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# A Historical and Scientific Perspective of Same Species Feeding of Animal By-Products

Draft Final Report

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## EXECUTIVE SUMMARY

The historical development of the organized rendering industry originated in the late 1800's when beef was produced primarily for table use, having been used for the hides and tallow prior to that time. The use of animal protein for poultry feed, probably the first such feeding practice, was reported to occur in the late 1880's prior to the establishment of the rendering industry. Rendering first occurred in New England and the tankage was sold by the barrel for poultry feed. The use of animal protein for swine feed was reported to have first occurred in California during the 1890's. The first rendering process was wet, very slow and inefficient. Dry rendering was reported in 1927 with many improvements since that time.

The nutritional benefits for feeding animal by-products in poultry, swine and fish have been well documented. Among the many advantages for feeding such ingredients are the improved digestibility of the amino acids in the protein fraction and the biological availability of minerals, phosphorus in particular. However, with recent events in Europe regarding the bovine spongiform encephalopathy (BSE) outbreak in cattle, which has been associated with the variant Creutzfeldt-Jakob Disease (vCJD) which affects humans, the practice of feeding animal by-products has been brought into question regarding food safety in humans.

The risk associated with same animal species feeding has been the topic of considerable discussion and has been the focus of regulatory action by both the USDA-APHIS and FDA in order to prevent the introduction of BSE into the U.S. The issue of consumption of tissues by animals of the same species has resulted in substantial review of the literature to assess the scientific evidence as well as the review of historical animal production and feeding practices. It is well documented that many farm animals, including poultry, swine and fish, demonstrate cannibalistic tendencies, by consuming raw tissues of the same species during social behavior, which are not fully understood. These include cannibalism attacks, consumption of dead carcasses and feather picking in poultry as examples. Similar behavior has been noted in swine, including the consumption of newborn pigs. The Harvard Center for Risk Analysis in the Harvard School of Public Health has conducted an extensive risk analysis in which they concluded that the U.S. is highly resistant not only to the introduction of BSE into the U.S., but also even more unlikely is the introduction of TSE in poultry and pigs as they are currently produced in the U.S.

The issue of food safety has been a long standing principle which the rendering industry has addressed through guidelines for rendering activities. This has been based on extremely large volumes of research which address the complex issue of controlling not only the animal disease agents of concern (such as Salmonella and certain viruses) but also the human pathogens of concern (including Salmonella, Campylobacter, Listeria, E. coli, and Clostridium) in animal products. The development of effective measures to prevent the spread of these pathogens and ensure control has received considerable attention. Great effort has been expended to ensure that the industry, through the adoption of effective Standard Operating Procedures, Good Manufacturing Practices, Sanitation Standard Operating Procedures and the implementation of Hazard Analysis Critical Control Point systems can provide a safe, high quality feed ingredient for use in animal feeding programs.

The economic implications for feeding animal by products clearly indicate that the utilization of these products impacts two critical areas. The elimination of these in the diets of animals will increase the cost of feeding by 5-10%. However, of even greater significance, the elimination of these rendered products requires the development of alternative systems for disposing of these resources. The currently available options (incineration, landfill, compost, etc.) are not only costly to the point of becoming economically not feasible, but these alternatives also result in environmental consequences which pose even greater costs than the economics of animal feeding.

In conclusion, the combined benefits of improved animal nutrition for poultry, swine and fish, the lack of significant food safety risks to the human population either from traditional microbial pathogens or BSE like disease, the lack of significant risk for animal disease exposure as well as the economic consequences of reduced overall meat food costs are exceptional. Perhaps the most significant benefit of all is the avoidance of the adverse consequences for the environmental, ecological and societal impact in general posed by the unacceptable alternative methods of disposal of these high quality resources. The rendering industry has demonstrated over a long period of time that this is a model system for minimal impact on the environment and society as a whole.

