A COMPARISON OF DRIED POULTRY WASTE, COTTONSEED MEAL AND UREA AS NITROGEN SUPPLEMENTS FOR SHEEP FED LOW QUALITY ROUGHAGE

by

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ABSTRACT

Three growing lambs were used in a 3x3 Latin square to determine utilization of nitrogen (N) from diets containing wheat straw supplemented with dried poultry waste (DPW), cottonseed meal (CSM) or urea. The supplements provided approximately 85% of the total dietary N and DPW, CSM and urea supplied 80%, 80% and 60% of the N in their respective supplements. Total dry matter intake averaged approximately 67 $g/W_{kg}^{.75}$.

Nitrogen intake was approximately 25.5 g/day for all diets. Apparent digestibility of N in the urea supplemented diet was higher ($P < .05$) 74%, compared with 68% for DPW and 67% for the CSM diets. Daily urinary N excretion was highest ($P < .05$) on the urea diet (16 g) followed by the DPW (14 g) and CSM diets (11 g). Approximately 35% of the N absorbed in the CSM diet was retained compared with 16% for the DPW and urea diets ($P < .05$).

Following completion of the Latin square, the lambs were fed only straw for 70 days. Daily *ad libitum* dry matter intake during this phase was approximately 52 $g/W_{kg}^{.75}$. The lambs were in negative nitrogen balance throughout this unsupplemented period, although the degree of negativity tended to decrease with each collection period. Estimates of metabolic fecal nitrogen (.61 g/100 g dry

matter intake) and endogenous urinary N excretion ($.15\ g/W_{kg}^{.75}$) were within ranges reported by other workers.

INTRODUCTION

It has been estimated that 3.4 million tons of raw manures were produced daily in the United States in 1971. On a yearly basis, this quantity of manure would contain 11.6 million tons of nitrogen, 3 million tons of phosphate and 3.2 million tons of potassium (Taiganides and Stroshine 1971). These nutrients, particularly nitrogen and phosphorus, are among those which are routinely supplemented to livestock diets.

Poultry waste has been studied extensively in recent years as a source of supplemental nitrogen in ruminant diets. In general, the nitrogen has been found to be effectively utilized in diets containing moderate to high energy levels (Noland, Ford and Ray 1955; Brugman et al. 1964; Bhattacharya and Fontenot 1966; El-Sabban et al. 1970; Tinnimit et al. 1972; Smith and Calvert 1972; Cullison et al. 1976) but when direct comparisons have been made it has not always been as effective as oilseed meal protein, particularly for supporting weight gains (Rodriguez and Zorita 1967; Bucholtz et al. 1971; Thomas et al. 1972).

Few studies have examined the value of poultry waste in low energy diets, particularly those containing high levels of low quality roughage. These diets when unsupplemented usually contain insufficient nitrogen to support satisfactory animal performance. Natural proteins are effective supplements but have the disadvantage of being relatively expensive. Lower cost (per unit of N) nonprotein nitrogen sources such as urea, while producing a positive response, are usually less effective in promoting weight gains than an equivalent amount of nitrogen oil seed protein (Briggs et al. 1947; Raleigh and Wallace 1963; Williams, Whiteman and Tillman 1969).

Poultry waste has several characteristics which suggest it would be a suitable supplement to low quality roughages in ruminant diets. It contains approximately 30% crude protein, of which approximately 40% is true protein and 60% is nonprotein nitrogen, primarily uric acid nitrogen (Bhattacharya and Taylor 1975; Eno 1962; Morgan 1970). Uric acid has been found to be less soluble and more efficiently utilized than urea or biuret by ruminants fed high roughage diets (Oltjen and Dinius 1976). In another study Slyter et al. (1968) found that steers receiving supplemental nitrogen from uric acid utilized cellulose more efficiently than those fed either urea or urea phosphate. In addition, the high phosphorus content of poultry waste (Bhattacharya and Taylor 1975) would be advantageous, since mature forages seldom contain sufficient phosphorus to meet the growing or adult ruminant's requirement for this nutrient (N.R.C. 1975; 1976).

This study was conducted to compare dried poultry waste, cottonseed meal and urea as nitrogen sources in supplements to wheat straw using growing lambs.

LITERATURE REVIEW

Chemical Composition of Poultry Waste

Dried Poultry Waste

Dried poultry waste (DPW) is the common name given to dehydrated manure from caged laying hens. This name is also used to differentiate the product from dried broiler litter (DBL) which includes bedding such as peanut hulls, wood shavings, corn cobs, etc. in addition to the manure. Occasionally literature reports refer to poultry waste without specifying whether it is with or without bedding.

Chemical composition of DPW is widely variable depending on several factors. Length of storage of the wet manure prior to drying affects the crude protein content of the final product. Flegal, Sheppard and Dorn (1972) found that crude protein of DPW decreased from 30 to 18 % as the storage period prior to drying increased from 7 to 100 days. Other factors influencing composition include: type of poultry production, method of drying and subsequent treatment of the material with chemicals (Manoukas, Colovos and Davis 1964; Brugman et al. 1967; Shannon and Brown 1969; Fontenot et al. 1971).

Average composition of laying hen manure obtained from different sources was assembled by Bhattacharya and

Taylor (1975) and is shown in Table 1. The data indicate that DPW usually contains less than 10% moisture with an occasional exception of up to 18%. Crude protein content is approximately 30% of which 40% is true protein. The remainder of the nitrogen is found as nonprotein nitrogen compounds, principally uric acid. Morgan (1970) reported that uric acid accounted for 20 to 60 % of the total nitrogen in DPW, while Eno (1962) reported values of 63 to 87 %.

The high ash content in DPW (28%), has been considered a handicap because it dilutes the energy content of the waste (Bhattacharya and Taylor 1975). However, the high levels of calcium (8.8%) and phosphorus (2.5%) may be important characteristics in certain types of diets. Calcium and phosphorus in DPW were found to be 95% and 75% available, respectively when DPW was used as the sole source of protein in diets for steers (Bull and Reid 1971). Morgan (1970) reported the sodium content of deep litter poultry manure was unusually low and provided only 3g/head daily when steers were fed a diet containing 80% manure. Steers in this study showed depressed feed intake and a reduced rate of growth which was alleviated when they were given access to sodium chloride. The content of several trace elements (Table 1) in DPW indicates it may be a useful source of these nutrients.

