POULTRY MANURE AS A FEED INGREDIENT FOR LIVESTOCK: RUMINANTS AND NON-RUMINANTS

by

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B.S., Kansas State University, 1969

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1980

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ACKNOWLEDGMENTS

The author wishes to express her deepest appreciation to Dr. A. W. Adams, Professor of Animal Science, for his counsel and guidance throughout my Master's program. Further acknowledgments are extended to Dr. J.V. Craig and Dr. W. Prawl who served on my graduate committee.

My family and members of my religious community, the Maryknoll Sisters, have been an inspiration to me. Special thanks are extended to those concerned people who through their generosity have made my education and further missionary activity possible. Special thanks to Miss Marian Tilford for typing this Master's Report.

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INTRODUCTION

Intensive production of livestock and poultry in confinement systems has led to a large accumulation of animal manure and the resulting problems of handling and utilization of this material. Commercial feedlots and broiler operations in the United States were developed on small areas of land making spreading manure on the land a problem. Wastes from large concentrated operations are a nuisance and source of pollution when located close to municipalities, lakes, and streams. It is imperative to handle waste properly if pathogenic microorganisms are present in order to avoid water and air contamination and risk to human health and comfort.

The world demand for protein could exceed supply from conventional sources and at the same time that intensive animal production systems are producing large amounts of manure and causing problems of pollution. This waste is largely nitrogenous and a potential source of crude protein for ruminants. There is a need for a nutritionally safe way to recycle these waste nutrients back into animal feeds thereby solving the pollution problem and conserving protein at the same time. The potential to incorporate waste into a balanced ration at a cost lower than that of conventional ingredients is a determining factor.

Recycling animal manure as a component of livestock feeds is not a new idea. The barnyard naturally recycles waste as the hogs follow cattle and chickens follow the hogs. Coprophagy is the act of eating manure and the nutrition of hogs and chickens can be supplemented by this practice. Durham et al. (1966) observed that cattle consuming an all concentrate ration produced high quality manure. Gohl (1975) noted that with intensive livestock and poultry operations, large amounts of manure and nutrients are wasted. Consumers may have aesthetic objections to the recycling of manure as an animal feedstuff but economy may rule.

Animal waste in the past has been used as fertilizer and played an important part in the development of agriculture. Commercial inorganic fertilizer replaced organic waste due to the high cost of collecting, handling, and spreading manure. More recently, there has been a renewed interest in organic products and byproducts with the advent of high cost of energy and limited use of fossil fuels and an increased emphasis on the environment.

There are problems in the handling and utilization of wastes as they can be dry and dusty or very wet; possess a strong odor and number of flies; in general be regarded as filth and therefore not considered a valuable resource; be a potential for disease transmission; and could carry residues of pesticides and other chemicals. With proper precautions animal manure can be used so as to avoid harm and discomfort to humans and animals. Fontenot (1979) mentioned four main alternatives for utilizing animal wastes: 1) a source of plant nutrients, 2) a substrate for microbial and insect protein synthesis, 3) a substrate for methane production by microorganisms, and 4) a feed ingredient for farm animals. The last alternative is discussed in this report which considers the value of poultry manure as a feed ingredient with its advantages, problems, hazards, and economic value. Imaginative uses for all types of industrial and agricultural byproducts are being researched. Fisher (1980) has studied over a two year period the use of cement kiln dust in feeding cattle and sheep rations with encouraging results of increasing the rate of growth 9% for cattle and 22% for sheep. Fontenot (1979) stated that 50% of animal waste output is produced in confinement, is collectable, and is therefore an available product to be researched as a feed ingredient.

ANIMAL MANURE

Researchers are extensively studying the utilization of poultry, cattle, and swine manure and to a lesser extent the value of sheep and rabbit manure as a feed ingredient. Poultry manure (PM) from caged layers is known as dehydrated poultry waste (DPW), dehydrated poultry manure (DPM), dehydrated poultry excreta (DPE), or poultry battery manure (PBM). Manure from houses where birds are on litter is known as poultry litter (PL), poultry house litter (PHL) or broiler litter (BL). Any poultry manure which has been ensiled is known as caged layer silage or broiler litter silage.

Cattle manure can originate from feedlots (cattle feedlot manure) or from confined dairy units (dairy cattle manure). As summarized by Gohl (1975), cattle manure is an "organic waste from ruminants with chemical composition similar to the feed ingested, enriched by an abundance of rumen microbes, and is a valuable feed ingredient when fed to cattle...From grain-fed cattle, manure contains high amounts of undigested feed and feed residues ...Organic waste as voided by ruminants is a fermentation product that seems to be safe for animals. Blending manure from ruminants with regular feed does not decrease palatability and in some experiments increased digestibility of the ration, especially the digestibility of cellulose. Manure has no effect on lactation or milk taste. Dried fresh manure smells like mixed feed. The dryness of manure affects palatability. Manure, fermented as silage, is well accepted. Once cattle are use to the feed, there is no effect on consumption. Manure is a fermentation product containing growth factors: B complex vitamins and some essential amino acids." Smith and Wheeler (1979) observed that daily gains of cattle fed manure were equal to the gains of cattle fed the control ration but it took slightly more feed per unit of gain. The nutrient and economic values of swine manure exceeds those of cattle manure. In dried and pelleted forms manure has been fed to cattle and refed to swine with adequate daily gains, but with poor feed efficiency when fed above 30% levels (Smith and Wheeler, 1979). All forms of animal manure can be air-dried, with drying time depending on climate, area of the country, level of humidity, amount of moisture in the manure, and composition of the feed.

Amount of Animal Manure Produced in the United States

Anonymous (1977) estimated that 2 billion metric tons of solid waste (including bedding) is dispersed over range and farmland, feedlots, dairy operations, and poultry facilities. Van Dyne and Gilbertson (1975) estimated the amount of livestock and poultry manure produced by each species at that time to be 47% from beef on pasture and range, 23% from dairy cattle (including replacement stock and calves), 12% from hogs, 9% from feeder cattle, 3% from sheep, 3% from laying hens, 2% from broilers, and 1% from turkeys. Manure remaining after losses from storage and waste handling systems was estimated to be 89% of the manure excreted. The recoverable manure is mainly from feeder cattle, layers and broilers. The utilization of manure from these sources will be emphasized. In order of economic and management importance it is desirable to facilitate the removal and utilization of manure from dairy cattle, hogs, broilers, and layers first followed by sheep and beef on range. Increased turkey production will necessitate utilization of this waste as well. Fontenot (1979) estimated that 50% of animal manure output is in confinement facilities and is collectable. He also estimated that approximately 1 billion metric tons of wet waste (150 million metric tons of dry matter) is available for utilization, assuming 15% dry matter in the waste. Comparing this to the amount of crop residues, e.g. assuming a corn crop of 152 million metric tons (approximate yield per year for the past 2 years), approximately 130 million metric tons of dry matter would be left in the field as crop residue. Smith and Wheeler (1979) reported that about 50% of the collectable nitrogen could be used in recycling as a feed ingredient.

Gohl (1975) summarized the amount of manure produced on a weekly basis by a hen of 2 kg weight to be .8 kg; a cow of 650 kg produces 150 kg; a pig of 80 kg produces 40 kg; and a pig of 45 kg produces 22 kg. Schaible (1979) summarized the production of fresh droppings from hens to be 140-180 g per bird per day or 64 kg per hen per year. In intensive confinement systems therefore, 1,000 hens produce 100 cm^3 of droppings with moisture (70%) per year. Table 1 summarizes the poultry manure production on a daily, weekly, monthly, and yearly basis.

Table 1. Poultry manure production of a 4 lb (1.8 kg) bird

Time period	lb/bird	Per 1,000 birds		
		Wt.	Cubic ft.	Gal. (U.S.)
Daily	.25	250 lb	4.9	37
Weekly	1.75	1.23 tons	34.0	257
Monthly	7.6	3.8 tons	5.5 cu. yd.	1,115
Yearly	91.3	45.6 tons	66.0 cu. yd.	13,379

Source: North (1978).

The amount of manure produced is largely influenced by the amount and/or source of protein in the ration. Patrick (1967) reported that chickens receiving 15, 20, and 25% protein rations, with most of the protein coming from corn and soybean meal, cast more feces and consumed more water as the level of protein increased. Chickens which received casein of milk albumen supplement produced less feces per unit of protein than those which received meat scraps, fish meal, or soybean meal. This indicated that the amount of protein in this case did not necessarily influence fecal production, but that the type or source of a protein could be a major controlling factor. Smith and Wheeler (1979) stated that animal manure products are of higher economic value as protein sources than as energy sources in balanced diets, but energy, protein, and minerals contribute to total value.

Composition of Animal Manure

Feces and urine from poultry, cattle and pigs have relative high amounts of essential amino acids, not because of grain particles present, but because manure has value as a feed (Miner, 1971). Martin et al. (1980) studied and summarized the characteristics of comparative animal manures with comparative values for grains and roughages (Tables 2, 3 and 4).

Table 2. Mean values for nutritional characteristics of dried poultry waste, broiler litter, and dairy cattle and beef cattle manures

Composition, % dry matter	Dried poultry waste	Broiler litter	Dairy cattle manure	Beef cattle manure
Crude protein	28.0	26.8	15.3	16.5
Digestible protein (ruminants)	12.9	22.8	3.2	5.1
True protein (amino acids)	14.6	15.8	12.5	6.8
Total digestible nutrients	52.3	58.9	45.0	48.5
Metabolizable energy, kcal/kg				
- for ruminants	1900	1627	1208	1777
- for poultry	1309	——	——	——
Neutral detergent fiber	52.4	47.4	66.0	54.8
Acid detergent fiber	27.4	30.4	43.7	33.1

Source: Martin et al. (1980).

The data in Table 2 illustrate that from the standpoint of total digestible nutrients and metabolizable energy values, manure is not a suitable energy feed plus the fact that it has a high fiber content. It should be noted that use of manure on a dry matter basis is attractive, but except for BL the "as produced" values are substantially less than the manure produced by caged layers. Nesheim (1972) suggested that DPW is a source of the mineral, phosphorus, and some amino acids by being similar to meat and bone meal. The particular characteristics of DPW and BL will be discussed in a later section.

Table 3. Nutritional characteristics of corn and sorghum grains and soybean and cottonseed meals

Composition, % of dry basis	Corn, grain (all analyses)	Sorghum, grain (all analyses)	Soybean meal 49% protein	Cottonseed meal 41% protein
Crude protein	10.9	12.6	47.6	44.0
Digestible protein (ruminants)	8.0	8.8	39.7	35.2
True protein (amino acids)	6.37	6.66	29.05	21.86
Total digestible nutrients	93.0	89.0	84.0	75.0
Neutral detergent fiber1/	20.3	23.0	14.0	28.0
Acid detergent fiber1/	3.2	5.0	5.1	20.0
Metabolizable energy, Kcal/kg				
- for ruminants	3.36	3.21	3.02	2.71
- for poultry	3.84	3.70	2.82	2.40

1/ Van Soest (1980) as cited by Martin et al. (1980).

Source: Martin et al. (1980).

Table 4. Nutritional characteristics of corn silage and timothy, alfalfa, and bermudagrass hays

Composition, % of dry basis	Corn silage, (all analyses)	Timothy hay, midbloom	Alfalfa hay, midbloom	Bermudagrass hay
Crude protein	7.0	9.5	18.8	9.8
Digestible protein (ruminants)	3.6	5.4	14.0	5.0
True protein (amino acids)	-	-	8.81	-
Total digestible nutrients	68.0	59.0	56.0	49.0
Neutral detergent fiber1/	45.0	68.2	47.5	78.0
Acid detergent fiber1/	27.0	37.3	36.1	38.0
Metabolizable energy, Mcal/kg - for ruminants	2.47	2.14	2.24	1.77

1/ Van Soest (1980) as cited by Martin et al. (1980)

Source: Martin et al. (1980).

Data in Tables 3 and 4 are shown for comparison for nutrient values of plant sources to those values of animal manure to justify the place of animal manure as a potential feed ingredient. Table 5 illustrates the estimated monetary value of animal manures based on 1979 market values. The data indicate the cost effectiveness of using PM and dairy cattle and beef cattle manures, particularly when utilization costs are considered. The monetary value can be estimated only by identifying conventional feedstuffs which are similar in nutrient composition and which can be replaced successfully by manure. For the data in Table 5 it was assumed that these manures were directly equivalent nutritionally to corn silage and hay on a dry matter basis. Because both the phosphorus and amino acid contents of meat and bone meal are greater than that of DPW by a factor of approximately 2.3, DPW cannot be directly substituted for meat and bone meal on a dry matter basis in an economic evaluation

Table 5. Estimation of the monetary value of animal manures

Animal manure	Type of animal fed	Conventional feedstuff comparable to	Cost of conventional feedstuffs per ton: Mkt. cost	Cost of conventional feedstuffs per ton: Dry matter cost	Estimated value of manure per ton: Dry matter basis	Estimated value of manure per ton: As produced basis
Dried poultry waste	laying hen	meat & bone meal	$250	$269	$117	$99 1/ (29 2/)
	ruminant	corn silage	15	58	58	49 1/ (14 2/)
		hay	72	80	80	68 1/ (20 2/)
Broiler litter	ruminant	corn silage	15	58	58	46 3/
		hay	72	80	80	64 3/
Dairy cattle	ruminant	corn silage	15	58	58	9 4/
		hay	72	80	80	12 4/
Beef cattle	ruminant	corn silage	15	58	58	12 5/
		hay	72	80	80	17 5/

1/ Value based on 85% dry matter.

2/ Value based on 25% dry matter.

3/ Value based on 85% dry matter.

4/ Value based on 15.5% dry matter.

5/ Value based on 21% dry matter.

Source: Martin et al. (1980).

(Martin, 1980). For this reason, the dry matter cost of meat and bone meal was divided by 2.3 to reflect this difference in composition. The use of all the manures considered as feedstuffs in Table 5 appears to be attractive when the monetary value is considered on a dry basis. However, "as produced" values (with the exception of BL) are substantially less. These data indicate that using DPW and dairy cattle and beef cattle manures as feedstuffs is questionable, especially when utilization costs are considered. Martin et al. (1980) suggested that these manures can best be utilized as forage substitutes. It must be understood that the true value of animal manures as feedstuffs can be determined only by way of animal response as identified in feeding trials. Local economic and environmental factors, grain prices, and a need for a particular nutrient by a particular type of animal determines the real monetary value. Anonymous (1977) reported in 1976 that the value of fresh manure utilized as a feed ingredient to be $6 per ton unprocessed to $110 per ton when dehydrated.

Composition of Poultry Manure

The composition of PM varies with the wide variety of nutrients supplied to the birds, age and type of birds, the condition under which housed, the treatment and storage of manure, and the ultimate consumption by the animals whose feed it may be a part. There can be conflicting reports in nutritional value in manures, a species best suited for recycling of a particular waste, and a recipient animal which best utilizes nutrients in manure.

Patrick (1967) stated that the moisture content of manure from current strains of chickens and ration structure averaged 71 to 74%. The moisture of hen manure in loose housing was 55 to 70.16% and under cage management, 74.35%. Table 6 summarizes the moisture content in PM, e.g. wet to dry.

Table 6. Average percentage of moisture in poultry manure

Manure condition	Moisture (%)
Wet, sticky	75
Moist, crumbly	50
Crumbly, no dust	25
Dry, dusty	15
Completely dry	0

Source: West Virginia Univ. Extension Bulletin 496T and Pennsylvania Univ. Leaflet 255 as cited by North (1978).

The ease of handling and utilization of poultry waste is greatly affected by the percent moisture of the raw product. Different types of PL and their moisture contents are listed in Table 7. Water content of cage hen manure is higher than manure from floor managed hens providing easier handling and processing of poultry litter.

Table 7. Reported composition of poultry manure and litter[1/]

Investigator[2/]	Description	Moisture (%)
Yushok & Bear, 1943	Old hen litter	47.2
White et al., 1944	Hen litter	15.8
Papanos & Brown, 1950	Droppings & litter	40.0
Parker et al., 1959	Mixed litter	36.9
Hileman, 1959	Broiler house litter (avg.)	28.86
Univ. of Arkansas	Manure with litter	30.0
Moore et al., 1964	Fresh hen, cage	74.35
Moore et al., 1964	Fresh hen, loose housing	70.16

1/ Results expressed as per cent of dry matter.

2/ Sources as cited by Patrick (1967).

Table 8 presents the composition of DPW and broiler litter silage.

Table 8. Composition of dried poultry manures (air dry basis) and broiler litter silage

	Poultry battery manure[1]	Poultry house litter[1]	Broiler litter silage[2]
Moisture (%)	11.40	15.50	——
Total protein (N x 6.25%)	28.70	25.30	21.13
Urea (%)	0.00	——	——
Uric acid (%) (NPN)	6.30	8.50	Absent
True protein (%)	10.50	16.60	24.88
Ether extract (%)	1.76	2.30	——
Nitrogen free extract (%)	35.61	27.10	——
Ash (%)	26.50	14.10	——
Ca (%)	7.80	2.50	1.57
P (%)	2.20 - 2.70	1.60	.38
Na (%)	.42	.42	.73
K (%)	1.37	1.77	1.50
Cu (ppm)	61.00	23.00	200.00
Fe (%)	.20	——	.07
Zn (ppm)	325.00	343.00	200.00
Mg (%)	.63	.35	.29
Mn (ppm)	291.00	——	——
Br (ppm)	16.00	——	——
Cl (%)	.93	——	——
Crude fiber (%)	13.84	18.65	59.26
Lignin (%)	——	8.04	——
Crude protein (%)	——	——	21.12
Fat (%)	——	——	3.48
Kcal M.E./kg	660	——	68.50

1/ Blair and Knight (1973) and Creger et al. (1973).

