

STUDIES ON THE NUTRITIONAL VALUE OF POULTRY
LITTER IN RUMINANTS AND POULTRY

by

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INTRODUCTION

Poultry litter, a poultry industry by-product, which is used primarily as a fertilizer is a potential source of nitrogen for ruminants. A large tonnage of this material is produced in the important poultry producing states. In Virginia, each year approximately 60 million head of poultry use some form of basic litter material. According to Ringrose (1962), the requirement for the basic litter material for poultry in Virginia amounts to 9.5 to 13 million cubic feet annually or approximately 38,000 to 53,000 tons (assuming that 250 cubic feet weigh one ton). At an assumed price of \$20 per ton, approximately one million dollars are expended annually for basic litter material. In commercial practice, the basic litter materials which are generally used include peanut hulls, oat straw, cane bagasse, ground corn cobs, wood shavings and saw dust. For broiler litter, usually one ton of basic material results in formation of approximately three tons of litter.

Considerable work has been conducted on the utilization of various non-protein nitrogen compounds by ruminants. Some of these compounds have been effectively used as a partial replacement for high protein supplements. It has been shown that rumen microorganisms can utilize uric acid nitrogen, a major non-protein nitrogen fraction of the chicken feces. Also, possible action by the microbial population in litter may lead to appreciable synthesis of protein and B-vitamins, and degradation of cellulose. Thus, poultry litter, a waste product of the poultry industry, may possibly serve as a feed supplement.

Published information concerning the proportion of the litter nitrogen that is in the form of protein is limited. If a high proportion of the

litter nitrogen exists in the form of true protein, possibly it could be used to supplement poultry and swine rations. Systematic research work on the nutritional value of poultry litter as a feed for farm animals is seriously lacking.

In order to determine the nutritional value of poultry litter in ruminants and poultry, investigations of the following problems have been conducted in the studies to be reported herein: (a) utilization of broiler litter nitrogen by lambs fed semi-purified rations when four different levels of nitrogen were supplied by litter; (b) protein and energy value of broiler litters, containing peanut hulls and wood shavings as basic materials when incorporated in natural lamb rations at 25 and 50% levels; and (c) feeding value of broiler litter when incorporated at different levels in a chick starter ration.

REVIEW OF LITERATURE

Studies concerning utilization of poultry litter nitrogen are very limited. Since the non-protein nitrogen constitutes a major fraction of the litter nitrogen, a discussion on the utilization of non-protein nitrogen by ruminants seems appropriate.

The concept that the rumen microorganisms may synthesize protein from simple nitrogenous compounds, to supplement the protein supply of the host animal was conceived as early as 1879, by Weiske et al. They suggested this possibility on the basis of nitrogen balance experiments, in which asparagine was fed to sheep on a low protein diet. Later, Zuntz (1891), from a study of cellulose digestion, expressed the view that rumen bacteria used amides, amino acids and ammonium salts by preference, over protein. A major objective of many of the subsequent studies in the field of rumen metabolism has been to study the conditions under which the protein component of ruminant rations can be replaced, at least in part, by non-protein nitrogen.

Utilization of Urea

Undoubtedly, urea has been the non-protein nitrogen compound most commonly used; much of the experimental work in this field has been concerning the optimum conditions for feeding urea. The fact that urea entering the rumen is very rapidly hydrolyzed was observed by Lenkeit and Becker (1938) by in vivo determination on fistulated animals, and by in vitro incubation of urea with rumen contents. Pearson and Smith (1943) demonstrated, by in vitro work, that the rumen had a high urease activity at all times of the day. They also studied the effect of temperature, pH and urea concentration on urea breakdown. They found that urea conversion was maximum at 49°F. The optimum pH range was between 7.0 and 9.0, and there was a

slight increase in conversion of urea to protein with each increased substrate (urea) concentration.

Wegner et al. (1940), in an in vitro experiment, reported that conversion of inorganic nitrogen to microbial protein could occur when urea served as the major nitrogen source. Agrawala et al. (1953) found that in fistulated calves maintained on a purified ration with urea as the nitrogen source, about 90% of the non-protein nitrogen had disappeared from the rumen within 8 hours after feeding. Data on protein in rumen contents indicated that an appreciable amount of protein, which varied from 33 to 100 gm., was synthesized by rumen microorganism in that 8-hour period.

The effect of source of carbohydrate on the conversion of urea to protein was reported by Mills et al. (1942, 1944). They studied the effect of addition of urea, protein, cane molasses and starch to a poor quality hay diet. They reported that urea was utilized more efficiently for ruminal protein synthesis when natural protein level was low and starch was present. They also found that starch was a more valuable energy source than cane molasses. Arias et al. (1951) studied the influence of dextrose, sucrose, cane molasses, starch, cellulose and ground corn cobs on the conversion of urea to protein in vitro by rumen microorganisms. They showed that soluble carbohydrates, such as dextrose, sucrose, and cane molasses tended to inhibit cellulose digestion and slow down conversion of urea to protein, compared to starch. The most marked effects were observed with low levels of soluble carbohydrate in the presence of cellulose. Thus, rations low in protein and high in starch appear to be most favorable for urea utilization by rumen microorganisms.

In vitro studies of Belasco (1954) showed that urea utilization and cellulose digestion gradually increased with increasing levels of urea, and

were maximum when the urea nitrogen level reached a protein equivalent level of 35%. A further increase in concentration resulted in a considerable reduction of bacterial population and cellulose digestion. Also, in promoting cellulose digestion, urea, in a 1:1 mixture with high-protein feeds such as cottonseed, linseed and soybean meal, was found to be superior to the protein meals alone.

Wegner et al. (1941) studied the extent to which urea can replace protein as a nitrogen source. On a basal ration of grain, silage and hay, urea was efficiently utilized when added at the level of 4.5% to a grain mixture containing 11.3% protein. When the protein content of the grain mixture was increased by the addition of linseed oil meal, a slight decrease in rate of urea utilization was observed. Gallup (1956) reported that, in feed lot experiments carried out over a period of 8 years, urea was used successfully to supply up to 50% of the total nitrogen intake of fattening steers. When the urea-nitrogen level comprised 85% of the total nitrogen weight gain and feed intake were reduced. Reid (1954) reported that in rations for fattening cattle, urea utilization declined when urea supplied more than 25% of the total nitrogen. Thus, it appears that the level of protein in the ration needs to be critical for maximum efficiency of urea utilization.

Hart et al. (1939) reported that urea nitrogen was utilized by dairy heifers for growth. Different levels of urea were added to increase the protein content of a corn-hay basal ration (5.4% protein) to protein levels varying from 9.5 to 17.6%. There was no growth on the basal ration, but all the animals on the other rations grew from the beginning of the experiment. At 12 weeks the control animals were given urea at the rate of 1.4 lb. per 100 lb. feed, and they started growing as well as the other animals.

Gallup (1956) reported that in fattening rations for lambs, urea could not replace any of the protein. Groves et al. (1954) showed, in a feeding trial with fattening steers, that urea could replace one-half of the protein equivalent of the soybean meal in a corn-barley-soy concentrate mixture, without any significant difference in average daily gain, feed efficiency, dressing percentage and carcass grade. Meiske et al. (1955), in a lamb fattening experiment, increased a 7% protein basal ration to 9% crude protein, by supplementing with either urea or soybean oil meal, and found no significant differences in rate of gain and feed efficiency between supplements. The rate of gain for the basal ration was significantly lower.

Thompson et al. (1952) showed that when the cottonseed meal portion of an 18% protein concentrate mixture was replaced by an approximately isonitrogenous amount of urea, there was no significant difference in milk yield. They also observed that when cottonseed meal or urea was added to an 11.2% protein control ration, to raise the crude protein level to 16.29 and 15.94%, respectively, a significant increase in milk yield resulted; no difference was observed between the supplemented rations. Lassiter et al. (1958) studied the effect of supplying 0, 30, 50 and 70% of the total nitrogen as urea in rations for dairy cows. They reported slight trends toward lowered milk yields and body weights at the higher urea levels which were not significant.

Thus, urea can be used satisfactorily in ruminants in the phases of growth, fattening and lactation, as a partial protein supplement in the ration. It appears that, in order to obtain efficient utilization, the urea nitrogen should not comprise more than 25 to 30% of the total nitrogen.

Utilization of Miscellaneous Non-Protein Nitrogen Compounds by Ruminants

Recent studies indicate that biuret, a urea condensation product, may have considerable value as a protein replacement. Meiske et al. (1955) reported that when a 7% protein ration was supplemented with either biuret or soybean oil meal to raise the protein content to 9%, no significant difference in rate of gain and feed efficiency was observed between supplemented rations. A significantly lower rate of gain was observed in control group (7% protein). Berry et al. (1956), in feeding trials with poultry, lambs and steers, found that biuret had no toxic effects. Steers fed biuret had poorer appetites and made less gains than those fed urea or protein.

Hatfield et al. (1959), in metabolism studies with lambs on rations supplemented with biuret, urea or both, found a positive nitrogen balance when biuret furnished the greater part of nitrogen intake. Growth and reproduction were satisfactory in sheep fed rations supplemented with either urea or biuret for 593 days. Campbell et al. (1963) reported that biuret produced slightly, but not significantly, lower growth rate and feed efficiency than urea in a study with growing Holstein heifers. This slightly lower response decreased with time.

Studies concerning uric acid metabolism by rumen microorganisms have been quite limited. In vitro studies by Jurtshuk et al. (1955) showed that some of the purines and pyrimidines, including uric acid, were attacked by rumen organisms to yield ammonia, carbon dioxide and acetic acid. Also in in vitro experiments, Belasco (1954) showed that uric acid nitrogen could be utilized by rumen microorganisms.

Kirsch and Jantzen (1933) reported efficient utilization of ammonium bicarbonate by milk cows when it supplied 25% of the nitrogen of the ration. Hart et al. (1939) showed good utilization of ammonium bicarbonate nitrogen in growing calves at a level of 60 to 66% of the nitrogen ingested. In in vitro experiments, Wegner et al. (1940) demonstrated that utilization of ammonium bicarbonate nitrogen was as efficient as for urea nitrogen.