Table 1. Nutrient composition of dried poultry waste[a]

Dry matter	%	89.65	± 7.7
Composition of dry matter			
Crude protein	%	28.8	± 3.2
True protein	%	11.3	
Dig. portein (sheep)	%	14.4	
Crude fiber	%	12.7	± 1.7
Ether extract	%	2	± .5
NFE	%	28.7	± 2.8
Gross energy	kcal/kg	3533	±234
DE (cattle)	kcal/kg	1875	
DE (sheep)	kcal/kg	1911	±171
ME (chick)	kcal/kg	1093	
ME (layer)	kcal/kg	1190	±208
TDN (sheep)	%	52.3	
Ash	%	28	± 1.5
Calcium	%	8.8	± 1.1
Phosphorus	%	2.5	± .6
Magnesium	%	.67	± .16
Sodium	%	.94	
Potassium	%	2.33	± .27
Chlorine	%	.94	± .11
Silica	%	3.85	
Salt	%	1.36	
Iron	%	.2	
Cobalt	mg/kg	.0007	
Copper	mg/kg	150	± 45
Manganese	mg/kg	406	± 9
Zinc	mg/kg	463	± 93
Alanine	%	1.14	
Arginine	%	.50	
Aspartic acid	%	1.14	
Cystine	%	1.17	
Glutamic acid	%	1.66	
Glycine	%	.88	
Histidine	%	.22	
Isoleucine	%	.53	
Leucine	%	.86	
Lysine	%	.51	
Methionine	%	.10	
Phenylalanine	%	.48	
Proline	%	.56	
Serine	%	.55	
Threonine	%	.51	
Tyrosine	%	.28	
Valine	%	.65	

[a]Bhattacharya and Taylor 1975

Dried Broiler Litter

Chemical composition of dried broiler litter (DBL) is also variable. Major sources of variation include the type of bedding used, diet composition and method of handling the manure (Flegal et al. 1972; Bhattacharya and Fontenot 1966; El-Sabban et al. 1969). Dried broiler litter is characterized, although not invariably, by a lower crude protein and ash content than DPW (Oliphant 1974; Bhattacharya and Taylor 1975). The crude fiber content of DBL (16.8%) is higher than DPW (12%), but the ash content is lower (15%) and so are calcium (2.3%) and phosphorus (1.8%) (Bhattacharya and Taylor 1975). These differences are probably due to dilution of the manure by the materials used for bedding. Digestible energy of DBL in sheep has been reported to be higher (2440 vs 1911 kcal/kg) than that of DPW (Bhattacharya and Taylor 1975), probably because of the inclusion of the cellulosic bedding material in the dried broiler litter.

Effect of Processing on Nutrient Content of Poultry Waste

Several studies have been conducted to determine the effect of processing on nutrient content of poultry waste. Manoukas et al. (1964) found significant losses of nitrogen and gross energy ranging from 7.1 to 15.2 % and 1.2 to 20.2 %, respectively, when poultry manure was dried in a convection oven at 65 C during 24 hours.

Brugman et al. (1967) found no significant changes in the chemical composition of broiler litter when processed with heat at 135 C during 11 hours, but he observed that crude protein digestibility decreased approximately 7.6% as a result of the heating.

Shannon and Brown (1969) reported that the average losses of nitrogen from poultry waste due to drying in a forced-air oven increased from 4 to 10 %, and that energy content decreased from 6 to 3 % as the temperature increased from 60 to 120 degrees centigrade.

Long, Bratzler and Frear (1969) found an inverse relationship between the temperature at which layer waste was dried and the total crude protein in the final product. When waste was hydrolized (steam treated), the crude protein and ether extract contents were higher (34.5 and 3.6 %) than when the waste was dried at 427 C (24.9 and 2.2 %, respectively.

Fontenot et al. (1971) noticed that heat treatment for 4 hours at 100 or 150 C successfully sterilized the litter but this processing decreased its crude protein and ether extract content from 42.5 and 6.2 % to 34.4 and 1.9 %, respectively. However, these losses resulted in an increase in the nitrogen free extract. They also reported that acidifying the broiler litter to pH 6 before drying, resulted in a reduction of nitrogen losses.

Digestion and Metabolism Studies with Poultry Waste

Several studies have been conducted to determine the digestibility of poultry waste and to examine its effect on utilization of other nutrients in the diet.

Brugman et al. (1964) fed diets containing 50% DPW to Hereford bulls and found the following digestion coefficients for DPW diets: crude protein, 77.8%; crude fiber, 91%; ether extract, 44.4% and gross energy 59%.

El-Sabban et al. (1970) fed autoclaved poultry waste (APW), cooked poultry waste (CPW) and soybean meal (SBM) as the sole nitrogen sources in semi-purified high energy diets for lambs. Apparent digestion coefficients for crude protein were: 65.5%, 69.4% and 74.3%, respectively. Nitrogen retention as percentage of intake was: APW, 7.5%; CPW, 7.5%; and SBM, 5.5%. Nitrogen intake of sheep fed the SBM diet was lower (11 g vs 12 g/day) than that of the sheep fed the poultry waste diets. Digestion coefficients for dry matter were as follows: APW, 72.1%; CPW, 76.2%; and SBM, 75.3%. Digestion coefficients for energy were: APW, 73.5%; CPW, 76.3%; and SBM, 74.7%.

In another study Lowman and Knight (1970) working with sheep reported a value of 77% crude protein digestibility for dried poultry waste. They also reported digestibilities of 56% for dry matter, 66% for organic matter and 60% for energy in DPW fed as the sole constituent in the diet. Considerable increase in digestibility of dry matter, organic matter and energy of the total diet was observed when barley was added at 25, 50 and 75 % in the diet.

Tinnimit et al. (1972) compared DPW and soybean meal as protein supplements in high energy diets for growing sheep. Dried poultry waste and soybean meal supplied 40 to 49 % of the dietary nitrogen. Nitrogen digestibility in the DPW diet was lower ($P < .05$) than in the SBM diet (58 vs 65 %). Retention of nitrogen expressed as percent of absorbed, the DPW diet was 20% higher than the SBM diet. Digestion coefficient for dry matter and organic matter were 60 and 61 % for DPW diets and 65 and 66 % for SBM diets, respectively. In the same study, when DPW and SBM comprised approximately 90% of the dietary nitrogen, crude protein digestibility was 63% for DPW and 66% for soybean meal. Nitrogen retention expressed in g/day was superior for the SBM (4.3 vs 2.9) than for the DPW diets. These workers reported that the overall digestibility of diet dry matter and organic matter decreased 20 and 10 %, respectively as the percent of DPW increased from 20 to 80 %.

Smith and Calvert (1972) substituted DPW for 0, 50 and 100 % of the SBM in diets for sheep. Nitrogen supplements were mixed with cornmeal, ground corn cobs, solka floc and molasses. These workers found no significant difference among the three diets in digestibilities of crude protein or dry matter. They also observed that sheep fed DPW as a nitrogen source produced average daily gains at least 90% as great as soybean meal.

Saylor and Long (1974) ensiled poultry waste with dried grass hay in different proportions from 100:0 to a 60:40 ratio. They observed that _in vitro_ dry matter digestibility, crude protein content and lactic acid concentration were higher for the silage containing 60% poultry waste than the other proportions.

Flipot, McNiven and Summers (1975) compared poultry waste treated with tannic acid (3%) or paraformaldehyde (2%) and incorporated at approximately 64% (wet basis) of the diet, with SBM in diets for sheep. Nitrogen retention, as a percent of nitrogen intake, was equal for the tannic acid treated poultry waste and the SMB diet, and 66% higher as compared to the paraformaldehyde treated poultry waste. Digestibility of total nitrogen, dry matter and energy were highest for the SBM diet. They concluded that the low nitrogen retention value for the paraformaldehyde treated poultry waste diet was related to the low nitrogen intake of this group and perhaps to the level of paraformaldehyde used which may have limited rumen microbial growth.

Gihad (1976) conducted a study with sheep to compare DPW with SBM and urea as protein supplements for low quality tropical hay. Dried poultry waste constituted approximately 30% of the daily ration. Differences in crude protein digestibility among the supplements were not significant. Nitrogen balance was positive for all supplemented diets and negative when hay was fed alone. Dried poultry waste and urea diets had a higher nitrogen retention expressed as percent of both intake and absorbed, than the SBM diet (13.87, 20.96; 15.59, 24.76; 11.8, 17.97 %, respectively). Crude fiber digestibility was higher in the DPW and urea diets than in the SBM diet. No difference was observed in energy digestibility among the three supplements.