# HISTORICAL PERSPECTIVE OF ANIMAL PROTEIN USAGE

The historical development of an organized rendering industry, similar to the one of today, occurred when beef was produced for the table and was no longer a by-product of the cattle industry (Burnham, 1996). Until the late 1800's, the main value of cattle was for the sale of hides and tallow with beef being of little importance. The main rendering of animal fat and carcasses occurred on farms with the production of tallow that was utilized for making soap and candles. The development of the rendering industry primarily occurred from 1850 through the end of the 19$^{th}$ century and was primarily associated with: 1) the building of centralized slaughter houses in the upper Midwest and East coast, 2) railroad expansion into the heartland of America which was needed to bring the cattle from the plains, 3) the Industrial Revolution helped bring immigrants to the cities with an increasing taste for beef, 4) the invention of the refrigerated freight car, 5) faster and more reliable transportation, 6) rudimentary evaporative cooling and 7) the commercial manufacture of ice (Burnham, 1996).

The use of **animal protein for poultry feed** was reported to occur in the late 1880's, prior to the establishment of the rendering industry. Rendering was completed in country slaughter houses in New England and tankage was made from air drying solids from the tank water on platforms outside the buildings. Burnham reported tankage was sold by the barrel for chicken feed.

The use of **animal protein for swine feed** may have first occurred in California during the 1890's. Nels Peterson Sr. was a hog farmer in California that collected waste suet and bone from butcher shops to supplement the diet of his animals. Peterson and his wife cooked the meat scraps in a huge iron kettle in their kitchen and skimmed off the liquid fat. Burnham reported, "The residue or cracklings as they were known, were used in the hog rations. The fat was stored in drums which solidified into tallow and was put aboard ships bound around Cape Horn to the east coast plants that converted the tallow into soap."

Haugen and Pettigrew (1985) reported that traditional wet rendering of an animal carcass was very slow and inefficient, and when the meat packing industry began to flourish, the resulting concentration of inedible materials required the immediate development of commercial rendering." The authors reported that "renderers started using steam as a heat source and the waste water (including meat and bone scraps) was dried to produce a product called cracklings." Cleland in his book *March of Industry* published in 1927 described cracklings as a product that contained "50 percent protein, 6 percent fat, and not over 2 percent crude fiber, 10-25 percent bone phosphate of lime." Haugen and Pettigrew (1985) reported that "the next major processing improvement for rendering animal products was the advent of the dry rendering procedure in the 1920's. The dry rendering process was more efficient and saved labor and energy costs and eliminated the foul odors of drying tankage."

Cleland (1927) described the dry rendering process in *March of Industry* "By the more recent method known as dry rendering, the raw material is cooked in a fat-melter, which is a steam-jacketed vessel with paddles as agitators. The moisture is driven off, the excess melted fat is drained off, and the solid matter is put into a screw press where the grease content is cut down to about 8 percent."

Haugen and Pettigrew (1985) reported that the rendering industry has made many improvements since

1927 but the fundamentals of rendering are the same as described by Cleland. Most meat meal products are made with a batch dry rendering or a continuous flow version of the same process.

Haugen and Pettigrew (1985) reported that during the early development of the rendering industry the cracklings were sold as fertilizer. They reported that this changed after people noticed that animals fed animal protein cracklings in their diets had a better growth rate compared to animals fed diets containing only plant proteins.

The use of **animal protein for poultry feed** may have been the first species to utilize the byproducts from country slaughterhouses and on farm butchering that were air dried and sold for chicken feed (Pearl, 2002). Scott et al. (1969) in *Nutrition of the Chicken* wrote "Early experience showed that animal protein sources such as fish meal, meat scrap and dried skimmed milk, when added to poultry diets, produced results which were vastly superior to those obtained with similar diets containing only plant proteins." Scott and associates reported "that during World War II, because of the known nutritional value of consuming liver to prevent pernicious anemia in people, there was an effort to eliminate expensive and scarce animal proteins from the diets of farm animals. The use of all-vegetable protein diets reduced the rate of growth in chickens and pigs and decreased the hatchability of eggs." Scott and group reported "The factors that were responsible for the early superiority of animal proteins as compared with plant proteins were 1) the calcium and phosphorus supplied by the bone in animal protein supplements; 2) B-complex vitamins, particularly riboflavin, in dried skimmed milk and whey; 3) vitamin $B_{12}$ which is present in all animal materials, but not plants; and finally 4) the amino acids methionine and lysine, which are present in the proteins of fish, eggs and milk at much higher levels than in the common protein supplements of plant origin."