Belasco (1954) evaluated the nutritional significance, for rumen microorganisms, in vitro of various urea derivatives, amides, amidines, and inorganic and organic ammonium salts. The data indicated high availability of nitrogen in numerous organic and inorganic ammonium salts. Ammonium formate, alpha-keto glutarate, carbonate, hydrochloride and acetate of guanidine, malate and especially ammonium succinate and ammonium lactate showed higher rates of nitrogen utilization and lower free ammonia levels than urea. Creatine, creatinine, uric acid and allantoin were also effective nitrogen sources for rumen microorganisms. Repp et al. (1955), while evaluating the relative nutritive value of urea, ammonium acetate, ammonium propionate, ammonium formate, formamide and propionamide, pointed out that all of these except formamide were of equal value in supporting growth of lambs when supplying 50% of the nitrogen of the ration. Russell et al. (1962), while comparing diammonium phosphate (D.A.P.) with urea, with respect to their effect on blood ammonia nitrogen in lambs and steers and nitrogen retention by lambs, reported that higher nitrogen equivalent amounts of D.A.P. than of urea were required to produce adverse effects in lambs.

Numerous organic and inorganic nitrogenous compounds may be used as sources of nitrogen in ruminant rations. It appears that these compounds can be efficiently utilized without any toxic effect when incorporated in the ration to supply a maximum of 25% of the total nitrogen.

Utilization of Ammoniated Products by Ruminants

Miller's (1944) experiment to study the ability of Holstein calves to grow on ammoniated plain sugar beet pulp indicated that the animals could use such a nitrogen source. The animals on a 7% protein control ration gained very little (0.279 lb. per animal per day). The calves fed ammoniated beet pulp gained at the rate of 1.60 lb. per day compared to 1.96 lb. for those fed toasted soybean meal. No diuresis, abnormality in blood constituents, discoloration or off-flavor of the meat were noticed from feeding the ammoniated product.

Knodt et al. (1951) conducted feeding experiments with growing Holstein bulls, in which rations containing ammoniated cane molasses, ammoniated inverted cane molasses, and ammoniated condensed distillers molasses as isonitrogenous replacements for soybean meal and oats were tested. They showed that nitrogen from these sources can be used by the calves only after 12 weeks of age and that nitrogen from these products was as digestible as that of the soybean meal and oats, in calves 15 to 16 weeks of age.

Tillman and Swift (1953) found that the inclusion of ammoniated products, including ammoniated condensed distillers molasses solubles and ammoniated cane molasses, resulted in a decrease in digestibility of all ration constituents except ether extract. Also, nitrogen retention was greater for rations containing urea and soybean protein than for those containing

ammoniated products. Metabolizable energy was lowest in the rations containing ammoniated products. Later, Tillman et al. (1957) indicated that in steer fattening rations, the nitrogen in ammoniated cane molasses and ammoniated furfural residue was not utilized very efficiently. These results were obtained in feeding trials and were confirmed in digestion and nitrogen balance trials. The digestibility of crude protein (calculated by difference) in the ammoniated cane molasses products which supplied 55% of the total ration nitrogen was only 59%. This was low when compared to that of the cottonseed meal. These workers also reported that feeding cattle a high test ammoniated molasses (32% crude protein) at a level of 2 lb. per day produced a peculiar nervous stimulation within 5 to 6 days. A similar response was observed by Richardson et al. (1956) in cattle fed fairly low levels of ammoniated cane molasses in the ration. Ferguson and Neave (1952) reported that nitrogen in ammoniated beet pulp was not as readily available as that in urea. McCall et al. (1953) reported that furameal (35% protein equivalent and composed of hydrolyzed and ammoniated corn cobs and oat hulls) was as effective as protein in producing gain in fattening steers, when it replaced 20 to 40% of the supplemental protein. Magurder et al. (1953) reported that gain in weight and feed efficiency of Holstein heifers receiving a grain mixture containing 10% ammoniated hemicellulose extract were comparable to those of heifers fed an isonitrogenous soybean oil meal-grain ration.

Thus, it seems that ammoniated industrial by-products and some other ammoniated feeds do provide nitrogen which is utilized to a certain degree by rumen microorganisms. However, the efficiency of utilization of the

nitrogen in these products does not appear to be as high as conventional protein supplements. Possibly this may be attributed to the nature of combination when nitrogen is incorporated into the products, which are perhaps less readily attacked by the enzyme systems, and to the relatively low readily available energy content of the products.

Poultry Industry By-Product Protein Supplements in Ruminant and Chick Diets

In the past few years, interest has developed in the use of poultry by-products in rations for sheep and cattle. Jordan and Groom (1957) fed feeder lambs on corn, hay, minerals and a protein supplement, containing feather meal in amounts varying from 25 to 50%. Rate of gain was not significantly altered by feeding supplements containing these levels of feather meal, compared to soybean meal. Feather meal did not affect palatability of the protein supplement. The effect of feeding feather meal to beef cattle was studied by Ray (1959). Steers were fed hay and a grain-protein supplement mixture composed of nine parts of corn and one part of either cottonseed meal, feather meal, blood and bone meal or a combination of equal parts of the three protein supplements. Average daily gain of the steers was highest when blood and bone meal or a combination of the three protein supplements was used. Digestion coefficients were comparable for feather meal, blood and bone meal, and the combination supplement, but was lower for cottonseed meal.

A number of investigators have found good quality feather meal to be a satisfactory substitute for a fraction of the soybean oil meal protein in chick starting rations composed largely of soybean oil meal and cereal grains. Wilder et al. (1955) found that feather meals could replace 2 to 4%

of the soybean oil meal protein in chick starter containing a total of 20% crude protein. Naber (1955) and Naber and Morgan (1956) demonstrated that feather meal could replace one-fourth of the protein in a corn-soy-fish meal broiler ration. Lillie et al. (1956) found that 5% feather meal could be substituted for 5% fish meal in a corn-soybean oil meal diet, without detrimental effect. Sullivan and Stephenson (1957) reported that feather meal at the 5% level supported chick growth that was equivalent to that for the corn-soybean oil meal control diet. A level of 7.5% feather meal depressed growth rate. Wisman et al. (1958) reported that feather meal was a satisfactory source of animal protein in broiler, grower and layer rations, when used to replace up to one-sixth of the crude protein. Bhattacharya (1962) confirmed that feather meal could replace satisfactorily up to 20% of the crude protein in a chick starter ration containing peanut meal and ragi, fortified with fish meal.

The detailed nutrient composition of poultry offal has been studied by Wisman et al. (1957) and Acker et al. (1959). They predicted that the high histidine, isoleucine, lysine and methionine content of poultry offal could be used to complement feather meal protein. The pepsinhydrochloric acid digestibility of poultry offal protein was 91% (Acker et al., 1959). Fuller (1956), Gerry (1956), Naber (1955, 1956) and Romoser (1955) have shown that chick growth was improved when poultry meat scrap was substituted for soybean meal protein in a corn-soybean meal ration. The material also appeared to be a good source of vitamin B₁₂ as reported by Naber and Morgan (1956). Blood meal has also been used successfully in experimental diets by Wilder (1953) and Wisman et al. (1958). A combination of blood meal and feather meal promoted better growth than feather meal alone. The

high histidine, lysine, phenylalanine, leucine and valine content of blood meal was probably responsible for the improved growth rate. Naber et al. (1961) reported on feeding poultry by-product meal in which blood, offal and feathers were recombined in naturally occurring proportions. They showed that substituting the combination product for a portion of the soy protein of a corn-soy ration stimulated chick growth, and gave results superior to those obtained from only feather meal supplementation.

Feeding Value of Feces

Anthony and Nix (1962) reported observations on the feeding value of fecal residues obtained from the feces of yearling bullocks on a high concentrate ration. The solid material in feces was settled in water, and, after rejection of the aqueous layer, the wet residue was stored and later fed to yearling bullocks at a level of 40% of the ration. Average daily gain, and dry matter intake per 100 lb. gain was 3 lb. and 643 lb., respectively.

Studies with poultry manure have been limited. Its high crude protein content ($N \times 6.25$) and its abundance justify its consideration as a potential feed stuff, with proper processing. Yushok and Bear (1943) observed that old litter manure from laying hens contained 2.50 percent nitrogen (15.6% crude protein) on an oven dried basis. Fresh hen manure contained 25.87% crude protein, dry basis. White et al. (1944) reported that dried hen manure contained 5.62% nitrogen. Parker et al. (1959) obtained samples of poultry litter from 31 hen houses and 82 broiler houses, and found their average nitrogen content to be 2.00 and 2.27%, equivalent to 12.50 and 15.28% crude protein, respectively.

Verbeek (1960) used dried fowl manure containing 4% nitrogen in supplementing cattle rations. When young oxen were given a concentrate ration containing 24% fowl manure to supplement mealie cob leaves, satisfactory weight increases were obtained. Later, Verbeek (1960), in a cattle feeding trial, used fowl manure containing 13.8% crude protein at levels of 0, 25 and 50% of a corn-oil cake concentrate mixture. Each animal received 10 lb. concentrate mixture and good quality teff hay ad libitum. Average daily gain was significantly higher in the fowl manure fed groups than in the control group.

A considerable portion of the total nitrogen of poultry manure exists in non-protein forms such as uric acid and ammonium salts. Ekman et al. (1949) reported that 66 to 89% of the total nitrogen in poultry excreta exists as non-protein nitrogen. Non-protein nitrogen is usually of little nutritional value to non-ruminants, although, under certain conditions, it may be used to synthesize non-essential amino acids. Rose et al. (1949) reported a marked acceleration in growth of rats when diammonium citrate, diammonium acetate, urea, glycine, or L-glutamic acid was added to a purified diet containing minimum levels of the 10 essential amino acids. Lardy and Feldutt (1950), also working with rats, obtained a growth response with diammonium citrate equal to that produced by an isonitrogenous mixture of non-essential amino acids, when used to supplement a purified diet containing the 10 essential amino acids. Sullivan and Bird (1957) observed an increase in chick growth when urea or diammonium citrate was added to low protein diets containing hydroxy analogues of methionine and glycine. Similar results have been reported by Machlin et al. (1957).