McNiven, Summers and Leeson (1976) attempted to avoid the process of drying poultry waste, which requires considerable expense and energy, by including poultry waste in a liquid feeding system. Mature sheep were fed a control diet made of corn-SBM (dry), the same diet mixed with water to give a dry matter-water content ratio of 1:4 and a third diet made of corn-wet caged layer manure with 80% moisture. Digestibilities of nitrogen, dry matter and energy were highest for the liquid SMB diet. Digestibility coefficients for the liquid poultry waste diet were approximately the same as for the dry SBM diet. Weight gain and feed efficiency were superior for the liquid poultry waste as compared to the dry corn-SBM diet.

Utilization of Uric Acid

Since uric acid is the primary source of non-protein nitrogen in poultry waste, a review of its utilization by ruminants appeared to be appropriate.

Belasco (1954) reported that uric acid could be utilized *in vitro* as a nitrogen source by rumen microorganisms. Rodriguez (1967) reported that uric acid digestibility on a lamb diet containing 80% DPW and 19.7 mg/g uric acid was 39%. When uric acid-N constituted about 12% of the dietary nitrogen, approximately 23% of the total nitrogen and 13% of the uric acid-N was retained.

Oltjen et al. (1968) evaluated uric acid, urea, urea phosphate and biuret as sources of dietary nitrogen in purified diets containing 28% acid detergent fiber for steers. Rumen microorganisms were able to degrade uric acid to ammonia more quickly after a 21 day adaptation. However, ammonia release was slower than with urea or urea phosphate suggesting a more favorable utilization. Nitrogen retention as percent of intake was highest for uric acid (23.1%), followed by urea (18.4%), biuret (16.9%) and urea phosphate (12.3%). Digestibilities of dry matter and energy were also greater for uric acid diets.

Oltjen and Dinius (1976) reported that about 34% of the ingested nitrogen was retained when steers were fed a high roughage diet consisting of 74% timothy hay and supplemented with uric acid (which provided 50% of the dietary nitrogen). This value was not significantly different than those obtained when sodium urate (41%) or a poultry waste product (30%) provided the nitrogen, although steers fed the poultry waste product had greater urinary nitrogen losses and retained less nitrogen daily.

Feeding Trials with Poultry Waste

The feeding value of poultry waste has been investigated extensively in recent years in experiments with feedlot cattle, sheep, lactating cows and young calves. However, many of these investigations have been carried out using broiler litter (Bhattacharya and Fontenot 1965, 1966; Harms et al. 1968; Galmez et al. 1970; Fontenot et al. 1971; Cullison, McCampbell and Warren 1973; Harmon, Fontenot and Webb 1975) not caged layer manure. The following is a review based exclusively on use of caged layer manure in ruminants' diets. For the purpose of this review the literature has been classified according to the relative energy level in diets used. High energy diets were considered to be those containing 35% or less roughage and low energy diets those where the roughage was 65% or more of the diet. This way of expressing the approximate energy level of a ration has been suggested by Jurgens (1974). An important observation is that very little research has been conducted with poultry waste as a nitrogen supplement for low energy diets, and more information is needed in this area.

High Energy Diets

Rodriguez and Zorita (1967) reported that fattening cattle fed a diet in which DPW replaced 55% of a barley-oil seed meal-wheat bran mixture, gained 78% as much as those fed a control diet without dry poultry waste. These workers considered this performance satisfactory.

Similar observations were reported by El-Sabban et al. (1970). Twenty-five angus steers were used in a 139 day feeding trial. Steers were fed finishing diets in which all supplemental nitrogen was provided by SBM, auto-claved poultry waste (APW), DPW or urea. The average daily gain and feed efficiency among steers fed SBM, APW or DPW, were not significantly different. Steers fed the diet containing urea gained more rapidly and more efficiently than steers receiving the other nitrogen sources. Carcass characteristics and meat acceptability were not significantly different among steers fed any of the four diets.

In another study Bucholtz et al. (1971) conducted an experiment with feedlot cattle, in which five diets were formulated to contain 12% crude protein (dry basis) with one of the following supplements: SBM, urea, DPW, ½ DPW-½ SBM, or ½ DPW-½ urea. The source of protein had a large and significant effect on average daily gain. The SBM supplemented group had higher ($P < .05$) daily gain (3.3 lb) than the groups supplemented with DPW (2.75 lb) or ½ DPW-½ SBM (2.9 lb), but was not significantly higher ($P > .01$) than the group supplemented with urea (3.3 lb) or ½ DPW-½ urea. They attributed the relatively poor performance of animals fed DPW to the high proportion (32%) of the product used in the diet. The steers refused to consume the DPW of the ration, leaving almost as much as had been presented. No actual consumption data for DPW was reported.

Smith (1974) reported no difference in dry matter intake, average daily gain, feed efficiency and nutrient utilization between cattle fed corn meal containing 12.8% CSM or 20.5% dried poultry waste.

Oliphant (1974) conducted an experiment over three years in which SBM and fish meal was substituted for DPW in a high energy beef cattle diet. The treatment diets were made iso-nitrogenous with a control (14.5% crude protein). When the crude protein of DPW was low (24%) it was necessary to include 27.6% in the diet, and poor performance resulted. When DPW contained 30% crude protein, or when urea was added to equalize the nitrogen content of diets containing up to 17.5% DPW, average daily gain and carcass quality was not markedly different from that shown with control diet. The reduced performance observed with animals fed DPW was associated with reduced daily intake of dry matter.

Cullison et al. (1976) compared the performance of steers fed high-corn diets supplemented with (1) DPW, (2) SBM or (3) broiler litter. Also included in this experiment was a negative control which contained 8% crude protein, as fed, but had no supplemental protein. Steers fed DPW had a lower rate of gain than did those fed the other diets, including the negative control. Average daily gain was not different among the other treatments. No differences were observed in daily intake or carcass characteristics among any of the treatments. These workers concluded that apparently something present in the DPW, either naturally occurring or as a result of the drying process, was responsible for the poor performance of this group.

Bucholtz et al. (1971) conducted three feeding trials with sheep fed diets containing 20 to 32 % DPW compared to SBM and cattle or swine feces. Nitrogen digestibility and average daily gains by lambs fed the

SBM diet were greater than for those fed DPW, which in turn were greater than for those fed diets containing cattle or swine feces. Digestibilities of dry matter and organic matter followed the same trend. They also report that lignocellulose digestibility in waste-containing diets was greater than in the SBM diet.

Thomas et al. (1972) compared three diets (17% crude protein) containing 0, 25 or 50 % dried poultry waste. Average daily gain and feed efficiency for sheep fed the diets containing 25 or 50 % DPW were significantly less than for those fed a control corn-corn cob-SBM diet, (.16, 10; .15, 12.5; .21, 7.1 kg, respectively). Carcass grades of sheep fed 25% DPW or the control diet were equal. Sheep fed the 50% DPW diet produced lower grading carcasses.

Smith and Calvert (1972) however, reported that when crude protein of SBM was replaced by that of DPW at levels of 50 and 100 % in diets for lambs, the average daily gain and feed efficiency were not significantly different, although, the performance tended to decline by 9 and 15 % respectively, at 50 and 100 % SBM replacement.