Haugen and Pettigrew (1985) wrote "By 1950, identification of **vitamin $B_{12}$ as the Animal Protein Factor**, and its commercial synthesis, allowed the development of diets without animal protein for non-ruminants. The corn-soybean meal diet became popular, and since then meat meal has had to compete in the marketplace with soybean meal and other plant protein products."

## NUTRITIONAL BENEFITS

### Cannibalistic behavior

Many farm animals, including fish, show natural cannibalistic tendencies during social behavior that are not fully understood. Feed that is deficient in various nutrients such as protein, amino acids, and minerals may trigger these cannibalistic traits in some species. A high stocking density environment for farm animals, poultry, and fish has been shown to increase this abnormal behavior. Some of these cannibalistic behavior traits would be feather and tissue picking by poultry, ruminants practicing placental consumption, tail biting by pigs and sheep, chickens and pigs preying on dead group mates, and natural fish predation that leads to reliance of most aquaculture species on some form of fishmeal in their diets (Keeling and Gouyou, 2001).

## Swine

Animal byproducts have been important to livestock and poultry industries for many years (Pearl, 2001). In one of the first reported animal nutrition experiments, Plumb (Purdue University, 1901) demonstrated a dramatic decrease in time required for swine to reach slaughter weight with the addition of animal protein tankage to traditional ear corn diets. Other researchers followed with even greater improvements through the use of tankage with dried blood and lead to the development of digester tankage. This trend lead to a continuous progress in swine nutrition (Pearl, 2001). These advances coupled with the agronomic development of soybeans significantly advanced swine nutrition. Review of the most frequently referenced composition tables indicate that the 1998 Nutrient Requirements of Swine is very representative, providing minimum values and a margin of safety for the descriptions of rendered meat meal (MM) and rendered meat with bone (MBM) (NRC, 1998). Cromwell (1997) reported on swine nutrition today and in the next century as affected by genetics, gender, health status, environment, carcass modifiers, and sow prolificacy. Included in his discussions were the diet formulation options based upon amino acid basis, net energy systems and diets which modify body composition. The alternative feed ingredients offered by the current increase in the amounts of available meat and bone meal, due to the recent restriction of feeding meat by-products to ruminants because of the BSE issue, indicate that these products can be successfully incorporated in swine diets when small amounts of tryptophan are included. Orias et al. (1999) reported variation in the composition and ruminal digestion kinetics among different sources of Pork Meal (PM). Hamilton (1996) reported that MBM made only from PM is suitable to use as a source of undegraded intake protein with variation being reduced by purchasing animal proteins from a single source. He further stated that any type of MBM may be fed to swine, poultry, fish and companion animals.

