PROCESSING AND NUTRITIONAL VALUE OF POULTRY LITTER AND SLAUGHTER HOUSE BY-PRODUCT

by

SAEED M. CHAUDHRY

Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Animal Science

APPROVED:

J. P. Fontenot, Chairman

D. R. Notter

H. J. Gerken, Jr.

V. G. Allen

R. F. Kelly

January 9, 1990

Blacksburg, Virginia

PROCESSING AND NUTRITIONAL VALUE OF POULTRY LITTER AND SLAUGHTER HOUSE BY-PRODUCT

by

SAEED M. CHAUDHRY
J. P. Fontenot, Chairman
Animal Science

(ABSTRACT)

Two experiments were conducted to study: 1) the different methods of processing broiler litter for use as a feed ingredient; and 2) preservation, fermentation and nutrient utilization of rumen contents and blood. Broiler litter was deep stacked in 1.2 x 1.2 x 1.2 m bins at 15, 25 and 35% moisture, and ensiled at 40% moisture, alone or with 5% added molasses. Litter was also ensiled with rumen contents at ratios of 60:40 and 50:50, wet basis. For digestion and palatability trials, wethers were allotted to five diets: 1) basal alone, or basal and broiler litter (1:1, dry basis) processed by; 2) deep stacking at 15% moisture; 3) ensiling; 4) ensiling with 5% molasses; and 5) basal and ensiled rumen contents and litter (50:50, wet basis).

Freshly collected rumen contents and blood, mixed in proportions of 1:1, 2:1 and 3:1, wet basis, were ensiled with wheat straw (60:40) untreated or treated with 5% urea, with or without 7.5% molasses. Formic/propionic acid (1% w/w)

and 10% dried sugar cane molasses were tested as preservatives for blood and rumen contents. Formic/propionic acids preserved rumen contents and blood were ensiled with wheat straw (45:15:40, wet basis) for use in a metabolism trial with sheep. Sheep were fed a basal diet and the silage at ratios of 100:0, 75:25, and 50:50, dry basis.

Litter deep stacked at 15% moisture showed a lower rise in temperature than litter stacked at 25 and 35% moisture. Desirable fermentation was achieved for litter ensiled alone or with molasses or rumen contents. Deep stacked broiler litter and silages were devoid of coliforms. Apparent digestibilities of OM and CP were lowest for the deep stacked broiler litter diets. Dry matter intake was similar among waste-containing diets.

Formic/propionic acids were the only preservatives which were effective for both blood and rumen contents. Desirable fermentation was achieved in rumen contents-blood-straw in silages containing untreated wheat straw. Apparent digestibility of CP of the ensiled slaughter house waste-straw was similar to that of the basal. The calculated digestibilities of OM and DM of the silage were 46% and that of CP was 69%. The results indicated that fresh rumen contents and blood can be ensiled successfully with wheat straw for use as roughage and protein source for ruminants.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to all individuals who have been so helpful throughout his graduate program.

To the members of his graduate committee, Dr. J. P. Fontenot, Chairman, Dr. D. R. Notter, Dr. V. G. Allen, Dr. H. J. Gerken, Jr. and Dr. R. F. Kelly, the author expresses his appreciation for their assistance.

The author is especially grateful to Dr. J. P. Fontenot for his expert guidance, valuable suggestions and moral support throughout the author's program and in preparation of this manuscript.

The author extends his sincere thanks to Mrs. Nancy Frank, Ms. Becky Barlow and Ms. Sylvie Beaty for their technical assistance. To Lisa Bettison, Judy Baker, Nancy Wade and Ellie Stephens, the author will forever remember their help, which made his goal achievable.

Special thanks are extended to Pakistan Agriculture Research Council for providing the facilities to conduct part of dissertation research at Islamabad, Pakistan, and for financial support throughout the author's program. To Ghulam Raza, Mohmmad Mustafa and Rahmat-ullah at the Animal Nutri-

tion Laboratory, National Agriculture Research Center, Pakistan, the author thanks for their help and many hours of assistance.

To his fellow graduate students the author wishes to extend his sincere thanks for their help and cooperation. Finally, the author is sincerely grateful to his parents, brothers and sisters for their support, encouragement and many sacrifices during his graduate program.

Special thanks to his wife for her help and many sacrifices during his graduate program.

Above all, the author would like to acknowledge the guidance and help from Almighty Allah (S.W.T.).

DEDICATION

This manuscript is dedicated to my parents, Mr. and Mrs. Mukhtar Hassan Chaudhry.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Ruminants in developing countries grow slower and produce less meat and milk than those in developed countries. According to Jasiorowski (1976), 70% of the world's cattle and buffalo population are in the developing countries but they produce only 34% of the world's beef and 18% of the world's total milk. The poor animal production in these countries is mainly associated with inadequate availability of feedstuffs. Traditional feeding based on cereal grains is too expensive for feeding ruminants in these countries. The cereal grains can be converted more efficiently to animal products by nonruminant animals. Thus, it is necessary to incorporate underutilized feed ingredients in order to promote production of livestock in a suitable and balanced form. Ingredients which have not been used to any significant extent are poultry wastes, including litter, and slaughter house wastes, such as blood and rumen contents. The use of these wastes as feed ingredients will not only reduce the waste disposal problem but will provide inexpensive feed components for cattle, calves, sheep and goats.

Broiler litter has to be processed prior to use as a feed ingredient. Various processing methods, including heat

and chemical treatments, have been used for the destruction of pathogenic organisms, improvement of palatability and the reduction of nutrient loss in poultry litter. Much of the research has involved the processing of freshly collected broiler litter. Although this is an excellent means of utilizing broiler litter, it may not always be feasible. A more common practice would be for a producer to accumulate the litter and store it protected from adverse weather until ready to be incorporated in a feeding regime. One objective of this study was to determine the effect of ensiling and deep stacking of broiler litter on intake and nutritive value when fed to sheep.

Blood and rumen contents are perishable products which must be processed or disposed of soon after collection from the slaughter houses. Ensiling is a possible method for preserving slaughter house waste, but ensiling must occur soon after collection. However, this is laborious, difficult and impractical on a daily basis under normal farming conditions. Consequently, it is imperative to find low cost and effective preservatives, which can be used to preserve the slaughter house waste at least for 1 wk. Another objective of this study was to develop effective methods of preserving slaughter house waste to determine fermentation characteristics and nutrient utilization by ruminants.