Thomas et al. (1972) fed lactating dairy cows a grain mixture containing 30% DPW (in a preliminary trial cows refused to consume a concentrate mixture containing 50% DPW) compared to other nitrogen sources. Level of milk production during the 60-day experimental period was approximately the same for cows fed DPW and control diets. The persistency was normal for cows fed DPW and greater than for cows fed a low protein diet. Flavor of milk from cows fed DPW was normal. Similar results have been reported with milking ewes when the concentrate mixture included up to 50% dried poultry waste (Zorita et al. 1967).

Low Energy Diets

Taylor et al. (1976) compared poultry waste and cottonseed meal as supplements to wheat straw for dry pregnant beef cows. Supplements were fed at the rate of 1.5 lb/day and supplied 100% of the N.R.C. (1976) protein requirements. Cows fed DPW with sliced wheat straw showed no gain during the 56-day experimental period whereas cows fed a similar amount of straw and cottonseed meal gained approximately 0.6 lb/day. The experimental cows started calving 20 days following the end of the trial, and no differences in birth weight or vigor at birth were observed.

In another study Oltjen and Dinius (1976) compared processed poultry waste with uric acid, sodium urate, urea and biuret as nitrogen supplements for beef cattle fed high roughage diets containing 74% timothy hay. Steers fed 50% of their dietary nitrogen from poultry waste (containing 28% uric acid), uric acid or sodium urate, digested nitrogen, dry matter and crude fiber equally well. Steers fed poultry waste during a 90-day growth trial consumed more dry matter daily and gained weight more rapidly and efficiently than steers fed urea or biuret diets. Concentration of plasma amino acids and ruminal fluid volatile fatty acids were not different among treatments. They concluded that poultry waste is similar to uric acid and sodium urate but superior to urea and biuret, when used as nitrogen supplement for beef cattle fed forage diets.

Health Aspects of Feeding Poultry Waste

Pathogens in Poultry Waste Capable of Affecting Human Health

Many pathogenic organisms capable of causing disease in humans have been isolated from poultry waste. Sporadic incidences of disease have been reported throughout the world (Bhattacharya and Taylor 1975), but such incidences seem to be rare in the United States. From the standpoint of public health and to insure the safety of the animals' products, animal scientists should never ignore the possibility of transmission of disease that may occur under certain circumstances.

Biester and Schwarte (1959) reported that poultry are potential carriers of several human pathogens that have been isolated from wastes. The virus of New Castle disease and Chlamydia or psittacosis that cause conjunctivitis and pneumonia in humans, respectively, were found in poultry waste. They also reported to have isolated E. rhusiopathia, that causes erysipelas M. Avium, one of the agents that can produce human tuberculisis or will cause tuberculin sensitivity without disease.

Davis et al. (1970) isolated from poultry waste L. monocytogenes, which causes listeriosis A. fumigatus, which causes rhinitis, asthma and chronic pulmonary disorder. They also found C. botulinum, which produces food poisoning.

Lovett, Messer and Read (1971) isolated Salmonella sp., the causative agent for different types of enteritis infection in man.

Pathogens in Poultry Waste Capable of Affecting Animal Health

There are several pathogenic organisms present in poultry waste that may affect other animals. Salmonella pollorum is an agent that produces infection in cattle and swine, and has been isolated from poultry wastes (Biester and Schwarte 1959). These workers also isolated E. Rhusiopathia which produces infection in birds and swine and L. monocytogenes which produces lysteriosis in cattle and sheep.

Wilson and Miles (1964) and Davis et al. (1970) isolated M. avium, which infects mink and swine, and is capable of sensitizing cattle causing them to react to mammalian tuberculin.

Nilo and Avery (1963) reported that of 44 different samples of poultry waste analyzed, 23 were positive for Clostridium spp., including 8 for C. perfringens, which causes bovine and ovine enterotoxemia. Clostridium pyogenes and C. equi, the agents that cause cystitis, abortion and pyelonefritis in cattle were also found. In addition, certain strains of Salmonella with potential for causing enteric disease in livestock were isolated.

Effect of Processing on Pathogenic
Microorganisms in Poultry Waste

The risk of causing human or animal disease by feeding poultry waste can be minimized by some methods of processing the material.

Messer et al. (1971) reported that Arizona Spp. were destroyed by heat at 47.2 C for 30 min and S. pollorum at 62.8 C for 30 minutes. They also reported that to destroy S. typhimurium 62.8 C for 60 min were required while in the case of E. colli heat at 69.3 C for 20 min was effective.

Fontenot et al. (1971), following the testing procedure of pasteurized milk, found that litter could be pasteurized in 15 min at a thickness of .63 cm and in 30 min at a thickness of 1.6 cm by dry heat at 150 degrees centigrade.

Caswell, Fontenot and Webb (1972) developed three methods for sterilizing poultry manure. The criteria for determining the effectiveness of the methods was the same as that used for pasteurized milk, which are: less than 10 coliforms and less than 20,000 total bacteria per gram of manure. The following methods were effective: (1) dry heat at 150 C at .63 cm litter depth for 20 min without chemicals; (2) the same process as (1) but heated for 15 min with paraformaldehyde added at 1 g/100g litter; (3) ethylene oxide fumigation at 22 C with vacuum of 2.5 mm Hg pressure for 60 min; (4) moist heat (autoclave) at 119 C with a pressure of 6.8 kg at litter depth of 5 cm for 10 minutes.

Strauch and Muller (1974) reported that Salmonella organisms from poultry waste were completely destroyed within 6 days in a summer temperature of 16 to 23 C and within 26 days in a winter temperature of 5 to 11 C when held in 50 liter drums.

Harmon et al. (1975) ensiled broiler litter containing 83% of dry matter with whole plant corn forage containing 25 and 38 % dry matter. They reported that total bacteria by plate count was increased when 30 or 45 % of the dry matter was supplied by litter. Coliform were not increased by including litter in the silage, on the contrary, decreased significantly when litter was used with the high dry matter forage.

Drugs and Chemicals in Poultry Waste

Antibiotics and many different drugs are commonly added to poultry feed to prevent disease and/or to improve production. Residues from these chemicals are potential problems if the manure is to be recycled.

Arsenicals are compounds used in the feed of poultry for increasing rate of gain, improving feed efficiency, increasing egg production or for preventing disease (Bhattacharya and Taylor 1975). Several studies have reported levels of residual arsenic in poultry waste ranging from 1 to 60 ppm with an average of approximately 40 ppm (Brugman et al. 1964; Morrison 1969; El-Sabban et al. 1969; Messer et al. 1971).

El-Sabban et al. (1970) reported that steers fed rations containing DPW had significantly higher liver arsenic levels (.38 ppm) than did the control animals (.12 to .28 ppm). The reports of Fontenot et al. (1972) show a maximum arsenic residue level of .19 and .62 ppm in muscle and liver tissue of steers fed a 50% litter diet for 198 and 121 days, respectively. Litter used in this study contained 38 ppm of arsenic and the feed was withdrawn 5 days before slaughter.

Fontenot et al. (1972) reported copper toxicity in ewes as a result of feeding diets containing 25 or 50 % of poultry manure, which contained 159 ppm of copper because of high levels of copper sulfate in the feed. However, Lowman and Knight (1970) found that the digestibility and level of available copper in poultry manure were lower than in barley.