2/ Young and Nesheim (1972).

Both poultry urine and feces are colloidal structures. Patrick (1967) reported "...poultry urine contains a viscous, mucin-like substance which presumable serves as a protective colloid for the uric acid. The colloidal substances in the feces holds the water so that feces containing 71 to 75% moisture appears firm, but 78 to 80% moisture produces a fluid appearance... Poultry secrete an average of 321 ml of urine per kilogram of body weight; however, most of the water is reabsorbed before the urine is cast with the feces. Uric acid makes up about 81% of the total urinary nitrogen. The type of protein in the diet influences the distribution of uric acid and ammonia in the urine, but the total combined percentage of uric acid and ammonia remain the same, approximately 91% of the total nitrogen." Amino acids contribute part of the nitrogen found in poultry manure. The amino acid content is summarized in Table 9.

Table 9. Amino acid content of dried poultry manures (air dry basis) and broiler litter silage

Amino acid %	Poultry battery manure	Poultry house litter	Broiler litter silage
Alanine	.61	.80	4.55
Arginine	.38	.43	.47
Aspartic acid	.71	1.15	2.61
Glutamic acid	.12	1.81	3.93
Glycine	1.33	2.55	1.67
Histidine	.23	.20	.23
Isoleucine	.36	.58	1.43
Leucine	.55	.92	2.07
Lysine	.39	.49	1.16
Methionine	.12	.13	1.21
Cystine	.15	.14	——
Phenylalanine	.35	.49	.78
Tyrosine	.27	.32	.06
Serine	.38	.53	.97
Threonine	.35	.52	1.03
Valine	.46	.74	1.34
Proline	——	——	.83

Source: Blair and Knight (1973) and Creger et al. (1973).

In PM such as poultry battery manure, poultry house litter, and broiler litter silage, the true protein values are 10.5%, 16.6%, and 24.88% respectively, as reported in Table 8. This indicated that of all three manures, broiler litter silage has the highest amino acid content.

The nitrogen and phosphorus contents of PM varies depending on the water content of the manure. Mayberry (1976) stated that manure can decrease in nitrogen content by 50% or more due to volatilization and denitrification losses as well as by leaching of nitrates. It is therefore important that the actual content of nitrogen and phosphorus should be known before a cash value can accurately be calculated for PM. Van Dyne and Gilbertson (1975) reported that the total nitrogen content of the 12 million tons of livestock and PM (dry basis) produced in 1974 was 4.1 million tons, 2.6 million tons of which remained after storage and handling losses, 1.4 million tons of which was economically recovered. Therefore, one third of the nitrogen was available. Phosphorus remaining after losses and waste separation and available for recovery was .5 to 1.0 million tons, and 2.4 million tons of potassium (about 52% was recoverable). The high recovery rate of potassium was due to bedding and other debris in the manure.

In summary, PM has many feed components which pass through the digestive tract without digestion and numerous byproducts from metabolism. Drying the manure permits safe and reliable storage of such nutrients and byproducts. Energy components of high energy poultry feed formulas are digested and metabolized to an extent of 70 to 80% as reported by Young and Neisham (1972). Poultry manure therefore contains the remainder of undigested gross energy together with indigestible components of the diet, and compounds of metabolic origin, e.g. nitrogenous components such as uric acid.

WASTE MANAGEMENT SYSTEMS

According to North (1978), poultry farm pollution consists of poultry manure, dead birds, hatchery debris, processing plant wastes, dust from feed manufacturing plants, exhaust from internal combustion engines, air (dust and chemicals), odors, noise, contamination of drinking water and feed, insects, unsightliness, and toxic chemical residues in tissues and eggs.

Daily clean out of poultry facilities by scraping and/or flushing, hauling away, spreading, or drying in the sun present immediate problems for poultry producers. The fact that feedlot cattle producers have large amounts of manure to handle has initiated the most response and results in beef cattle operations. One such example is the Anthony Process, U.S. Patent 3,375,116; March 26, 1968 as described by Gutcho (1973). This process consists of hosing down sloping concrete floors in steer or dairy barns with water and holding the material inside the barns in pits with agitators. The agitator forms a slurry of water and manure and the pump conducts the slurry to vibrating washer screens for dewatering. Coarse fibrous residues are collected and water residues are conducted to a holding bin. A grain storage bin and a feed supplement holding bin are available. A ration composed of wet waste residue + grain + supplement + molasses provides a complete feed for cattle. Water used in washing manure on screens is rich in vitamins. Residues of bacteria, protozoa, and other microbial materials are high in protein. Concentrated wash water is high in microbial residue, fine particles of feed residues, B vitamins, and other undefined biological and organic residues and has a value as a feed supplement for various classes of animals and for use as a common growth medium of microorganisms. While the Anthony Process is not completely adaptable for poultry producers, it is a good example for handling wastes without the expensive aspect of drying. DPW for example has many advantages over fresh, wet manure but dehydration is expensive, though often necessary.

Anonymous (1977) described three processing methods for processing and refeeding cattle wastes. In all three processes the manure is collected frequently and processed before major losses of nutrients can occur. One system consists of a liquid/solid separator which breaks down waste which undergoes fermentation to encourage production of single-cell protein. It is then dried, pasteurized, blended with other feed and pelleted. The pellets are suitable for cattle, poultry, or fish feed. A second system separates liquid and solid portions of waste. The liquid portion is used to apply to crops by flood irrigation or by sprinkler system. The solids portion is composted, ensiled, or treated by a pathocide process before refeeding. The third system involves adding a formaldehyde solution to the waste with the resulting mixture called "formulage." Formaldehyde improves acceptability, kills pathogens, and controls odors. The treated manure is mixed with other feed ingredients and fed to livestock. The latter system can be used with small or large operations while the first two systems are best for large operations.

Smith (1974) stated that the best method to process poultry excreta for ruminant feeding is dehydration (the most practical providing greater flexibility of utilization) by pelleting, dry heat, aerobic fermentation, anaerobic fermentation, or a combination of these processes. Greater expense is required with each added treatment. One basic principle in waste systems is to collect excreta regularly to preserve nutrients, especially nitrogen. According to Smith (1973) an average of volatilization nitrogen losses over time in feces/urine mixture after excrement is 35% total nitrogen lost by the 2nd week, 50% lost by the 10th week. Table 10 presents data in which it is apparent that at least one-half of the nitrogen present in animal manure is in the urine, emphasizing the need for frequent and total collection to avoid nutrient losses. Fecal nitrogen is often associated with single-cell protein. Only amino acid nitrogen is completely available for utilization to a large extent by monogastric animals. Smith (1973) stated that only 21.8% of the total animal manure nitrogen is identified as amino acid nitrogen, therefore raw and unprocessed animal manure is of little nutrient value for refeeding to monogastrics and therefore is better for ruminant rations.

Table 10. Distribution of nitrogen in feces and urine of livestock

Species	Feces	Urine
	% of total nitrogen	
Beef cattle	50	50
Dairy cattle	60	40
Sheep	50	50
Swine	33	67
Poultry	25	75

Source: Smith (1973).

In order to better handle poultry waste and preserve nutrients, the major methods of processing include natural drying, artificial drying, ensiling, liquid-solid separation, chemical treatment, lagoons, composting, and digestion. The purpose of processing wastes is to increase palatability, recover nutrients, destroy pathogens, and control odor.

Natural Drying

Hunton (1979) discussed the air drying process in handling PM. The removal of water (from 75% to 20%) retards breakdown and produces a stable and palatable product. To dry with oil fired equipment was estimated to cost $80 per ton in 1979. Air drying could minimize the cost of dehydration by allowing the manure to build up beneath cages and dehydrating by providing aeration from exhaust ventilation air in the poultry house; use of solar heat; or treating manure with propionic acid (powerful bacteriacide) which inhibits the bacterial breakdown leading to nitrogen loss in fresh caged manure. Advantages of natural drying as described by Arndt et al. (1979) are dry material is easy to incorporate into a complete diet, low air pollution, dry material is easy to stockpile, low drying energy costs, and low handling requirements. Disadvantages listed by them are that nitrogen (protein equivalent) losses are high, nutrient energy losses are relatively high, manure may contain pathogens, dried material often contains large clumps and chunks that require pulverization before subsequent utilization, feasibility is limited by slow drying rates, and successful natural drying is limited primarily to arid/semi-arid regions.

Artificial Drying

All classes of bacteria, molds, and yeasts in litter increase with time the first 8 weeks of use according to Halbrook et al. (1951). Disease transmission from poultry litter is not a likely hazard as it can be sterilized at 150 C for 3 or more hours (Fontenot and Webb, 1974). BL can be pasteurized to meet the same standards as pasteurized milk by heat treatments for shorter periods of time with a combination of heat and chemical treatment. Perhaps ensiling or stacking would produce enough heat by thermophilic bacteria for pasteurization. North (1978) reported that heat dried manure processing requires high temperatures of 371 C (700 F) to 982 C (1800 F) with the disadvantage of nitrogen loss as the temperature increases. Acidifying the litter to a pH of 6 with sulfuric acid prior to heating resulted in reduction in the nitrogen loss according to Harmon et al. (1975). However, drying the manure with heat is best for consistent, if not maximum, nutrient composition.

Usually a small volume of manure can be processed at one time, e.g. decreasing moisture content of two and one-half tons from 70% to 12% in 1 hour as described by North (1978). The capacity of a dehydrator is governed by the number of pounds of moisture which can be removed in 1 hour.

Advantages of heated air drying as described by Arndt et al. (1979) are good animal acceptance, dry material is easy to incorporate into the diet and stockpile, high temperature kills pathogens, and dry material is deodorized. Disadvantages listed by them are air pollution may occur during processing (requiring odor control equipment), processing (dehydration) plant may be affected by zoning and/or regulatory restrictions, high drying energy costs may be prohibitive, high equipment costs, and time and energy requirements are high for collecting and transporting to and from dehydrators.

There is variability in the composition of PM due to the dietary and physiological status of the birds, age of excreta before stabilization, and temperature of drying. An increase in storage time and drying temperature reduce the nitrogen content in dehydrated excreta. Smith (1974) reported that up to 30% nitrogen losses occurred during dehydration, mostly ammonia-nitrogen as a result of bacterial degradation of protein and uric acid. Table 11 presents the loss of energy and nitrogen of two samples of PM differing in nitrogen and dry matter content by drying with forced-air oven, freeze-dried, and vacuum oven. Nitrogen content was determined by the Kjeldahl method. These data show the loss of energy on drying manure was smallest when freeze-dried (average loss 1.3%) and largest (2.8 to 5.5%) when using a low drying temperature (120 C to 60 C) in a forced-air oven. Loss of nitrogen was smallest from freeze-drying and highest as drying temperature increased from 60 to 120 C (Shannon and Brown, 1969). The method of drying depends on whether the energy or nitrogen content is important.

The suggested drying temperature for caged layer waste should not be higher than 90 C (as not to damage the protein in the manure) and not lower than 70 C according to Gohl (1975). The final product should be ground. Anonymous (1977) suggested the use of high temperatures for short periods for practical reasons because they would result in a granulated product with about 10 to 15% moisture.

Use of low heat process with a high volume of air in processing helps

Table 11. Loss of energy and nitrogen from poultry manure on drying

Treatment	Sample	Dry matter (%)	Nitrogen		Mean loss of nitrogen on drying (%)	Mean loss of energy on drying (%)
			Fresh	Dried		
Forced-air	A	28.67	2.51	8.09	7.57	1.95
oven 120 C	B	22.04	1.56	6.13	13.45	3.62
Forced-air	A	28.99	2.51	8.27	4.52	2.36
oven 100 C	B	22.13	1.56	6.27	11.08	4.15
Forced-air	A	29.41	2.51	8.10	5.05	5.85
oven 60 C	B	29.13	1.56	6.47	4.17	5.15
Freeze dried	A	30.91	2.51	7.83	3.58	1.37
	B	23.66	1.56	6.20	5.94	1.16
Vacuum oven	A	27.17	2.51	5.50	40.50	17.37
40 C	B	22.28	1.56	5.89	15.85	6.64

Source: Shannon and Brown (1969).

to retain the nutrient values while destroying pathogenic organisms at the same time. A close control of what goes into the poultry rations guarantees a uniform feeding product of high quality with an absence of drug residues, and a beneficial effect on fermentation in the rumen of feedlot cattle.

Ensiling

The fermentation of vegetation and forage in an anaerobic environment with the production of lactic acid, heat, and preservation of nutrients for ruminants is an accepted practice. Ensiling animal manure with vegetation and forage is a potential for economic and nutritional utilization. The ensiling process will be discussed in greater detail in a following section concerning ensiling BL. Advantages cited for ensiling by Arndt et al. (1979) are that it increases animal acceptability, low nutrient losses, fits many existing feeding systems, permits stockpiling, and pathogen control after approximately 3 weeks of ensiling. Disadvantages listed by them are seasonability of forage diluting materials, handling or labor requirements (harvesting, transport to storage, ensiling material at ensiling time), transporting from storage to feedbunk, and storage facilities are required (upright, airtight bunker).

Liquid-Solid Separation

While processed solids have good animal acceptability, such systems are designed for large feeding operations with high initial investment in equipment, operating and maintenance costs.

Chemical Treatment

Chemical treatment has been referred to in the discussion of the use of formaldehyde and sulfuric acid. The main advantages of such treatment is that it increases animal acceptability and allows for immediate harvesting and refeeding with resulting reduced nutrient losses and with low energy and labor requirements. Shannon and Brown (1969) reported nitrogen losses were from

4.6 to 15.2% of the total nitrogen depending on temperature and method of drying, while loss of energy was reported to be small. Adding formaldehyde retarded the loss of nitrogen. A simple method reported by Lamm (1977) as cited by Arndt et al. (1979) described alkali treatment (adding sodium hydroxide flakes) of cattle waste (60% fresh cattle waste, 40% legume-grass hay) at 2 - 12% dry basis, mixed and ensiled for 33 days. Results showed an enhanced digestibility of fibrous material. The higher the level of sodium hydroxide, the higher the pH and the lower the lactic acid resulting in higher digestibility and a dry matter loss of less than 1 per cent. At 2% sodium hydroxide level, the odor was like that of good quality haylage; at 8 - 12% there was a soapy and strong ammonia smell. Some disadvantages of the chemical process are the required daily harvesting and processing, shorter shelf life with no extensive stockpiling, and the cost of the chemical and equipment for mixing.

Lagoons

Lagoons are a form of management consisting of flushing PM into an oxidation ditch or into open, shallow ponds. Aerobic lagoons require 1 acre of lagoon surface for every 1,000 to 1,500 hens in the northern U.S. and not over 2,000 hens per acre in the southern U.S. (Ostrander, 1965). The principle of bacterial action reducing the waste material to a smaller volume works best in warm months. Oxidation ditch-mixed liquor obtained from aerobically treated liquid wastes, as described by the Anonymous (1977), provides a nutrient rich drinking water for animals. The odorless process converts organic matter to single-cell protein. For poultry there is an oxidation ditch continuous flow-through trough under the housed birds which catches manure which is mixed with water and agitated by a paddle.

Problems with anaerobic lagoons exist as they possess strong, unpleasant odors. Environment control agencies question the pollution of ground or surface water. Anaerobic lagoons require a large isolated area with a fence.

Oxygen is required for microbial breakdown. The usual amount of oxygen solution in water is 8 to 10 ppm; with waste this increases to 10 times that amount according to Schaible (1979). Waste disposal through microbial activity must be combined with oxygen delivery via algae. The main disadvantage with lagoons is that they require a high degree of management capability and constant monitoring, but it is a system which can produce single-cell protein upgraded from non-protein nitrogen and can control pathogens.

Composting

Composting involves the digestion of fecal solids by bacterial action which can be aerobic or anaerobic, the former generating little odor and accomplishing reduction rapidly and efficiently. Once composted organic solids are completely treated, they are stable and undergo little further decomposition. Composting is not successful in the northern U.S. as the process is slow due to too much inclement weather and because there is a limited market for the product. Anthony (1967) reported on the adding of an inoculum (½ lb per sq ft of space) in confinement turkey litter housing systems. The resulting compost is usually more valuable as a feedstuff than the untreated manure. Howes and Rollo (1967) described the inoculum, Litterlife[R], in which a continual balance of cellulose, fecal material, water, and Litterlife were mechanically mixed to initiate aerobic action. Birds were placed on this litter once it had lost water, nitrogen, and other volatile compounds. Improved feed efficiency resulted from birds on this composted litter due to higher B vitamins and antibiotic activity compared to fresh shavings or untreated litter. Body weight of males was increased.

Composted PM is a dark brown color with a slightly musty, earthy odor. Aerobic composting, as described by Miner (1971), can be handled by windrowing

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[R]Registered trademark for an inoculum for litter supplied by Blenders, Incorporated, Lithonia, Georgia, 30058.

manure in rows 5 to 6 feet in height for 15 to 21 days with an internal temperature of 48.8 - 73.8 C (120 - 165 F) killing many pathogenic bacteria and eggs of parasites. Above 76.6 C (170 F) biological activity can be retarded. PM can also be collected in pits under cages or slats or wire floors and allowed to accumulate for several years. North (1978) reported that after 6 years the debris in one pit was 2 to 4 feet deep depending on the number of hens above. The top 1 foot was fresh manure, the bottom foot was in an anaerobic condition, and the central portion was composting. To assure no odor and no flies, the pit must be tight with no leaky waterers in the housing unit, the manure must be stirred and dried down to 35 - 40%, and for final use as an organic fertilizer complete drying down to 10% moisture is desired. Composting permits stockpiling, pathogen control, and is relatively simple, but there can be extensive loss of nutrients. Evans et al. (1978a) reported that composting layer hen manure significantly reduced ($P<.05$) water, nitrogen, and organic matter; significantly increased ($P<.05$) ash content of manure; and resulted in a decrease in nitrogen with losses occurring in the uric acid fraction. The stage of production of the hens is one factor which explains the compositional changes in hen manure.