## Poultry

The poultry industry is still the major utilizer of animal protein, using over 36% of all production of by-products (FDA-ANPR, 1996). The NRC sets guidelines for broiler chicken diets (NRC, 1994). Poultry nutritionists have utilized MBM in broiler diets for many years (Kraybill, 1928, Prange et al., 1928a, Prange et al., 1928b, Prange et al., 1927, Kratzer and Davis, 1959, Skurray, 1974, Parsons et al., 1997, Dale, 1997, Waldroup and Adams, 1994). The primary advantages associated with the utilization of MBM in broiler diets have been the high digestibility coefficients for the amino acids in MBM as well as the biological availability of phosphorus in animal protein (Parsons, 1996, Parsons, 1998, Waldroup, 1994, and Sell, 1996). Work by Drewyor and Waldroup (2000) reassessed the utilization of animal by-products in broiler diets as a result of favorable supply and pricing created by the ruminant to ruminant feeding ban. Inclusion of MBM in broiler diets at higher levels than traditionally used (up to 12.98% of high-ash and 17.76% of low-ash MBM) had no adverse effects on broiler performance. However, the economics of protein sources as well as supplemental phosphorus sources must be considered. Another consideration is the increased output of fecal phosphorus resulting from the incremental increase in dietary phosphorus, which can create an environmental concern in areas of intensive poultry production. Another issue of some concern regarding the negative effects of biogenic amines has been addressed by work conducted by Friday and Firman (1999). These naturally occurring compounds (phenylethylamine, putrescine, cadaverine and histamine) are found at low concentrations in a number of animals, plants and microorganisms (Pearl, ). Friday and Firman (1999) indicated that even when fed at levels double those previously reported to cause problems with broilers there were no adverse effects in gross lesions or histopathologic examination. This indicates that these biogenic amines are of little concern at the levels utilized.

## FOOD SAFETY

The issues pertaining to microbial food safety of animal and poultry products derived from animals fed animal products as part of a well-balanced and high quality diet have been well documented. Despite this documentation, very little data exist which address the issue of feeding these products to the same animal specie from which the product is derived. However, there has been no attempt to avoid same specie feeding of animal by products until recent concerns regarding the BSE issue in Europe. This resulted in the ban on the feeding of ruminant by-products back to ruminants. Further restrictions on the use of animal by-products were not implemented.

The primary issue relative to food safety is the naturally occurring microbiological flora contained in the raw animal by-products and either their subsequent survival and growth or re-contamination of product following the rendering process. Re-contamination of animal by-products after processing is believed to be the principal factor accounting for the presence of *Salmonella spp.* in the final product (Wedman, 1961). The development of animal by-products (meat meal, meat and bone meal, poultry meal, feather meal, etc.) which can be effectively utilized in animal and poultry diets has been made possible by effective processing procedures being adopted by meat renderers.

The primary issue in microbiological control during the early stages of the development of rendering procedures was control of *animal disease agents.* The importance of control of *human microbial pathogens*, which have the potential for transmission from animals to humans, during the rendering process has been identified more recently. Much of the focus on microbiological control in rendered products has been on *Salmonella spp.*, even in the early work reported by Morehouse and Wedman (1961). Recent work by Troutt et al. (2001) reported that *Clostridium perfringens, Listeria monocytogenes, Campylobacter jejuni and Salmonella spp.* were recovered from raw material entering the cooker but were not recovered following the cooker. With the exception of *Salmonella spp.*, pathogens were not recovered in final rendered product.

### Risk of BSE Exposure

As a result of the bovine spongiform encephalopathy (BSE) disease outbreak in Europe in 1986, with variant Creutzfeldt-Jakob Disease (vCJD) in particular affecting the human population, consumer concerns have been expressed regarding the potential exposure of the American population to increased risk of BSE related human illnesses. The Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture joining with the Public Health Service supported voluntary industry efforts to keep the U.S. free of BSE (Franco, ). In the interim, the Food and Drug Administration, through its Center for Veterinary Medicine (CVM) took responsibility for implementing regulations prohibiting ruminant protein in ruminant rations. These were part of 33 specific, aggressive and proactive regulatory policies and control measures taken by the U.S. (Pearl, 2002).