Prior to the discovery of vitamin B₁₂, Rubin et al. (1946) reported on the unidentified growth factor activity of various types of manure when used in poultry rations. Fuller (1956) reported that hydrolyzed poultry manure was as effective as fish meal in supplementing a commercial type broiler ration under practical conditions. Wehunt et al. (1960) studied the protein value and unidentified growth factor activity of hydrolyzed hen and broiler manure. About one-half of the crude protein of the hen manure and one-third of that of the broiler manure used in this study existed as true protein. Growth rate of chicks was improved when these materials were added to diets, sub-optimal in protein, to provide additional 1.5 and 3.0% crude protein in the diet. Feed efficiency was not improved and at higher levels of manure, it was depressed slightly. The autoclaved manure appeared to be nearly equal to a combination of fish solubles and dried distillers' solubles in unidentified growth factor activity. Pryor and Conner (1964) used chicken feces in broiler diets as an energy and protein-rich concentrate. They found that metabolizable energy content of the chicken feces, when fed with sorghum in 20:80 ratio was about 30% of that of the feed from which the feces originated.

Durham et al. (1964) studied the feeding value in pullets of feces from cattle fattened on all-concentrate rations. In the feeding experiment, feces containing 19% crude protein were incorporated into the diet at levels ranging from 0 to 40%, as a replacement for milo. Pullets fed manure gained faster and consumed more feed than those on the control diet.

Use of Poultry Litter in Rations of Ruminants and Poultry

Noland et al. (1955) found that ewes fed chicken litter as the protein supplement performed as well as those fed soybean meal. In fattening steers,

chicken litter was inferior to cottonseed meal. Litter-fed steers gained slower than those fed cottonseed meal. The difference was significant when nitrogen and dry matter intake of the two groups were equal. When the intake of the chicken litter ration was increased by 15% to more nearly equate the energy intake of two groups, no significant difference in the rate of gain between the groups was observed.

Southwell et al. (1958) used ground corn cob poultry litter in a steer fattening trial. The rations compared were: a) litter, 30% and cracked shell corn, 70%; b) litter, 15%; cottonseed meal, 7.5%; and ground snapped corn 77.5%; c) cottonseed meal, 15%; and ground snapped corn, 85%. All animals received 8.5 lb. of Bermuda grass hay per head per day. There was little difference in average daily gain among the groups. The group receiving 30% litter required more feed per pound of gain.

Fontenot et al. (1963), in studies with fattening steers, showed that weight gain of steers fed a peanut hull litter ration was approximately the same as for those fed a control ration containing soybean meal as the protein source. The cattle fed a wood shavings litter ration gained slightly less than those on the other two rations. Feed efficiency was higher for the litter rations than for the control ration. The highest feed efficiency was for the peanut hull litter ration. Feeding poultry litter did not adversely affect the flavor of the meat.

Fontenot et al. (1964) conducted a 56-day winter feeding trial to study the value of dehydrated broiler litter as a protein supplement for wintering steers and heifers. The feeding of litter had no marked effect on daily gain of cattle. The average daily gain was 1.25 lb. for the three lots fed cottonseed meal and 1.22 lb. for three fed poultry litter.

Research on use of poultry litter in poultry rations has been very limited. Elam et al. (1954) added an autoclaved water suspension of poultry litter to a corn-soybean meal basal diet supplemented with recommended levels of necessary vitamins and minerals. Growth was increased equally by addition of the litter preparation, fish soluble or an antibiotic combination. Wehunt et al. (1960) conducted an experiment to obtain a measure of the biological value of the crude protein in hydrolyzed peanut hull broiler litter. The litter was processed by cooking at 30 lb. pressure for one hour, dried, ground and the coarser materials removed by screening. A 15% protein, high energy diet was used as control. Additional amounts of crude protein at levels of 1.5 and 3% were supplied by broiler litter, by inclusion of 10 and 20% litter respectively, in the diet. Energy and fiber were equalized by varying the levels of the ingredients. The results indicated that chicks could utilize part of the protein of hydrolyzed broiler litter when added to a diet that was suboptimal in protein. Feed conversion did not show any improvement at lower levels and was inferior at higher levels of litter.

EXPERIMENT 1. UTILIZATION OF DIFFERENT LEVELS OF POULTRY LITTER NITROGEN BY SHEEP

The purpose of this experiment was to study the efficiency of utilization by sheep of the nitrogen in peanut hull poultry litter. Four different levels of nitrogen were supplied by litter in semi-purified rations.

Experimental procedure

Three digestion and nitrogen balance trials were conducted with eight lightweight (av. initial wt., 29.5 kg.) yearling wethers from February 8 to April 20, 1964. The experimental design consisted of two randomized blocks of four wethers each for each trial. The four sheep within each block were randomly allotted to four ration treatments for each trial.

Broiler litter¹ containing peanut hulls as the basic material was collected in jute bags and sterilized in a large size autoclave for 40 minutes at 240° F. under steam pressure of 15 lb. per square inch. The litter was then air dried by spreading it in a thin layer. After the litter was dry, it was ground in a hammer mill fitted with a screen of 1/4 inch mesh size, and stored at room temperature.

The composition of the rations used in this study is shown in table 1. The control diet (Ration 1) was composed of purified ingredients. The protein was supplied by isolated soy protein, assay protein C-1. In rations 2, 3 and 4, sterilized litter was incorporated at such levels as to replace 25, 50 and 100% of the soybean protein nitrogen. The proportions of the ingredients were altered in an attempt to equalize crude protein, crude fiber, calcium and phosphorous contents of the rations. The

¹ Obtained from Rocco Feeds, Inc., Harrisonburg, Virginia

mineral mixture used in the basal ration was that of Oltjen et al. (1962). In the litter rations calcium and phosphorus contents were lowered in order to adjust for the calcium and phosphorus supplied by litter, but the proportion of other minerals in the mineral mixture was the same as for the

TABLE 1. INGREDIENT AND CHEMICAL COMPOSITION OF RATIONS

Ration no.	1	2	3	4
Level of litter-N (%)	0	25	50	100
Ingredient composition (%)				
"Solka floc" ^a	44.40	43.26	42.13	39.85
Assay protein C-1 ^b	12.49	9.37	6.25	-----
Poultry litter	-----	8.97	17.94	35.88
Cerelose ^c	16.01	14.14	12.27	8.34
Corn starch	16.01	14.14	12.27	8.34
Corn oil ^d	3.90	3.90	3.90	3.90
CaHPO ₄ ·2H ₂ O	3.52	2.44	1.35	-----
CaCO ₃	-----	0.1088	0.2060	-----
Mineral mixture ^e	3.68	3.68	3.68	3.68
Vitamins A and D ^f	+	+	+	+
Alpha-tocopherol ^g	+	+	+	+
"Santoquin" ^h	+	+	+	+
Chemical composition (%)				
Dry matter (%)	92.85	92.80	92.57	91.98
Percent composition of dry matter				
Crude protein	11.44	11.42	11.39	11.26
Crude fiber	38.18	39.20	40.14	40.49
Ether extract	4.12	4.05	4.53	4.74
Ash	5.86	6.69	7.63	9.46
NFE	40.56	38.63	36.32	34.05
Calcium	0.92	0.91	0.94	0.98
Phosphorus	0.78	0.72	0.66	0.68

- ^a Purified cellulose. The Brown Co., Berlin, N.H.
^b Purified soybean protein. Archer-Daniels-Midland Co., Cincinnati, Ohio
^c A commercial preparation of glucose. Corn Product Refining Co., New York
^d "Mazola". Corn Product Refining Co., New York
^e Oltjen *et al.* (1962)
^f 20,000 U.S.P. units of Vit. A. and 2,500 U.S.P. units of Vit. D/gm. of vit. mixture. Included at level of 7.62 gm./100 lb. feed
^g Alpha tocopherol: 570 gm./100 lb. feed
^h Monsanto Chemical Co., St. Louis, Mo., 5.68 gm./100 lb. feed

basal ration. Vitamins A, D and E, and antioxidant were added to all rations. All the rations were fed at the same level of 600 gms. per day per sheep. This intake furnished nutrient levels which were above the maintenance requirements established by N.R.C. (1957).

The sheep were placed in metabolism stalls, similar to those of Briggs and Gallup (1949), two weeks prior to starting the experiment for adjustment to the environment. Before the sheep were placed in the stalls, they were sheared and their hooves were trimmed. During the adjustment period, the animals were drenched at weekly intervals with anthelmintic until the internal parasite count was within the normal range. Initially, the sheep were fed a ration containing 50% mixed hay, 35% shelled corn and 15% cottonseed meal. In order to adjust the sheep to the experimental rations, the natural ration was gradually replaced by the rations the sheep were to be fed, with successive increases at the rate of 20% of the ration each day. The sheep were fed twice daily at 6:00 A.M. and 5:00 P.M. The feeding period lasted two hours. The wethers had access to water all times, except during feeding periods. Each trial consisted of a 10-day preliminary period followed by a 10-day collection period, during which total feces and urine collections were made. Weights of the sheep were recorded before and after the trials, following a 6-hour period away from feed and water.

Feces were collected in metal boxes, were picked up once daily and dried for 24 hours in a forced-draft oven at a temperature of approximately 55° C. The total daily collections were composited in metal cans. At the end of the trial representative samples were taken for analysis after thorough mixing of the feces. Urine was collected in glass jars containing 20 ml. of dilute sulphuric acid (1:1 by wt.) and 500 ml. of water. Each

24 hr. collection was diluted to 7 kg. with water, and a 2% sample, by volume, was taken. The daily samples were composited in tightly covered glass jars under refrigeration. Each ration was sampled at each feeding during preliminary and collection periods, and the samples were composited for a given trial.

Urine was analyzed for nitrogen and feed and feces for the proximate components except crude fiber according to A.O.A.C. (1960) methods. Crude fiber was determined by the method of Whitehouse et al. (1945). In partitioning litter nitrogen, uric acid was determined by modification of the direct colorimetric method of Benedict and Franke (1922), after extraction with LiCO_3 solution according to Buys et al. (1958). True protein was determined by the method of Agricultural Education Association (1945) with the modification of using 0.5% LiCO_3 solution instead of water. Urea was determined by the method of Coulombe and Faurean (1963) and creatine according to the Folin method (1914). Free ammonia was determined according to the A.O.A.C. (1960) method for free ammonia in fertilizer. Lignin was determined according to the method of Sullivan et al. (1959). Amino acid composition was analyzed by the method of Spackman et al. (1958).