A recently marketed mechanical composter for PM is the Brill Digester which composts 8 to 10 tons of manure every 48 hours (American Digester Corporation, Harper Woods, Michigan, 1980, personal communication). The initial purchase cost of equipment is $52,000 (as of January, 1980) with a cost of $2.70 per ton to process the manure.

Digestion

Digestion is a management system in which fly larvae are used to digest wastes, then the larvae are used as a source of protein and fat for poultry. Anthony (1971) reported the use of fly larvae in England to produce pupae which are harvested and fed to chicks as a substitute for soybean meal. This system is undergoing continuous research as there are physical and practical limitations to such a process.

Other Processes

There are other methods of animal waste disposal such as incineration which is expensive and a potential danger of air pollution. Incineration is usually considered only when the human population is dense. One major problem of such a method is that manure of over 75% moisture content cannot be used. Edwards et al. (1977) reported that hatchery incinerated ash can completely replace limestone as a calcium source in laying hen rations when added in place of 5.75% limestone and .05% defluorinated phosphate with no significant differences in egg production, egg weight, egg shell thickness, specific gravity, or hen weight.

Rockey et al. (1980) reported on a digester which could handle manure from 160,000 hens. The fermented manure could produce methane gas which also helps in the overall energy budget of the operation itself. The production of this methane was at a cost of $0.76/m^3$ whereas comparable commercial production of methane for the same time period cost $0.078/m^3$, therefore the use of PM is not an economical source at this time. One disadvantage of such a use of PM is that after the production of methane the residues from the process are still a pollutant and must be handled as such. However, Timmons (1976) reported that the state of Colorado considers blending of poultry and livestock waste for methane gas production to be economically and environmentally feasible.

Pelleting of fecal material, removal of water by dehydration and an extrusion process, as mentioned by Smith (1974), are expensive methods. These methods eliminate sorting and adaptative difficulties by livestock, but usually lower feed consumption. More economical methods are preferred.

The best climatic area for manure processing is in temperate-dry and hot-dry zones of the southwest where waste can be disposed of year round with high evaporation techniques. The ideal area for a livestock facility is in an agricultural area, downwind from nearby residental areas, on sufficient land to permit adequate treatment of waste disposal of surplus materials. Increasingly poultry production does not meet such ideal production criteria and therefore promising methods such as inside and outside lagoons, drying by bacterial actions or by electrical charge must be researched and developed. There is a need for development of PM as a feed ingredient especially in areas where poultry operations are on limited amounts of land.

UTILIZATION OF NUTRIENTS IN POULTRY MANURE

Arndt et al. (1979) stated that animal manure should be formulated into animal diets in the same manner as other dietary ingredients based on chemical content, nutritive content, and digestibility. The total diet should be formulated from the composition of all the ingredients, including the animal manure. If there is mere substitution for animal manure for a percentage of the complete diet by adding animal manure to a well-formulated diet based upon dry matter, it is only likely to result in poor performances.

Other poultry byproducts such as poultry offal and hatchery byproducts have been and are being utilized as feed ingredients for livestock and poultry. They can serve as examples or potential guidelines for PM utilization. Poultry offal meal is a mixture incorporated into poultry diets, but results will vary as ingredients and starting materials vary. Hatchery byproducts consist of infertile eggs, dead embryos, shells and unsalable chicks. Wisman (1964) reported hatchery byproducts to contain 26% protein and 20.9% calcium and that it is an acceptable ingredient in a corn-soybean broiler type diet as measured by one to four week growth and feed efficiency. Wisman and Beane (1965) reported that hatchery byproducts supplied in laying hens ration at the 15% level supplied 4% protein and 3% calcium. A combination of hatchery byproduct meal, poultry byproduct meal, poultry blood meal or hydrolyzed feather meal can be a satisfactory supplement when used to replace up to one-half of the soybean meal protein according to Wisman and Beane (1965). Vandepopuliere et al. (1977) stated that once waste from broiler and egg type chicken hatcheries is processed through a triple pass dehydrator, it can be incorporated at 8 and 16% levels in laying diets as a substitute for soybean meal, meat and bone meal, wheat middlings, and ground limestone with results in egg production, feed conversion, eggshell and interior quality comparable to that of the control. There is apparent utilization of amino acids, energy, and calcium comparable to those in the replaced ingredients.

Uses of Poultry Manure

Blood, feathers, and offal are processed in rendering plants and recycled as feedstuffs or for industrial uses in urban and rural areas where there are a large number of poultry slaughter plants. These slaughter plants and rendering plants are either located at one and the same site or in close proximity to one another. The same situation can exist for recycling PM, e.g. byproduct handlers and utilization must be in the area of greatest concentration of production. Concentrating efforts of PM utilization will ensure proper handling and marketing.

Fertilizer. As a fertilizer, PM contains higher amounts of plant nutrients than cow or swine manure according to Schaible (1979). However, poultrymen have a problem with intensive and confinement rearing systems. Frequent removal, spreading on fields, flies, odors, and disease organisms cause concern along with the high cost of labor and equipment for scraping and removal. The problem with removing poultry manure is that a hard-surfaced lot and daily scraping for collection is recommended, but costly in time and labor. A simple method to collect and recycle manure is needed if this is to be carried out on a large scale. Anonymous (1972) stated that as a rule of thumb, 450 hens, 590 pullets, 690 broilers, or 300 turkeys per acre per year would be required for manure application to the land assuming 50% of nitrogen is lost and based on a land application rate of 225 lb nitrogen per acre. Manure from 30,000 hens would be adequate for 66.7 acres per year. An increasing problem is that the amount of land available is not enough for all the poultry waste which must be disposed of and the cost of handling has increased. It is observed that the plant nutrient content of the materials is not sufficient to justify the cost of handling. It may be more economical to recycle poultry wastes to ruminants as this manure is of substantial nutritive value. One exceptional example of handling poultry waste to be utilized as a fertilizer is the Prohoroff Poultry Manure Disposal Plant in southern California. As described by Dunk (1979) this plant handles the output from 5 million birds and is expanding. Poultrymen are paid for PM by the yard. The processing method is patented so there is no step by step details available but the material is dried, ground, and undergoes a five step process for odor control (24 odor units) involving sulfuric acid. The process involves a dryer operated on natural gas which is a high cost factor. The final product is a dried poultry waste fertilizer called "Organo" for lawns, shrubs, fruit trees, and vegetables. Depending on grain and livestock feed prices, such a process or modification of it could utilize poultry manure as a feed ingredient in the future.

PM can still provide nitrogen for rye grass or other all grass sod, that is turned under to decompose, and for grains and pastures. An efficient usage of PM on the land is best when humidity is low so the manure can dry quickly and be plowed under. Loaders, spreaders, pumps, and tractors are required for either dry or liquid handling.

<u>Feed Ingredient</u>. The use of animal manure as a feed ingredient is an attractive concept as there is the potential to reduce the costs of producing

animal products. The most expensive animal feedstuff is protein, followed by energy feeds, and forages. While it is difficult to estimate its monetary value due to absence of formal markets for the materials, researchers are involved in maximizing the nutrients in PM in a recycling process. Anthony (1971) reported that poultry litter is used widely for animal feeding in Britain. Wastelage is a concept of manure utilization developed in 1968. PM was used as substrates to produce yeast, algae, and for maggots to be used as poultry feed. The simplest use is as a direct feed. Couch (1974) noted that as a feed ingredient it may be impossible to recycle a sizable amount of manure produced by a laying flock even if the dried poultry manure is included in the ration at levels of 12 or 22%. The amount of manure which must be handled by other waste management systems will amount to 75 to 80% of that produced by laying hens fed a standard laying ration.

Schaible (1979) mentioned that fresh PM containing only voided feces collected under cages is known as "pure quill" and usually contains 12.5 to 35% crude protein with most of the nitrogen tied up as uric acid and ammonium salts. Sixty-five to 90% of the nitrogen in PM or litter is non-protein nitrogen and of little value to monogastric animals. Gohl (1975) characterized fresh PM as possessing 30% crude protein (dry matter basis) with 50% of this crude protein derived from uric acid. The digestibility of crude protein is approximately 80% for ruminants and the manure is of high mineral content, making further supplementation of rations with a dried poultry manure unnecessary. Fresh PM ferments very quickly and Gohl (1975) emphasized that it is important to dry PM without delay if the manure is to be used for feeding purposes. After 2 days, one-half of the uric acid may have fermented into ammonia (if wet manure is stored in a warm poultry house) and after 5 days storage, uric acid is sometimes not detected in the manure. Schaible (1979) reported that fresh PM contains 10 to 11% true protein, but the level of nitrogen decreases over time as it is stored. The energy content of fresh PM is reduced when dried. Schaible (1979) reported a study in which wet caged layer manure was fed to sheep and was found to be acceptable and well utilized. Intake increased when molasses and propionic acid (to delay loss of nitrogen which results after long storage) were added as both additives increased palatability and provided energy.

Anthony (1967) reported on studies at Auburn University in which fresh caged layer poultry litter was fed as a substitute for cottonseed meal to fattening cattle. Twenty-five percent litter + 0% cottonseed meal was unpalatable, while 15% litter + 3% cottonseed meal was consumed, but performance declined. The conclusion was that fresh litter as a substitute decreased feed cost, but also depressed performance. Possible problems of drug residues and disease transfer are matters of concern.

Evans et al. (1978b) added propionic acid to fresh unprocessed PM to avoid nitrogen loss. In Trial I, ewes were fed high protein nitrogen PM (HPN) or low protein nitrogen PM (LPN) in untreated form or treated with 1% propionic acid or 2% molasses. The ewes had access to corn silage in excess of their energy requirement. Ewes preferred unprocessed LPN over HPN manure. Intakes of both diets were stimulated by addition of molasses and propionic acid, with propionic acid being the most effective. In Trial II, the manure was processed by freeze-drying and the same procedure as Trial I was followed. The results showed no preference due to source after freeze-drying.

Gutcho (1973) reported a simplified method of feeding cattle manure back to cattle with a minimum of collection and handling. Yearling steers were confined on concrete and fed a high grain feed mixture. The manure was collected daily and thoroughly mixed with water. The solid material was allowed to settle and the aqueous layer poured off. The water washing was repeated and fecal residues remaining were stored at .5 C (33 F) until needed for feeding. The wet fecal residue was mixed with the basal feed at the rate of 40 parts wet residue to 60 parts of basal feed. The feed was mixed thoroughly and at the time of mixing, dried yeast added at a rate of 1 pound per 100 pounds of feed. The final mixture was held in burlap bags for 12 hours before feeding.

Creger (1976) observed that feeding wet PM without benefit of fermentation or drying may increase the chance of salmonella contamination of the feed. Antibiotics can alleviate growth depression. Fresh hen feces fed to chicks depressed chick growth, except in groups receiving high levels of antibiotics (Yates and Schaible, 1961). It must be concluded that for reasons of disease control and handling, fresh wet PM is not desirable as a feed ingredient and therefore should be processed prior to feeding.

The American Association of Feed Control Officials (AAFCO) definition is followed for DPW in all states where it is an approved feed ingredient (Anonymous, 1980). Tables 8 and 9 refer to the nutrient composition of DPW. There are no drug residues in layer rations or in layer manure, but organic arsenicals may be found in poultry litter after oven drying as well as copper residues (Schaible, 1979). At the present time, DPW is not being used in large quantities. It is mainly obtained from layers. It has substantial nutritional value for ruminants with no deleterious effect on ruminants (Timmons, 1976).

Smith and Wheeler (1979) reported that dried caged layer manure will generally contain between 4.5 and 5.6% nitrogen depending on diet, collection and processing procedures. Hens fed diets with 18% crude protein produced manure containing 38 to 46% crude protein and those fed 16% crude protein diets produced manure with 28 to 36% crude protein according to Smith (1974). The water content varied in relation to physiological status of the hen and environmental conditions. He reported that in the southern United States in open-sided structures for housed caged layers (mild to warm climates), water loss is a result of the natural environment. Dry matter content from manure from such a house could be as high as 80%. In cooler climates, a manure handling system, as described by Bressler and Bergman (1971), consisted of mechanically timed scrapers for stirring and cleaning manure pits under caged layers and provided constant air movement (assisted by fans), resulted in water loss (dry matter content of manure generally higher than 40% varying with relative humidity, temperature, stirring frequently and air velocity) and odor control. Manure as dropped by the hen normally contains 25% dry matter and in the case of management systems where flush gutters are used, the dry matter content will be less than 25%. If houses are cleaned daily, the water content of caged hen manure is between 70 to 75%; left to stand for 6 months the water content will be 5.44% according to Schaible (1979).

DPW is suitable for feeding to ruminants as they can utilize uric acid and digest crude fiber better than a monogastric. Waldroup and Hazen (1974) stated that the energy content of poultry manure is about 25% of that present in the initial diet, therefore it is not as valuable for poultry where high energy diets are needed. Metabolizable energy has been accepted as the most useful practical measure of the energy value of the poultry diet (Shannon and Brown, 1969). The energy content of PM is probably less than 400 M.E. kcal per pound and therefore not a useful ingredient in cases where high energy feedstuffs are desired. The true digestibility of crude protein in dehydrated broiler manure is estimated to be 81% compared to 96% in fresh forages (Couch, 1974). DPW contributes significant amounts of essential amino acids and a significant level of protein in formulated feeds. Its calcium content can vary widely, its sodium content should be considered in formulation, and both DPW and BL contain trace minerals.

The real feeding value of DPW will determine its economic use. It is an economical protein supplement for ruminants as the dehydrating cost, the major expense, could be relatively low compared with current cost of conventional feeds at a given time. Anyone processing DPW for sale must register it as a feed ingredient containing certain maximum or minimum guarantees for protein, fiber, ash, feathers, and moisture (Timmons, 1976). McAnally Enterprises, Yucaipa, California, is an example of an organization that raises laying hens, and feeds a consistent ration and produces a DPW product for sale as a ruminant feed. The product is guaranteed to have 35 to 40% crude protein, 8 to 11% fiber, and 24 to 35% ash, less than 20,000/g bacterial plate count, less than 10/g coliforms, and no Salmonella (Hartman, 1976). High quality DPW is obtained by getting manure to the drier in less than 24 hours after being produced with no putrefaction, little reduction in nutrient values, no flies, and no odor.

Performance with DPW influences growth, fattening, lactation, or reproduction as the result of nutrient intake, digestion, absorption, and utilization. High level voluntary intake of feed is important in performance. Smith (1974) reported that the problem with adequate levels of consumption of DPW rations is that adaptative periods of 7 to 21 days are necessary before maximal levels of intake are achieved (Smith, 1974). Steers at first discriminated against DPW and sorted out shelled corn and corn silage (Bucholtz et al., 1971). Pelleting of 79.5% corn meal and 21.5% DPW eliminated sorting and adaptative difficulties. However, when fed to dairy cattle, pelleted DPW plus corn silage resulted in lower consumption due to the moist silage permitting ammonia release from the pullets. DPW has been fed successfully as a crude protein supplement to beef cattle, sheep, and lactating dairy cattle.

Sloan and Harms (1973) as cited by Couch (1974) fed DPW to broiler type chicks at levels of 5, 10, 15, and 20% for 4 weeks. Body weight and feed conversion were depressed as the level of DPW was increased. In contrast to other studies, there was no increase in feed consumption when the diet contained DPW. It was suggested by the authors that uric acid in this experiment may have been an appetite depressant. Couch (1974) noted that the low metabolizable energy content of DPW can be compensated for by the addition of fat. While chicks can utilize non-essential amino acids found in the true protein portion of DPW, the nitrogen in uric acid of PM is not utilized by chicks and can be toxic (Couch, 1974).

Coon et al. (1978) and Rinehart et al. (1973) stated that a low level of DPW (5.0%) resulted in no change in weight gain of chicks, but did result in higher feed consumption and lower feed efficiency indicating less metabolizable energy in DPW than in a corn based ration. Shutze and Muller (1974) reported that chicks fed up to 20% DPW were healthy and well feathered. Schaible (1979) reported on chick feeding trials in which levels of 0, 5, 10, and 20% DPW replaced corn and soybean meal in the regular rations of Leghorn chicks. Results demonstrated that weights at 4 weeks were not statistically different with feed conversion being 2.39, 2.47, 2.47, and 2.62, respectively for 0, 5, 10, and 20% DPW. These results indicated the waste product was low in energy and even 5% caused some reduction in feed conversion. In a second trial, feeding 20% DPW and 20% DPW + 5% fat demonstrated that DPW + fat resulted in higher weight gain and better feed efficiency. Similarly, Flegal and Zindel (1971) found that broiler chicks could tolerate only 5% DPW with only slight effect on feed conversion. Feed conversion and weight gains were depressed at the 20% level. These effects were prevented by adding 4% fat to the formula.

Lee and Blair (1972) reported that PM can substitute for glutamic acid in glutamic acid deficient diets. As the nitrogen in uric acid is completely unavailable and may be toxic to growing chicks, an increase in growth response is probably due to an unidentified growth factor.