Summary of Literature Review

The literature review shows that the chemical composition of poultry waste is variable depending on length of storage of the material prior to drying, treatment of the material and type of poultry production. Poultry waste is characterized by high levels of nitrogen and ash, but a low level of energy. Caged layer manure usually contains higher levels of crude protein and ash and less fiber than broiler litter. Uric acid accounts for 20 to 87 % of the total nitrogen in dried poultry waste. Calcium and phosphorus content of DPW are high and could contribute to the mineral balance in the diet.

Methods of processing poultry waste do have an effect on its nutrient composition. The process of drying decreased the nitrogen and energy content of poultry waste. Hydrolyzed poultry waste (steam treated) had more crude protein and ether extract than air dried manure.

Metabolism and feeding trials indicate that poultry waste is an acceptable ingredient in ruminant diets. Performance of animals fed diets containing poultry waste has generally been acceptable, but sometimes lower than for animals consuming diets with natural protein. In most of these cases the lower performance of animals fed poultry waste has been considered to be due to a lower energy intake. Diets containing high level of poultry waste have a reduced energy concentration because of the high ash content in the waste. Intake may also be reduced because of poor palatability of the waste diets.

In the few studies conducted using poultry waste or uric acid in low energy diets, the nitrogen has been more effectively utilized than other sources of nonprotein nitrogen.

Pathogenic organisms as well as drugs and chemicals capable of causing disease in humans and animals have been isolated from poultry waste. Fortunately because of improved management systems and methods of processing wastes, the risk of spreading disease is minimal.

EXPERIMENTAL PROCEDURE

Three Suffolk x Hampshire ram lambs, averaging 47 kg initially, were used in a 3x3 Latin square experiment to determine utilization of nitrogen and digestibility of energy from diets containing wheat straw supplemented with dried poultry waste (DPW), cottonseed meal (CSM) or urea. Supplements were formulated (Table 2), using each of the nitrogen sources, to contain approximately 36% crude protein and to meet or exceed calcium, phosphorus and vitamin A requirements for growing lambs (N.R.C. 1975) when fed at the level specified in this experiment. The wheat straw (Cajeme 71 variety) was ground through a 2.5 cm screen in a hay mill and mixed with 5% molasses and 7.5% water to control dust.

Each period of the Latin square was 28 days. Lambs were confined to individual pens (1.2 x 4.8 m) for the first 18 days and to metabolism cages for the last 10 days of each period. Supplement intake was held constant throughout the study at 400 g/lamb/day (as fed basis). Wheat straw was offered free choice for the first 14 days of each period and then intake was held constant for the remainder of the period at a level judged to be maximum for each lamb. The daily allowance of supplement and straw was fed in two equal portions at 7 am and 4 pm. Water and block

Table 2. Ingredient composition of supplements[a]

Ingredient	Intern'l Ref. No.	Nitrogen Source: Dried Poultry Waste	Cottonseed Meal	Urea
Dried poultry waste[b], %		73.50	---	---
Cottonseed meal, %	5-01-621	---	67.00	---
Urea 45% N, %		---	---	7.50
Sorghum grain, steam processed, flaked, %	4-04-383	20.00	24.25	82.50
Molasses, %	4-04-696	5.00	5.00	5.00
Salt, %		1.50	1.50	1.50
Limestone, %	6-02-632	---	2.00	1.50
Dicalcium phosphate, %	6-01-080	---	.25	2.00
Vitamin A, IU/kg		6250	6250	6250

[a]As fed basis

[b]McAnnally Enterprises, Inc., Yucaipai, CA.

salt were available at all times. Upon completion of the Latin square, supplements were withdrawn and the lambs were maintained on straw alone for 70 days. Fecal and urine collections were begun 10, 28 and 63 days after supplement withdrawal.

During the last 7 days of each period, total feces and urine from each lamb were collected daily. A 10% aliquot of the daily fecal excretion was dried to constant weight at 45 C in a forced air oven. At the conclusion of the trial, the daily samples for each lamb were pooled and ground through a 1 mm screen in a Wiley mill and a portion of the ground composite was retained for analysis. Urine was collected in glass containers to which 25 ml of hydrochloric acid diluted 1:2 with water had been added. Daily urine collections were filtered through glass wool and a 5% aliquot (by weight) was retained. Daily aliquots were composited and stored in glass containers under refrigeration until analyzed. Straw and supplement samples were taken each collection period and prepared for analysis in the same manner as were fecal samples.

Nitrogen, final dry matter, ether extract and ash determinations were according to A.O.A.C. (1970). Acid detergent fiber in DPW and water soluble nitrogen in DPW, CSM and urea were determined as described by Goering and

Van Soest (1970). Uric acid in DPW was determined by the method of Praetorius and Poulsen (1953) following extraction with .1N NaOH. Amino nitrogen content of DPW was calculated from its amino acid composition determined by the method of Moore, Spackman and Stein (1959).

Analysis of variance and Duncan's New Multiple Range Test (Steel and Torrie 1960) were used for statistical treatment of data.

RESULTS

The DPW used in this study was a commercially available product obtained from caged laying hens. Its composition is shown in Table 3. This product contained a higher level of crude protein, approximately 42% on a dry matter basis, than has been reported as average for dried poultry waste (Bhattacharya and Taylor 1975). Approximately 31% of the total nitrogen was amino nitrogen. Uric acid accounted for approximately 38% of the total nitrogen and 56% of the non-amino nitrogen. These values for percentages of nitrogen in the various fractions are within ranges reported by other workers (Eno 1962; Morgan 1970; Bhattacharya and Taylor 1975). The values for ash, ether extract and gross energy are similar to those given in the recent review by Bhattacharya and Taylor (1975). The fiber value determined using the acid detergent method is approximately twice as high as the average crude fiber value for DPW given in that review. Approximately 74% of the total nitrogen in DPW was soluble in boiling water. This compared with 98% and 32% solubility of nitrogen in urea and CSM, respectively.

Nitrogen, organic matter and gross energy contents of the supplements and wheat straw used in this study are

Table 3. Chemical composition of dried poultry waste.

Item	Percent
Dry matter	94.0
Composition of dry matter	
Total nitrogen	6.77
Water soluble nitrogen	5.00
Amino acid nitrogen	2.09
Uric acid nitrogen	2.59
Acid detergent fiber	21.60
Ether extract	2.34
Ash	29.0
Gross energy, Kcal/kg	3684

shown in Table 4. The supplements were approximately iso-nitrogenous and the wheat straw contained very little nitrogen. The DPW and CSM supplied approximately 80% of the total nitrogen in those supplements while urea provided about 60% of the nitrogen in that supplement.

As would be expected from the high ash content in poultry waste, the DPW supplement contained less organic matter than the other two supplements. The lower gross energy content of the DPW supplement reflects this high ash content.

Dry matter intake of straw was not influenced ($P \geq .05$) by the source of supplemental nitrogen (Table 5). In each case, the supplement supplied approximately 30% of the total dry matter intake and 85% of the total dietary nitrogen.