On the twenty-first day of each trial rumen samples were taken by stomach tube approximately 2 hours after the morning feeding. The samples were filtered through four thicknesses of cheese cloth. One ml. aliquot of each sample was added to 9 ml. of 11% trichloroacetic acid solution and preserved by freezing. At that time, blood samples were obtained from the jugular vein in oxalated tubes. Rumen samples were analyzed for free-ammonia and non-protein nitrogen according to the method of Smith et al. (1956). The semi-micro colorimetric method of Coulombe et al. (1963) and

the modified ninhydrin colorimetric method of Fisher et al. (1963) were ~~use-~~ used for the determination of urea and alpha-amino nitrogen in blood plasma, respectively. Protein and non-protein nitrogen of the blood were determined according to procedures outlined by Hawk et al. (1954). Blood ammonia was determined according to the method of Smith et al. (1956). The data from the trials were subjected to analysis of variance. The multiple range test (Duncan, 1955) was used to test for significance among treatment groups.

Results and Discussion

The chemical composition of the peanut hull broiler litter is shown in table 2. The proportions of the various nitrogen fractions are given in table 3 and the amino acid composition in table 4. The litter contained 32.6% crude protein and 13.1% crude fiber, dry matter basis. Apparently, a large portion of the fiber consisted of lignin, since the litter contained 9.4% lignin. The calcium and phosphorus contents were quite high, amounting to 2.77 and 2.86% respectively, dry basis.

It was found that true protein nitrogen comprised 46% of the total nitrogen. Apparently, feed particles, shed feathers and bacterial synthesis contributed to this fraction. The true protein was very high in glycine, glutamic acid and aspartic acid (table 4). The uric acid nitrogen fraction was found in the next highest amount, the figure being 30.5%. The litter used by Noland et al. (1955) contained only 17% of the total nitrogen as uric acid. As fresh chicken feces contains about 70% of the total nitrogen in the form of uric acid (Albritton, 1955), the value of 30% of the total nitrogen obtained in this study seems reasonable, considering the dilution effect of the basic litter material, and loss through ammonia formation. Also, possibly, some of the uric acid

was used in microbial protein synthesis in the litter bed of the broiler house. Free ammonia was the fraction occurring in the next highest amount (13%). The ammonia in the processed litter seemed to be in a very stable combination with the basic material, since there was insignificant loss during storage. The strong smell of ammonia during collection and processing indicated that some of the ammonia volatilized.

TABLE 2. CHEMICAL COMPOSITION OF PEANUT HULL POULTRY LITTER

Dry matter (%)	85.5
Percent composition of dry matter	
Crude protein	32.58
Crude fiber	13.06
Ether extract	3.0
Ash	17.40
NFE	33.96
Lignin	9.40
Calcium	2.77
Phosphorus	2.86
Gross energy of dry matter (kcal./gm.)	3.86

TABLE 3. PARTITION OF THE NITROGEN IN PEANUT HULL POULTRY LITTER

Form of nitrogen	Gm. N per 100 gm. total N
True protein	46.25
Uric acid	30.49
Ammonia	13.24
Urea	2.69
Creatine	4.48
Others	2.85

TABLE 4. AMINO ACID COMPOSITION OF PEANUT HULL POULTRY LITTER

Amino acid	Composition (%) ¹
Lysine	1.76(3.80)
Histidine	0.73(1.58)
Arginine	1.55(3.35)
Asparatic acid	4.12(8.91)
Threonine	1.86(4.01)
Serine	1.89(4.08)
Glutamic acid	6.49(14.03)
Proline	2.95(6.51)
Glycine	9.14(19.76)
Alanine	2.86(6.19)
Cystine	0.49(1.05)
Valine	2.65(5.74)
Methionine	0.48(1.03)
Isoleucine	2.09(4.51)
Leucine	3.29(7.12)
Tyrosine	1.16(2.50)
Phenylalalanine	1.77(3.82)

¹ Figures in parenthesis refer to gm. of amino acid per 100 mg. of true protein and those not in parenthesis refer to gm. per 100 gm. of crude protein. Tryptophan content was not determined.

No digestive disturbance or significant feed rejection was observed in the sheep on the rations containing litter. One sheep was lost after trial 1 due to urolithiasis. In trial 2, one observation was lost due to heavy feed rejection of one sheep on the control diet. Missing values were replaced, for statistical analyses, according to the method described by Snedecor (1956).

Apparent digestion coefficients of the constituents of each ration are presented in table 5. The digestion coefficient for crude protein was 71.3% for the ration containing no litter nitrogen. When 25% of the nitrogen was supplied by litter there was no significant change. When 50% of the nitrogen was supplied by litter, there was a small depression in protein digestibility to 68.3%, which was significant. There was a large decrease

in digestibility of crude protein to 57.7% ($P < .01$) when 100% of the nitrogen was supplied by litter. Crude fiber digestibility of the control ration was 73.9%. There was no significant difference in crude fiber digestibility. Among the litter rations, there was a trend toward a depression in digestibility as the level of litter increased. For example, the crude fiber digestibility was 76.8, 74.1 and 71.0% for rations containing 25, 50 and 100% litter nitrogen. The average values for ether extract and NFE digestibility were lowest at the high litter levels (100% litter nitrogen) but differences were not significant. For dry matter digestibility, the low value at the highest litter level was significantly different.

Apparent digestibility of the poultry litter crude protein (table 5) as calculated by difference was 67.1 and 64.8% when 25 and 50% of the total nitrogen in the ration was supplied by litter. These values for litter crude protein digestibility when litter supplied 25 and 50% of the total nitrogen are not much lower than the 71%, for soy protein digestibility. In practical rations, usually no more than 50% of the nitrogen would be supplied by litter. In the studies with sheep, reported under experiment 2, the digestion coefficient for litter protein was 73% when 50% of a typical hay-corn natural ration was replaced by peanut hull litter. Recently, Brugman et al. (1964) reported that the digestion coefficient for crude protein of laying house poultry litter in Hereford bulls was 77.8% when fed in a ration containing a 5:2 mixture of litter and dried potato pulp. Thus, the crude protein digestibility of peanut hull poultry litter appears to be higher when incorporated in natural rations than when fed with purified ingredients, as in this study.

TABLE 5. APPARENT DIGESTION COEFFICIENTS OF SEMI-PURIFIED RATIONS CONTAINING DIFFERENT LEVELS OF LITTER NITROGEN

Ration no.	1	2	3	4
Level of litter-N (%)	0	25	50	100
Apparent digestibility (%)				
Dry matter	78.4 ^b	79.1 ^b	76.6 ^b	71.2 ^c
Crude protein				
Total in ration	71.3 ^d	70.4 ^d	68.3 ^e	57.7 ^f
Poultry litter ^a		67.1 ^d	64.8 ^d	57.7 ^e
Crude fiber	73.9	76.8	74.1	71.0
Ether extract	89.0	88.0	88.9	85.8
NFE	85.2	84.3	84.9	80.6

^a Calculated by difference for lots 2 and 3

^{b, c} Means on the same line having different superscript letters are significantly ($P < .05$) different

^{d, e, f} Means on the same line having different superscript letters are significantly ($P < .01$) different

Nitrogen utilization for the four levels of litter nitrogen in the rations is presented in table 6. Nitrogen intake was similar for the sheep fed all four levels of litter nitrogen. Fecal nitrogen excretion for the sheep fed the ration containing 25% litter nitrogen was not markedly different than that of sheep fed the control ration. At the 50 and 100% litter nitrogen levels, there were increases in fecal nitrogen to the extent of 0.3 and 1.2 gm. per day, respectively. There were no significant differences in urinary nitrogen excretion among the treatment groups. Percent nitrogen retention was 22.0, 15.4, 14.9 and 7.6, respectively, for sheep on rations 1, 2, 3, and 4. The value of 22.0% for lot 1 (no litter nitrogen) was significantly greater than that of 7.6 for lot 4 (100% litter nitrogen). The other differences in nitrogen retention were not significant. The values for percent utilization of absorbed nitrogen were 30.8, 21.8, 21.8

and 13.18 for the rations 1, 2, 3 and 4, respectively. The value 13.2 for the 100% litter nitrogen level was significantly lower than the value of 30.8 when no litter nitrogen was fed. Again, the other differences were not significant. Thus, the utilization of poultry litter nitrogen up to 50% of the total nitrogen was not significantly different from that of soy protein nitrogen.

TABLE 6. NITROGEN UTILIZATION IN WETHERS FED SEMI-PURIFIED RATIONS CONTAINING DIFFERENT LEVELS OF LITTER NITROGEN

Ration no.	1	2	3	4
Level of litter-N (%)	0	25	50	100
Nitrogen intake, gm./day	9.70	9.50	9.75	9.39
Nitrogen excretion, gm./day				
Fecal	2.76	2.80	3.08	3.97
Urinary	4.80	5.24	5.21	4.71
Total	7.56	8.04	8.29	8.67
Nitrogen retention, gm./day	2.14 ^a	1.46 ^{ab}	1.46 ^{ab}	0.71 ^b
Nitrogen retention, %	22.03 ^a	15.36 ^{ab}	14.94 ^{ab}	7.61 ^b
Percent util. of absorbed N	30.80 ^a	21.77 ^{ab}	21.84 ^{ab}	13.18 ^b

a, b Means on the same line having different superscript letters are significantly ($P < .01$) different

Levels of non-protein and ammonia nitrogen in rumen fluid are shown in table 7. Level of litter nitrogen did not consistently affect the levels of these constituents in rumen fluid; however, the non-protein nitrogen level was lower ($P < .01$) for the 50% litter nitrogen level, and the ammonia nitrogen levels were higher ($P < .01$) for the 25% and 100% litter nitrogen levels. Annison *et al.* (1954) reported ammonia nitrogen values ranging from 44 to 54 (mg./100 ml.) among sheep fed rations with casein as the source of protein.