According to a study by Waldroup and Hazen (1974), the effect of feeding diets formulated with 0, 5, 10, 15, 20, and 25% DPW and fermented PM indicate that hens fed non-fermented products maintained production better at levels of 20 and 25% than those fed fermented manure. Young and Nesheim (1972) recommended a maximum of 20 to 25% dietary DPW. Miner (1971) fed up to 20% DPW to layers with no significant effect on egg production or mortality. Waldroup and Hazen (1974) found that both DPW and fermented PM fed to layers decreased egg production but did not affect egg size. Interior albumen quality as measured by Haugh units increased with the addition of poultry waste but egg production decreased. Daily feed intake increased as the amount of PM in the diet increased as low energy feeds were fed and high intake resulted. More calories were required to produce a dozen eggs as increasing levels of DPW were added. Droppings from hens fed high levels of DPW in this study were extremely watery. It is thought that the amount of PM that hens will tolerate is controlled in part by salt content of the litter. Ousterhout and Presser (1971) reported that feeding DPW to hens increased fecal production rapidly and depressed egg production and feed efficiency. Flegal and Zindel (1970) added fat to DPW diets and reported no improvement in its adverse effect on feed conversion.

Young and Nesheim (1972) added wheat bran to DPW to increase the energy level of layer diets. The laying hens adjusted feed intake to achieve a constant daily ME intake. There was no effect on egg production or egg weight, but feed conversion and body weight gain were adversely affected by the addition of both PM and wheat bran. Fecal volume increased directly in proportion to the level of PM or wheat bran consumed.

Vogt (1973) incorporated 10% DPW in all-mash laying rations. Egg production and feed conversion were adversely affected with no effect on egg weight in three laying tests of 308 days each. Blair and Lee (1973) illustrated that laying hens were able to utilize some of the essential amino acids in DPW. A low protein (11.5%) diet was fed to hens in one laying period. The percentages of egg production from hens fed a basal ration deficient in amino acids, a ration containing 9.6% autoclaved DPW, and from a ration supplemented with amino acids, was 53.5, 62.8, and 76.5, respectively.

Young and Nesheim (1972) and Scott (1973) substituted DPM for corn at 22.5% of the ration. Both production and feed efficiency dropped. Laying hens increased feed intake to achieve a constant ME intake of 300 kcal of ME per day. The fecal dry matter increased from 5.8 to 9 lb per day per 100 hens. Hodgetts (1974) as reported by Martin (1980) concluded that 10% DPW had no effect on egg production, but feed conversion decreased at 6% addition of DPW. Flegal et al. (1972) reported that hens receiving 12.5% DPW produced 3.4% more eggs on a hen-day basis, but the increase was reduced to .6% at a level of 25% DPW.

Flegal and Zindel (1970) observed no significant difference in egg production, shell thickness, or weight of day-old eggs from layers fed DPW. In one study they gathered eggs on five consecutive days and held them for storage periods of 10, 20, 30, 40, or 50 days. In another study eggs were gathered on four consecutive days and stored for periods of 11 or 20 days. The results were that 10, 20, or 30% DPW fed to layers showed no significant deleterious effects on quality of shell eggs as measured by Haugh units, storage weight loss, color, odor, or microbial content. With the addition of 40% DPW, there was a decline in egg quality. Zindel (1972) presented boiled eggs from layers fed 30% DPW to a consumer's preference panel with no difference reported between control eggs (0% DPW) and eggs from hens fed DPW.

Because only 30% of the dry matter in DPW is digested, laying hens cannot utilize more DPW without it affecting nutrient intake and subsequent production (Martin, 1980). Laying hens and chicks are not the most efficient utilizers of DPW and in certain cases production can be affected. Flegal and Dorn (1971) reported a consistency of composition in DPW when recycling DPW through caged layers. Few differences were demonstrated in nutrient composition of DPW after 14 cycles of 12 days each. In spite of such consistency, recycling DPW in laying hen diets from a specific flock will not dispose of more than 25% of the manure produced by laying hens fed a standard laying ration. Therefore, it is necessary to consider other waste management disposal systems to handle at least 75% of the manure produced by laying hens and other species of farm animals to utilize DPW in a more efficient manner.

Similar to layers, Coon et al. (1978) stated that when DPW at a 30% level was fed to broilers, they consumed less ME from DPW than from the control ration because of high fiber and ash content (47.7% by weight of DPW). Gohl (1975) reported that DPW was included up to 5% in broiler type rations, up to 20% in feed for Leghorn-type chicks, and up to 40% in layer feed, before performance was affected. Feed efficiency was inversely proportional to the amount of DPW in the diet. Rinehart et al. (1973) reported that broiler fecal volume increased in direct relationship with the consumption of DPW suggesting almost complete lack of nutrient utilization.

Cunningham (1976) reported on flavor and composition of meat from broilers fed DPW. Lewis (1955) added 10% DPW to both natural and synthetic broiler rations. A taste panel gave highest scores to meat from birds fed natural ration + 10% DPW; lowest to meat from birds fed synthetic ration + 10% DPW indicating that poultry manure alone is not the only factor contributing to improved palatability of broiler meat. Cunningham and Lillich (1975) studied flavor differences caused by feeding 0, 9.6, 19.1, or 38.2% DPW. The taste panel could not accurately detect flavor differences between the two extreme treatments, but performance of the 38.2% DPW group was poorest for live weight, eviscerated weight, and feed conversion. Carcass composition changes (studied by analysis of dark meat for protein, ether extract, calcium, phosphorus, and TBA value) showed no significant differences among treatments in any of these factors and they concluded that feeding DPW had no noticeable effect on carcass quality, although growth was somewhat depressed when the feed contained 38.2% DPW. The most efficient and productive rate of DPW used in broiler feeds was 20%.

Fadika et al. (1973) incorporated DPW in turkey feed at 0, 5, 10, and 30% in rations formulated to be isocaloric and isoprotein. Results were that body weight gain was not significantly affected at 17 weeks of age and the plasma uric acid was not altered but plasma phosphorus was raised in birds fed 30% DPW. Feed conversion increased as level of DPW increased. This group of researchers coined the word "anaphage" for DPW. In similar tests, Zindel (1974) concluded livability was not affected by increased levels of DPW.

Gohl (1975) found feeding DPW to swine to be successful at levels of 5 and 10%. Above 10% DPW growth rate was not affected, but feed conversion became poorer with increased additions of DPW to the ration. DPW is low in the essential amino acids required by swine and has an excess amount of calcium. Growth rate was affected at very high levels of DPW. Clark et al. (1979) noted similar results when feeding pelleted grain dust to swine. Grain dust, as a 25 and 50% substitute for a corn and soybean ration, was pelleted and crumblized before being mixed and pelleted with other ingredients. Results showed an increase in feed intake as the level of dust fed increased. Babatunde et al. (1979) reported that the use of DPW with nonruminants is limited. Mixing 5 and 10% DPW with yellow corn and groundnut cake, rice bran, dicalcium phosphate, oyster shell, palm oil, mineral premix, and sodium chloride resulted in a significant increase in feed consumption and a poor feed to gain ration. Growth rates or apparent digestibility of nutrients were not significantly influenced by levels of DPW.

Smith and Wheeler (1979) stated that emphasis on ruminants as food producers is emphasized by the Council for Agriculture, Science and Technology (1975). Bhattacharya and Fontenot (1965) reported that in vitro studies by Belasco (1954) and Jutshuk et al. (1955) suggested BL is a potential source of nitrogen for ruminants because rumen microorganisms can utilize uric acid as a nitrogen source. Smith and Wheeler (1979) reported that the economic value of manure products as a feed ingredient in balanced diets for ruminants is 3 to 10 times greater than their value as plant nutrient sources. Productivity, measured by milk production, growth, and fattening of ruminants fed manure diets, is equal to that of ruminants fed diets containing only traditional ingredients, suggesting manure can be used to balance diets for ruminants. Corn silage and corn grain diets are naturally low in protein and minerals, therefore manure products can be used in a mixture for ruminants, particularly as a silage feed.

True digestibility of crude protein appears to be lower in diets containing cattle manure than in diets containing PM or traditional supplements. This could be the result of heat damage during processing or an inherent property of cattle manure which contains a proportion of nitrogen in microbial cell wall debris; therefore, when microbes are destroyed, so is nitrogen. Apparent digestibility of crude protein for diets fed to ruminants increases as the concentration of protein increases in the diet. This relationship is illustrated in all-forage diets and mixed diets of forages and concentrates (Holter and Reid, 1959; Dijkstra, 1966, as cited by Smith and Wheeler, 1979). Nitrogen in PM appears to be used more efficiently than other non-protein nitrogen sources in high forage diets by growing ruminants. High forage diets supplemented with PM could reduce feed costs and increase efficiency of animal production.

Maintaining breeding stock on diets of cellulose crop residues supplemented with manure products is an opportunity for decreasing animal production costs. Fisher (1974) as cited by Smith and Wheeler (1979) noted that the nutrient content of animal manure products is primarily influenced by the level of intake and roughage to concentrate ratio in ruminant diets.

Smith (1974) assumed manure from 18 hens would provide sufficient supplemental crude protein to grow and finish one beef animal. Based on chickens excreting an average of 28 g dry manure per day per hen with a minimum of 30% crude protein, beef consuming 6.5 kg per head per day of 11.5% crude protein ration, caged layer manure would have enough crude protein to grow and finish one-half of the cattle slaughtered in 1971 in the United States.

When energy levels of a DPW ration are maintained at a normal level, weight gains and milk production of cattle will be satisfactory. The low energy value of DPW may cause lowered palatability when fed at high levels. Adding molasses or fat to DPW to increase palatability did not affect meat or milk flavor according to Couch (1974) and Smith (1974).

According to a study by Smith and Wheeler (1979), when the crude protein content was reduced to 17% in a DPW blended ration in which beef cattle were previously receiving a 32% DPW blended ration, there was ingredient sorting by cattle with resulting poor performance. Creger (1976) reported a study in which DPW was mixed with one-half corn or sorghum grain and fed to feeder steers. Molasses was added to this 16 to 18% protein ration. The 350 feeder calves had an average daily gain of 2.63 lb and consumed an average of 10.8 lb per head per day. A 60:40 mix of DPW and milo over 120 days provided favorable results. There was no residue of Salmonella or Staphlococcus microorganisms in meat or organs after slaughter with withdrawal periods of 3 to 4 weeks.

Smith (1974) reported fattening steers fed DPW blended rations had an average daily gain of 1.15 kg per head per day while those on a urea ration gained 1.43 kg. Feed to gain ratio was lower and most efficient with the urea ration. Bucholtz et al. (1971) reported fattening steers fed 12% crude protein rations of soybean meal, urea, or DPW had average daily gains of 1.52 kg, 1.41 kg, and 1.38 kg, respectively. The feed to gain ratio was 6.91:1 for soybean meal and urea rations and 10.43:1 for DPW. However, El-Sabban et al. (1970) fed soybean, autoclaved poultry manure (APM), DPW, or urea to 25 Angus steers over a 139 day period. Rate of gain and feed efficiency were no different between steers fed soybean meal, APM, or DPW, but were higher and more efficient with urea. There was no treatment effect on carcass characteristics and meat acceptability. Amount of chlorinated hydrocarbons in back fat and arsenic in liver tissues were at safe levels, below 1 ppm. Anthony (1971) finished steers on soybean meal, APM or cooked poultry manure. Carcasses were of similar characteristics and acceptability and chlorinated hydrocarbons in back fat and arsenic in liver were found in amounts less than 1 ppm (far below permissable tolerances).

Timmons (1976) stated that PM is best used in beef cattle rations. He questioned the energy value of high DPW rations which is a good protein source. He stated that the price of the fat market would have to be very low to afford the use of fat as an energy supplement for DPW. The economic potential of DPW is not developed because there are not enough firms producing it to develop valid feeding costs. According to Anonymous (1974) using 1973 prices, a ration of one-half DPW and one-half soybean meal was more efficient and economical than a DPW blended ration. Beef cattle fed one-half DPW and one-half soybean meal had an average daily gain of 2.88 lb with a feed cost of $16.84 per hundred weight of gain; those fed DPW based ration had an average daily gain of 2.75 lb with a feed cost of $18.87; and those fed soybean meal had 3.35 lb average daily gain with feed cost of $15.31. Feed costs were based on 35% dry matter corn silage at $8.50 per ton, shelled corn at $45 per ton, soybean meal at $45 per ton, trace mineral salt at $60 per ton, dicalcium phosphate at $80 per ton, DPW at $30 per ton, and vitamin A and D premix at $10 per hundred weight. Obviously, the cost of the ingredients at a particular time and the price of energy will determine which is most economical.

Bucholtz et al. (1971) reported a higher nitrogen retention by sheep fed conventional DPW than those fed soybean meal. There was significantly higher nitrogen retention in sheep fed citrus pulp litter than those fed a basal diet. Thomas et al. (1972) fed sheep 19% crude protein rations containing DPW or soybean meal. Those on DPW gained significantly less weight than those fed soybean meal, .16 kg and .21 kg, respectively. High supplementary levels of excreta needed to obtain 19% crude protein rations could have accounted for the lower gain.

Smith and Wheeler (1979) reported that 25% DPW is the maximum level for feeding dairy cattle as higher levels result in unpalatable diets and lower feed intake and therefore unacceptable animal performance. Fontenot and Webb (1974) stated that up to 30% DPW can be used with no effect on milk production and flavors in meat or milk. Thomas et al. (1972) also reported that milk from cows fed DPW is indistinguishable from milk from cows fed conventional feeds. El-Sabban et al. (1970) and Bucholtz et al. (1971) reported that taste panels found no difference from the control in meat and milk. Carcass evaluation of the DPW fed cattle was the same or similar to that of the control fed animals.

Smith and Fries (1973) reported cows fed DPW and maize silage for 90 days consumed less feed, gained less weight, and produced less milk than cows fed a control ration. However, ratios of feed dry matter intake to fluid milk produced were the same, suggesting a nearly equal use of nutrients. Anonymous (1974) reported that a 60 day experiment (with a 25 day adjustment to the ration) was conducted in which diets containing soybean meal diet or 5% DPW diet were fed to dairy cows. Results showed cows fed soybean meal had lower milk production and fat percent and lower body weight gain for those fed DPW (Table 12).

Table 12. Milk yield, fat content and body weight gain from feeding soybean meal and DPW to dairy cows

	Soybean meal	DPW (5%)
Milk (lb per day)	46.5	47.9
Fat content (%)	3.51	3.85
Body weight gain (lb per day)	2.01	1.24

Source: Anonymous (1974).

Bull and Reid (1971) reported that DPW can serve as a sole source of supplemental nitrogen for lactating dairy cattle producing at least 28 kg of milk per day. Kristensen et al. (1976) as cited by Smith and Wheeler (1979) reported that a commercial product composed of 90% DPW, 5% animal fat, and 5% molasses can be used for dairy cows by paying attention to the use of non-protein nitrogen and the low digestibility of the energy in DPW. Milk cows fed this product had slightly lower (.25 kg) milk production, similar butterfat levels, and slightly higher feed consumption (.3 kg) than cows fed control rations.

According to Fontenot (J.P. Fontenot, 1980, personal communication), the use of DPW from caged layers has proven to be a safe feed ingredient for dairy cows. He stated however, "Concerning the use of broiler litter in dairy rations...if the poultry are fed medicinal drugs, there is a possibility of the residues appearing in the milk. In fact we recommend against using broiler litter in milk producing dairy cows." While DPW is a safe product, there can be some hesitation on the part of dairy producers in incorporating PM of any type in their rations for lactating animals.

BL is an accumulation of poultry manure, bedding, waste feed, and feathers from floor-raised birds providing a potential valuable feedstuff for ruminants (Fontenot, 1979). It has been traditionally used as plant fertilizer but economic studies show that plant nutrient value from animal wastes is not sufficient to justify the cost of handling a bulky product such as BL. It is now a potential source of protein and energy for feeding ruminants. Gohl (1975) stated that as a feed it should be dried immediately after being removed from the poultry house and preferably milled and run over a magnet to remove metal scraps. Dried litter can be stored for a long time. Smith and Wheeler (1979) observed that the use of dried broiler manure for ruminants is similar to dried layer manure, except that total ash and calcium contents are lower and nitrogen content could be higher in dried BL than in layer manure. BL can be blended in diets in the dry form, heat treated, and can also be ensiled with forage or grain.

Pathogens are decreased in BL by autoclaving, fumigation, and dry heat alone or in combination with paraformaldehyde. Autoclaving litter is effective in preserving nitrogen and energy (Fontenot et al., 1975). Fontenot et al. (1971) stated that processing by dry heat for three or more hours is the only method which completely sterilized the litter, but this method reduces the amount of nitrogen. Acidifying the litter (litter normally has a pH of 7.7, but with 30 ml of 1 N sulfuric acid it is reduced to a pH of 6) before heating reduced the nitrogen loss substantially and did not alter the nitrogen utilization in poultry litter fed to lambs. The authors noted that dry heat alone resulted in 13.9% loss of nitrogen and acidification prior to heat treatment reduced the loss to 7.5%.

The chemical and nutrient composition of litter will vary among producers, however several lots of litter should be analyzed as is commonly done for forages. Table 13 gives examples of the nutrient composition of different types of poultry litter.

Table 13. Composition of different types of poultry litter

Litter	D.M.	CP	CF	Ash	EE	NFE	Ca	P
			- % of dry matter -					
Wood shavings broiler litter, dried	88.9	30.6	14.6	19.0	2.8	33.0	2.48	2.26
Peanut hull broiler litter, dried	89.1	32.0	15.1	17.9	2.8	32.2	2.77	2.86
Bagasse chicken litter, dried	92.3	2.8	44.9	2.2	.8	49.3	——	——
Citrus meal broiler litter	——	26.5	11.8	9.5	3.0	49.2	——	——
Wheat bran broiler litter	——	27.2	17.1	19.9	1.7	34.1	——	——
Corn cobs broiler litter	——	26.5	16.7	13.9	4.3	38.6	——	——
Sugar beet pulp broiler litter	——	31.6	14.1	17.7	1.9	34.7	——	——

Source: Gohl (1975).