CHAPTER II

REVIEW OF LITERATURE

Broiler litter is a solid waste composed of bedding material, excreta, wasted feed, and feathers, which has been used successfully as a feed for ruminants (Fontenot, 1977).

Nutritive Value of Broiler Litter.

The nutrient content and digestibility of broiler litter depend largely on the bird density, amount and type of litter, feed composition, feed spillage and length of time from excretion to collection (Forsht et al., 1974).

Nitrogen. Broiler litter is usually high but variable in N (CP) content, averaging 31%, dry basis (Bhattacharya and Taylor, 1975).

The CP content of 13 broiler litter samples taken in three different locations in Virginia was 30.0 ± 2.5% (Fontenot et al. 1975a). The average CP content from a number of sources was 30.81% (NRC, 1983). In broiler litter about 50% of total N is in the form of protein N and 50% is in the form of NPN (NRC, 1983). Bhattacharya and Fontenot (1966) reported that 28.80% of the N is in the form of uric acid and 15.40% is in the form of NH_3. The main NPN constituent in poultry waste is uric acid (Noland et al., 1955; Bhattacharya and Fontenot, 1966; Fontenot et al., 1971).

Other NPN fractions include NH_3, urea and creatine. Nitrogen from poultry waste has been shown to be efficiently utilized (Smith and Calvert, 1972) by ruminants. It has been shown that rumen microorganisms are capable of efficiently utilizing uric acid as a source of N to synthesize protein (Belasco, 1954; Jurtshak et al., 1958). Uric acid is more efficiently utilized than urea (Oltjen and Dinius, 1976), probably because it is less soluble in water (Muller, 1980). Oltjen et al. (1968) indicated that uric acid is broken down more slowly than urea, with a gradual release of soluble NH_3, which allows efficient utilization of NPN. Koening et al. (1978) conducted an in vitro study and showed that ruminal microbes required 2 to 3 d to adapt and utilize uric acid. However, the adapted microbes were capable of degrading uric acid within 6 h of incubation period. Stallcup (1958) reported NH_3 from litter is a potential source of N for ruminants.

Bhattacharya and Fontenot (1965) mixed the broiler litter in a purified diet to replace 25, 50 and 100% of the N. They found positive N balance in sheep fed the three diets. Nitrogen retention was lower when 100% of N was supplied by litter than when 100% was supplied by soybean protein. Retention for the sheep fed diets with 25 and 50% litter N was

not significantly lower than when soy protein supplied all the dietary N.

Ammerman et al. (1966) used dried citrus pulp as bedding material for broilers. Broiler litter or citrus pulp comprised 65% of the diets, a third diet contained hay, corn meal and soybean meal. They found a N retention of 4.76 g per day and 21.64% of daily N intake for sheep fed the poultry litter diet, which was higher than for sheep fed the other two diets.

Thomas et al. (1970) fed diets containing dehydrated cattle waste, poultry waste or soybean meal to sheep. They found that the sheep fed poultry waste retained N equal to those fed soybean meal, but greater than the sheep fed cattle waste. Using the chromic oxide indicator method, Brugman et al. (1964) found the digestion coefficient for CP and CF of laying house litter to be 77.8 and 91.0%, respectively, when fed to Hereford bulls. Further, they stated that poultry litter is high in protein and low in vitamins A and D. The apparent digestibility of N of poultry litter averaged 72.5% (Ammerman et al., 1966; Bhattacharya and Taylor, 1975) when the litter constituted 50% of a sheep diet.

Smith and Calvert (1972) substituted poultry waste for 0, 50 and 100% of the N provided by soybean meal in sheep

diets. The results indicated no differences in digestibility of CP among treatments.

Smith and Calvert (1976) fed diets containing 19, 38, 57 and 100% of DM from dehydrated broiler excreta to sheep. Dried broiler excreta provided 94 to 100% of the dietary N in the semipurified diets. They found higher digestibilities of DM and OM for diets containing 38% dried broiler excreta, compared to other waste-containing diets. The N digestibility increased from 9.9 to 57.5% when dried broiler excreta was increased from 19 to 38% in the diet. No differences were found among the N digestibilities of diets containing 38, 57 and 100% dehydrated broiler excreta.

Filipot et al. (1975) reported a reduction in apparent digestibility of N when ensiled caged layer waste treated with paraformaldehyde was fed, compared to waste treated with tannic acid. Treating poultry waste by autoclaving, ethylene oxide, sulfuric acid or paraformaldehyde had no significant effect on N utilization in sheep (Fontenot et al., 1971; Harmon et al., 1974; Caswell et al., 1975).

Energy. Broiler litter may serve as an important source of energy, depending upon the level of structural carbohydrates in bedding material and poultry waste. Brugman et al. (1964) reported a gross energy value of 3.6 kcal/kg for poultry litter. The TDN values of wood shaving broiler lit-

ter fed as 25 or 50% of the diet were 61.0 and 58.0%, respectively, as compared to 60.7 and 59.3%, respectively, for peanut hull litter (Bhattacharya and Fontenot, 1966). Digestible energy value for the wood shaving and peanut hull litters were 2429 and 2504 kcal/kg of DM, respectively, when fed as 25% of the diet. At 50% of the diet, the respective values were 2385 and 2440 kcal/kg.

Lowman and Knight (1970) reported apparent digestibilities of energy of 59.2% by cattle and 60.3% by sheep. Digestible energy values of 1911 kcal/kg in cattle and 1875 kcal/kg in sheep have been reported (Bhattacharya and Taylor, 1975).

Minerals. Bhattacharya and Fontenot (1966) reported that broiler litter is an excellent source of Ca and P. They found higher values of Ca and P for peanut hull litter than wood shaving broiler litter. Bhattacharya and Taylor (1975) reported that broiler litter contained 2.4 and 1.8% of Ca and P, dry basis, respectively. Bull and Ried (1971) found that Ca and P in poultry waste were 95 and 75% available, respectively, as the only source of minerals in ruminant diet. The waste also contains substantial level of most of the trace elements (Bhattacharya and Taylor, 1975).

Tagari et al. (1981) supplemented the basal diet with dicalcium phosphate and broiler litter as sources of P. Ex-

perimental diets supplied .143 and .182% P. They found no difference in net P utilization and net P availability for two levels of P by lambs. However, the net P availability was 63.7 and 39.0% and net P utilization was 63 and 38% for P supplied by dicalcium phosphate and poultry litter, respectively. Cooke and Fontenot (1985) supplemented the basal diet with broiler litter, swine waste, dicalcium phosphate and soybean meal. Supplemented diets supplied .27 to .31% P and .38% Ca, dry basis. They found that sheep absorbed P more efficiently ($P<0.10$) from swine waste and broiler litter than from dicalcium phosphate and soybean meal. Calcium absorption and serum Ca level were higher for the sheep fed broiler litter than those fed swine waste. Magnesium was well utilized from all diets.