The Harvard Center for Risk Analysis in the Harvard School of Health was also charged by the USDA to evaluate the U.S. measures to prevent the spread of BSE to animals and humans. The results of this study (Cohen, et al., 2001) finds that the U.S. is highly resistant to any introduction of BSE or a similar disease and BSE is extremely unlikely to become established in the U.S. In a hypothetical scenario where 10 cattle are imported into the U.S. only three new cases of BSE would occur. The disease is virtually certain to be eliminated from the country within 20 years after its introduction. The new cases of BSE would come primarily from lack of compliance with the regulations enacted to protect animal feed. In addition, there appears to be no potential for an epidemic of BSE resulting from scrapie, chronic wasting disease, or other cross-species transmission of similar diseases found in the U.S. Measures in the U.S. that are most effective at reducing the spread of BSE include the ban on the import of live ruminants and ruminant meat and bone meal from the UK (since 1989) and all of Europe (since 1997) by USDA/APHIS, and the ruminant to ruminant feed ban instituted by the Food and Drug Administration in 1997 to prevent recycling of potentially infectious cattle tissues. The study concluded that measures taken by the U.S. government and industry make the U.S. robust against the spread of BSE to animals or humans should it be introduced into this country.

**Pigs**

There is a theoretical risk that cattle could be exposed to a transmissible spongiform encephalopathy (TSE) as a result of consuming feed supplemented with porcine derived protein. There are two potential sources of this exposure; a natural TSE that infects pigs and BSE-contaminated feed in the gut at the time the pig is slaughtered. Cohen et al. (2001) concluded that in practice neither infectivity source will make a substantial contribution to cattle exposure because only a small portion of porcine-derived MBM is used in cattle feed, primarily because of its higher price relative to soy protein. Much of the rendered porcine protein is used in feed for pigs. The existence of a porcine-specific TSE is unlikely. No naturally occurring TSE has ever been reported in pigs (MAFF, 2000). In addition, pigs inoculated orally with BSE have not developed disease (MAFF, 2000). The fact that a naturally occurring spongiform encephalopathy has never been reported in pigs may indicate that pigs are particularly resistant to this type of disease (Cohen, 2001). Even if pigs could become infected with a TSE, most are slaughtered at a young age, making it unlikely that the disease would have time to generate more than a small amount of infectivity

**Poultry**

Cohen et al., (2001) concluded that many of the same factors that make pigs an unlikely source of infectivity for cattle make chickens an unlikely source, particularly the natural resistance to TSE. Marsh et al. (1969)

noted the recovery of TME from the spleen of *one* chicken and from caecum, tonsils and bursa of Fabricious after i.v. inoculation. Matthews (2002) reported that studies incorporating intracranial, intraperitoneal and oral inoculation of BSE infected brain stem cells into chickens showed no transmission from either inoculation route when chickens were taken to a 57 month of age endpoint. Experimental data do not support the existence of a poultry-specific TSE (Cohen, 2001). Experiments have subjected chickens to TSE challenge via both parenteral and oral administrations routes. No evidence of transmissible encephalopathy was found (MAFF, 2000). In addition, there is no evidence to date of residual infectivity in any tissue. Even if there were a poultry-specific TSE, the fact that chickens are typically slaughtered at an early age makes it unlikely that a prion disease would have time to develop. Although chickens themselves appear to pose no substantial risk to cattle of exposure to a TSE, the use of chicken litter as a feed supplement could pose a risk (Public Citizen, 2001). It is possible that cattle-derived protein feed supplements administered to chicken could contain BSE infectivity, and that BSE infectivity could pass through chicken and become available in cattle feed supplemented with chicken litter (Cohen, 2001).

### *Animal Disease Agents (Pathogens)*

Probably the earliest U. S. report of salmonellosis in poultry feed was that of Edwards et al., (1948), when the isolation of both *Salmonella typhimurium and S. bareilly* from chicken feed was documented. The isolation of salmonella from commercially prepared and distributed poultry feed in the U.S. was first reported by Erwin (1955). Edwards (1958) was perhaps the first to call attention to the importance of salmonellae in poultry feeds. He further noted that any effort to eliminate salmonellosis from domestic animals must consider the continuous seeding of the population through infected feedstuffs. Ellis (1968) reported that the presence of salmonellae in animal feeds is likely since the time animals were first domesticated.