Fontenot et al. (1966) summarized poultry litter as being a source of nitrogen and minerals with 30% crude protein composed of 46% true protein, 31% uric acid, 14% ammonia, 2.7% urea, 3.5% creatine, and 4.8% other. Noland et al. (1955) analyzed BL with peanut hulls and oat straw as a base and found it contained 30.31% crude protein of which 19.2% was uric acid. Therefore, litter is a valuable source of nitrogen present as true protein and uric acid. Fontenot and Webb (1974) examined lots of BL produced from one or more crops of birds and found the waste to contain 28% crude protein. Bhattacharya and Fontenot (1966) found 45% or more total nitrogen in BL with the non-protein nitrogen fractions coming from uric acid, ammonia, urea, and creatine. They reported evidence that uric acid can be broken down in the rumen at a slower rate than urea, with a trend toward more efficient non-protein nitrogen utilization of uric acid. They fed a semi-purified diet to sheep in which 100%

of the nitrogen was from BL. In these studies when 25 or 50% of the dietary nitrogen was supplied by litter, nitrogen retention was not significantly lower than when soy protein supplied all of the dietary nitrogen.

The apparent digestibility of nitrogen from poultry litter varies from 65 to 82% (Ammerman et al., 1966, as cited by Fontenot and Webb, 1974). Bhattacharya and Fontenot (1966) reported the average digestibility by ruminants of the energy in wood shaving and peanut hull BL fed at 25 and 50% levels to be 64%. Poultry house litter may vary widely in energy content depending on the type of litter material used and the number of batches of broilers that have been reared on the litter (Couch, 1974). Young and Nesheim (1972) noted that there is a primary metabolizable energy deficiency in poultry battery manure as it may contain as little as 792 to as much as 1350 Kcal ME per kg. Variations can be due to different feed formulations and the quantity of feed spillage in the manure. Bhattacharya and Fontenot (1966) observed that the ash content of BL can be high and therefore limit its energy value.

Gohl (1975) described deep litter as a mixture of suitable litter material and poultry droppings developed over a period of 6 months or more and maintained in a dry friable condition and can be used after composting as an animal feed. The growth rate and health of birds raised on deep litter is superior to those raised off the floor because the microflora in the litter produces vitamin B_{12} and antibiotic substances. Wood shavings and peanut hulls are types of suitable litter material which will absorb water, be coarse enough so packing doesn't occur, and capable of decomposing. The addition of lime keeps the litter dry and superphosphate reduces the loss of ammonia. The water in the PM will be used in decomposition and will eventually evaporate.

Fontenot et al. (1971) observed that because of interest in the utilization of BL, research was intensified to develop processing methods that would destroy pathogenic organisms in BL, determine the effect of sterilizing on nutritional value, determine variations in chemical composition, determine palatability, and determine the magnitude of pesticide residues in broiler litter.

As broilers are fed rations with drugs, the problem of drug residues must be researched before BL is considered safe to feed to cattle and sheep. Studies have been made in feeding BL to fattening steers, beef brood cows, and sheep with favorable results. Creger (1976) reported that heifers as well as feeder calves respond well to either straight litter (fresh or dried) or ensiled litter. Hunton (1979) concluded that the main value of BL is as a source of uric acid and phosphorus but that it has low energy and high fiber contents. The quantity of BL to be fed depends on the price of BL, alternative feedstuffs, and the desired rate of gain. It can be fed as either part of the concentrate ration or as an additive to silage, hay, or other roughage. He found that it supported normal feedlot growth rates of 2 lb per day.

Creger et al. (1973) fed BL at levels supplying 50% of total nitrogen intake with no adverse effect on carcass quality. Fontenot et al. (1971) fed cattle rations containing 25% and 50% levels of BL and observed that acceptability of the rations decreased as the level of litter increased. There was no marked effect on taste panel evaluation of the meat, no substantial levels of pesticide residues in the BL, and feeding litter to the cattle did not markedly affect pesticide residue levels in the fat or liver.

Miner (1971) observed that feeding 15 to 30% ground corncob poultry litter to steers had no effect on meat taste. Feeding steers up to levels of 40% manure and 60% feed concentrate resulted in net gains comparable to the controls. Feeding feedlot steers unprocessed litter blended rations improved feed to gain ratios with no effect on meat taste or carcass quality

(Fontenot et al., 1966). Southwell et al. (1958) as cited in Fontenot et al. (1966) reported that fattening steers fed 15 to 30% ground corncob poultry litter gained at approximately the same rate as those fed a cottonseed meal protein supplemented control ration but feed efficiency was lower for the steers on the 30% litter ration. Fontenot et al. (1966) noted that daily gains were similar and feed efficiency higher for fattening steers fed 25% mixture of peanut hull poultry litter and ground corncobs than those fed a standard ration.

Anthony (1967) reported Alabama farmers had used 80% BL, 10% ground ear corn, and 10% cane molasses as a feed for beef cows during the harsh winter of 1962-63. Although the feed had a strong ammonia odor, the farmers reported that the brood cow consumption was 20 lb per mature cow per day. Ray and Child (1965) reported on a winter feeding study with beef cows which he considered to be the greatest potential use for BL. The ration contained 40% broiler house litter, 38% ground sorghum grain, 10% alfalfa meal, 1% deflorinated rock phosphate, and 1% salt which was fed at 3 to 5 lb per day per animal. The BL proved to be a good substitute for cottonseed meal. The cows had healthy calves with no disease and the calves carried more bloom at the end of the feeding period than those cows on hay only. They successfully wintered beef cows and calves on tall fescue pastures supplemented with a mixture of 20% corn grain and 80% oat straw BL.

Ray (1978) advised as a rule of thumb, concerning the direct feeding of BL to cattle, a mixture of 70:30 litter/grain for wintering cows and 30:70 litter/grain mixture for finishing steers. The ratios must be manipulated according to whether the animals are lactating, dry, and what gains are expected.

Tests were conducted at Auburn University (Anthony, 1967) to determine the nutritive value of BL for sheep. A control ration of 78.6% hay, 10%

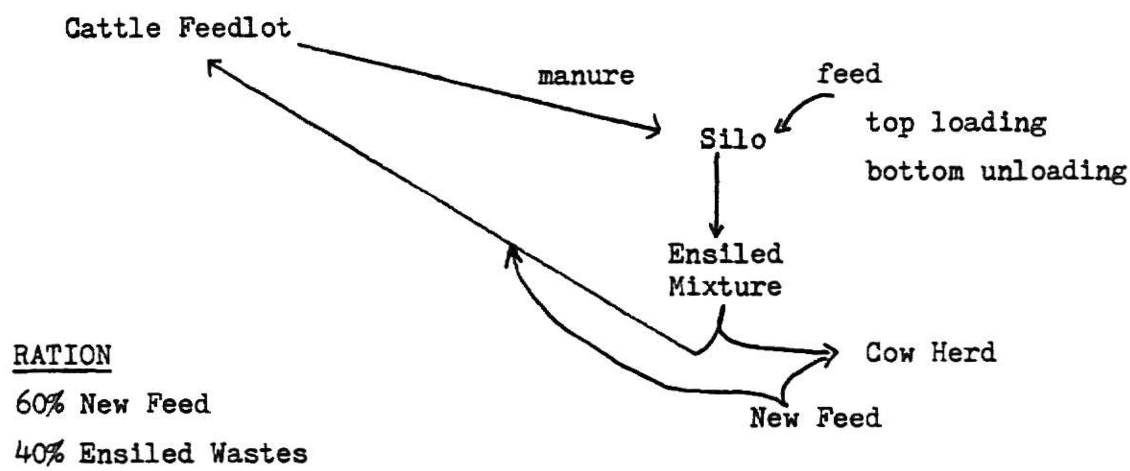
ground ear corn, 10% cane molasses, and 1.4% urea was fed to a group of ewes. A ration of 80% litter, 10% ground corn, and 10% cane molasses was refused by another group of ewes. A third ration of 50% litter was accepted. They consumed 1 lb per head per day, but picked at and left cobs, shucks, bedding, and fibrous material. A fourth ration of 50% litter, 35% ground corn, and 15% cane molasses was pelleted and ewes consumed 2 3/4 lb per head per day. Pelleting the ration improved its acceptance. Cellulose in the control ration was more highly digested from one brood litter and the amount of sawdust was low in this litter. The digestibility of dry matter from one brood litter was 41%, from several broods 48%, and if litter from floor raised layers was used, digestibility improved to 57%.

Fontenot et al. (1966) observed the digestibility of sheep rations containing 25 or 50% woodshaving and peanut hull litter. The control ration contained equal parts of alfalfa hay and ground shelled yellow corn. The digestibility of the control ration was 76.4%, only 3.7% higher than the 25% ration. Results showed that the type of litter had no effect on digestibility of the ration and that rations with litter were a potential for ruminants. Digestible protein of litter ration was 22.7% with litter and those not containing litter was 12%. Digestible energy per kg was 2240 kcal per kg with litter ration and in those not containing litter was 2479 kcal per kg. They concluded that BL nitrogen was utilized efficiently as long as it was less than 50% of the total nitrogen intake. In another trial Fontenot et al. (1966) noted that autoclaved peanut hull BL containing 32.6% crude protein on a dry basis had an apparent digestibility of crude protein in rations which was significantly lower with each increase in litter nitrogen levels above 25%. Bhattacharya and Fontenot (1966) fed autoclaved peanut hull and wood shaving BL to wethers and found the digestibility of crude protein to be similar. The addition of these types of litter improved the digestibility of crude fiber being highest at the 50% level of litter. The dry matter, NFE and digestible energy were lower for the litter ration than the control.

Brugman et al. (1967) tested the effect of sterilization on poultry litter and its digestibility. The litter was heated to 57.2 C (135 F) for 10 hours which destroyed bacteria, but decreased protein and fiber digestibility.

Ensiling PM may be the most economic and advantageous method of controlled processing of PM by allowing fermentation of caged layer manure or BL. The ensiling process is characterized by the production of heat and organic acids, followed by quiescence at which time the pH of the fermented mass becomes stable at approximately 4 (Fontenot et al., 1975). Ensiling PM with forage or grain and additional water is advantageous as it enhances the nutritional value of additional feedstuffs, reduces dustiness, and improves palatability resulting in a more complete and accepted feed. Rumen contents and blood are other examples of byproducts which are added to silage especially when lactic acid production is rapid. Litter silage, as described by Couch (1974), has been produced by packing BL from which three to four batches of broilers have been raised into an upright, air-tight silo and adding water until total moisture content is 35 to 38%. The silo is sealed and left undisturbed for 6 weeks. This results in an excellent ingredient for feeding cattle and therefore a good disposal method for BL in the future.

Corn silage is palatable and is a high energy feed source, but is deficient in protein, calcium, and phosphorus. Use of poultry litter with corn silage-corn grain apparently presents the greatest opportunity for more efficient utilization of nitrogen and minerals in the litter. Caged layer waste is abundant in protein, calcium, and phosphorus and can be used to improve the nutritional value of ensiled manure and results in a complete feed (Albert et al., 1977). Ensiling provides processing the litter at the least cost which may result in reduction or elimination of pathogens and drugs, maintenance of nutritional value of litter, enhanced palatability, and production of a final product that approaches a complete feed (Caswell et al., 1977). Figure 1 illustrates a simple ensiling method using cattle manure as a feed source (Day, 1977 as cited by Arndt et al., 1979).



Certain principles should be followed for ideal manure-blended silage. Moisture content should be 40% for best development of lactic acid (whereas for good fermentation of forage 65 to 70% is best) (Fontenot and Webb, 1975). Temperature for best lactic acid bacterial growth is between 20 and 40 C with an optimum of about 30 to 32 C (Pederson, 1971). A pH of 3.9 to 4.8 with lactic acid from 3.13 to 13.6% (dry basis) prevents development of potential pathogens which are in manure and on forage prior to fermentation (Langston et al., 1958).

Creger et al. (1976) reported that ensiling BL (moisture content brought up to 35 to 40%) resulted in an average percent crude protein from 10.6 to 25.8, the level depended on the number of birds on litter and the type of feed management. The better the feed efficiency of the bird, the less the protein content of the feed. The fermentation of PM resulted in no coccidiostats, uric acid, urea, or creatine residues while the majority of non-protein nitrogen was converted to amino acid nitrogen (Creger, 1976).

Caswell et al. (1977) compared ground corn grain (26.3% water) ensiled alone to ground corn grain ensiled with ground poultry litter (18.7% water) in a 2:1 ratio. The pH of the ground corn grain alone was lower than corn grain ensiled with poultry litter. Bacteria and coliform counts were lower in the litter silage, and crude protein content of the corn grain silage alone was 9.4% (dry basis) while the litter silage was 20.1% (dry basis).

Gohl (1975) suggested mixing energy rich feedstuffs with litter silage such as a 65% litter, 25% citrus meal, 9% molasses, and 1% minerals for beef and dairy cows. A disadvantage of this mixture is that once mixed it must be used quickly. Citrus meal is a good litter that is high in energy. Care must be taken not to include citrus seeds as this causes mortality among birds.

As 11 million tons of whey are produced annually in the United States, Duque et al. (1978) suggested adding liquid whey to alfalfa hay/broiler litter silage up to a moisture content of 40 to 50%. The silage showed a decrease in pH with each additional increment of whey (or with water in the control) with putrefaction and an unpleasant odor resulting from adding 60 to 70% whey or up to 50% water. The level of carbohydrates generally decreased with each increment of water or whey above 40%. Therefore 40% moisture is best in using a byproduct such as whey to increase the carbohydrate and lactic acid content and ensure proper ensiling to destroy pathogens and to preserve nutrients. The dry matter and crude protein digestibility for a whey or water litter silage at 40% mositure in their sample was 53.8% and 37.3%, respectively.

Turkey and beef producers in Georgia are ensiling turkey litter before feeding it to steers with good results, but hesitate to use it consistently because it is not sanctioned by the FDA (Timmons, 1976). He stated that while there is no problem in using caged layer litter, there is a problem in using broiler to turkey litter as there is a threat of drug residues (especially with dried BL), pesticides, aflatoxin, parasite eggs, and heavy metals. Fontenot et al. (1975) listed a few reasons for the potential value of ensiling PM: ensiling of BL alone, with optimum moisture level, or with lower protein feedstuffs is a feasible processing method; ensiling lowers or eliminates coliforms; digestibility of ensiled material is efficient and nitrogen from waste is efficiently utilized; and addition of BL to corn forage or high moisture corn grain improves the palatability of ensiled material.

A variation of ensiling PM is wastelage. As described by Gohl (1975), wastelage is fresh manure mixed with ground grass hay in a 57:43 ratio, stored in a silo from 10 days to 3 weeks, and then fed in the same way as silage. Fermentation occurs with a resulting silage odor. Using coastal bermuda hay the crude protein content would average 13%. Miner (1971) described wastelage as a low moisture silage, palatable and nutritious with a dry matter content of 57% and 12% crude protein (dry matter basis). Disease and parasites were no problem. Antibiotics were present in low amounts if present in the manure. When diethylstilbesterol (DES) was used in cattle feeding programs, there were no residues in cattle wastelage. Cows fed wastelage cycled, bred, and calved normally. Bandel and Anthony (1969) suggested a wastelage corn ratio of 2:3 as this proved efficient for slaughter cattle. In a later study, Anthony (1971) reported that use of wastelage results in high rate of gain and good feed efficiency. A ratio of 3:2 wastelage/corn fed to cattle provided too little corn with a resulting reduced rate of gain. Gohl (1975) reported using wastelage and concentrates for finishing cattle and also as a sole feed for ewes and beef cows. A complete ration recommended for feedlot cattle, as suggested by Gohl (1975), is 40% fresh cow manure, 42% cracked corn, and 18% corn silage which is ensiled for 10 days prior to feeding. Miner (1971) conducted a 126 day feeding trial in which steers were fed 40% wastelage, 60% whole shelled corn, and 2 lb liquid protein supplement with a resulting 2.57 average daily gain. One limitation to feeding wastelage is that it is necessary to add vitamin A and phosphorus or feeds rich in growth factors when feeding for long periods.

In a recent study, Dana et al. (1979) compared the process of ensiling PM (40% moisture) with deep stacking in a 124 day experiment. Twenty tons of fresh wood shaving based broiler litter was deep stacked in a covered building, open on all sides at a depth of 4 feet without packing. The same amount of BL was ensiled at 40% moisture. Both were deep stacked and ensiled for 6 weeks. A feeding trial was conducted with 30 weanling beef steers. They were full-fed on corn silage and the following supplements on a dry matter basis: deep stacked BL substituted for 30% of corn silage, ensiled BL substituted for 30% of total silage, and soybean meal and defluorinated phosphate supplementation (control). The dry matter intake per lb of gain was highest among those fed corn silage and deep stacked litter and lowest among those fed soybean meal. The average daily gain was highest (1.91 lb) for those fed deep stacked litter, followed by 1.77 lb and 1.76 lb for those fed ensiled litter and soybean meal, respectively.

Smith and Wheeler (1979) reported poultry litter is adequate to make silage as it is a good source of TDN and protein. A good balance for beef and dairy cattle is a mixture of corn silage + corn grain + manure products, using up to 11% poultry litter. This limited use emphasizes unrealistic values placed on poultry, cattle and swine manure products as primary energy sources.