Performance of Ruminants Fed Broiler Litter. Noland et al. (1955) studied the effects of feeding litter to ruminants. Performance of gestating-lactating ewes fed a diet containing ground chicken litter was similar to that of ewes fed a diet containing soybean meal. When energy intake was equalized, the performance of steers fed litter was similar to that of steers fed cottonseed meal. Southwell et al. (1958) reported that rate of gain of steers fed a diet containing 30% corn cob broiler litter was similar to that of steers fed control diet.

Fontenot et al. (1966) found no difference in rate of gain in steers fed fattening diets containing 25% peanut hull or wood shaving broiler litter, as compared to steers fed a control diet. Feed efficiency was highest for the steers fed peanut hull litter and was lowest for those fed the control diet. Cullison et al. (1976) incorporated wood shaving and peanut hull litter and hen manure at 20, 20 and 13% of the total diet, respectively. Higher daily gain and feed efficiency were recorded in steers fed wood shaving litter than those receiving peanut hull litter, hen manure and control diets. Steers fed hen manure had lowest weight gain and feed efficiency than those fed the other diets.

Drake et al. (1965) studied the effects of feeding four different base litters (peanut hulls, corn cobs, grass hay, and soybean hulls) to steers at 25 and 40%. They found no difference in performance of steers fed broiler litter with different base materials. However, performance was higher for the steers fed a diet containing 25% litter, compared to 40% litter. Ray and Child (1964) reported similar performance for fattening steers fed diets containing 12% protein, rice hulls or rice hull broiler litter.

Galmez et al. (1970) fed rice hull base broiler litter at levels of 38, 48, 58 and 68% to lambs. A control group was fed alfalfa hay. Daily gains were 84 g for lambs fed

alfalfa hay and 208, 186, 174 and 170 g for animals fed the respective levels of broiler litter.

Chester-Jones et al. (1980) fed deepstacked and ensiled broiler litter to growing cattle at levels of 0, 20, 40 and 60%. Daily gain and DM intake were not lowered by feeding 20 or 40% deepstacked or ensiled litter. Weight gain and feed efficiency were decreased markedly when the level of litter was increased to 60%. Feeding 20% ensiled or deepstacked litter resulted in higher rates of gain than feeding the control diet (1.23 vs .91 kg/d). Feed efficiencies were similar for cattle fed the 20% litter and control diets. Incorporation of 40 and 60% litter decreased the feed efficiencies.

Ray and Child (1966) reported that beef calves fed cottonseed hull or cottonseed hull broiler litter as a roughage source gained more rapidly and efficiently than steers fed prairie hay. Galmez et al. (1970) found better performance in ewes fed a diet containing 68% broiler litter, as compared to ewes fed a diet containing 87% alfalfa hay.

McClure et al. (1979) studied the performance of finishing steers fed corn silage alone or ensiled 70% corn forage and 30% broiler litter, dry basis. Average daily gain was .75 kg for the unsupplemented corn-silage diet, .94 kg for soybean meal supplemented corn silage diet and 1.02 kg

for the corn litter silage diet. Feed efficiency was higher for cattle fed the corn-litter silage than those fed corn silage alone and corn silage supplemented with soybean meal.

Processing of Broiler Litter

Processing of litter not only destroys the pathogens but also reduces the nutrient losses and improves the palatability, and in some cases the storage quality. Processing methods of broiler litter which have been studied include drying, autoclaving, fumigation, deep stacking, composting, oxidation ditch, and ensiling.

Drying. Flagel and Zindel (1971) suggested that dehydration of cage layer waste may be an attractive processing system. Surbrook et al. (1971) reported that drying cage layer waste at 37.0 to 70.5 C eliminated the pathogenic organisms. They also observed that this method of processing poultry manure reduced the bulkiness of animal waste by 20 to 30% of the original volume. Nevertheless, this method is a costly process and may not be economically feasible.

Dehydration may be effective against pathogens, but processing by this method resulted in a considerable loss of N (Caswell et al., 1975). Shannon and Brown (1969) reported that drying of poultry waste at 60 and 120 C resulted in a 4.6 and 10.6% loss in nitrogen and 5.5 and 2.5% loss of energy, respectively. Kubena et al. (1973) found that higher

drying temperature and longer drying period increased loss of N from broiler waste. Fontenot et al. (1971) reported that drying broiler litter at 150 C for 3 h resulted in a 20% loss of total N. The acidification of broiler litter with H_2SO_4 acid (up to pH 6) prior to dehydration resulted in a 50% reduction in N loss when litter was dried at 150 C for 4 h (Harmon et al., 1974). In-house drying of poultry waste, a two-stage drying of poultry litter, was introduced by Pennsylvania State University (Ostrander, 1975). The method involved collection of waste on the timber slats of different widths. The loss in moisture content ranged from 7.5 to 12.7% with subsequent reduction in odor.

A solar dryer using plastic cover was used by Horsfield (1975). He reported that solar dryer may reduce the weight to about 72% of original weight. He found that under weather conditions like in central Indiana, a solar dryer with a surface area equivalent to 18.6 sq m per dairy cow can remove about 79% of the total moisture added in the course of 1 yr. He estimated a total cost of $13 per year for the solar dryer of excreta for one cow.

Autoclaving. Autoclaving of broiler litter at 116 C under steam pressure of 1.05 kg/cm^2 for 30 to 120 min did not totally eliminate the bacterial growth (Fontenot et al., 1971), whereas heating at 100 or 150 C for 4 h resulted in

sterilizing the litter. Caswell et al. (1975) autoclaved wood shaving broiler litter in the metal pans to a depth of 5 cm at 121 C under steam pressure of 1.05 kg/cm for 5, 10, 15 and 30 min. They found that unprocessed broiler litter was highly contaminated with coliform bacteria. Coliforms were eliminated at all processing times. Further, they found the lowest losses of NPN in autoclaved litter, compared to dry heat, paraformaldehyde and ethylene oxide treated broiler litter. Harmon et al. (1974) reported a N loss of 10.8% and a complete elimination of bacteria in autoclaved broiler litter.