Salmonella contamination of animal by-products, including fish meals, has been documented in several countries, including Germany (Bischoff, 1955; Bischoff and Rohde, 1956), Denmark (Muller, 1957; Walker, 1957: Watkins et al., 1959), Israel (Hirsch and Sapiro-Hirsch, 1958), Australia (Kovacs, 1959) and the U.S. (Boring, 1958). Boyer et al., (1958) demonstrated a direct relationship between infection of turkey poults, with 34 % mortality, and the presence of *S. thomasville* in feed samples fed to the poults. Rendered feed ingredients that were initially salmonella free became re-contaminated as a result of poor handling and storage practices.

Another key factor in microbial contamination of feed is the presence of Salmonella serotypes in imported vegetable protein concentrates and mixed concentrates in Norway (Hauge and Bφvre, 1958). Additional evidence is provided by Grumbles and Flowers (1961) who reported Salmonella in cottonseed meal, soybean oil and mixtures and Rutquist (1961) who reported Salmonellae in feeds of vegetable origin.. These findings clearly illustrate that microbial contaminants are not limited to animal by-product sources. Pomeroy (1958) reported that feed ingredients can be contaminated with salmonellae in bins, elevators and other equipment. The issue of cross contamination or re-contamination of rendered products with pathogens from raw product sources is best addressed by effective use of Sanitation Standard Operating Procedures.

*Animal By Product Meals*

Early research by Keil and Keller (1961) reported that total bacterial counts from 9 specimens of carcass meal ranged from $9x10^3$ to $2x10^{10}$ organisms per gram. Morehouse and Wedman (1961) reported that Salmonella serotypes were isolated in 12.5% of 5,712 animal products and Keil and Keller (1961) also reported that these products contained pathogenic bacteria. Gunnarsson et al. (1974) reported that meat meal and other by-products were responsible for the largest number of *Salmonella* isolates in Sweden from 1968-1972. They also regarded the isolation and reporting of such isolates as the initial effort for prevention of the spread of salmonellosis to man. Leistner et al. (1961) reported that 61% of meat and bone meal samples were positive for salmonellae while Leistner et al. (1963) found that 37% of meat and bone meal samples were positive for salmonellae. *Salmonella spp.* were also isolated from carcass meal in the Republic of South Africa by Van den Heever and Van der Made (1977).

Although he was unable to obtain sterile material from the continuous rendering process in 5 different sterilizing plants in the USA, Tittiger (1971) found that the degree of bacterial contamination was indirectly related to the maintenance of high levels of hygiene in the plant. Van der Made et al. (1980) reported *Salmonella spp.* contamination ranging from 3 to 17% in blood meal, bone meal, and carcass meal. Likewise *E. coli* contamination ranged from 54 to 68%, while *Clostridium* contamination ranged from 28 to 44% of samples evaluated in the Republic of South Africa. Recent work by Troutt et al. (2001) revealed that *Clostridium perfringens, Campylobacter jejuni and Listeria monocytogenes* were not recovered from final rendered products.

Andrews et al. (1984) stated that most of the research regarding the isolation of *Salmonella* reported in the literature has reported incidence, positive samples as a percentage of total samples, and has not quantified levels of organisms present. Concentrations are a better indication of the effectiveness of microbial control programs for use in decision making by mill managers. The *Salmonella* reduction/elimination efforts of the rendering industry have been investigated and summarized (Burdick et al., 1983; Davis, 1989). *Salmonella* organisms were reported, based on the Most Probable Numbers (MPN) estimate, at the level of 4.43 organisms per 100g of meat meal.