Nitrogen utilization and apparent digestibility data are also shown in Table 5. Nitrogen intake averaged 25.7 g daily and was not different among supplements ($P > .05$). Fecal nitrogen tended to be lower when supplemental nitrogen was supplied by urea, thus the apparent digestion coefficient for nitrogen was highest in the urea supplemented diet ($P < .05$). Fecal nitrogen and apparent digestibility of nitrogen were not different between the DPW and CSM supplemented diets. Urinary nitrogen excretion was highest ($P < .05$) on the urea and DPW supplemented diet and lowest on the CSM diet. Nitrogen retention,

Table 4. Nitrogen, organic matter and gross energy content of supplements and wheat straw[a]

Item	Supplement			Wheat Straw
	DPW	CSM	Urea	
Nitrogen, %	5.84	5.82	5.87	.46
Organic matter, %	72.94	88.53	91.47	89.22
Gross energy, Kcal/kg	3410	4404	4075	4182

[a]All values on a dry matter basis. Values are means of duplicate values for each of three collection periods.

Table 5. Dry matter intake, nitrogen utilization and apparent digestibility by lambs of diets containing wheat straw supplemented with DPW, CSM or urea.

Item	Supplement DPW	CSM	Urea	Standard Deviation
Dry matter intake/day				
Supplement, g	369	380	378	
Straw, g	802	802	833	71.9
Total, g	1171	1182	1211	
Total, $g/W_{kg}^{.75}$	65.8	68.3	66.2	3.50
Nitrogen utilization, g/day				
Intake	25.3	25.8	26.0	0.73
Fecal	8.1	8.5	6.8	0.57
Urinary	14.5[b]	11.2[c]	16.2[b]	0.50
Retained	2.7[b]	6.1[c]	3.0[b]	0.22
% of intake	10.7[b]	23.6[c]	11.5[b]	1.40
% of absorbed	15.7[b]	35.3[c]	15.6[b]	2.30
Biological value[d]	47.0	57.1	45.0	10.23
Net protein utilization[e]	41.4	50.1	43.0	11.56
Apparent digestibility, %				
Dry matter	53.6	57.7	58.7	1.73
Organic matter	55.1	58.4	60.2	1.70
Nitrogen	68.0[b]	67.0[b]	73.8[c]	1.33
Energy	54.3	57.4	58.9	2.50

[a]All values are means of 3 observations

[b,c]Means on the same line with different superscripts are different ($P < .05$).

[d]Calculated by the method of Mitchell (1923).

[e]Calculated by the method of Miller and Bender (1955).

whether expressed in terms of g/day, percent of intake or percent of absorbed, was approximately twice as high for the CSM diet as for those diets supplemented with DPW or urea. No differences were observed between DPW and urea supplemented diets in these parameters.

Biological value (BV) and net protein utilization (NPU) of the diets were calculated by the methods of Mitchell (1923) and Miller and Bender (1955), respectively. For these calculations, metabolic fecal nitrogen was considered as .45 g N/100 g dry matter intake (Mitchell 1964) and endogenous urinary nitrogen as .146 gN/kg$^{.72}$ (Brody, Proctor and Ashworth 1934). The CSM diet had a considerably higher biological value and net protein utilization than DPW and urea, but the differences were not significant ($P > .05$).

Apparent digestibility of dry matter, organic matter and energy were considerably lower for the DPW supplemented diet than for the other diets, but the differences were not significant ($P > .05$). These digestibilities were similar for urea and CSM supplemented diets.

Results of the collection periods when straw was fed alone are shown in Table 6. Dry matter intake was similar during each of the three collection periods. Straw intake during these periods was actually higher than in the periods when protein supplements were fed, however, total dry matter intake was lower (Table 5). Daily

Table 6. Dry matter intake, nitrogen balance and apparent digestibility by lambs of wheat straw fed alone[a].

Item	Days after supplement withdrawal 10	28	63	Standard Deviation
Dry matter intake				
g/day	997	969	1048	92.9
$g/W_{kg}^{.75}/day$	49.3	49.2	56.6	4.95
Nitrogen balance g/day				
Intake	4.6	4.5	4.9	0.35
Fecal	5.9	6.0	6.5	0.27
Urinary	3.6[b]	2.9[c]	2.3[d]	0.22
Retained	-4.9	-4.4	-3.9	0.35
Apparent digestibility, %				
Dry matter	40.3	34.5	38.7	3.56
Organic matter	40.6	35.0	39.5	3.53
Nitrogen	-28.3	-33.3	-32.6	6.71
Energy	38.3	31.7	36.7	3.87

[a]All values are means of three observations.

[b,c,d]Means on the same line with different superscripts are different ($P < .05$).

nitrogen intake was less than 5 g throughout this 70-day period compared with an average of 25.7 g intake during the supplemented periods. No difference ($P > .05$) was seen in fecal nitrogen excretion as the time after supplement withdrawal increased but urinary nitrogen losses decreased ($P < .05$). Lambs were in negative nitrogen balance throughout this unsupplemented period.

Digestibilities of nitrogen, dry matter, organic matter and energy were not different ($P > .05$) with time after supplement withdrawal.

DISCUSSION

Crude protein has been shown to be the most variable fraction in dried poultry waste primarily because of the nitrogen losses which occur upon storage of the wet material prior to drying (Flegal et al. 1972). The poultry waste used in the present study was collected and dehydrated daily which probably accounts for its higher than average nitrogen content.

The high fiber value reported for DPW in this study was due to the method used for its determination. Acid detergent fiber contains minerals insoluble in the detergent solution as well as the lignocellulose (Goering and Van Soest 1970). With the high ash content of poultry waste, this residual mineral (although not determined in this study) was probably a significant fraction of the acid detergent fiber.

The more efficient utilization of nitrogen in the CSM supplemented diet compared with that in DPW and urea supplemented diet was not unexpected. Several studies have shown natural protein to be superior to nonprotein nitrogen for use in high-roughage diets (Briggs et al. 1947; Raleigh and Wallace 1963; Williams et al. 1969; Ammerman et al. 1972). This is apparently due to differences in the relative rates of hydrolysis in the rumen between urea and lignocellulose of low quality roughages. Urea hydrolysis in the rumen proceeds at a faster rate than conversion of lignocellulose to the keto acids necessary for synthesis of microbial protein. As a result, a significant percentage of the urea nitrogen is absorbed from the rumen as ammonia and excreted in the urine (Bloomfield, Garner and Muhrer 1960; N.A.S. 1976).

The failure of nitrogen in the DPW diet to be utilized more efficiently than nitrogen in the urea diet was surprising. Approximately 30% of the total nitrogen in DPW was found in amino acids, presumably as true protein. As discussed above, protein nitrogen would be expected to be more efficiently utilized than nonprotein nitrogen under the conditions of this experiment. In addition, studies have shown uric acid nitrogen, which comprised nearly 40% of the total DPW nitrogen, to be more efficiently utilized in high roughage diets than urea or other sources of nonprotein nitrogen (Oltjen and Dinius 1976; Slyter et al. 1968).

It is not clear why DPW was not superior to urea in this study. Perhaps it is related to the readily available carbohydrate and energy content of the two diets. The DPW supplement contained only 24% sorghum grain compared with 82% in the urea supplement, thus, the DPW diet contained only 8% grain as compared with 26% in the urea diet. Other studies have shown utilization of urea nitrogen to be directly related to the content of readily available carbohydrate, such as grain or molasses, in the diet (Hart et al. 1939; Gallup, Pope and Whitehair 1953; Hungate 1966; Klett 1971). In addition, digestible energy intake was approximately 20% higher when the diets were supplemented with urea than with DPW because of the higher gross energy content (Table 4) and higher digestibility of energy (Table 5) in the urea supplement.