Fumigation. The bacterial population of broiler litter was reduced when litter was treated with ethylene oxide at a depth of .64 to 3.81 cm for a period of 4 to 17 h at room temperature (Messer et al., 1971). Harry et al. (1973) reported that treatment of broiler litter with methyl bromide was effective in destruction of Salmonella typhimurium.

Caswell et al. (1975) found that fumigation of broiler litter with ethylene oxide at 22 C at a depth of 7.6 cm for 30, 60 and 120 min at atmospheric pressure was effective against coliform. However, the treated broiler litter lost a significant amount of total-protein and NH_3-N.

Deep Stacking. Deep stacking of poultry waste involves the storage of materials in an open shed while the inner part

undergoes anaerobic fermentation. Dana et al. (1978) studied the characteristic of litter, stacked at a depth of 1.55 m in a roofed building open on all sides, over a period of 6 wk. The results suggested that upper part of litter underwent an intense aerobic process due to rise in temperature. Maximum temperature of 54 C was recorded after 7 d at 46 cm depth. At the depth of 82 cm, 3 wk were required to attain the maximum temperature of 45.8 C. After d 14 the upper and lower parts maintained a constant temperature. Fecal Coliform, Salmonella, and Shigella were not found at any time during the 6 wk study. Total Coliform and Proteous were eliminated by this process.

Hovatter et al. (1979) stacked broiler litter at a depth of 1.22 m in a covered building open on all sides for a period of 42 d. Total and fecal Coliform counts, Salmonella, Shigella and Proteous were totally eliminated after 1 wk.

Composting. Composting of broiler litter involves storage of the material in an open shed and then the material is turned over once or several times during the composting process. According to American Public Works Association composting is described as "rapid but partial decomposition of the organic matter by the use of aerobic microorganism under controlled conditions" (Anonymous, 1970). Wiley (1962) stated that aerobic composting is a themogenic biochemical

process which is more efficient and faster than the anaerobic process. He also reported that the destruction of pathogenic organisms occurred by thermal and biological destruction.

Reed (1969) composted the sawdust-based poultry litter and observed that temperature reached 60 C at 55 to 60% moisture levels. He stated that maximum microbial activity occurred at 55 to 60% moisture levels. Albin and Sherrod (1975) found that feed containing composted feedlot waste increased the cell wall digestibility by 100% but decreased CP digestibility.

Abdelmawla et al. (1988) fed composted, deepstacked and ensiled broiler litter to sheep at the level of 30% of a basal diet, dry basis. They found lower ($P<.01$) CP digestibility for animals fed deepstacked and composted than animals fed ensiled broiler litter. The composted litter supplemented diet had higher hemicellulose digestibility, 61% than deepstacked and ensiled litter, 48 and 53%, respectively.

Oxidation Ditch. The oxidation ditch is a technologically advanced aerobic process applicable to all livestock waste. It comprises a continuous open-channel ditch and an aeration motor that circulates the liquid in the ditch and supplies oxygen (Muller, 1980). Poelma (1974) reported that use of a floating aerator in an underfloor-manure storage system resulted in about 50% N loss. Muller (1980) suggested

that the system may be feasible but is unreliable for nutrient recovery. About 80% of OM is mineralized or converted into gases.

Ensiling. The ensiling process involves achieving a stable pH in the ensiled material and production of a sufficient concentration of lactic acid and other organic acids, as a result of the presence of microorganism within the ensiled mass (Barnett, 1954). The process inhibits other forms of microbial activity, and thus preserves the material until silages are fed.

The ensiling process depends upon following three interrelated factors: 1) the composition of the material to be ensiled, 2) degree to which anaerobic conditions are maintained in the silos, and 3) the bacterial population in the ensiled material (Kohler and Hellwig, 1985). During the ensiling process there is production of heat due to continued plant respiration and activities of aerobic bacteria until all of the entrapped oxygen is utilized. Once anaerobic condition is established, the anaerobic bacteria utilize soluble carbohydrates to produce organic acids. These acids in turn lower the pH of the material and stop further activity of the bacteria (Barnett et al., 1954). There is minimal loss of readily-fermentable carbohydrates, once anaerobic conditions are established (MacDonald, 1982). Muller (1980)

stated that the entire ensiling process is completed in 12 to 18 d. If proper pH is not reached within a specific period, butyric acid-producing bacteria dominate and an increase in pH is observed (McDonald, 1981). This type of fermentation is generally called clostridial type of fermentation, which produces a foul-smelling, slimy, unpalatable silage. The clostridial bacteria attack the protein or amino acids and convert them to VFA, NH_3 and amines. This results in N loss and reduced acceptability of the silage by the animals (McDonald et al., 1973).

Ensiling of animal waste results in the improvement of palatability, reduction of nutrient loss, elimination or reduction of pathogenic organisms and decreased energy cost (McCaskey and Anthony, 1975).

Harmon et al. (1975) ensiled corn forage harvested at two stages of maturity with broiler litter supplying 15, 30 and 45% of the total DM of the ensiled mixtures. They suggested that the production of lactic and acetic acids from corn forage-broiler litter was responsible for destroying the pathogenic bacteria present in litter. They found greater ($P<.05$) N retention for sheep fed silages containing litter than animals fed control or urea-treated silage. They also suggested that ensiling broiler litter with corn forage is more economical and convenient than use of artificial heat.

Caswell et al. (1977) ensiled high moisture corn grain (26.3% moisture) alone and with broiler litter in a ratio of 2:1. The coliforms were not completely eliminated by ensiling process. The number was reduced from 695 and 290 x 10^3/g to 199 and 149/g for corn alone and corn-litter mixture silage, respectively. A positive proteus test was observed in initial and fermented materials. The initial high DM content of corn and corn litter mixture (73.7 and 76.6%, respectively) could have had an effect on the fermentation process of the material. Caswell et al. (1978) investigated the ensiling of broiler litter with moisture levels of 15.6 (no water added), 20, 30, 40 and 50%. They found that the maximum fermentation was approached at 40% moisture, as measured by pH and levels of lactic acid, acetic acid and water-soluble carbohydrates. Coliform bacteria were eliminated by ensiling the litter at 20 to 50% moisture. Nitrogen retention was lower ($P<.05$) in animals fed the heat dried litter diet than those fed ensiled litter and soybean meal. They also found higher N retention in animals fed litter silage with 40% moisture than those fed litter silage with 22% moisture. Duque et al. (1978) ensiled broiler litter with 22, 30, 40, 50, 60 and 70% moisture levels, respectively. Addition of water markedly reduced the pH from 8.4 to 7.5 and increased the lactic and acetic acid production

in the litter. The litter ensiled with 40 and 50% moisture levels had the highest level of acetic acid and eliminated the coliform bacteria in the ensiled mixture. Smith and Danials (1977) ensiled the rice hulls or wheat straw based broiler litter with 40 and 50% moisture levels. They reported lower pH in straw-based litter than rice hulls litter. They also reported that both the moisture levels are optimum for ensiling the broiler litter.