Various heat treatment methods have been shown to be effective in reducing *Salmonella* (Rouse et al., 1988), as have the use of chemical disinfection agents (Hinton and Linton, 1988). Nape and Murphy (1971) reported that meat meal with low numbers of salmonellae was the apparent source of infection in swine. They also reported that this source of contamination can be eliminated by heat treatment of rendered protein. A decrease in the percentage of *Salmonella*-positive broiler carcasses leaving a poultry plant has been linked to reduced incidence of Salmonella-positive feed and feed ingredients consumed by the bird (Rouse et al., 1988; John et al., 1989). A Food and Drug Administration (FDA) survey conducted in 1993 indicated that 56.4% of animal protein samples were positive for *Salmonella spp.* (McChesney et al., 1995). Natural contamination of meat and bone meal by *Salmonella spp.* is low, with MPN estimates less than 10 organisms per 100g of feed as reported by Bisplinghoff (1992), Davis (1986) and Smittle and Kornacki (1992).

## Fish/Marine By Product Meals

Lamming (1993) reported the results of both voluntary and mandatory testing for Salmonella in feedstuffs which revealed contamination rates were declining in recent years. However, imported fish meal supplies were of particular concern, with somewhat higher rates than domestically produced meals. They did conclude that the removal of feed contamination alone would not necessarily have a significant effect on *S. enteritidis* disease incidence in the human population.

Morris et. Al. (1970), in epidemiological studies of the fish meal industry, reported that fresh fish were free of salmonella infection. However, the organism was recovered from fish taken from boats at the plant with 50% of samples in the processing area being contaminated. Contamination decreased through various stages of processing to approximately 15% of samples in finished product. Salmonella contamination was reduced to undetectable levels by reprocessing the first 45 minutes of each day's production.

A task force of the FDA, reported by Bixler (1975), concluded that although salmonella in rendered animal and marine by products contribute to salmonellosis in animals and man, new regulatory programs initiated by FDA were not recommended for the animal and marine by products industry.

## Human Microbial Pathogens

In one of the earliest documented associations of human salmonellosis with meal and bone meal, Hirsch and Sapiro-Hirsch (1958) investigated an outbreak of human salmonellosis in Israel caused by *S. hadar* (a rare serotype) in which chicken livers were the suspected vehicle of infection. The same serotype recovered from the patients was also isolated from poultry meal and bone meal fed to the chickens. A report from WHO (Anon., 1967) reported that animal feeds are not only the primary source of subclinical salmonella infections in animals but they also contaminate food for human use and ultimately result in infection in man. Pennington et al. (1968) directly associated an outbreak of *S. virchow* infection in humans with infection of breeding flocks of chickens through contaminated feedstuffs, which in turn, led to contamination of the hatchery. Hobbs and Hugh-Jones (1969) associated a human outbreak of *S. senftenberg* infection with contaminated poultry feedstuffs. The spread of *S. agona* throughout the world in contaminated fish meal and then to humans underscores the role of feeding in spreading salmonellae (Clark, et al., 1973). Troutt et al. (2001) demonstrated that raw material contained high concentrations of five pathogenic bacteria including Clostridium sp., Listeria sp., Campylobacter sp., Salmonella sp. and Escherichia coli. Work by Pirtle (1990) reported that the pseudorabies virus was completely inactivated by the rendering process of 240-270 F. Underhill (Canadian Feed Regulatory Agency, 1999) reported Salmonella isolations from oil seed (18%), rendered products (20.5%), fishmeal (22%) and feed grain (5%) indicating that control of this pathogen is the responsibility of the entire industry. The key to establishing successful control measures is the implementation of Sanitation Programs, Standard Operating Procedures and Good Manufacturing Practices.

**Vehicles of Spread/Control Measures**

Considerable research has been focused on identifying the vehicles by which salmonellae contaminate feed and feed ingredients. Wedman (1961) and Magwood (1965) reported that re-contamination of the finished rendered products was the single most important factor responsible for the presence of salmonellae in animal by-products and rations. Allred et al. (1967) suggested reductions in salmonella contamination of animal by-products and pelleting of finished feeds as logical approaches to lower salmonella contamination in poultry feed. The British Public Health Laboratory Service reported that salmonellae were present in 9% of raw ingredients, 2.8% of finished meals and only 0.3% of pelleted feeds where a total of 4,140 samples were evaluated (Anon., 1961). This gives strong support to the statement that pelleted feed provides effective control where the feed is approaching Salmonella-negative states and the issue of concern is re-contamination of the finished product.