Another factor involved in the unexpected poor utilization of DPW nitrogen compared with urea nitrogen might be the forms of nitrogen found in the DPW. As has already been discussed, one would expect amino- and uric acid-nitrogen to be more efficiently utilized than urea nitrogen. However, these two sources accounted for only 70% of the total nitrogen in DPW and no information was obtained on the form of the remaining 30%. According to the report of Eno (1962) the remaining nitrogen probably occurred as ammonium salts. It is unlikely that nitrogen in this form would be utilized more efficiently than urea nitrogen (N.A.S. 1976). Furthermore, the high solubility of the nitrogen in the DPW (74%) raises questions concerning the forms of nitrogen present in that product. The method utilized for measuring soluble nitrogen was developed to estimate the true protein content of forages (Goering and Van Soest 1970). In theory, true protein is coagulated by the heat and thus retained on the filter along with the cell walls, while nonprotein nitrogen forms are solubilized. The forms of nitrogen solubilized in this study were not determined. However, since uric acid is insoluble in water (Handbook of Chemistry and Physics 1971), and since it accounted for 38% of the total nitrogen in DPW, the remaining forms of nitrogen were apparently totally soluble. If that is correct, then perhaps much of the amino nitrogen is in the form of free amino acids and not true protein. It was not determined whether this was actually the case or whether the method used was not appropriate for analysing the soluble nitrogen in DPW. The results of this study (Table 5) support the findings of Wohlt et al. (1976) that absorbed and urinary nitrogen increase, and retained nitrogen decreases as solubility of dietary nitrogen increases.

Biological value and net protein utilization values calculated in this study are relative values only and are not directly comparable with other such values since diets were not iso-caloric and crude protein intake was above the maintenance requirements.

No explanation is apparent for the lower digestion coefficients for dry matter, organic matter and energy obtained for the DPW supplemented diet. Wohlt et al. (1976) reported that these coefficients decreased with increasing protein solubility and that could be a factor in the differences observed between the CSM and DPW diets. However, despite a large difference (98% vs 31%) in solubility of nitrogen in urea and CSM, very small differences were observed in digestion coefficients between these diets. These data support the findings of Swingle and Waymack (1975) who also found no difference in digestion coefficients for high roughage diets supplemented with urea or plant protein (alfalfa). The digestion coefficients for dry matter, organic matter and energy in DPW averaged about 5 percentage units lower than for the other two diets. These differences are large enough to be of biological significance but were not statistically significant ($P > .05$). The lack of statistical significance can be attributed to the low number of degrees of freedom (2) remaining for error in the 3x3 Latin square. Variation in the data was quite small as indicated by the standard deviations shown in Table 5.

The data indicate that DPW is at least as effective as urea as a nitrogen supplement for low quality roughage but that neither of these sources is as effective as cottonseed meal. These data are in direct contrast to those of Gihad (1976) who reported that nitrogen in urea and DPW was utilized more effectively than SBM by sheep fed low quality tropical hay. No reasons for the differences between the two studies are apparent.

The sustained intake of straw dry matter following withdrawal of the nitrogen supplements (Table 6) was unexpected. Straw intake remained nearly constant for 70 days in spite of the low nitrogen content (.46%) and low daily nitrogen intake (5 g). Miller and Morrison (1942) observed dry matter intake by sheep decreased from 600 to less than 300 g/day when a diet supplying less than 2 g of nitrogen per day was fed. Many other investigators have reported a depression in dry matter intake with diets containing less than 1% nitrogen (Miller 1937; Harris and Mitchell 1941; Campling, Freer and Balch 1962; Oh, Longhurst and Jones 1969; Bhattacharya and Pervez 1973). It is interesting that most of the low-protein diets which have been used to determine metabolic and endogenous nitrogen losses have contained wheat straw (Sotola 1930; Turk, Morrison and Maynard 1934; Harris and Mitchell 1941; Miller and Morrison 1942).

As expected, the lambs were in negative nitrogen balance throughout the unsupplemented phase of this study (Table 6). This is in contrast to the positive nitrogen balances observed with the supplemented diets (Table 5) and confirms the need for supplemental nitrogen in straw diets for growing lambs. The progressive decrease in urinary nitrogen which was seen following supplement withdrawal (Table 6) has been previously observed (Allison and

Wannemacher 1965; Biddle, Evans and Trout 1975) and has been interpreted as indicating the depletion of labile protein (or nitrogen) reserves from the body.

The effect of nitrogen supplementation on digestibility of straw was evaluated by comparing the digestion coefficient for energy determined for straw fed alone with the coefficient calculated for the supplemented straw by difference. For this calculation, digestible energy (DE) content of the supplements was estimated using the DE value for DPW reported by Bhattacharya and Taylor (1975) and DE values for other supplement ingredients listed in the Atlas of Nutritional Data on United States and Canadian Feeds (N.A.S. 1971). The average digestion coefficient calculated by difference for energy in straw was 51% (across the three diets) compared with the values of 32 to 38 % determined for straw alone (Table 6). Other investigators have observed digestibility of roughage components is depressed in diets containing suboptimal levels of nitrogen (Harris and Mitchell 1941; Campling et al. 1962; Oh et al. 1969; Bhattacharya and Pervez 1973). The calculated digestion coefficient of 51% is the same as was obtained for Cajeme 71 wheat straw supplemented with adequate nitrogen in an earlier study at this station using steers (Swingle and Waymack 1975).

Nitrogen excretion during this extended period of low nitrogen intake was used to estimate metabolic fecal nitrogen (MFN) and endogenous urinary nitrogen (EUN). Fecal nitrogen was .59, .62 and .62 g/100g of dry matter intake (DMI) for collections made 10, 28 and 63 days following withdrawal of the supplements. These values are within the range of .55 to .65 g/100g DMI reported for sheep by other workers (Sotola 1930; Turk et al. 1934; Miller and Morrison 1939; Harris and Mitchell 1941). However, the values calculated in the present study would overestimate MFN by the amount of undigested straw nitrogen in the feces. When the values were corrected for this loss by using the true digestibility coefficient for crude protein in cereal straws given by Blaxter and Mitchell (1948) the mean value for MFN was .46 g/100g of dry matter intake. This agrees quite closely with the widely used values of .45 g/100g DMI (Mitchell 1964) and .5 g/100g DMI (Maynard and Loosli 1969) for MFN in ruminants.

Urinary nitrogen during this period averaged .065, .055 and .047 g/kg of body weight for the collections at 10, 28 and 63 days, respectively. Expressed per unit of metabolic body size ($W_{kg}^{.75}$) the values were .18, .15 and .12 for the three collections. The average value of .056 g/kg is considerably higher than the values of .035 g/kg and .037 g/kg reported for lambs by Smuts and Marais (1938) and Miller and Morrison (1942). However, the average value of .15 g/$W_{kg}^{.75}$ agrees quite closely with the interspecies value of .146 $g/W_{kg}^{.72}$ given by Maynard and Loosli (1969). These data confirm the validity of values for MFN and EUN in current use.

CONCLUSIONS

The following conclusions were made based on the results reported in this thesis.

1. Wheat straw alone will not support a positive nitrogen balance in growing lambs. Despite negative nitrogen balance, the lambs continued to eat the low nitrogen diet for 72 days.

2. Supplements containing DPW, CSM or urea are all effective in correcting the nitrogen deficiency of wheat straw diets for lambs.

3. Nitrogen was utilized approximately twice as effectively in the CSM supplemented diet as in those supplemented with either DPW or urea.