Health Aspects of Feeding Animal Waste

In 1967, the Food and Drug Administration (FDA) passed a regulation that the agency would not sanction the use of poultry waste as animal feed due to the presence of drug residues or their metabolic derivatives, and potentially hazards from possible disease organism (Kirk, 1967; Taylor et al., 1974). In 1980 the FDA delegated the responsibilities of regulating the use of animal wastes as feedstuff to the individual states (FDA, 1980). After consideration of number of state regulatory options the Animal Waste Task Force of the American Association of Feed Control Officials developed a model regulation, which emphasizes testing, labeling and registration requirements for processed animal waste products as animal feed ingredients (AAFCO, 1984).

Pathogenic Organisms. Burrow (1968) reported that enteric facultative anaerobes (coliforms) are responsible for

several disorders such as clidera, cystitis, local infection such as abscess and conjunctivitis, white scours in young animals, mastitis and accumulation of intraluminal fluid.

The members of coliform group are Escherichia coli and Aerobacter aerogenes (Pelezar and Reid, 1965). In the family of Enterobacteriaceae, Burrow (1968) included Salmonella, Shigella and Proteus spp. A wide variety of disorders, including bone infection, infection of central nervous system, gastroenteritis and abortion are caused by these organisms. Salmonella spp. are mainly found in poultry waste (Smith et al., 1984, Kraft et al., 1969). Alexander et al. (1968) reported that 23 out of 44 samples of broiler litter tested positive for Clostridium, Corynebacterium, Salmonella, Actinobacilli, Mycobacterium and Enterobacteriaceae.

Bacillus spp, Proteus spp, E. coli and other members of Enterobacteriaceae family were found in 40% of fresh poultry fecal waste, while 60% of the samples were positive for coliforms (Zindal, 1970).

Halbrook et al. (1951) reported that 1-yr-old broiler litter exhibited fewer counts of coliform than litter changed weekly or between groups of broiler. Lactobacilli and coliform counts ranged from 1,000 to 200,000/g in 1-yr-old litter, 600,000/g in unused litter and 3 million/g for litter used 1 to 8 wk.

Lovett et al. (1971) reported approximately 10% of total bacterial population of litter to be coliforms of which approximately one third were E. coli.

Antimicrobial Drug Residues. Antibiotics and other antimicrobial drugs like sulfa drugs, coccidiostatics, etc. are used in disease control in poultry. They are excreted via the intestinal and urinary route, which may be the source of potential hazards in waste feeding. Bergman et al. (1964) did not find any residue of the drugs except arsanilic acid, in the litter of laying hens fed diets containing arsanilic acid, zoalene, unistat, nicarbazin, furan and sulfaquinoxaline.

Morrison (1969) investigated the fate of organo-arsenicals as feed additives to broiler diets. They found these drugs in broiler litter but quantities detected were too low to create any hazard. Messer et al. (1971) detected furan derivatives in poultry litter. The furazoidone level ranged from 10.2 to 21.5 ppm and nitrofurazone from 4.5 to 26.7 ppm.

Webb and Fontenot (1975) reported 10.9 ppm oxytetracycline, 12.5 ppm of chlortetracycline, 27.3 ppm amprolium, 81.2 ppm nicarbazin, 40 ppm arsenic and 255 ppm copper in broiler litter. Longissimus muscle, liver and kidney fat of steers fed diets containing 25 and 50% broiler

litter showed no residues of amprolium, neomycine, zinc bacitracin and nicarbazin after 5 d of withdrawal period. Low levels of chlortetracycline were found in kidney fat of 3 of 20 steers. They suggested increased arsenic residues in both longissimus muscle and liver with the increasing levels of litter. Copper level was higher in the liver (355 ppm) than muscle (34 ppm). They also suggested that drug residues are frequently found in broiler litter but feeding litter to cattle resulted in little or no drug accumulation in the tissue after a 5-d withdrawal of litter.

Bruggemann et al. (1963) fed the recommended levels of amprolium, zoalene, arzene and arsanilic acids to broiler chicks for 8 wk. Analysis of liver, kidney, fat and muscle tissue of the individual birds for the specific residues showed a constant low level, which indicated that drugs did not accumulate. They also found constant low levels of residues in the tissues when drug levels were increased from 1 to 10 times in the feed. El-Sabban et al. (1970) fed a diet to steers containing poultry manure containing 17 mg/kg of the arsenic. They found higher ($P<0.05$) levels of arsenic accumulation in liver samples from steers fed diets supplemented with cage layer waste compared to arsenic levels in liver samples from steers fed soybean meal and urea.

Pesticide Residues. El-Sabban et al. (1970) reported that feeding a diet containing 28% dried poultry waste to fattening cattle did not result in accumulation of pesticide residue in backfat of steers. Fontenot et al. (1971) reported that broiler litter contained low levels of pesticides, but when fed to cattle no accumulations were found in the liver and kidney fat after the 5-d withdrawal period. Wasti et al. (1970) detected residues of Rabon, an orally administered pesticide used to control internal parasites in the poultry manure. Ivey et al. (1968) sprayed the cattle with .125, .25, and .5% concentrations of Gardona to control the Hypoderma spp. Samples of muscles, liver, kidney, brain, spleen and fat were taken after 7, 14 and 21 d. They reported that traces of drug residue from all tissues were completely eliminated within 21 d. They stated that the drug was non-hazardous to cattle.

Mineral Residues. An excessive accumulation of minerals in broiler litter is encountered when a high level of mineral is fed to animals (Muller, 1980). Copper values of 150 ppm (Long et al., 1969; Hodgetts, 1971) and 94 ppm (Calvert and Smith, 1978) were reported for dried poultry manure.