Nape (1968) reported several measures which were effective in producing uncontaminated feed which included control of dust, keeping ingredients and finished feeds dry, periodic removal of accumulations, pelleting and control programs for insects, birds and rodents in the plant and surroundings. Orthoefer (1968) reported that the main factors responsible for spread of contamination were inadequate sanitation, airborne dispersion and insufficient cooking. The American Meat Institute Foundation report (Hansen et al., 1962) concluded also that dust is an important vehicle for salmonella contamination of finished product in rendering plants. Critical measures required for implementing effective intervention and control strategies iclude development of Standard Operating Procedures and Good Manufacturing Practices which specifically address control of human pathogens.

## ECONOMIC IMPLICATIONS

The animal industries generate approximately 143 billion pounds of product of which 60-70% is edible product and 30-40% is processed during rendering and converted to high quality by-products used in animal feeds (Pearl, 2002). These products, meat and bone meal (MBM), meat meal (MM), poultry meal (PM), hydrolyzed feather meal (HFM), blood meal (BM) and fish meal (FM) are used in feeding for swine, poultry and other species, converting products which otherwise have little or no value to a usable product. With the exception of fish meal all of these ingredients are the direct result of capturing further value from the production of livestock and poultry for food purposes (Pearl, Render Magazine)`. The implications for not utilizing these resources as feed ingredients, not only for the cost of producing animal feeds but also for the cost of alternative disposal of these products seriously impact economic, biosecurity and environmental issues affecting society in general. The prohibitive energy costs associated with incineration eliminate this option. Leeson (2002) reported that the inability to use rendered animal products adds approximately 5-10% to the cost of producing animal feeds. While the use of these products has been banned in Europe, in North America the ban is only on feeding meat meals to ruminants. Because of the low world demand these products have been used to maximum advantage in poultry diets. Leeson (2002) also reported that future use of these products may be restored in Europe, particularly for pigs and poultry. Replacement of the meat meals in the diet create unique considerations from the standpoint of electrolyte balance in young poultry, requiring greater attention to potassium and sodium levels in the diet.

## ENVIRONMENTAL/SOCIETAL BENEFITS

Alternative disposal of these products, either by burial, burning, incineration, landfill, composting or extruding would be costly and in many cases not acceptable to society in general if the potential for pollution of the air with noxious odors and ground water with potential human pathogens is considered. When the costs of human and animal health, environmental, ecological and economic costs are compared, it is clear that rendering is the far superior alternative (Pearl 2002). When the capital investment of the rendering industry, particularly the emissions control and pollution control investments, is factored in this discussion, it is clear that the efforts of this industry to accomplish the rendering process with minimal impact on the environment is a model for other industries to emulate.

## CONCLUSIONS

Taken cumulatively, the information presented confirms that the proper processing of rendered products and effective pelleting of feeds, when combined with thorough sanitation programs, are clearly the key to control of *both animal and human* pathogens in animal and poultry feeds. Perhaps the most comprehensive assessment of human pathogen contamination (Salmonella) for animal feed ingredients and finished feed was conducted by the FDA-Center for Veterinary Medicine by McChesney et al. (1995). The data collected from 78 animal and 46 vegetable protein processors accounted for 4,530 individual samples. Salmonella was detected in 56.4% of animal protein samples and 36% of vegetable protein products. Although the data indicate that salmonellae occur in both protein sources and may be slightly less in vegetable meal than in animal meal products, they concluded that the exclusion of one of the products in favor of the other is not a valid approach to ensuring salmonella -negative feed. The risk assessment for BSE exposure conducted at Harvard by Cohen (2001) also concludes that the risk for exposure to BSE in the U.S. is very minor, almost negligible.

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