The blood plasma nitrogen fractions are shown in table 8. There were no significant differences in plasma nitrogen fractions among the

rations containing different levels (0 to 100%) of litter nitrogen. A tendency for a rise in the blood urea level was observed in sheep on the litter rations but the differences were not significant. Ammonia and urea levels in peripheral blood were in good agreement with those for sheep on a hay-casein ration as reported by Lewis (1957). Normal ranges of total non-protein nitrogen, urea nitrogen and alpha-amino nitrogen (mg./100 ml.) in blood of sheep are 20-38, 8-20 and 4.68-8, respectively, (Dukes, 1955). The values obtained in this study are within the normal ranges. According to Lewis (1957) the overall pattern of rumen ammonia and blood urea concentrations are roughly parallel, and the measurement of their concentration was proposed as a supplementary test for the efficiency of nitrogen utilization in ruminants. The apparently normal values in the blood and rumen fluid suggest efficient utilization of litter nitrogen by rumen organisms under these conditions.

TABLE 7. NON-PROTEIN AND AMMONIA NITROGEN CONCENTRATION IN RUMEN FLUID OF WETHERS FED SEMIPURIFIED RATIONS CONTAINING DIFFERENT LEVELS OF LITTER NITROGEN

Ration no. Level of litter-N (%)	1 0	2 25	3 50	4 100
Non-protein nitrogen (mg. per 100 ml.)	79.37 ^a	78.75 ^a	66.45 ^b	76.25 ^a
Ammonia nitrogen (mg. per 100 ml.)	44.20 ^a	51.05 ^b	42.67 ^a	47.93 ^b

^{a, b} Means on the same line having different superscript letters are significantly ($P < .01$) different

TABLE 8. CONCENTRATION OF VARIOUS NITROGEN FRACTIONS IN BLOOD PLASMA
(mg./100 ml.) OF SHEEP FED SEMIPURIFIED RATIONS CONTAINING
DIFFERENT LEVELS OF LITTER NITROGEN

Ration no. Levels of litter-N (%)	1 0	2 25	3 50	4 100
Urea nitrogen	10.77	12.50	11.97	11.42
Ammonia nitrogen	0.1989	0.1831	0.1564	0.1607
Alpha-amino nitrogen	5.63	4.87	6.06	5.67
Non-protein nitrogen	34.22	38.22	35.11	38.0
Total protein nitrogen	916.7	958.3	966.7	946.2

EXPERIMENT 2 . ENERGY AND PROTEIN VALUE OF PEANUT HULL AND WOOD SHAVING POULTRY LITTERS WHEN INCORPORATED IN A NATURAL RATION

The objective of this experiment was to determine the efficiency of utilization of energy and protein of peanut hull and wood shaving poultry litter, when these were incorporated at different levels in a natural ration.

Experimental procedure

Three digestion and metabolism trials were conducted from July 16 to September 8, 1964 with 10 light-weight yearling wethers averaging approximately 29 kg. initially. The experimental design consisted of two randomized blocks of five wethers each, for each trial. In each trial, the five sheep within each block were randomly allotted to five ration treatments.

The rations and their chemical composition are shown in table 9. The control ration was composed of alfalfa hay and shelled yellow corn in a 1:1 ratio. In rations 2 and 3, peanut hull poultry litter was incorporated at levels of 25 and 50%, respectively. Similarly, in rations 4 and 5 wood shaving poultry litter comprised 25 and 50% of the ration, respectively. When fed, litter replaced equal parts of the shelled corn and alfalfa hay. Iodized salt was fed at the rate of 10 gm. per head per day. The hay and corn were ground in a hammer mill through a 5/16 inch screen. Feed needed for all three trials was stored in excess prior to the beginning of the first trial. Ration ingredients were mixed by hand just before feeding twice daily to insure uniform intake of all ingredients at each feeding.

The peanut hull and wood shaving broiler litter used were obtained from a commercial broiler producer¹. Both kinds of litter were obtained

¹ Rocco Feeds, Inc., Harrisonburg, Virginia

from similar types of broiler houses. One crop of broilers had been housed in each of the two houses for a comparable length of time. Thus, the only important difference between the two litters was the kind of basic material (peanut hulls and wood shavings) used. The peanut hull litter was from the same batch as used in experiment 1. The litters were processed, including grinding, as described for experiment 1. Both kinds of litters were analyzed for proximate components, nitrogen fractions and for amino acid content, using the methods outlined for experiment 1.

TABLE 9. RATIONS AND THEIR CHEMICAL COMPOSITION

Ration no.	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Kind of litter		Peanut hull		Wood shaving	
Level of litter (%)	0	25	50	25	50
Rations (gm./day) ^a					
Alfalfa hay	400	300	200	300	200
Shelled yellow corn	400	300	200	300	200
Peanut hull litter	---	200	400	---	---
Wood shaving litter	---	---	---	200	400

Chemical composition					
Dry matter (%)	88.83	88.89	88.95	88.83	88.84
Percent composition of dry matter:					
Crude protein	13.77	18.35	22.92	17.97	22.16
Crude fiber	15.21	15.20	15.27	15.21	15.00
Ether extract	3.67	3.44	3.24	3.43	3.24
Ash	4.11	7.37	10.80	7.47	11.29
NFE	63.26	55.64	47.77	55.92	48.30
Calcium	0.72	1.05	1.62	1.05	1.42
Phosphorus	0.28	0.81	1.38	0.67	1.14

^a The sheep were fed 10 gm. iodized salt per head per day, in addition.

During the trials, the sheep were kept in the digestion and metabolism stalls described for experiment 1. Each trial consisted of a 10-day preliminary period followed by a 7-day collection period, during which total fecal and urinary collections were made. The sheep were weighed before and after each trial after a 6-hour period away from feed and water. The methods used in the collection of feces and urine and sampling of feeds and excreta were as described for experiment 1. Feed, feces and urine were analyzed using the methods outlined for experiment 1.

The urine was prepared for energy determination by drying in a VirTis mechanically refrigerated, vat type freeze dryer. The procedure was similar to that described by Paladines et al. (1964). Specifically, the procedure for each sample was as follows: A 200 ml. sample of urine was weighed in a tared plastic freezer container (2 3/4 in. x 3 in. x 2 1/2 in.). The sample was frozen overnight. The plastic containers containing the samples were then placed on the cooled heat racks of the freeze dryer. Heat was applied to the heat racks (approximately 90° F.) during drying. Samples were completely dried after 3 days, when they were removed and stored in air tight containers in a prewarmed hot air oven. Energy determinations were made using about 0.5 gm. of representative samples of urine solid.

Methane production was calculated using the formula of Swift et al. (1948).

Digestibility of the various components including that of energy in the poultry litters was calculated by difference, from the digestibility data of the rations. Total digestible nutrient (TDN), digestible

protein, digestible energy and metabolizable energy were calculated, by difference. In calculating the digestion coefficients and metabolizable energy the formula outlined by Crumplin and Lloyd (1959) was used (tables 22 and 23). The data were subjected to analysis of variance and differences between levels and kinds of litter were tested for significance by Duncan's (1955) multiple range test.

Results and Discussion

Data on the chemical composition, partition of nitrogen and amino acid content for the two kinds of litter are given in tables 10, 11 and 12, respectively.

The chemical composition of the two litters were similar. The crude protein content of the peanut hull litter was higher only by 1.5 percentage units than that of wood shaving litter. The lignin content was higher for the wood shaving litter. This is not surprising, since wood is higher in lignin content than peanut hulls (Bonner, 1950). Peanut hull litter contained a slightly higher proportion of true protein and uric acid and a lower proportion of ammonia. No marked differences were observed in the amino acid composition between the litter proteins. In fact, for almost all the amino acids the contents were almost identical. A notable exception was glycine, which was higher for the peanut hull litter.

All of the rations were readily consumed by the sheep. No digestive disturbance or significant feed rejection was observed.

Apparent digestion coefficients for the five rations are presented in table 13. Crude protein digestibility for the litter rations was similar as for the control ration. There were no significant differences in protein digestibility due to level or kind of litter in the rations. Crude fiber digestibility showed no significant differences among the litter rations. The digestibility for these rations was significantly ($P < .01$) higher than that for the control ration. Ether extract digestibility for the ration containing 50% peanut hull litter was significantly lower than for the other rations, but no significant differences were observed among other treatments.

TABLE 10. CHEMICAL COMPOSITION OF PEANUT HULL AND
WOOD SHAVING POULTRY LITTER

Component	Peanut hull litter	Wood shaving litter
Dry matter (%)	89.07	88.86
Percent composition of dry matter		
Crude protein	32.05	30.58
Crude fiber	15.11	14.61
Ether extract	2.81	2.77
Ash	17.93	18.99
NFE	31.85	33.08
Lignin	9.4	10.36
Calcium	2.77	2.48
Phosphorus	2.86	2.26
Gross energy (kcal./gm. dry matter)	3.86	3.75

TABLE 11. PARTITION OF NITROGEN IN PEANUT HULL AND WOOD SHAVING
POULTRY LITTER

Form of nitrogen	Gm. nitrogen per 100 gm. total nitrogen	
	Peanut hull litter	Wood shaving litter
True protein	45.40	44.38
Uric acid	30.45	28.80
Ammonia	13.20	15.40
Urea	2.72	2.81
Creatine	3.54	3.64
Others	4.69	4.97

TABLE 12. AMINO ACID COMPOSITION OF PEANUT HULL
AND WOOD SHAVING POULTRY LITTER¹

Amino acid	Peanut hull litter	Wood shaving litter
Lysine	1.88(4.13)	1.88(4.23)
Histidine	0.79(1.74)	0.79(1.05)
Arginine	1.61(3.55)	1.67(3.77)
Aspartic acid	4.06(8.94)	3.99(8.99)
Threonine	1.81(3.92)	1.85(4.16)
Serine	1.88(4.15)	1.87(4.16)
Glutamic acid	6.57(14.47)	6.00(15.86)
Proline	2.88(6.34)	3.03(6.84)
Glycine	8.12(17.89)	6.98(15.74)
Alanine	2.74(6.04)	2.88(6.49)
Cystine	0.40(0.88)	0.29(0.64)
Valine	2.61(5.76)	2.69(6.07)
Methionine	0.43(0.94)	0.42(0.95)
Isoleucine	2.02(4.45)	2.09(4.70)
Leucine	3.17(6.99)	3.28(7.39)
Tyrosine	1.12(2.46)	1.07(2.41)
Phenylalanine	1.73(3.82)	1.76(3.97)

¹ Figures in parenthesis refer to percentages of the true protein and those not in parenthesis refer to percentages of the crude protein. Tryptophan content was not determined.