Caswell et al. (1975) evaluated the feasibility of ensiling BL alone or with added water on fermentation characteristics, nitrogen utilization, digestibility and palatability when fed to ruminants. BL with moisture levels of 15.6, 20, 30, 40, and 50% respectively was tested. Coliforms were eliminated at 20% moisture or higher and total bacteria counts dropped at 30% or higher moisture content. The higher the moisture level, the lower the pH in silages. Ensiling with different levels of moisture did not greatly change nitrogen components of silages. Caswell et al. (1974) also conducted a study ensiling high moisture corn grain with woodshaving based broiler litter at a ratio of 2:1. Total bacteria and coliform counts were low. Ensiled high moisture corn had 199 coliforms per g while ensiled corn litter had 149 per g. No Salmonella was observed in either silage. The crude protein in ensiled corn was 9.4% dry basis, while an addition of one-third BL prior to ensiling increased the crude protein to 20%. Yearling steers were fed ensiled corn silage (control), corn-litter silage, or ensiled corn-soybean meal rations with the result that the steers consumed more litter silage than ensiled corn or ensiled corn-soybean meal silages, but had the same average daily gain as the steers fed the soybean meal.

McCartor (1979) fed poultry litter silage with water or brewers condensed solubles to heifers. Dry matter consumption (kg per head per day) ad libitum of the litter silage with added water (W) or brewers condensed wastes high (BCS-H) or low (BCS-L) was 2.4, 3.0, and 2.4, respectively for W, BCS-H, and BCS-L. Liveweight gain (kg per head per day) for heifers fed W, BCS-H, and BCS-L was .06, -.06, and -.15, respectively. Poultry litter silage ensiled with water or BCS failed to provide more than a maintenance level of nutrient intake.

Creger et al. (1973) ensiled BL from groups of broilers reared on pine shaving litter. The broilers were fed a standard broiler diet (19 to 24% protein for 8 weeks) containing the coccidiostat amprolium, zinc bacitracin, and a growth promoter, 3-nitro-4-hydroxyphenylarsonic acid. Water was added to the BL to provide a 35 to 38% moisture content. Forty tons of this mixture was ensiled for 6 weeks in an airtight, upright silo. Fifteen heifer calves, each weighing 477 lb, were fed BL silage free choice at 8 lb per head of a 12% protein mixture containing ground milo, dehydrated alfalfa meal, soybean meal, molasses, and vitamins A and D. The mixture was poured over the silage litter daily. Twelve pounds of silage was consumed per head per day. After 120 days of feeding, the animals were weighed and slaughtered with the following results: average daily gain, 2.54 lb per head per day; no coccidiostats detected in fermented silage nor in any animal tissue; no drug residues (either destroyed during fermentation process or not absorbed by the animal); no high microorganisms counts and negative for Salmonella, Staphlococcus, and coliform (absence due to high temperature and high acidity levels). The litter silage proved to be an excellent source of calcium, phosphorus, magnesium, potassium, sodium, zinc, copper, and iron. A 50-member taste panel sampled test and control steaks and detected a small but significant difference between the two samples. They expressed a preference for steaks from the control animals.

Westing et al. (1977) observed that heifers fed corn silage ensiled alone or with BL (at 30% of dry matter) for 201 days showed higher tissue levels of copper and cadmium than heifers fed soybean meal. While liver copper levels were elevated in heifers fed BL silage, bromine values were lower in loin and liver and zinc liver values were lower. The heifers showed no evidence of toxicity as indicated by performance and physical observation. The mineral profile was obtained by neutron activation of ration components and liver and loin muscle.

Trevis (1979) has investigated the effect of zeranol (Ralgro[R]) implants (active synthetic growth stimulator for ruminants) on cattle fed corn silage

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[R]Registered trademark for implant supplied by IMC-Chemical Group, Terra Haute, Indiana, 47808.

and corn-litter silage (70:30 dry basis) plus a soybean supplement. Results showed that steers, without zeranol implant, fed corn-litter silage with no soybean supplement had better feed efficiency and average daily gain than cattle fed corn silage with soybean supplement. The average daily gain of steers fed corn silage with no soybean meal was 1.99 lb, corn silage with 2 lb soybean meal per day 2.41 lb, corn-litter silage with no soybean meal 2.53 lb, and corn-litter silage with 2 lb soybean meal per day 2.39 lb. Carcass grades were low to average choice. Steers with zeranol implants performed even better with corn-litter silage indicated by a .2 lb per day gain advantage. Carcass grades and dressing percentages were higher for corn-litter silage fed steers with zeranol implants than the non-implanted steers. Therefore, less concentrates were required per pound of gain for implanted steers fed corn-litter silage. Fontenot and Webb (1979) as cited by McClure et al. (1979) also conducted a similar experiment with heifers and concluded that BL ensiled with corn forage can completely replace protein supplements in a ration for fattening beef cattle at a substantial savings in feed cost and would be a good method to process waste. Heifers implanted with zeranol gained at a faster rate than those not implanted and response was greater when implanted heifers were fed corn-litter silage.

McClure et al. (1979) fed ensiled corn forage and BL to finishing heifers. The BL was mixed with corn forage at a level of 30%, dry basis, and ensiled. The results demonstrated a higher silage intake of the heifers fed corn-litter silage than those fed corn silage alone with an average daily gain of 1.02 kg for corn silage fed heifers and .77 kg for those fed corn silage and a soybean meal supplement. Schaible (1979) stated that poultry litter silage can be fed directly to steers up to a 25% level with the primary utilization being for the maintenance for beef cattle.

Dairy heifers were fed turkey litter silage in a 84 day study (Cross and

Jenny, 1975). Turkey litter silage (TLS) and corn forage was ensiled separately, mixed prior to feeding with a 10% concentrated supplement. The best results were obtained with 30% TLS. There was a reduction in feed conversion with higher levels of TLS. Hunton (1979) reported that Holstein steers fed a mixture of ensiled poultry litter and sunflower hulls had a 2.03 lb average daily gain over a 3 months period. Those fed alfalfa haylage had a 2.29 lb average daily gain over the same period. He reported on a 180 day study involving Holstein heifers in which corn silage supplemented with soybean meal resulted in a 1.96 lb average daily gain; corn silage supplemented with DPW resulted in a 1.93 lb average daily gain.

Creger et al. (1973) reported that poultry litter silage fed to sheep up to levels of 50% of total nitrogen intake had no adverse effects on carcass quality. However, levels above 50% had an adverse effect on feed efficiency.

Utilization of poultry wastes, particularly caged laying hen manure, as a feedstuff for ruminants is not always economically practical. Results of studies examining the feeding of aerobically stabilized swine manure to feeder pigs suggests this system has merit for laying hens. The cost of dehydration and incorporation of DPW as a feedstuff may be greater than the value. In certain situations aerobically stabilized PM could be an alternative.

Martin (1980) conducted a study to verify the merit of aerobically stabilized PM (ASPM) for laying hens. He based his study on the established practice that aerobically stabilized swine manure is of value to swine production. With swine manure, as the particle size of aerobically stabilized manure decreased, the amino acid factor of the dry matter increased. Swine receiving aerobically stabilized swine manure (ASSM) + a corn-soybean diet deficient in protein grew more rapidly and efficiently than those receiving the same diet but with tap water instead of ASSM. Since ASSM can be substituted for tap water with good results, Martin (1980) decided to utilize

ASPM from an undercage oxidation ditch as a substitute for tap water. Several strains of White Leghorn hens were fed a ration of 15.6% crude protein and 2998 kcal ME per kg for one year. The results were that the ASPM fed group had higher egg production than the group that was fed a control ration. Statistical analysis of egg production data for each trial indicated that the stimulation in egg production was significant ($P < .01$), but the reason was unclear. There was no difference in body weights, total mortality, egg or eggshell quality due to the treatments. Assuming a 2.6% increase in egg production above a typical commercial level of 20 dozen eggs per hen-year and a market price of $.60 per dozen eggs, the increase in annual revenue for 100,000 hens from using ASPM would be a net return of $31,200 less capital and operational costs.

ASPM is an excellent environment for survival of excreted oocysts from birds with subclinical cases of coccidiosis and therefore it is inadvisable to use ASPM unless laying hens receive coccidoistats as a feed additive.

The use of poultry waste byproducts in developing countries is not a new idea, but very often it is restricted only to plant byproducts for animal feeding. While countries in the Orient have been recycling animal wastes for centuries, it is an unheard of practice in other areas. The use in developed countries is restricted due to health concerns. PM has been recycled in the United Kingdom, but it must be heat treated on approved premises and therefore has limited use (Hunton, 1979). An added advantage of recycling PM is that few if any feed additives or medicinals are used in poultry feeding in developing countries.

Due to the increased interest in utilization of every available resource for maximizing production, Koch (1979a) has developed a plan of feeding for better backyard cattle production in the Philippines. An example of utilizing PM in beef rations is shown in Table 14.

Table 14. Rations for beef/carabeef in the Philippines

Ingredient	Rations I		Rations II
Rice bran	20	%	37.5
Copra meal	20		——
Chicken manure[1]	10		37.5
Rice straw	—		25.0
Green grass or Corn stalks or Legume forage or Silage or Rice straw	*Ad lib* or Full feed		Handful of green grass
Salt	Free choice		Free choice
Mineral mix[2]	Free choice		Free choice

1 Freshly collected and air dried

2 Mineral mix = 60% calcium carbonate or ground oyster shell
20% dicalcium phosphate or bonemeal
20% trace mineralized salt or plain salt

Source: Koch (1979a).

Koch (1979b) described a ration for goats (which produce meat and milk) as 50% medium rice bran and 50% air-dried fresh PM plus salt and a mineral mix (the latter two ingredients being supplied at all times). The mineral mix is composed of 60% ground limestone or ground oyster shells, 20% strained bonemeal or dicalcium phosphate, and 20% salt.

These rations devised for ruminants are based on economic and nutrient utilization, palatability by the animal, and the ease with which such a scheme can be incorporated by local farmers for their livestock. It must be understood that the previously mentioned feeding practices utilizing PM with goats and beef are based on small scale, individual farm basis where the material is prepared and utilized on a day-to-day basis. In the case of the dry season when hot, dry weather is prevalent, rapid air-drying and more promising storage capabilities can be realized. No disease or deleterious effects have been observed or reported in such feeding programs (B. Koch, 1980, personal communication).

Baula et al. (1978) in a five months feeding study, tested a ration (A) of 75% rice bran and 25% rice straw and another ration (B) of 37.5% rice bran, 25% rice straw, and 37.5% PM as feed for yearling Murrah buffaloes. The PM was composed of 30% crude protein (dry matter basis) and 50% of that crude protein was from uric acid. The digestibility of the manure was approximately 80%. The results demonstrated that the Murrah buffaloes utilized uric acid for protein synthesis and had a significantly higher weight gain in ration A than those fed ration B. Buffaloes fed ration A gained .45 kg per day, those fed ration B gained .65 kg per day. While there was no difference in average roughage consumption, the amount of concentrates consumed was greater with those fed ration B, demonstrating a poorer feed efficiency.

According to Lavee (1980), PM has been used for 15 years as a feed for livestock in Israel, first as a protein supplement for beef cattle and later for dairy cattle and lambs. Manure is added at the rate of 10 to 15% of concentrate-fed mixture and results in a decreased price for feed. In 1977, there were two outbreaks of botulism in which 400 plus cows and calves died. Manure-blended feeds were suspect and their use suspended pending an investigation. The 1976 standards in Israel for use of PM stated that PM must be heat-dried at 130 C for 10 to 12 minutes, and that a plant for heat treatment was to be established. The investigation determined that during the summer to save energy, the manure was sun-dried instead of oven drying and was turned periodically. While it was treated with sulfuric acid, the acid acted on only one-half of the manure. Research proved that thermal treatment at 130 C and pelleting afterwards resulted in feed free of intoxication with Clostridium bolulinum toxin. Moore (1964) reported that in India cattle manure (dried) was added at 1 or 3 percent levels to poultry rations composed of maize, damaged wheat, rice polishings, wheat bran, groundnut oil cake, fish meal, and a mineral mixture. It is advisable to utilize PM on a day-to-day basis for the safest and most efficient utilization in the tropics.

POTENTIAL HAZARDS FROM WASTE-BLENDED RATIONS AND SOLUTIONS

As expressed by Anonymous (1977) the health problems concerning recycling of PM are the presence of viable microorganisms, drug and drug metabolites, toxic elements, pesticides, and end products of metabolism (some of which are toxic). Hunton (1979) listed the major concerns with recycling PM as bacterial or viral contamination and chemical and pesticide residues.

The nature and amount of drug residues and the results of processing of waste on drug residues and their metabolites are not generally known. The danger is that drugs are usually biotransformed by the first species into metabolites of less toxicological concern, but this is not always so. There is the possibility that bioaccumulation of parent drugs or metabolites or a combination may occur in the waste. However, limited research data is available to verify this assumption. Another implication is that there is some difference in metabolism and drug retention among species and therefore PM is of limited use and value if fed to an "unapproved" species (Anonymous, 1977). At this time the USDA monitoring program is not designed to monitor tissue residues from animals fed waste produced by other animals that may have transformed the drug into metabolites (Anonymous, 1977). A summary of potential hazards from feeding animal wastes is in Table 15.

Table 15. Potential hazards from feeding animal wastes

Pathogenic microorganisms	Antibiotics and drugs
Microbial toxins	Hormones
Mycotoxins	Coccidiostats
Parasites	Pesticides
Viruses	Heavy metals
Arsenicals	Trace elements

Source: McCaskey and Anthony (1979).

Heavy Metals

Anonymous (1977) noted that metals of natural origin in fish meal are mercury and arsenic and in plant products, cadmium, lead, and selenium. The resulting levels in animal feed are variable. However, it is certain that the heavy metals lead, inorganic mercury, and cadmium are poorly absorbed by animals. There is a potential for these metals to exist at higher levels in animal waste than in conventional feed ingredients. As a large proportion of the ingested feed is absorbed and the unabsorbed elements are concentrated in a relatively small amount of fecal matter, the recycling of wastes, especially over repeated cycles, could result in a significant increase in the levels of these elements in feed derived from animal waste, and could contribute therefore to an increased build up of residues of these elements in tissues and organs of animals fed recycled waste. It is also possible that an increase in the levels of residues of these elements in tissue may occur because of species difference or because of metabolism, digestion, heat, chemical, or waste treatments (Anonymous, 1977).

Heavy metals of concern, which are known to accumulate to some extent in muscle tissues and/or edible organs of animals once absorbed, are lead, cadmium, and mercury. Exposure of food animals to high levels has resulted in high residues in edible tissues (Anonymous, 1977). Arsenic and selenium are known to be depleted from edible tissues of animals following a withdrawal from exposure and are therefore less likely to cause toxicological problems. Muscle tissues are relatively poor accumulators of these five elements of concern, but higher than normal concentrations of these elements in milk and eggs, which represent significant portions of the human diet, are possible. Varghese and Flegal (1974) conducted a study which demonstrated that continuous recycling of waste for 33 cycles over a period of 400 days did not result in increased levels of mercury, copper, or zinc in tissues or manure of hens.

Doyle et al. (1974) fed lambs 15 to 60 ppm of cadmium in a ration with resulting decreased performance, but 5 ppm had no apparent effect. They suggested that waste-formulated rations with .61 ppm or less of cadmium would not result in accumulation in tissues of waste-fed cattle.

Fontenot et al. (1972) noted that the only documented evidence of harmful effects of feeding animal waste to animals is copper toxicity in sheep fed BL with high copper levels. The litter contained an average of 195 ppm copper. Sixty-four percent of the ewes fed a ration for 254 days that contained 50% BL died of copper toxicity and 55% of the ewes fed 25% BL died. Liver copper levels were higher in ewes fed 25 and 50% BL than ewes fed the control ration. Rations containing 0, 25, and 50% BL contained 17.8, 57.1, and 109.1 ppm copper, respectively.

Westing and Brandenberg (1974) and Webb and Fontenot (1975) found beef cattle more tolerant to high copper levels than sheep. They fed up to 259 ppm copper in BL in trials lasting 121 or 198 days with litter withdrawn 5 days prior to slaughter. Results showed that copper levels were higher in the liver than in the longissimus tissue, irrespective of the copper level in the litter of the ration. Fontenot and Webb (1975) also discovered that the copper problem was not likely as severe in cattle as it was for sheep. They fed beef cows 80% BL containing 200 ppm copper for two wintering periods without deleterious effects. There were moderate increases in liver copper levels but none high enough for copper toxicity and levels were reduced substantially following a summer grazing period. Felsman et al. (1973) stated that calves were fed up to 900 ppm copper for 98 days with no harmful effect on health or performance. Webb et al. (1978) also reported on the influence of copper residues in BL-fed cattle. Forty-two heifers were fed 50% ear corn and 50% BL. BL (wood shavings) was stacked in an open shed and fed with no processing. The average daily gain was better for litter-fed heifers in the winter but the cattle fed non-litter ration compensated for slower gains by growing faster in the summer. Liver samples by biopsy showed the high copper levels in spring followed feeding of BL rations in the winter. No levels were high enough to suspect a toxicity problem. By the end of the summer grazing period, liver copper levels declined markedly.

Bunn and Matrone (1966) noted that high levels of dietary cadmium have been shown to be antagonistic to copper and zinc metabolism in mice, rats, and chicks. A high level of dietary cadmium (.7 to 12.3 ppm) resulted in low levels of liver copper of sheep (Mills and Dalgarno, 1972).

Pathogenic Microorganisms

Zindel (1970) found that 40% of random samples of fresh layer manure contained *Bacillus*, *Proteus*, *Escherichia coli*, and other members of the *Enterobacteriaceae*; coliforms were present in 60% of the samples. Poultry wastes are not expected to be free of bacteria as normal ingredients of poultry diets have substantial levels. However, animal wastes to be fed should not contain pathogenic bacteria and toxigenic molds. Alexander *et al.* (1968) found out of 44 PM samples high populations of *Clostridium perfringens* and smaller populations of other *Clostridium* species. One sample of *Salmonella* was found, and all samples had *Staphylococcus* and *Streptococcus*.