Sheep do not tolerate as high a Cu level in the diet (below 25 ppm) as other livestock (Underwood, 1977). A potential danger exists, particularly when higher level of

broiler litter is incorporated in the diet (Fontenot et al., 1971). In another trial Fontenot et al. (1972a) reported Cu toxicity in ewes fed broiler litter containing 57.1 and 109.1 ppm of Cu. Thomas et al. (1972) reported that sheep fed 0, 25, and 50% of dehydrated poultry waste containing 30, 24 and 35 ppm Cu, respectively, did not show any signs of Cu toxicity. In a feeding trial substitution of poultry waste containing 94 ppm of Cu resulted in liver Cu of 333 ppm, compared to 158 ppm in control animals. However, blood, muscle and kidney Cu levels remained unchanged (Smith and Calvert, 1976). Webb and Fontenot (1975) conducted two feeding trials with steers fed 25 or 50% broiler litter containing 230 or 289 mg/kg Cu. They reported that liver and muscle Cu levels increased from 361 to 488 ppm and 3.1 to 3.7 ppm, respectively. Webb et al. (1979) fed cows diets containing high levels of broiler litter with high Cu levels, alone and in combination with supplementary Cu to add an equivalent of 200 ppm during the winter period. They reported that performance was not affected, but liver Cu levels increased from 58.8 mg/kg in the control to 561.3 mg/kg in the test diet. They found that by the end of summer grazing period, the liver Cu levels were decreased and no Cu toxicity sign was found in the animals throughout the experimental period.

Bruhn et al. (1977) reported no significant difference in Cu content of milk when cows were fed diets supplemented with 9.9% dried poultry waste containing 51.1 ppm Cu over a 4-wk period, compared to the milk of cows fed a control diet. They reported that Cd in dried poultry waste was 1.3 ppm, which was higher than the control diet. The level of Cd found in raw milk for both dried poultry waste and control diet fed cows averaged 6.24 and 3.7 ug/g, respectively. Feeding diets containing 7 ppm of Pb resulted in 49.6 ug/kg of Pb in raw milk, compared to 56.2 ug/kg for cows fed the control diet.

Fontenot et al. (1979) stated that arsenic, Cu and Se are used as feed additives in the diets of poultry, while Cd, Pb and Hg are not added to the diets but occur naturally in the feedstuff. Calvert and Smith (1976) reported no significant differences in Cd and Pb of the diets of steers which contained 12.1% dried poultry waste. The level of Cd in the kidney of steers averaged .5 ppm for controls and 1.7 ppm for dried poultry waste fed steers. In the same trial they found 333 ppm Cu in the liver samples of waste fed steers compared to 158 ppm in the control animals.

Hormone Residues. Calvert et al. (1978) reported the presence of androgenic and estrogenic activity in poultry manure. Abortion in beef cows fed low levels of broiler litter in wintering ration and subsequently grazed on pasture

fertilized heavily with poultry litter was reported by Griel et al. (1969). The cause of abortion was not identified. However, estrogenic activity of broiler litter was 10 ug/100 g of litter. They suggested that the presence of dienesterol diacetate in the poultry diet, which was excreted in the droppings may cause hormonal imbalance when fed to cattle. Feeding of this drug is no longer approved.

Hertelendy et al. (1965) reported the presence of 17β estriol in hen urine. Mathur and Common (1969) detected measurable levels of estrone and estradiol-17β in layer manure. The levels were significantly higher in waste from laying than from non-laying hens.

Slaughter House Wastes

Slaughter house wastes include blood, trimmings, fleshings, condemned organs, unused offals, hides, hairs and stomach contents (Mann, 1962).

Nutritional Value of Rumen Contents. The quantity of rumen contents has been estimated at 24.5 kg per animal or 3.8 kg dry weight per animal in cattle (Witherow and Lammers, 1976; Kampheus, 1981). In the United States landfill or field spreading are the most common disposal method (Witherow, 1974) for the rumen contents of small slaughter plants. However, large plants are efficiently utilizing it as a feed for animals.

The nutrient and digestibility of rumen contents varies with feeding practices used prior to slaughter (Mann, 1978). The CP content of the rumen contents varies from 10 to 25% (Antongiovanni et al., 1973; Jovanovic and Cuperlovic, 1974; Rao and Fontenot, 1987; Reddy and Reddy, 1980; Oshida et al., 1986; Reddy et al., 1985 and Ricci, 1977). Of the total CP 73.4% was in the form of amino acids (Jovanovic and Cuperlovic, 1977).

Meyer (1984) preserved the rumen contents with 2.1% urea. The preserved mass contained 5.5% N, 70% of which was in the form of NPN. Nitrogen of rumen contents was efficiently utilized by ruminants and nonruminants (Javanovic and Cuperlovic, 1977; Prokop et al., 1974). The rumen content is low in fat (2.7 to 3%, dry basis) (Kampheus, 1981 and Golubyatnikov et al., 1984). The CF values vary from 10 to 45% (Massersmith et al., 1974; Javanovic and Cuperlovic, 1977; Kamphues, 1981; and Meyer et al., 1985). Rumen contents had feed value similar to that of poor-quality alfalfa hay when fed to ruminants (Messesmith et al., 1974).

The available energy value of the rumen contents is influenced by the type of feed fed to the animals before slaughter (Meyer, 1984). Shebata et al. (1984) reported a metabolizable energy of 2470 kcal/kg DM when dried rumen contents were fed to quails. Coenen et al. (1985) calculated

the digestible and metabolizable energy of 1861 and 1551 kcal/kg DM, respectively, when dried rumen contents were fed to bulls. In another trial Meyer et al. (1985) reported the digestible energy of 1169.44 kcal/kg DM, when rumen contents were fed to sheep.

Golubyantniko et al. (1984) reported that rumen contents contained 1.5% Ca and 3.2% P, dry basis. They reported that rumen contents are also a good source of carotene (40.2 mg/kg of DM). Meyer et al. (1985) and Shebata et al. (1984) reported that dried rumen contents contained .046% P and .088% Na, DM basis. Copper contents ranged from 46.5 to 200 mg/kg DM. Values for Zn, Fe, and Mn were 81, 1595 and 98 mg/kg DM.

Kamphues (1981) showed that ensiling rumen contents with molasses and sugar beet pulp improved palatability of rumen contents when fed to sheep. The DM digestibility of the silage was 40%. Messersmith et al. (1974) reported that feeding 5, 7.5, 10 and 15% dried rumen contents to ruminants did not affect body weight gain, feed intake or feed efficiency. Ziolecka et al. (1984) fed 450 mg stabilized rumen extract daily for 90 d to calves. The gross energy utilization, net protein utilization and average daily gains were higher for rumen extract supplemented group, compared to the nonsupplemented group.