TABLE 13. APPARENT DIGESTION COEFFICIENTS FOR THE RATIONS CONTAINING DIFFERENT LEVELS OF PEANUT HULL AND WOOD SHAVING POULTRY LITTER

Ration no.	1	2	3	4	5
Kind of litter		Peanut hull		Wood shaving	
Level of litter (%)	0	25	50	25	50
Apparent digestibility (%)					
Crude protein	75.0 ^a	74.5 ^b	74.0 ^b	74.6 ^b	72.9 ^b
Crude fiber	59.6 ^a	62.6 ^b	63.2 ^b	62.2 ^b	62.9 ^b
Ether extract	69.4 ^a	67.6 ^a	62.9 ^b	66.9 ^a	66.0 ^a
NFE	83.6 ^a	80.2 ^b	76.7 ^c	81.2 ^b	76.1 ^c
Dry matter	76.7 ^a	73.1 ^b	70.1 ^c	74.1 ^b	69.1 ^c
Energy	76.4 ^a	72.7 ^b	69.2 ^c	72.7 ^b	69.4 ^c

a, b, c Means on the same line having different superscript letters are significantly ($P < .01$) different

Dry matter digestibility of 76.7% for the basal ration was greater ($P < .01$) than that of the rations containing 25 or 50% litter. The kind of litter used had no significant effect on ration dry matter digestibility. For example, when the rations contained 50% litter the values were 70.0 and 69.1% for the rations containing peanut hull and wood shaving litter, respectively. Level of litter in the ration had a highly significant effect; when the litter level was increased from 25 to 50% dry matter digestibility was decreased by 3 to 5 percentage units. Similar results were observed concerning NFE and energy digestibility. For example, digestibility of energy was 76.4% for the control ration which was higher ($P < .01$) than the value of 72.7% for both rations containing 25% peanut hull or wood shaving litter. The values for the rations containing 50% litter were significantly lower than those for the rations containing 25% of the comparable litters. Kind of litter had no significant effect on energy digestibility.

Nitrogen retained by sheep on peanut hull or wood shaving litter ration, as shown in table 14, was 1.9 and 1.6 gm. per day at the litter levels of 25 and 50%, respectively. No significant difference was observed due to kind or levels of litter in the rations. The comparatively lower nitrogen retention at higher levels of nitrogen intake may have been due either to lack of sufficient energy in the ration or lower efficiency of utilization at the higher nitrogen levels (50% litter levels).

Digestibility of the litter constituents, calculated by difference, is shown in table 15. Dry matter digestibility was not significantly different between kinds or levels of litter although it tended to be higher for the ration containing 25% wood shaving poultry litter. The value for digestibility of litter protein for the ration containing 50% wood shaving litter was 70.4%, which tended to be lower than for the other litter containing rations. The digestibility of litter crude protein was not significantly different between kinds or levels of litter. The average digestion coefficient for the litter crude protein was 72.5%. There were no significant differences or consistent trends in digestibility of litter ether extract and NFE among the rations. For crude fiber digestibility there were significant differences between levels of litter but not between kinds. The values were 71 and 70% respectively, for peanut hull and wood shaving litters, when these were fed at the 25% level. These values were significantly higher than 66.8 and 66.1% for the comparable litters fed at the 50% level. There were no significant differences in energy digestibility between the kinds and levels of litter. Brugman et al. (1964) reported higher digestibility values for crude protein, crude fiber and energy, and lower values for ether extract in laying house litter fed to bulls than

TABLE 14. NITROGEN UTILIZATION IN RATIONS CONTAINING DIFFERENT LEVELS OF PEANUT HULL AND WOOD SHAVINGS POULTRY LITTER

Rations	2		3		4		5	
	Peanut hull				Wood shaving			
Kind of litter	Peanut hull				Wood shaving			
Level of litter (%)	25		50		25		50	
Nitrogen intake, gm./day	20.88		25.46		20.43		25.07	
Nitrogen excretion, gm./day								
Fecal	5.33		6.64		5.19		6.81	
Urinary	13.66		17.23		13.35		16.70	
Nitrogen retention, gm./day	1.89		1.59		1.89		1.56	

TABLE 15. APPARENT DIGESTION COEFFICIENTS OF THE PEANUT HULL AND WOOD SHAVING POULTRY LITTER (CALCULATED BY DIFFERENCE)

Kind of litter	Peanut hull litter		Wood shaving litter	
	25	50	25	50
Level of litter in ration (%)	25		50	
Apparent digestibility (%)				
Dry matter	62.5		63.4	
Crude protein	73.1		73.5	
Crude fiber	71.5 ^a		70.0 ^a	
Ether extract	62.2		59.5	
NFE	69.8		74.0	
Energy	64.7		64.8	

a,b Means on the same line having different superscript letters are significantly ($P < .01$) different

the values obtained in the study. For example, they reported a crude protein digestibility of 78%, compared to 72.5% in this study. The results of the two experiments are not comparable, however, since the kind of litter, species of animal and location of the experiments were different.

Values (dry matter basis) for digestible protein, TDN, digestible energy and metabolizable energy (calculated by difference) for the two kinds of litters, fed at two levels, are given in table 16. Digestible protein values for litter were not significantly different between kinds or levels of litter. The average value was 23.4% for the peanut hull litter and 22% for the wood shaving litter. The average value for both kinds of litter was 22.7%.

TABLE 16. PROTEIN AND ENERGY VALUE (DRY MATTER BASIS) OF PEANUT HULL AND WOOD SHAVING POULTRY LITTER (CALCULATED BY DIFFERENCE)

Kind of litter	Peanut hull litter		Wood shaving litter	
	25	50	25	50
Digestible protein (%)	23.4	23.4	22.5	21.6
Total digestible nutrients (%)	60.7	59.3	61.0	58.0
Digestible energy (kcal./kg)	2504	2440	2429	2385
Metabolizable energy (kcal./kg.)	2249	2174	2197	2103

Total digestible nutrient (TDN) content of the peanut hull litter was 60.7 and 59.3% for the 25 and 50% feeding levels, respectively. The corresponding values for wood shaving litter were 61.0 and 58.0%, respectively. No significant difference due to level or kind of litter was

observed. The average TDN value for both kinds of litter was approximately 60%, dry matter basis. Digestible energy (kcal./kg.) for peanut hull litter was 2504 and 2440 respectively at 25 and 50% litter levels. The corresponding values for wood shaving litter were 2429 and 2385 respectively. There was no significant difference due to level or kind of litter. The average value was 2440 kcal. per kg. of litter dry matter. Metabolizable energy values, likewise, did not show any significant effect due to level or kind of litter. Average metabolizable energy value for both kinds of litter was 2181 kcal. per kg. of litter dry matter.

Thus, the poultry litter with approximate digestible protein and TDN values of 23 and 60% (dry matter basis), respectively, is far superior to peanut hulls, which contains 1.7% digestible protein and 20.4% TDN, dry matter basis, (Morrison, 1956). The increased protein value of the litter resulted primarily from the accumulated excreta. Undoubtedly, the increased energy value resulted from the broiler excreta and feed wastage.

The potential value of poultry litter in ruminant rations appears quite promising. The values of 23% digestible protein and 60% TDN (dry basis) compare very favorably with corresponding values of 13.5% and 58.7% for dehydrated alfalfa meal (Morrison, 1956), a high quality roughage. The high calcium and phosphorus contents of broiler litter would also contribute to its nutritive value, if these are efficiently utilized.

Although palatability tests were not conducted in the experiment reported here, the acceptance of the product did not present any problem in the trials conducted with natural or semi-purified rations (experiment 1). Brugman et al. (1964) reported a preference by cattle for litter rations over control rations, when given a choice.

EXPERIMENT 3. VALUE OF PEANUT HULL POULTRY LITTER AS A PROTEIN SUPPLEMENT IN CHICK STARTER RATIONS

The objective of this experiment was to study the value of processed peanut hull poultry litter as a protein supplement, when it supplied different proportions of crude protein in a practical type broiler starter ration.

Experimental procedure

A 3-week growth trial was run with 160 Vantress X Arbor Acres male chicks fed a typical corn-soybean broiler starter ration in which different levels of peanut hull poultry litter were used to replace protein. All chicks were fed the basal control diet from 1-day-old to 1 week of age, at which time they were distributed by weight into 16 groups of 10 chicks per group. Four diets were allotted to the 16 groups at random, thereby assigning 4 groups of 10 chicks each per ration treatment.

The composition of the four diets is shown in table 17. Peanut hull broiler litter, collected and processed as described in experiment 1, was used in this experiment. The all-vegetable basal diet (diet no. 1) contained soybean meal as the protein supplement, and contained adequate quantities of all nutrients known to be required by growing chicks. It contained no animal protein, unidentified growth factor sources, antibiotic, or other growth promotants. In diets 2, 3 and 4, different levels of peanut hull poultry litter were isonitrogenously substituted by replacing essentially the soybean meal; the proportions of the other ingredients, mainly ground corn, were adjusted to allow for the greater weight of litter required. In diets 2, 3 and 4 approximately 1/6, 1/5 and 1/4 of the protein content of the basal corn-soy diet was replaced by poultry litter

crude protein. Solka floc was added in the diets 1, 2 and 3, adjusting other ingredients, in order to make the diets equal in fiber content. Calcium and phosphorus content of all the rations were approximately equalized by lowering the proportions of limestone and dicalcium phosphate in litter diets.