Anonymous (1977) reported that fresh manure from caged layers rapidly undergoes "autosterilization" with respect to *Salmonella*. Fontenot and Webb (1975) reported a certain amount of "autosterilization" in BL. Kraft *et al.* (1969) tested fresh and old samples of manure and found 1 - 34,000 *Salmonella* per g (dry weight basis) in 8 of 12 fresh samples of manure and 1 - 148 *Salmonella* per g (dry weight basis) in 3 of 6 samples of old manure. Higher concentrations of *Salmonella* in caged layer manure than in fresh broiler waste suggests that cage housing may promote the shedding of *Salmonella*. In the ensiling process, where the pH range is 4 to 4.5 or lower and with a temperature of 25 to 35 C, Salmonella was destroyed after 7 days due to acid production by bacteria in ensiled manure-feed mixture. Smith (1974) stated that Salmonella and fecal coliforms are eliminated from manure by dehydration (80 C for 15 minutes), ensiling, pelleting, or pasteurization (71 C for 15 seconds). Heating at 68 C for 30 minutes destroyed Escherichea coli (E. coli) but Salmonella was more resistant according to Messer et al. (1971).

Creger et al. (1973) found that ensiled BL was negative for Salmonella, Staphylococcus, and coliforms. Caswell et al. (1974) found that ensiled BL with added water (moisture content 20 to 50%) eliminated coliforms and reduced total bacteria counts. Fontenot and Webb (1975) reported that deep stacking or ensiling should be helpful as the heat produced should free the ensiled material of pathogenic microorganisms.

Patrick (1967) mentioned that the ash content increases as litter ages because of the cellulose and protein structures which are lost through escape of carbon dioxide, water vapor, and free ammonia. The high ash content, which may be greater than 50%, perhaps "salts-out" many microorganisms.

Messer et al. (1971) recommended pasteurizing BL 15 minutes at a thickness of .63 cm, 30 minutes at 1.26 cm by dry heat at 150 C. E. coli and Salmonella typhimurium can be destroyed if heated at 68.3 C for 30 minutes and Salmonella pullorum at 62.8 C for 30 minutes. Anonymous (1977) stated that processing at 65 C for 15 to 30 minutes eliminates most known pathogenic microorganisms of concern.

Smith (1974) reported cattle fed DPW were intradermally tested for tuberculosis by a caudal method after 241 days on DPW with all tests negative.

Messer et al. (1971) summarized that heat, paraformaldehyde, autoclaving, ethylene oxide, and methyl bromide are all some methods which will destroy pathogenic microorganisms.

Fungi, Molds, and Yeasts

According to McCaskey and Anthony (1979), fungi can cause infection, allergic response, and mycotoxins. Fungal densities in feeds varied from 7×10^2 to 3.2×10^5 per g sampled from a single source. Knight et al. (1977) found that the addition of animal manure to a ration of ground corn containing 10^6 per g yeasts and molds enhanced the potential for possible toxigenic fungi. Therefore it is necessary for good management in processing and storing feeds to minimize risk to human and animal health. Halbrook et al. (1951) studied wood shavings, bark, and corncob base litter prior to use in poultry houses and after various periods of use. The results were that all classes of bacteria, molds, and yeasts increased in time during the first 8 weeks of use by broilers. Patrick (1967) reported that storage of droppings at 30 to 37 C caused levels of yeast to drop to zero and a marked drop in the level of molds. Lovett (1972) stated that the toxigenic fungi of concern in poultry litter and feeds are *Aspergillus*, *Penicillium*, and *Fusarium*. Aflatoxin (potential mold metabolite of *Aspergillus flavus*) is found in feeds. He also reported that of 103 mold isolates from commercial feed and poultry litter, 13 were toxic for embryonated chick eggs. Fifty percent of the genus *Aspergillus* isolates were toxic.

Hendrickson and Grant (1971) reported less aflatoxin in stockpiled, partially decayed feedlot manure than in fresh manure. Patrick (1967) stated that the pH of litter usually increases with age due to calcium and ammonium salts. The yeasts and mold population decreases as the pH of litter increases. Westing and Brandenberg (1974) reported that composted beef waste had no aflatoxin residues. Howes and Rollo (1967) reported that *Aspergillus* is found in hardwood shavings, but any fresh litter may be a source of some infection. Disease can be transported in fresh litter.

Parasites

Ciordia and Anthony (1969) observed the survival of nematodes in an ensiled mixture of 57 parts coastal bermudagrass hay and 43 parts manure (wastelage). All samples were negative for larvae, although eggs were present in the feces. No larvae were present in silage after 4 weeks of ensiling. Therefore there is a disinfection process of silage by the development of acid during the ensiling process or by addition of acid to forage. Pavlov et al. (1958) as cited in McCaskey and Anthony (1979) stated that non-embryonated ascarid eggs were viable for 6 months in silage and developed into an embryonated, infective stage when placed in a favorable environment. However, embryonated ascarid eggs did not appear viable after 3 months and were noninfective for white mice after 5 months.

Tarczynski and Szepelski (1970) as cited by McCaskey and Anthony (1979) reported that there is a 60% loss of infectivity of Fasciola hepatica (after 23 days) by ventilator drying of meadow grass. The loss of infectivity and viability from ensiling is due to a rapid drop in pH caused by lactic acid production and change in microbial flora.

Gohl (1975) noted that the risk of disease and parasites is less after ensiling for 4 weeks. Manure was completely free of nematode eggs after 4 weeks of ensiling. Heating and cooking have the same effect.

Liebmann (1953) as cited in McCaskey and Anthony (1979) attributed the failure of the establishment of parasite infection in suckling animals to the presence of lactobacilli bacteria in the alimentary tract.

Viruses

McCaskey and Anthony (1979) reported that while the source is not known, it is suspected that foods consumed raw or partially cooked are sources of viruses. Viruses, unlike most bacteria, are more infectious and require a living host for propagation. In foods they can persist for days or months.

The role of rations containing waste in the dissemination of the foot and mouth disease (FMD) virus, for example, and other viruses infective to man and animal is not known, but Cunliffe and Blackwell (1977) noted that viruses survive the acidic condition of casein production even after pasteurization at 72 C for 15 seconds. Blackwell (1976) observed that the FMD virus survived the acidic content of cheese making, but not the cheese curing process. Larkin (1973) inoculated aerated swine manure with swine enterovirus and rapidly inactivated the virus.

As some viruses are found in human food and in manure of food animals, waste recycling research should include a study of their health significance to humans and animals.

Chemical Residues

Calvert (1973) and Anonymous (1971) reported possible problems with more than 20 feed additives currently used in animal production. The feed additives commonly used with broilers and layers are shown in the Appendix Table 1A.

McCaskey and Anthony (1979) noted that the most concern in the recycling of animal wastes is residues from additives. Arsenic-containing compounds are permitted in poultry feed at the following levels: arsanilic acid (4-aminophenylarsonic acid) 50 to 100 ppm, 3-nitro-4-hydroxyphenylarsonic acid 25 to 50 ppm, and 4-nitrophenylarsonic acid 187.5 ppm. Tolerance levels of arsenic residues in market poultry established by the FDA are 2 ppm for liver and .5 ppm for edible meat. According to the FDA, there is no problem of arsenic residues in the tissues of ruminants fed rations containing PM at current levels of arsenic permitted in poultry feed.

Morrison (1969) observed measureable amounts of arsenic (15 to 30 ppm) in BL from birds fed organoarsenicals. Fertilizing the soil with this litter resulted in no increase in arsenic in the soil or alfalfa and clover grown in this soil over a 20 year period. Arsenic in birds raised on this type of litter did not increase. Moody and Williams (1964a) stated that arsanilic acid appears to be excreted unchanged following oral administration to hens, but limited levels of other organic arsenicals are converted to other organic forms in the digestive tract.

Smith et al. (1973) as cited by Fontenot and Webb (1975) observed that arsenic accumulation in tissues of ruminants fed different levels of arsanilic acid was proportional to the amount of arsanilic acid ingested. Arsenic was increased in the blood, liver, kidney, and muscle tissues, while withdrawal of arsenicals prior to slaughter resulted in rapid depletion of liver arsenic and in other tissues as well. Fontenot and Webb (1974) also reported that arsenic was consistently high in liver tissue of cattle fed BL, but levels were lower than normally accepted safe levels. Brugman et al. (1968) observed that there were no residues detected in the heart, spleen, 12th rib, kidney fat, liver, or brain of lambs fed BL with amprolium and an arsenical.

Caged layer manure is low in levels of arsanilic acid with negligible amounts of Zoalene[R], Unistat-3[R], Nicarb "25%"[R], furans, and sulfaquinoxaline (Brugman et al., 1964).

Caswell et al. (1977) observed that there was no marked effect on the level of arsenic or amprolium in a ration consisting of 2 parts ground corn and 1 part BL ensiled for 80 days. Ensiling reduced sulfaquinoxaline and erased Zinc bacitracin.

Antibiotics and Drug Residues

Certain antibiotics are absorbed by animals, however, absorption is not complete for any antibiotic and at least a portion of the amount ingested is

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[R] Zoalene (3,5-dinitro-o-toluamide) available from Salsbury Laboratories, Charles City, Iowa, 50616.

[R] Unistat-3 (3,5-dinitrobenzamide) available from Salsbury Laboratories, Charles City, Iowa, 50616.

[R] Nicarb "25%" (4,4-dinitrocarbanilide. 2-hydroxy-4, 6-dimethylpyrimidine) available from Merck & Co., Inc., Agvet Division, Rahway, N.J., 07065.

excreted (Fontenot and Webb, 1975). Filson et al. (1965) reported that younger birds possess greater ability to absorb chlortetracycline than older birds and birds in production have greater ability to absorb chlortetracycline than those that are not in production. Bacitracin and penicillin were detected in the contents of the cecum and small intestine of chicks fed these additives (Bare et al., 1965), but the concentration generally declined with time from 1 to 4 weeks. No penicillin was detected at a 4 week sampling. Elmund et al. (1971) reported that bioassays of fresh feedlot manure show approximately 75% of dietary chlortetracycline was excreted but there was a high variability in drug residue in BL. This depends on the level fed and how metabolized.

Fontenot and Webb (1975) analyzed muscle, kidney fat, and liver tissues from steers fed rations containing 0, 25, and 50% BL for 121 days and 198 days and with a 5 day withdrawal for amprolium, nicarbazine, and chlortetracycline. None of these drugs were consistently high in the tissues. It is not surprising that tissue levels of medicinal drugs are not usually substantially high as Bruggeman (1963) reported residues of amprolium, arzene, and arsanilic acid remained at constantly low levels over a period of time, in spite of a steady increase in dietary intake of these drugs.

Webb and Fontenot (1975) analyzed BL collected from different broiler houses in Virginia for drug residues. They reported finding the antibiotics penicillin, oxytetracycline, chlortetracycline, neomycin, and Zinc bacitracin. They conducted a feeding study using 25 and 50% BL in rations for steers with a 5 day withdrawal prior to slaughter. An analysis of tissues for antibiotic residues resulted in no problem with tissue residues. It is apparent that residues of antibiotics, coccidiostats, arsenicals, and metals appearing in BL (as a result of being fed to broilers) do not build up in cattle tissues as sampled from the liver, kidney fat, and longissimus muscle.

Elmund et al. (1971) reported no serious problem with antibiotic residues resulting from the use of bovine waste in rations. Amounts were even less after aging of manure. Smith (1974) stated that if drugs are used with caged layers to control health problems, the manure should not be used for refeeding unless information establishing its safety is available. Couch (1974) reported that there is little if any drug residues in DPW from caged layers.

Pesticides

Now that the use of chlorinated hydrocarbon pesticides for agriculture is greatly curbed, lower levels in food, feed, and animal waste should be expected (McCaskey and Anthony, 1979). Messer et al. (1971) analyzed poultry feed and litter from five commercial farms for DDT and DDE residues. Detectable residues were found in only two of the litter samples (.02 and .01 ppm) and in one feed sample (.01 ppm), and therefore did not exceed tolerances. Fontenot et al. (1971) found that feeding of BL containing negligible levels (average .095 ppm) of DDT and its metabolites did not result in the accumulation of residues in liver or omental fat of steers fed 25 or 50% BL in their rations. There were no increases in polychlorinated biphenyl (PCB), DDE, or their metabolites in the tissues of fattening cattle fed 15% peanut hulls or corncobs for 109 days. Peanut hull diets had .116 and .008 ppm of PCB and DDE, and the corncob diets had .36 and .003 ppm, respectively.

Smith et al. (1976) reported that feeding PM at 32% level in a dairy cow ration for 50 days resulted in illegal levels of PCB in milk fat as the manure came from poultry fed 20 ppm PCB in the diet (100 times the level permitted by FDA of .2 ppm for complete animal feed). The highest level reported in milk fat was less than 5 ppm, only two times the FDA guideline of 2.5 ppm. Therefore, this should be no problem provided that PCB level in DPW is .4 ppm or less (McCaskey and Anthony, 1979).

El-Sabban et al. (1970) fed rations consisting of 25 to 28% DPW (from caged layers, autoclaved or dried) to fattening cattle and reported no pesticide accumulation in back fat or liver of the steers.

Residues of RABON[R], used as an orally administered insecticide to control ectoparasites and fly larvae in manure and at present doses, is apparently non-hazardous to farm animals (Ivey et al., 1968). Miller and Gordon (1973) fed RABON[R] at levels up to 252 ppm and did not find evidence of accumulation in milk of dairy cows. They noted no effect on the general health and reproductive performance of the cows.

Hormones

Estrogenic hormones are present in PM and urine of cycling cows (McCaskey and Anthony, 1979). Westing and Brandenberg (1974) noted that the levels of estrogenic hormones are so low as not to be detected in a manure formulated ration. Griel et al. (1969) noted one incident of abortion attributed to estrogens in cattle fed BL. The BL was from poultry fed rations with 150 to 250 ppm of diensterol diacetate. This hormone is currently not permitted in poultry rations. Gohl (1975) observed that fresh cow manure could be included in rations for growing birds to produce much faster growth (B complex vitamins and some essential amino acids), but it cannot be used for layers as there is hormone activity in the manure.

Webb and Fontenot (1975) reported that cattle fed 10 mg of diethylstilbesterol (DES) per head per day excreted uniform amounts of estrogen over a 168 day period, e.g. 68% was found daily in combined fecal and urinary excretions. Lambs fed 1 and 2 mg of DES per day excreted 76 and 84% of the DES, respectively.

Conclusions Regarding Health Hazards of Feeding Animal Wastes

Fontenot and Webb (1975) reported that there is no evidence that recycling of animal wastes presents hazards to human health. Feeding the wastes has not altered the taste of meat, milk, and eggs. The only documented evidence of harmful effect on animal health from feeding animal wastes has been copper

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[R] RABON (2-chloro (2,4,5 - trichlorophenyl) vinyl dimethyl phosphate) available from Shell Chemical Co., Agricultural Division, San Ramon, Calif., 94304.

toxicity in sheep fed broiler litter with high copper levels. There seems to be no problem as there is evidence that high level usage of copper in animal diets will be discontinued and the copper problem is not serious in other food producing animals since they are not as sensitive to high dietary copper.

Pathogenic bacteria in animal wastes can be destroyed by treating litter with heat or chemicals. Deep stacking or ensiling the wastes may inactivate or destroy the pathogens. Mold should not be a serious problem if waste is properly handled and stored. Pesticide residues in wastes or edible products from animals fed waste does not appear to be a serious threat. There is no evidence reported of a serious health problem from medicinal drug residues, although there are residues in wastes from animals fed the drugs. A build-up of such residues is suspect concerning the effect of build-up in human tissues and/or a resistance to these drugs.

More information is needed concerning the effects of high levels of drugs on animals and particularly withdrawal times. Information is too limited to draw a definite conclusion, but there is no evidence of a problem with heavy metals causing contamination in wastes either.

GOVERNMENT REGULATIONS CONCERNING USE OF POULTRY MANURE AS A FEEDSTUFF

Animal byproducts currently listed in the official publication of American Feed Control Officials (Anonymous, 1980) as feed ingredients are meat meal tankage, blood meal, poultry byproduct meal, hydrolyzed poultry feathers, and dehydrated paunch product.

The use of PM as an animal feed is not sanctioned by the FDA as there is concern with potential drug residues and disease organisms in such material and variation of quality (Hunton, 1979). Anonymous (1977) reported that the policy statement on use of animal manure as a feedstuff states that "in addition to contributing to the nation's protein supply, recycling of animal waste may reduce water and air pollution which originates in livestock and poultry facilities. On the other hand, since animal waste could contain disease-producing organisms and parasites, residues of drugs and metabolites, and toxic elements and other contaminants of natural and industrial origin, the feeding of animal waste could present hazards to animal and human health unless such contaminants (if present at unsafe levels) are eliminated or reduced to acceptable levels." The threat of adverse public reactions and legal regulations are additional factors preventing more widespread acceptance of recycling manures.

In a policy statement, 21 CFR 500.40, published in the Federal Register of September 3, 1967 (32 FR 12714) as cited by Anonymous (1977), the FDA announced it did not sanction the feeding of poultry litter to animals and has since extended the scope of the statement to include wastes from other species. One concern is feeding manure to dairy cows in production compared to feeding waste to meat animals where there are withdrawal periods prior to slaughter. Although data is not available, it is known that the extent of feeding of animal waste has increased in recent years as methods of processing, e.g. drying, ensiling, etc. have been further researched. The FDA realizes that recycling manure as a feed ingredient is an alternative to land disposal problems. Anonymous (1977) noted that water pollution is an increasing problem as 20% of livestock and PM runoff into streams or leach into drainage tiles or subsurface water. Nitrogen in the form of ammonia may be converted to mobile nitrate form by microorganisms and is a potential hazard. There is no documented evidence of health impairment to man or animal when litter is properly used. Anthony (1967b) noted that poultry litter containing feeds could be of greatest economic value for wintering brood cows with no health impairment as long range research has been conducted in this area. Fontenot and Webb (1974) stated that there was no disease problem reported from including poultry waste in practical rations for beef cattle nor from including cattle manure.

