	41	3	7.32

Table 2. *Salmonella* in Feed Ingredients.

Feed Ingredient	No. Run	No. Pos.	% Pos.
Brewers Grains	3	0	0.00
Corn Gluten Feed	1	0	0.00
Corn	18	1	5.55
Cotton Seed Meal	3	3	100.00
Debris	1	1	100.00
Dust	11	3	27.27
Fish Meal	1	1	100.00
Limestone	1	0	0.00
Meat & Bone Meal	1	0	0.00
Soybean Hulls	5	0	0.00
Soybean Meal	10	1	10.00
Wheat	1	0	0.00
Wheat Midds	24	1	4.17
Whey	1	0	0.00
TOTAL	80	10	12.50

Table 3. Moisture, fungal and mycotoxin contamination in feeds.

Sample Description	Moisture (%)	Fusarium (CFU/g)	DON ¹ (PPB)
Dust Corn Tank 1	31.44	310,000,000	242
Dust Corn Tank 2	32.20	258,000,000	130
Dust - Pellet Supply Bin	19.14	10,000,000	77
Unpelleted (Mash) Feed	12.35	71,000	150
Pelleted Feed	13.49	0000	96

DON, deoxynivalenol or vomitoxin

From: Jones and Wineland, 1994

Table 4. Productivity of broilers

Productivity Parameter	Productivity Class		
	Good	Mediocre	Poor
Body Weight (g)	1760	1737	1719
Feed Conversion	2.13	2.15	2.16
Livability (%)	95.98	95.61	92.78
Condemnations (%)	1.39	1.19	1.73
Grower Pay (¢/chick)	12.02	11.49	10.86

From: Jones *et al.*, 1982

Table 5. Relation of microbial counts and aflatoxin concentration to farm productivity class

Productivity Parameter	Productivity Class		
	Good	Mediocre	Poor
Bacteria (Log CFU/g)	6.46	6.60	6.71
Coliforms (Log10 CFU/g)	4.60	5.40	5.43
Fungi (Log10 CFU/g)	3.90	4.54	4.64
Aflatoxin (ppb)	6.13	6.50	14.0

From: Jones *et al.*, 1982

Table 6. Characteristics of pellets and fines.

Item	No. of Assays	Particle Size (µm)	Resp. CO ₂ ¹ (mm Peak Ht)
Pellets	62	3650	10.17
Fines	62	1100	21.65

Respiratory CO₂ is a measure of microbial activity.

From: Jones and Hamilton, 1986