TABLE 17. INGREDIENT AND CALCULATED CHEMICAL COMPOSITION OF THE CHICK STARTER RATIONS CONTAINING DIFFERENT LEVELS OF LITTER CRUDE PROTEIN

Diet no.	1	2	3	4
Level of litter protein	0	1/6	1/5	1/4
Ingredient composition (%)				
Ground yellow corn	46.9	62.48 ^y	41.40	39.85
Soybean meal, 50% protein	36.3	29.92	28.63	26.72
Alfalfa meal, 17% protein with 1% added fat	2.5	2.5	2.5	2.5
Peanut hull poultry litter	0	13.89	16.67	20.83
Animal and vegetable fat	7.50	7.45	7.43	7.34
Solka floc	2.1	0.45	0.34	0
Dicalcium phosphate	2.0	0.37	0.05	0
Ground limestone	0.9	1.13	1.18	0.96
Mineral mixture ¹	0.6	0.6	0.6	0.6
Vitamin mixture ²	1.0	1.0	1.0	1.0
Methionine	0.2	0.2	0.2	0.2

Calculated chemical composition (%)				
Crude protein	22.55	22.94	22.96	22.96
Ether extract	9.52	9.63	9.63	9.49
Crude fiber	4.75	4.54	4.69	4.73
Ash	2.98	4.63	4.96	5.43
Calcium	0.97	0.95	0.96	0.94
Phosphorus	0.71	0.70	0.70	0.78

¹ Contained the following as percent of the mixture: 73.16 NaCl, 1.754 Mn, .14 Fe, .092 Cu, .011SS, .011 Co, .033 I, .257 Mg, .643 Zn and 5.97 Ca.

² Supplied the following per pound of ration: 3640 I.U. vitamin A, 390 I.C.U. vitamin D₃, 4.41 I.U. vitamin E, .5 mgs. menadione sodium bisulfite, 4 mgs. riboflavin, 7.4 mgs. D-calcium pantothenate, 20 mgs. niacin, .3 mgs. folic acid, .05 mgs. biotin, .006 mgs. vitamin B₁₂, 186 mgs. choline Cl and 56.7 mgs. ethoxyquin.

The chicks were reared in electrically heated wire floored batteries during the 4 weeks. At 1 week of age the chicks were wingbanded, individually weighed and fed the various treatment diets up to 4 weeks of age. The birds were weighed individually every week. Feed was supplied ad libitum. Water troughs with automatic watering devices were cleaned daily. Total feed consumption was recorded for the 3-week trial. All analyses were done as described for experiment 1. Growth and feed efficiency data of the chicks on the different diets were subjected to analysis of variance and differences among treatment means were tested for significance by Duncan's (1955) multiple range test.

Results and Discussion

The chicks in all 16 groups were found to be active, in general, throughout the experimental period. No symptoms of a deficiency or other pathological conditions were observed in any group.

The composition of peanut hull poultry litter and certain other protein supplements is shown in table 18. When compared to the other supplements, poultry litter cannot be considered a very high protein supplement. It is similar to hatchery by-product meal in crude protein content. Litter is high in crude fiber, as compared to the other supplements. It is fairly high in ash content. Calcium and phosphorus content of the litter is appreciable.

As was shown in table 3, almost one-half of the litter nitrogen existed as true protein. Wehnut et al. (1960) reported that almost one-third of the broiler manure used in their study existed as true protein. In the peanut hull litter used in the studies reported here, uric acid and free ammonia nitrogen comprised 30 and 13%, respectively, of the total

TABLE 18. CHEMICAL COMPOSITION OF PEANUT HULL POULTRY LITTER AS COMPARED TO OTHER PROTEIN SUPPLEMENTS

	Crude protein	Ether extract	Crude fiber	N.F.E.	Ash	Ca	P
Peanut hull poultry litter	27.9	2.6	11.2	29.0	14.9	2.4	2.5
Hatchery by-product meal ^a	26.0	11.4	0.57	8.2 ^d	33.7	20.6	0.40
Hydrolyzed feather meal ^b	82.8	1.5	0.51	1.6	3.4	0.65	0.32
Meat and bone meal ^c	45.5	12.3	2.3	2.9	31.0	10.6	5.5
Menhaden fish meal ^c	61.3	8.3	0.70	4.2	18.2	6.4	4.2
Soybean oil meal ^c	50.4	1.0	3.2	31.0	6.1	0.26	0.19

^a Wisman (1964)

^b Bhattacharya (1962)

^c Ewing (1963)

^d Apparent low value was due to correction for conversion of some CaCO_3 in the meal to CaO , during ashing

nitrogen. Albritton (1955) reported that 63 to 87% of the total nitrogen in poultry excreta existed as uric acid nitrogen.

Amino acid composition of the litter protein compared with that of certain other protein supplements is shown in table 19. The values for litter are the same as reported for experiment 1. Glycine content of litter is remarkably high, especially when the proportion of amino acids in true protein content of litter is considered. Arginine, histidine and lysine show comparatively lower values than in most of the other supplements.

The growth and feed efficiency of the chick, as affected by the levels of poultry litter crude protein in the diet, are shown in table 20. When the litter crude protein replaced 1/6 and 1/5 of the crude protein in the basal diet (13.9% and 16.7% poultry litter, respectively), there was no significant difference in the rate of gain compared to the basal diet. A non-significant depression from 463 gm. gain for the basal to 448 gm. for the litter groups was noted. When 1/4 of the protein in the basal diet was replaced by litter crude protein (about 20.8% poultry litter in the diet) a significant growth depression from 463 gm. to 430 gm. was observed. This shows that crude protein in the poultry litter, at a limited level, can replace a part of that in a typical corn-soy starter ration and thus can act as protein supplement in a chick diet. Although no research work on the utilization of uric acid-nitrogen in chicks has been reported, there are evidences that other non-protein nitrogen compounds have been used for synthesis of non-essential amino acids or to aminate hydroxy analogues of certain essential amino acids. Sullivan and Bird (1957)

TABLE 19. AMINO ACID COMPOSITION OF PEANUT HULL POULTRY LITTER
AND OTHER PROTEIN SUPPLEMENTS¹

Amino Acid	NRC requirement ²	Peanut Hull poultry litter	Poultry blood meal ³	Hydrolyzed feather meal ³	Meat and bone meal ⁴	Soybean meal ⁴	Yellow corn meal ⁴
Arginine	6.0	1.55 (3.35)	5.2	5.8	7.0	7.3	4.8
Glycine	5.0	9.14 (19.76)	4.4	7.0	1.2	5.4	3.4
Histidine	1.5	0.73 (1.58)	4.1	0.8	3.5	2.9	2.5
Isoleucine	3.0	2.09 (4.51)	3.6	4.1	3.4	6.0	6.4
Leucine	7.0	3.29 (7.12)	8.7	6.7	8.0	8.0	15.0
Lysine	5.0	1.76 (3.80)	6.8	2.4	5.6	6.8	2.3
Methionine	2.25	0.48 (1.03)	1.2	0.7	2.0	1.7	3.1
Methionine + Cystine	4.0	0.97 (2.08)	2.0	4.1	3.2	3.6	4.6
Phenylalanine	3.5	1.77 (3.82)	4.8	3.8	4.1	5.3	5.0
Phenylalanine + tyrosine	7.0	2.93 (6.32)	6.9	5.1	8.3	9.3	11.0
Threonine	3.0	1.86 (4.01)	3.9	3.5	3.9	3.9	3.7
Valine	4.0	2.65 (5.74)	6.3	6.7	6.1	5.3	5.3

¹ Figures within parenthesis refer to percentages of the true protein and those not in parenthesis refer to percentages of crude protein

² N.R.C. (1960)

³ Wisman et al. (1957, 1958)

⁴ Block and Bolling (1951), except for glycine (Wisman, 1964)

observed an increase in chick growth when urea or diammonium citrate was added to low protein diets containing hydroxy analogues of methionine and glycine. Similar results were reported by Machlin et al. (1957). The result of this study is in agreement with that of Wehunt et al. (1960) who reported that when hydrolysed poultry litter was added to supply 1.5 or 3 percentage units of crude protein in a basal diet, suboptimal in protein, it was utilized by chicks, as evidenced by increased growth rate. In this study, since poultry litter replaced mostly corn and soybean meal in the diets, the drop in energy value of the ration might have been a limiting factor for promoting better growth response, especially at the highest litter level (21% of the diet).

When the feed efficiency of the litter-fed groups was compared with that of the chicks fed the control diet (table 20), a significant decrease in feed efficiency was observed in litter-fed groups. The difference amounted to 7% when 1/6 of the nitrogen was supplied by litter, 13% when 1/5 and 11% when 1/4 of the nitrogen was supplied from litter. This effect was also observed by Wehunt et al. (1960) who reported that feed efficiency was not altered when 10% litter was used and was decreased when 20% was included. Since poultry litter is a very cheap by-product, even with a little lower feed efficiency, cost of feed per lb. of gain may be appreciably less.

High proportion of glycine and appreciable amount of other amino acids in litter protein as seen in the amino acid analysis leaves scope for further study in the light of its utilization with other poultry by-products. Also, the possible synthesis of B-vitamins in litter can be a source of further studies in its value in feeding poultry.

TABLE 20. EFFECT OF BROILER LITTER AS PROTEIN SUPPLEMENTS
ON GROWTH RESPONSE AND FEED EFFICIENCY

Treatment No.	Protein Content (%)	Level of litter crude protein	Percent protein in diet supplied by		Three week weight gain(gm)	Feed efficiency gm. of gain per gm. of feed	Feed consumed gm
			Soybean meal	Poultry litter			
1	22.55	---	18.1	---	463 ^a	0.61 ^a	759
2	22.94	1/6	15.0	3.9	448 ^a	0.57 ^b	786
3	22.96	1/5	14.3	4.7	448 ^a	0.53 ^b	845
4	23.96	1/4	13.4	5.8	430 ^b	0.54 ^b	796

a,b Means on the column having different superscript letters are significantly ($P < .01$) different

SUMMARY

Three experiments were conducted to study the nutritional value of poultry litter in ruminants and poultry.

In the first experiment three metabolism trials were conducted with eight yearling wethers to study the utilization of the nitrogen in autoclaved peanut hull broiler litter. The broiler litter contained 32.6% crude protein (dry matter basis). Different proportions of nitrogen were supplied by the litter in isonitrogenous rations, composed of purified ingredients (except litter). Apparent digestibility of crude protein in the ration was not significantly altered when litter supplied 25% of the nitrogen. When litter supplied 50% of the nitrogen a small depression ($P < .01$) resulted. When 100% of the nitrogen was supplied by litter, a marked decline ($P < .01$) resulted. Digestibility of the litter nitrogen, calculated by difference, was 67 and 64% respectively at 25 and 50% level of the nitrogen, which were not much lower than 71% when only soy protein was used. Nitrogen retention and percent utilization of absorbed nitrogen were significantly lower at the 100% litter-N level than when no litter was used. There were no marked differences in the nitrogen fractions of the rumen liquor and blood plasma among the rations.