The amounts of poultry waste that can be fed limit the use of animal waste that can be incorporated into diets without the loss of efficiency. Fontenot et al. (1971) limited the amount of BL for steers to 25% of the ration as higher amounts caused poor performance and decreased feed intake. The type of mix or preparation of the ration concentrate plus manure will affect palatability and production results. The Federal Food, Drug and Comestic Act (21 U.S.C. 301 et seq), Section 402, as cited by Anonymous (1977) states that "a food shall be adulterated if, among other things, it bears or contains any poisonous or deleterious substances; or if it is, or it bears or contains, any food additive which is unsafe...".

While the FDA hedges on approval of regulations for recycling animal wastes through feeding, several states took the initiative and enacted their own regulations. The FDA allows feeding of poultry wastes, but doesn't officially approve it and in the future it can be predicted that rather than a blanket approval, there will be more of an approval such as use of DPW fed legally to overwintering ruminants.

California and Mississippi were the first states to publish regulations, followed by Colorado, Iowa, Oregon, and Georgia. Timmons (1976) suggested that if state regulations checkered the United States, the FDA would then publish regulations for interstate commerce of animal waste. According to him, California was first to establish regulations and bear example to other states to establish a point of control in the chemical analysis of the finished product at slaughter. DPW from cage layers must be uniform and contain not less than 25% crude protein, not more than 15% crude fiber, not more than 30% feathers and not more than 15% water, 12% being preferred. Colorado regulations followed with a minimum of 18% crude protein, not more than 40% crude fiber and amount of water limited to 12% for all processed animal wastes. A safe, uniform and consistent production of PM which can be controlled results from drying plants located where birds are raised, known rations, analyzed with no residues, and therefore no hazard to humans from consumption of the meat.

Presently PM is sold only within the state producing it. If the FDA published one regulation approving DPW, then perhaps more people would feel better about using it. Commercial feeders hesitate to get involved without the blessing of the FDA. Anonymous (1977) stated that the FDA essentially faces three alternatives for regulation of animal waste intended for use as an animal feed: 1) regulate only such waste which is shipped in interstate commerce; 2) regulate such waste which is shipped in interstate commerce as well as that sold commercially in intrastate commerce; or 3) regulate all such waste, whether or not it is sold commercially interstate or intrastate.

According to Anonymous (1977), the AAFCO has the following definition for dried poultry waste: "Dried Poultry Waste (D.P.W.) is a product composed of freshly collected feces from commercial laying or broiler flocks not receiving medicaments...It shall be thermally dehydrated to a moisture content of not more than 15 percent. It shall not contain any substances at harmful levels. It shall be free of extraneous materials such as wire, glass, nails, etc. The product shall be labeled to show the minimum percent protein, minimum percent fat and percent fiber...It may be used as an ingredient in sheep, lamb, beef and dairy cattle, broiler and layer chicken feeds. Broiler and laying rations shall be limited to 20 percent and 25 percent D.P.W. respectively." Since the moisture content is limited to 15 percent, the practical effect of the definition is to require the drying of the wastes by some processing method. State allowance of animal waste products as a feed ingredient are under model state feed bills (Hunton, 1979). States with specific requirements for usage of DPW are California, Colorado, Minnesota, Washington, Alabama, and Virginia. Georgia, Florida, Oregon, and Iowa have started registering DPW as a feed ingredient according to standards listed by Anonymous (1977). This same source mentioned that those states with specific requirements for usage of DPW have recognized two categories of animal wastes: 1) those that are collected from animals that have been fed drugs, or that contain drug residues as identified by testing, and 2) products that are free of drug residues in that the wastes are collected from livestock and poultry that have not been fed or are free of drugs. Anonymous (1977) noted concerning the first category that there is a 15 day withdrawal period (before slaughter) in the states of Virginia, Mississippi, Washington, and Alabama. Colorado requires a 30 day withdrawal period and California requires no withdrawal period, but specifies that the waste shall not contain levels of drugs that could result in unlawful tissue residues or be harmful to animals consuming the product. California and Oregon do not provide for the waste to be fed to lactating animals while Virginia, Georgia, Mississippi, Washington, Alabama, and Colorado allow animal waste not containing drugs to be fed to laying hens and dairy cattle in production. Mississippi approves DPW from caged layers only if no drugs are fed to the group.

In the foreseeable future limited amounts of animals waste can be transported interstate. It will be limited mainly to caged layer waste from birds not normally fed drugs continuously, because it is less bulky than BL waste. Because of the local nature of animal waste recycling on an intrafarm basis, intrastate movement will be accomplished on a direct farmer - to - farmer basis rather than commercial marketing. Caged layer waste is considered to be of suitable protein and mineral content for ruminants and has a potential in interstate trade channels. As floor-raised poultry have a coccidiostat added to their diet, their litter can be expected to contain one or more drugs and unless stacked or ensiled be considered unsuitable for large commercial and interstate usage. It should be noted that while poultry litter is considered the least desirable, birds on floor-rearing consume a certain amount of PM anyway.

In conclusion, before any final regulations from the FDA can be forthcoming, further research in the utilization of PM must be conducted. Fontenot and Webb (1975) suggested the following research is needed to facilitate such regulations or approval: extensive data is needed concerning drugs and minerals in different kinds of animal wastes from various locations allowing for a more accurate assessment of potential concerns; effect of feeding high levels of drugs and minerals on animal health and tissue levels; withdrawal times for animals fed high levels of drugs and minerals; survey made of mycotoxin problem, and if serious, means to alleviate it; effect of processing on potential toxic substances in wastes; and seriousness of aesthetic aspects of feeding animals wastes to be determined by well-controlled sociological research.

As reported by Anonymous (1977), the Commissioner of the FDA anticipates six choices regarding modifications of the agency's present regulatory position: 1) No change in agency policy is indicated; 2) No change in agency policy is indicated for the time being, but request that additional research be conducted; 3) Propose a regulatory control program that prescribes certain characteristics for waste intended for feeding to livestock, e.g. maximum allowable levels of potentially harmful substances. Processing and/or withdrawal periods could be other forms of control; 4) Propose a regulatory control program as described with processing and withdrawal specifications, and in addition could propose research be conducted as a basis for subsequent adjustments in the regulatory program; 5) Propose to ban the feeding of waste, on the basis that currently available data fail to show that the material is safe even under practicable control programs, providing opportunity for the industry to submit evidence that the use of the material is safe; or 6) Propose to affirm processed animal waste as Generally Regarded As Safe (GRAS) under certain conditions - e.g. where no drugs have been fed to the donor species, or propose to declare such waste to be a food additive which could be fed under provision of one or more food additive regulations.

At the present time the responsibility for obtaining the data will fall principally on the proponents of recycling of animal waste.

CONCLUSION

PM is a feed resource that is presently not used to its nutritional and economic potential. Problems of handling, processing, energy cost, up-to-date research as to the best utilization for livestock are needed to make recycling a desirable feature for the producer. Adequate data to substantiate less concern for residue presence in animal muscle and tissue are needed before an official FDA approval can be forthcoming, stimulating confidence in utilization among producers and processors.

While DPW may contribute significant amounts of amino acids and phosphorus and varied amounts of calcium and trace minerals to feeds, it is deficient in ME and if used for poultry feeding must be compensated by addition of fat. ASPM, presently being researched, may be one of the best methods of recycling PM for layers. BL is best utilized as an ensiled product as drug residues, heavy metals, and parasites can be better controlled by the ensiling process. Use of PM seems to be best utilized by ruminants, especially beef brood cows, and with proper feed combinations, it is desirable for fattening cattle. Feeding systems based on corn-silage grain offer great opportunity and vast potential for more effective use of manure resources for increasing efficiency of animal production. High forage diets supplemented with PM could reduce feed costs and increase efficiency of animal production. Maintaining breeding stock on diets of crop residues supplemented with PM offers an opportunity for decreasing animal production costs. As PM cannot be merely substituted in a ration, but must be balanced in a feed, it is necessary to know its composition, as well as the value of all ingredients to ensure the presence of necessary nutrients for a particular species.

Responsible management on the part of poultrymen, processors, and utilizers of PM can best ensure its safety and ensure its nutritional and economic advantages for the future. In the meantime, additional research is required on every level of production and feeding to different farm animal species to reinforce the utilization of this abundant byproduct.

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A P P E N D I X

Appendix Table 1A. Feed additives commonly used with broilers and layers

Feed Additives: Nutritional Uses

Additive	Uses	Pre-Slaughter Withdrawal Time*
Arsanilic Acid or Sodium Arsanilate	Bloom and feathering	5 days
	Egg production	5 days
	Feed efficiency	5 days
	Pigmentation	5 days
	Rate of gain	5 days
Bacitracin	Egg hatchability	None
	Egg production	None
	Feed efficiency	None
	Growth promotion	None
	Maintaining appetite	None
Bacitracin Methylene Disalicylate	Egg hatchability	None
	Egg production	None
	Feed efficiency	None
	Growth promotion	None
	Rate of gain	None
Bacitracin, Zinc	Egg hatchability	None
	Egg production	None
	Feed efficiency	None
	Maintaining appetite	None
	Rate of gain	None
	Stomachic appetizer	None
Bambermycins	Feed efficiency	None
	Weight gain	None
Chlortetracycline	Egg hatchability	None
	Egg production	None
	Feed efficiency	None
	Rate of gain	None
Erthromycin	Egg production	None
	Feed efficiency	None
	Growth promotion	None
Furazolidone	Feed efficiency	5 days
	Growth promotion	5 days
Lincomycin	Feed efficiency	None
	Growth promotion	None
	Weight gain	None
Nux Vomica Extract	Stomachic appetizer	None
Oleandomycin	Feed efficiency	None
	Rate of gain	None
Oxytetracycline	Egg hatchability	None[1/]
	Egg production	None[1/]
	Eggshell quality	None[1/]
	Feed efficiency	None[1/]
	Improve fertility	None[1/]

Feed Additives: Nutritional Uses (Continued)		
Additive	Uses	Pre-Slaughter Withdrawal Time*
Penicillin	Feed efficiency	None
	Rate of gain	None
Roxarsone	Egg production	5 days
	Feed efficiency	5 days
	Growth promotion	5 days
	Pigmentation	5 days
Tylosin	Feed efficiency	None
	Weight gain	None

Feed Additives: Medicinal Uses	
Disease/Additive	Pre-Slaughter Withdrawal Time*
Bacterial Enteritis	
Neomycin	
(layers)	14 days
(broilers)	5 days
Blackhead	
Furazolidone	5 days
Nihydrazone	4 days
Nitarsone	5 days
Bluecomb (Non-Specific Enteritis)	
Bacitracin	None
Bacitracin Methylene Disalicylate	None
Bacitracin, Zinc	None
Chlortetracycline	None
Furazolidone	5 days
Neomycin	14 days
Oxytetracycline	None or 3 days1/
Penicillin	None
Breast Blisters	
Novobiocin	4 days
Cholera, Fowl	
Novobiocin	4 days
Oxytetracycline	3 days1/
Sulfaquinoxaline	10 days
Chronic Respiratory Disease (CRD)	
Bacitracin	None
Bacitracin Methylene Disalicylate	None
Bacitracin, Zinc	None
Chlortetracycline	None

Feed Additives: Medicinal Uses (Continued) Disease/Additive	Pre-Slaughter Withdrawal Time*
Chronic Respiratory Disease (CRD) Continued	
Erythromycin	24-48 hours[2/]
Furazolidone	5 days
Nihydrazone	4 days
Oxytetracycline	None or 3 days[1/]
Penicillin	None
Tylosin	5 days
Coccidiosis	
Arsanilic Acid or Sodium Arsanilate	5 days
Aklomide	None
Amprolium	None
Buquinolate	None
Clopidol	5 days[3/]
Decoquinate	None
Furazolidone	5 days
Monensin Sodium	72 hours
Nicarbazin ,	4 days
Nihydrazone	4 days
Nitrofurazone	5 days
Nitromide and Sulfanitran	5 days
Robenidine Hydrochloride	5 days
Sulfadimethoxine and Ormotoprim	2 days
Sulfaquinoxaline	10 days
Zoalene	None
Coryza, Infectious	
Erthromycin	24 hours
Sulfadimethoxine and Ormetoprim	2 days
Hepatitis, Infectious	
Furazolidone	5 days
Oxytetracycline	3 days[1/]
Mucus	
Ethylenediamine Dihydriodide	None
Mycosis, Crop	
Gentian Violet	None
Nystatin	None
Mycotic Diarrhea	
Nystatin	None
Paracolon	
Furazolidone	5 days

Feed Additives: Medicinal Uses (Continued) Disease/Additive	Pre-Slaughter Withdrawal Time*
Paratyphoid	
Furazolidone	5 days
Nihydrazone	4 days
Pullorum	
Furazolidone	5 days
Nihydrazone	4 days
Quail Disease	
Furazolidone	5 days
Stress	
Bacitracin	None
Bacitracin Methylene Disalicylate	None
Bacitracin, Zinc	None
Chlortetracycline	None
Erthromycin	24 hours
Furazolidone	5 days
Oxytetracycline	None1/
Synovitis	
Chlortetracycline	None
Furazolidone	5 days
Novobiocin	4 days
Oxytetracycline	3 days1/
Typhoid, Fowl	
Furazolidone	5 days
Nihydrazone	4 days
Sulfaquinoxaline	10 days
Worms	
Capillary Worms	
Coumaphos	None
Hygromycin B	48 hours
Cecal Worms (Heterakis)	
Butynorate, Piperazine and Phenothiazine	7 days
Coumaphos	None
Hygromycin B	48 hours
Phenothiazine	None
Piperazine and Phenothiazine	None
Large Roundworms (Ascaris)	
Butynorate, Piperazine and Phenothiazine	7 days
Hygromycin B	48 hours
Piperazine	None
Piperazine and Phenothiazine	None

Feed Additives: Medicinal Uses (Continued) Disease/Additive	Pre-Slaughter Withdrawal Time*
Tapeworms	
Butynorate, Piperazine and Phenothiazine	7 days

* Times specified are for drugs used alone, except for the few combinations listed for treatment of worms. Where a drug is used in combination with another drug, a longer withdrawal time may be indicated.

1/ At the 200 g/ton use level, withdraw oxytetracycline from feed three days before slaughter. No withdrawal is necessary at lower use levels.

2/ When erythromycin is used at the rate of 92.5 g per ton as an aid in the prevention of CRD, the withdrawal time before slaughter is 24 hours. When erthromycin is used at the rate of 185 g per ton as an aid in lowering the severity of CRD, the withdrawal time prior to slaughter is 48 hours.

3/ Withdraw five days before slaughter if clopidol is being given at a level of 0.0250%, or reduce the level to 0.0125% five days before slaughter.

Source: Mimeograph copy received July 14, 1980, personal communication from David Ducharme, DVM, Director, Division of Drugs for Avian Species, Scientific Evaluation, FDA, Rockville, Maryland.

POULTRY MANURE AS A FEED INGREDIENT FOR LIVESTOCK: RUMINANTS AND NON-RUMINANTS

by

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B.S., Kansas State University, 1969

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Abstract

The one billion metric tons of animal manure produced in the United States in cattle feedlots, layer and broiler confinement housing systems per year presents a waste disposal problem. However, much of this is recoverable for recycling as a feed ingredient for livestock. Composition of poultry manure (PM) varies with the wide variety of nutrients supplied to the birds in the ration, age and type of birds, housing conditions, treatment and storage methods, and the ultimate consumption by the animals whose feed it may be a part.

Dehydrated poultry manure (DPM) contributes significant amounts of essential amino acids and protein in formulated feeds, but because of its low energy levels and resulting poor feed efficiency, should not be added above 20 - 25% levels in poultry feeds. Poultry meat and eggs produced from DPM fed birds do not differ in quantity or quality from eggs and meat produced by hens fed regular feed.

Feeding DPM to swine at 5 and 10% levels is successful, but feed conversion is affected above the 10% level. Ruminants utilize the non-protein nitrogen content of PM. Corn silage and grain diets are low in protein and minerals, therefore PM can be used in a mixture for ruminants, particularly as a silage feed. Direct feeding of broiler litter to cattle is possible. A mixture of 70:30 litter/grain for wintering cows and 30:70 litter/grain mixture for finishing steers is advised. Ensiling PM for beef cattle in a mixture of corn silage + corn grain + poultry litter provides an economical use of poultry litter and a nearly complete feed for ruminants. At this time, recycling PM through dairy cattle is not advised due to possible chemical and medicinal residues which may appear in the milk. Sheep prefer recycled PM blended rations in pelleted form, however, they are most sensitive to the amount of copper in PM.

The only documented case of a harmful effect of feeding PM to livestock

is copper toxicity in sheep. Beef cattle are more tolerant to high copper levels than sheep.

Aerobically stabilized poultry manure (ASPM) fed to laying hens results in increased egg production with no difference in body weight, mortality, egg or eggshell quality.

The Food and Drug Administration does not sanction the recycling of PM due to the potential residues of heavy metals, pathogenic microorganisms, parasites, chemicals, antibiotics, drugs, pesticides and hormones. Individual states have formulated standards and control regulations for the use of DPM. Individual producers have ensiled poultry waste with no documented cases of harmful effects.