Meyer (1984) found that after pressing (increase of DM up to 25%) rumen contents can be preserved by adding 2% urea, fresh basis. The preserved rumen contents was fed to sheep with pressed sugar beet pulp silage (.65% DM/kg of body weight). The apparent digestibilities of OM, total N and CF were 45, 50.8 and 43.5%, respectively. In a fattening trial with heifers, urea-conserved rumen contents were used as a sole source of roughage. He observed higher daily weight gain by animals fed urea-conserved rumen contents, compared to animals fed an equal amount of hay.

Coenen et al. (1985) conducted a digestibility trial with bulls fed 2% urea (wet basis) preserved rumen contents. The OM, CP, total N and CF digestibilities of preserved rumen contents were 46, 51, 85 and 44%, respectively. The calculated digestible and metabolizable energy for rumen contents were 1.86 and 1.5 Mcal/kg DM.

Golubyatnikov et al. (1984) preserved rumen contents with .8% W/W of dilute HCl (.2%) solution. Preserved rumen contents were supplemented at a level of 242 g/d to pigs for 210 d. The animals supplemented with rumen contents gained more weight than those fed the basal diet alone. No difference was observed in quality of carcass and internal organs. Oshida et al. (1987) showed that feeding 60%, aerobically fermented rumen contents, fresh basis, to pigs resulted in

no significant reduction in weight gain, feed intake or feed efficiency. Meyer (1984) showed that acceptance of fresh rumen contents by pigs was low, however, 250 g DM/d of 2% urea conserved rumen contents was eaten by pregnant sow when mixed with conventional feed without any adverse effect on health.

Javanovic and Cuperlovic (1977) prepared rumen contents meal by mixing rumen contents with maize meal. The meal was given to chicks (0-8 wk old) as 23 or 60% of the diet, wet basis. The diet containing 23% rumen contents meal gave better performance than control diet. Higher levels of rumen contents meal reduced the final body weight of chicks. Charper et al. (1989) showed that feeding 2 or 4% of dried rumen contents to chicks resulted in no significant difference in feed intake, daily weight gain and feed efficiency. A chick diet, based on rice polishing, was replaced by 0, 30, 60, 90 or 120 g/kg dried rumen contents or 0, 29, 59, 88 or 119 g/kg sieved and dried rumen contents (Reddy et al., 1985). The dried rumen contents and sieved dried rumen contents contained 8.8 and 12.2% CP, respectively. Results indicated no difference in weight gain of chicks fed dried rumen contents but sieved dried rumen contents showed higher weight gains than those fed control, rice polishing based diets.

Shebata et al. (1984) filtered rumen contents and the liquid was dried at 60 C. The dried rumen liquor contained 25.92% CP. Japanese quail were given diets containing 1, 4.28 and 8.56% dried rumen liquor. The results showed that feeding quails 1 and 8.56% dried rumen liquor resulted in similar feed intake, weight gain and feed efficiency as birds fed a control diet. However, birds fed 4.28% dried rumen liquor gained faster than those fed the control diet.

Jovanovic and Cuperlovic (1977) showed that feeding 10% dried rumen contents to rats had no effect on growth rate, but increased feed consumption. In one trial, apparent digestibilities by rats fed rumen contents protein in a semi-synthetic diet containing 50% dried rumen contents were 44.6% for protein and 56% for DM. Summerfelt and Yin (1974) found that feeding 10 and 20% rumen contents, dry basis, resulted in no significant difference in final weight of pond-reared catfish fed a commercial diet.

Nutritional Value of Blood. Blood is an excellent source of protein. In some countries, hygienically collected blood is used as human food, but the major use of blood is protein source for farm animals (Divakaran, 1982).

The CP content of whole blood varies from 85 to 92%, dry basis (El-Yassin et al., 1984; and Rao and Fontenot, 1987). Of the total protein, 80% was in the form of amino acids

(Kramer et al., 1978). Blood meal contains higher levels of leucine and there is evidence indicating that a high level of dietary leucine elevates the isoleucine requirement (Taylor et al., 1977). Fresh blood preserved with 60 and 100 ml/kg of 50% H_2SO_4 had 7.4 and 20.0% soluble protein, respectively (Aranda, 1980).

Petkove et al. (1981) showed that feeding 3% blood meal to chicks resulted in lower weight gain. They concluded that the proportion of blood meal in the diet of chicks was too high and estimated that blood meal can replace only 30 to 50% of fish meal in diets of broiler chicks. In another trial, they found contradicting results when 4% fish meal was replaced with blood meal in a broiler diet. Results indicated higher weight gain and feed efficiency in chicks fed blood meal diet than chicks fed fish meal diets.

Abou-Raya et al. (1973) showed that feeding 2% blood meal to chicks resulted in higher body weight gain and feed efficiency. There was 7.7% increase in carcass CP, compared to chicks fed a basal diet. Coser et al. (1979) fed commercial blood meal and meal prepared in the laboratory, with or without isoleucine supplement, to young rats. Rats on diets without isoleucine supplement and those on commercial blood meal with isoleucine, had lower feed intake and lost weight. No significant differences were observed in weight gain and

feed efficiency of rats given laboratory meal supplemented with isoleucine and control groups supplemented with casein. Available lysine and total lysine values were lower in commercial blood meal than in laboratory blood meal.

Fitzpatrick and Bayley (1977) fed piglets diets containing 20% protein in which the supplemental protein was supplied by soybean flour, freeze dried blood, and commercial blood meal supplemented with methionine and isoleucine. They found no significant differences in weight gain and feed efficiency. However, amino acid and protein digestibilities were lowest for pigs fed commercial blood meal.

King and Campbell (1977) showed that pigs receiving 5.9 or 8.9% blood meal grew more efficiently than those receiving either 0 or 11.8% blood meal. In another experiment they found that supplementing 0.1% isoleucine to a 12% blood meal diet significantly increased both feed intake and growth rate. Barbosa et al. (1983) showed that replacing soybean meal with 0, 2, 4 and 6% of blood meal in a pig diet resulted in no significant difference in weight gain. Daily intake tended to increase and feed efficiency tended to decrease with increasing blood meal levels. Walker (1977) showed that protein content and available lysine values of formalin-treated blood varied from 90.7 to 94.5% and 6.9 to 7.8%, respectively.

Reggiardo et al. (1981) indicated that supplying 10 or 20% of the digestible protein in a sheep diet with blood meal had no significant effect on weight gain or carcass yield.