4. No difference was observed in utilization of nitrogen between the DPW and urea supplemented diets. Since low quality roughages are deficient in both nitrogen and phosphorus it is suggested that the relative cost of supplementing both nutrients, not nitrogen alone, should be considered when deciding which of these nitrogen sources to use.

5. Nitrogen supplementation increased digestibility of energy in wheat straw.

6. Metabolic fecal nitrogen and endogenous urinary nitrogen values determined during the period of low nitrogen intake were similar to those in current use.

APPENDIX

RAW DATA AND STATISTICAL ANALYSIS

Table 7. Chemical analysis and gross energy of supplements and wheat straw in metabolism trials[a]

	Nitrogen %	Ash %	Organic Matter %	Gross Energy Cal/g
DPW supplement				
Period I	5.79	26.7	73.2	3373
Period II	5.89	27.5	72.5	3392
Period III	5.86	26.9	73.1	3465
Average	5.85	27.0	72.9	3410
CSM supplement				
Period I	5.71	11.7	88.3	4437
Period II	5.82	10.6	89.4	4409
Period III	5.94	12.1	87.9	4366
Average	5.82	11.5	88.5	4404
Urea supplement				
Period I	5.80	9.8	90.2	4092
Period II	5.86	8.0	92.0	4094
Period III	5.97	7.8	92.2	4038
Average	5.87	8.5	91.5	4075
Wheat straw				
Period I	0.40	11.9	88.1	4132
Period II	0.55	10.4	89.6	4129
Period III	0.46	10.1	89.9	4298
Fed alone	0.46	11.5	88.5	4171
Average	0.46	11.0	89.0	4182

[a]All values on dry matter basis.

Table 8. Feed consumption and feces excretion of lambs during collection periods[a]

Diet Lamb	Intake g Supplement	 Straw	Total	Feces g
DPW				
Lamb #1 (III)[b]	2576	5843	8419	3723
Lamb #2 (I)	2594	5137	7731	3529
Lamb #3 (II)	2587	5865	8452	4158
CSM				
Lamb #1 (I)	2612	5138	7750	3151
Lamb #2 (II)	2681	5865	8546	3667
Lamb #3 (III)	2688	5843	8531	3703
Urea				
Lamb #1 (II)	2600	5865	8465	3508
Lamb #2 (III)	2525	5843	8368	3582
Lamb #3 (I)	2806	5779	8585	3401
Straw alone First collection				
Lamb #1	---	7294	7294	4032
Lamb #2	---	8081	8081	4949
Lamb #3	---	5565	5565	3514
Second collection				
Lamb #1	---	6657	6657	4291
Lamb #2	---	7287	7287	5145
Lamb #3	---	6415	6415	3948
Third collection				
Lamb #1	---	7273	7273	4312
Lamb #2	---	7413	7413	4984
Lamb #3	---	7315	7315	4270

[a]All values on dry matter basis.

[b]Numbers in parentheses refer to period of Latin square.

Table 9. Chemical analysis and gross energy of feces from lambs fed wheat straw supplemented with DPW, CSM or urea and wheat straw fed alone[a]

Diet Lamb	Nitrogen %	Ash %	Organic Matter %	Gross En. Cal/gm
DPW				
Lamb #1 (III)[b]	1.47	17.5	82.5	3878
Lamb #2 (I)	1.50	20.6	79.4	3856
Lamb #3 (II)	1.50	17.5	82.5	3912
CSM				
Lamb #1 (I)	1.81	13.5	86.5	4295
Lamb #2 (II)	1.65	13.4	86.6	4159
Lamb #3 (III)	1.65	10.4	89.6	4217
Urea				
Lamb #1 (II)	1.36	11.3	88.7	4194
Lamb #2 (III)	1.15	12.3	87.7	4157
Lamb #3 (I)	1.57	11.8	88.2	4236
Straw alone				
First collection				
Lamb #1	1.01	12.7	87.3	4301
Lamb #2	0.98	12.7	87.3	4223
Lamb #3	1.01	12.3	87.7	4360
Second collection				
Lamb #1	0.93	12.4	87.6	4400
Lamb #2	0.94	12.2	87.8	4253
Lamb #3	0.98	12.2	87.8	4406
Third collection				
Lamb #1	1.02	12.5	87.5	4362
Lamb #2	0.98	12.2	87.8	4218
Lamb #3	1.02	12.2	87.8	4287

[a]All values on dry matter basis.

[b]Numbers in parentheses refer to period of Latin square.

Table 10. Weight and nitrogen content of urine from lambs fed wheat straw supplemented with DPW, CSM or urea and wheat straw fed alone.

Diet Lamb	Total urine g	Nitrogen %	Nitrogen g
DPW			
Lamb #1 (III)[a]	12441	0.842	105.0
Lamb #2 (I)	27370	0.352	96.3
Lamb #3 (II)	10318	1.0	103.2
CSM			
Lamb #1 (I)	20034	0.352	70.6
Lamb #2 (II)	10934	0.726	79.4
Lamb #3 (III)	11162	0.763	85.1
Urea			
Lamb #1 (II)	9674	1.2	116.0
Lamb #2 (III)	25548	0.424	112.0
Lamb #3 (I)	15644	0.717	112.2
Straw alone First collection			
Lamb #1	10752	0.224	24.0
Lamb #2	18647	0.155	29.0
Lamb #3	12993	0.176	22.9
Second collection			
Lamb #1	14437	0.133	19.2
Lamb #2	17285	0.147	25.4
Lamb #3	12961	0.123	16.0
Third collection			
Lamb #1	17410	0.08	13.9
Lamb #2	21595	0.08	17.3
Lamb #3	12699	0.13	16.3

[a]Numbers in parentheses refer to period of Latin square.

Table 11. Analysis of variance of data in Table 5

Source of Variation	df	Mean Squares: Intake: Straw g	Total $g/W_{kg}^{.75}$	Nitrogen Utilization: Intake	Fecal	Urinary	Retained	% of Intake	% of Absorbed	B.V.	NPU	Digestibility: Dry Matter	Organic Matter	Nitrogen	Energy
Lambs	2	940.3	5.85	0.93	0.77	0.25	0.55	9.00	13.00	21.33	3.61	3.74	6.18	7.10	7.06
Periods	2	940.3	37.85	1.99	0.20	1.05	0.20	1.90	5.20	52.52	25.47	3.98	3.69	1.87	4.40
N-source	2	940.3	4.00	0.36	2.65	19.55*	12.10*	175.45*	410.70*	50.78	65.61	21.71	19.52	42.50*	14.74
Error	2	5167.1	12.30	0.54	0.32	0.25	0.05	1.95	5.14	104.70	133.80	3.00	2.92	1.77	6.19

*Significance ($P < .05$)

Table 12. Analysis of variance of data in Table 6

Source of Variation	df	Mean Squares: Intake: Straw g	$g/W_{kg}^{.75}$	Nitrogen Utilization: Intake	Fecal	Urinary	Retained	Digestibility: Dry Matter	Organic Matter	Nitrogen	Energy
Lambs	2	4734.30	12.20	0.45	1.40	0.50	1.90	37.70	36.00	95.40	20.10
Periods	2	20748.00	55.70	0.10	0.25	1.30*	0.75	27.40	25.75	24.85	36.10
Error	4	8627.00	24.60	0.12	0.07	0.05	0.12	12.70	12.50	45.05	14.95

*Significance ($P < .05$)

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