In the second experiment, three digestion and metabolism trials were conducted with 10 yearling wethers to study the protein and energy utilization of autoclaved peanut hull and wood shaving broiler litters, when each was incorporated in a natural (corn-hay) ration at the level of 25 and 50 percent. Apparent digestibility of crude protein did not show any significant difference among the rations. Crude fiber digestibility of the litter rations was higher than that of the control. Ether extract

digestibility of the 50% peanut hull litter ration was significantly lower than for the other rations. Dry matter, NFE and energy digestibility were lower ($P < .01$) for the litter rations and decreased significantly when the litter level in the ration was increased from 25 to 50%. In the case of nitrogen retention, no significant difference was observed due to kind or level (25 vs. 50%) of litter in the rations.

Crude fiber digestibility calculated by difference was significantly depressed when the level of litter was increased from 25 to 50%. There were no other significant differences in digestibility between kind or level of litter. The apparent digestibility of crude protein was 71.7%. The digestible protein content (on dry matter basis) for peanut hull and wood shaving litter were 23 and 22%, respectively. The average TDN value for both kinds of litter was 60% (dry basis). Average digestible energy values (kcal/kg., on dry matter basis) were 2472 and 2407, respectively for peanut hull and wood shaving litter. The corresponding values for metabolizable energy were 2212 and 2150 kcal/kg. There was no significant difference for any of the values due to kind or level of litter.

The third experiment was conducted to study the values of different levels of processed peanut hull litter as a partial protein supplement in a practical type broiler ration. When 1/6 or 1/5 of the protein in the basal diet was replaced with litter crude protein (13.9 or 16.7% poultry litter in the diet), there was no significant difference in the rate of gain, compared to the control. When 1/4 of protein in the basal diet was replaced by litter crude protein (20.3% litter in the diet), a significant growth depression resulted. Feed efficiency of the litter fed groups was significantly lower than that of the groups on the basal diet.

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APPENDIX

TABLE 21. SUMMARY OF ANALYSIS OF VARIANCE FOR EXPERIMENT 1

Source	Degree of freedom	Apparent digestibility (%)					Nitrogen retention (%)	Util. of absorbed nitrogen (%)
		Crude protein	Crude fiber	Ether extract	NFE	Dry matter		
		m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.
Treatment	3	254.33**	12.67	33.27	24.66	71.73*	162.19**	222.70
Trial	2	57.88	4.50	23.50	4.25	11.55	87.1	137.41
Block within trial	3	59.24	5.67	29.33	5.73	13.37	146.23	240.25
Error	12	2.175	4.59	49.03	9.12	14.70	40.92	114.87
Total	20							

* P < .05

** P < .01

TABLE 22. CALCULATIONS OF APPARENT DIGESTIBILITY OF POULTRY LITTER CRUDE PROTEIN BY DIFFERENCE^a

Trial no.	Block no.	Ration no.	Sheep no.	Digestion coeff. ^b	T-A	$\frac{(T-A) 100}{s}$	S
1	1	1	75	73.90			
		2	77	76.20	-2.30	9.20	83.10
		3	84	76.09	2.19	4.38	79.28
		4	80	75.23	1.33	5.32	79.22
		5	91	71.76	-2.14	-4.28	69.62
	2	1	81	73.56			
		2	79	74.97	1.41	5.64	79.20
		3	73	71.38	-2.18	-4.36	69.20
		4	74	73.47	-0.09	-0.36	73.20
		5	72	73.99	-0.43	-0.86	72.70
2	1	1	84	75.56			
		2	91	73.00	-2.56	-10.24	65.32
		3	80	73.46	-2.10	-4.20	71.36
		4	75	74.32	-1.24	-4.96	70.60
		5	77	74.18	-1.38	-2.76	72.80
	2	1	79	75.83			
		2	73	73.57	-2.26	-9.04	66.79
		3	74	73.42	-2.41	-4.82	71.01
		4	72	73.44	-2.39	-9.56	66.27
		5	81	72.73	-3.10	-6.20	69.63
3	1	1	80	75.08			
		2	84	74.92	-0.16	-0.64	74.44
		3	75	75.33	0.25	0.50	75.58
		4	77	75.80	0.72	2.88	77.96
		5	91	74.29	-0.79	-1.58	73.50
	2	1	74	75.84			
		2	72	74.26	-1.58	-6.32	69.52
		3	81	74.21	-1.63	-3.26	72.58
		4	79	75.32	-0.52	-2.08	73.76
		5	73	70.14	-5.70	-11.40	64.44

^a Method outlined by Crampton and Lloyd (1959).

Basic equation: $S = \frac{100(T-A)}{s} + A$

(S=digestible coeff. of litter, T=digestible coeff. of litter rations; A=digestible coeff. of control ration; s=% of litter in the ration).

^b Digestion coefficients for the various rations.

TABLE 23. MODEL CALCULATIONS FOR METABOLIZABLE ENERGY OF POULTRY LITTER (BY DIFFERENCE)^a

Trial No.	Block No.	Ration No.	Sheep No.	% Met. energy of the rations	T-A	$\frac{(T-A)100}{s}$	S	Gross energy of litter (kcal/gm)	Met. en. of litter (kcal/kg)
1	1	1	75	71.97					
		2	77	68.64	-3.33	-13.32	58.64	3.41	2000
		3	84	63.86	-8.11	-16.22	55.75	"	1901
		4	80	69.14	-2.83	-11.32	60.65	3.40	2062
		5	91	63.74	-8.23	-16.46	55.51	"	1887
	2	1	81	71.18					
		2	79	68.98	-2.20	- 8.80	62.38	3.41	2127
		3	73	63.80	-7.38	-14.76	56.42	"	1924
		4	74	67.71	-3.47	-13.88	57.30	3.40	1948
		5	72	65.50	-5.68	-11.36	59.82	"	2034

^a Method outlined by Crampton and Lloyd (1959).

Basic equation: $S = \frac{100(T-A)}{s} + A$

(S = Percent metabolizable energy of litter; T = Percent metabolizable energy of the litter ration; A = Percent metabolizable energy of the control ration; s = % of the litter in ration)

TABLE 24. SUMMARY OF ANALYSES OF VARIANCE^a FOR EXPERIMENT 2

Source	Degrees of freedom	Apparent Digestibility (%)					Dig. protein (%)	TDN (%)	Dig. energy (kcal/kg)	Met. energy (kcal/kg)
		Crude protein	Crude fiber	NFE	Dry matter	Energy				
		m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.
Treatment	3	11.56	194.57**	33.09	23.80	4.11	11.92	47.91	.0117	.0164
Trial	2	80.74	184.44	9.04	35.12	33.02	8.28	25.22	.0532	.0161
Block	1	78.77	8.14	121.68	38.69	5.40	4.26	18.94	.0060	.0028
Error	17	14.03	59.34	13.43	8.57	14.39	44.98	128.50	.0159	.0104
Total	23									

^a Data calculated by difference, based on the values for the control ration.

** P<.05

STUDIES ON THE NUTRITIONAL VALUE OF POULTRY LITTER IN RUMINANTS AND POULTRY

Asok Nath Bhattacharya

An Abstract

Three experiments were conducted to study the nutritional value of poultry litter in ruminants and poultry.

In the first experiment, eight yearling wethers were used in a series of three metabolism trials to study the utilization of the nitrogen in autoclaved peanut hull broiler litter containing 32.6% crude protein (dry matter basis). Poultry litter nitrogen replaced 25, 50 and 100% of the nitrogen of a purified diet containing isolated soybean protein as the nitrogen source. Apparent digestibility of crude protein in the rations decreased significantly at each increase of litter nitrogen level beyond 25%. However, the depression of crude protein digestibility at 50% litter nitrogen level was small. Digestibility of the litter nitrogen, calculated by difference, was 67 and 64%, respectively at 25 and 50% level of the nitrogen, which were not much lower than 71% when only soy protein was used. Nitrogen retention and percent utilization of absorbed nitrogen were significantly lower at the 100% litter-N level than when no litter was used. There were no consistent differences in the nitrogen fractions of the rumen fluid and blood plasma among the rations.

In the second experiment, three digestion and metabolism trials were conducted with 10 yearling wethers to study the protein and energy utilization of autoclaved peanut hull and woodshaving broiler litters when each was incorporated in corn-hay natural ration at levels of 25 and 50 percent. Apparent digestibility of crude protein did not show any significant difference

among the rations. Crude fiber digestibility of the litter rations was higher than that of the control ration. Dry matter, NFE and energy digestibility were lower ($P < .01$) for the litter rations and decreased significantly when the litter level in the ration was increased from 25 to 50%. No significant difference was observed in nitrogen retention, due to kind or level of litter in the rations. Crude fiber digestibility, calculated by difference, was significantly depressed when the level of litter was increased from 25 to 50%. There were no other significant differences in digestibility between kind or level of litter. The apparent digestibility of crude protein was 71.7%. Digestible protein content (on dry matter basis) for peanut hull and wood shaving litter were 23 and 22%, respectively. The average TDN value for both kinds of litter was 60% (dry basis). Average digestible energy values (kcal./kg. on dry matter basis) were 2472 and 2407 respectively for peanut hull and wood shaving litter. The corresponding values for metabolizable energy were 2212 and 2150 kcal./kg. There was no significant difference in digestible protein, TDN, digestible energy, and metabolizable energy values due to kind or level of litter.

The third experiment was conducted to study the value of different levels of processed peanut hull litter as a partial protein supplement in a practical type broiler ration. When 1/6 or 1/5 of the protein in the basal diet was replaced with litter crude protein by the inclusion of 13.9 or 16.7% litter in the diet, there was no significant difference in rate of gain, compared to the control. When 1/4 of protein in the basal diet was replaced by litter crude protein (20.8% litter in the diet), a significant growth depression resulted. Feed efficiency of the litter fed groups was significantly lower than that of groups on the basal diet.