Stock et al. (1981) showed that supplementing blood meal and urea in a steer diet resulted in higher weight gain than urea alone. Conversion of feed to gain, as well as the conversion of protein to gain was 216%, relative to soybean meal (100%). They concluded that feeding high quality slowly degradable protein (blood meal) with urea in growing steers reduced the cost of protein supplementation, while providing better performance compared to soybean meal. Padgett et al. (1978) showed that substituting peanut meal with 0, 5, 10, 14 and 18% whole blood preserved with .74% formaldehyde resulted in equal TDN, ME, digested N retained and apparent absorption of S, P and Ca. The calculated digestibility of CP of blood was 70.4%.

Silage Additives

Molasses. Molasses contains over 50% sucrose and has been widely used as an additive (Thomas, 1978). It provides available energy for the growth of lactic acid bacteria. The presence of sufficient quantities of readily-fermentable carbohydrate in the silage suppresses the production of deaminating enzymes by spoilage microbes in the by-product (Thomas, 1978). Thus, NH_3 production and increase in pH are

prevented (Raa et al., 1983). Lanigan (1961) reported that addition of molasses in alfalfa silage decreased pH, increased lactic acid and decreased DM loss. Ayangbile et al. (1986) tested addition of 10% dry sugar cane molasses to preserve the cage layer waste. They found that 84% of the molasses was converted to lactic acid, which lowered the pH and preserved the waste for several days.

Andrighetto et al. (1987) reported that large quantities of volatile compounds were formed with significant losses in OM when 4% molasses was added to Italian ryegrass (Lolium multiforum). Parigi-Bini et al. (1987) ensiled corn stover with 2% molasses and found lactic acid increased from .75 in corn stover alone to 1.16% in treated stover. Reed and Filch (1971) found that molasses-treated alfalfa silage was consumed in greater quantities by steers than alfalfa with treated wheat straw, ground corn or sweet sorghum stover. McCullough and Neville (1960) reported that performance of steers fed molasses-treated alfalfa silage was greater than that of control animals fed alfalfa and corn silage. Pratt et al. (1958) fed molasses-treated alfalfa silage and found no difference in milk production between cows fed the treated alfalfa silage and corn silage over a 2-yr period.

Inoculants. Wittenbury (1961) defined the following criteria which a potential organism should satisfy for use

in silage: 1) It must grow vigorously and be able to compete with and preferably dominate other organisms; 2) It must possess a homofermentative pathway; 3) It must be acid tolerant and capable of producing a final pH of 4; 4) It must be able to ferment glucose, fructose, sucrose, fructans and pentose sugars; 5) It must not produce dextran from sucrose; 6) It should have no action on organic acids; 7) It should be thermophillic; 8) It should have no proteolytic activity; 9) It should be economical.

Leisms and Schultz (1968) studied the effect of Lactobacillus cultures on clover and crownvetch silage, and found that microbial treatment resulted in lower pH and higher lactic acid, compared to control silages without inoculants. Wieringa (1960) studied the effect of wilting, O_2, temperature, lactic acid producing bacteria and level of sugars on herbage fermentation characteristics. He reported a decrease in digestibility from 76 to 60% due to warm fermentation silage when aeration time was increased from 0 to 2 d. He found that wilting the herbage had favorable effect because the pH tolerance of butyric acid producing bacteria decreased with increasing osmotic pressure. Further, he stated that inoculation of herbage with lactic acid bacteria resulted in well-preserved silage, provided the grass contains more than 6% sugar on DM basis. Kirov (1962)

treated alfalfa (30% DM) with .5% lactobacillus cultures and 1.5% molasses. The culture plus molasses-treated silage had higher lactic acid, lower pH and lower total bacterial counts than untreated silage. They concluded that inoculation of the clovers with lactic acid bacteria gave better results when 6.5%, sugar, dry basis, was present in the initial mixtures.

Ohyama et al. (1973) reported that inoculation with L. plantarum did not affect silage quality, but enhanced the fermentation in the presence of water soluble carbohydrate and proper sealing of silos. Wittenberg et al. (1983) reported no improvement in preservation of DM, CP, ADF or gross energy when corn silage was treated with L. plantarum. Bolsen et al. (1984) reported that the addition of L. plantarum and S. faecium improved DM recovery in a rapidly filled stave silo, but DM recovery was lower in silos where filling was delayed.

Urea. Urea has been added to low-protein forages to improve the protein content, DM intake and digestibility of the feed (Dias-Da-Silva and Sundstol, 1986). Using laboratory and experimental silos, several workers have shown that urea addition extended fermentation. This is shown in increased pH, increased lactic acid, and increased NPN (Owens et al., 1970; Colenbrander et al., 1971; Holter and Kabuga,

1974). Woodward and Shepard (1944) ensiled corn with .5% urea. They found no difference in milk production when animals were fed the silage compared to animals fed untreated silage with low protein concentrate. Davis et al. (1944) ensiled sweet sorghum with 0, .5, 1.5 and 2.5% urea. The CP, lactic acid and pH of the silage were increased with urea. Wise et al. (1971) treated corn silage with .5% urea. Crude protein content and pH were increased. The intake of the treated silage was less, as compared to the intake of untreated silage, but milk production was similar (11.2 vs 11.3 kg/d). Huber and Thomas (1971) and Huber and Santana (1972) fed lactating dairy cows urea-treated corn silage. They found a slight increase in milk production (1 to 6%) over control silage, even when supplemented to the same protein level.

Sodium Metabisulfite. Several chemicals have been used in an attempt to stop the decomposition of high moisture organic material. Zetter (1960) reported that .4% sodium metabisulfite had bacteriostatic effect on the butyric acid producing organisms, but was less effective against proteolysis and loss of nutrients. Murthy (1969) showed that the use of .2 to 1 g of sodium metabisulfite per liter of whole milk had no bactericidal effect, and high protein instability was observed within a 7-d storage period. Beutling

(1983) used sodium metabisulfite at a rate of 2% (w/w) in homogenized slaughter house offal, which allowed preservation for 8 to 10 d without any cooling. Lanigan (1961) used sodium metabisulfite at rates of .3 and .45% of DM in alfalfa silage and found that sodium metabisulfite helped the preservation process by preferential inhibition of undesirable fermentative changes, presumably by enhancing lactate-producing and reducing lactate-metabolizing bacteria in the silage. Meiske et al. (1965) found that the addition of .4% (w/w) sodium bisulfite inhibited nitrogen dioxide production in the silo. The bisulfite-treated silages contained more residual nitrate, which resulted in higher pH and lower concentrations of acetic and lactic acids. Scalleti et al. (1961) reported that sodium metabisulfite-treated silage inhibited toxic gas production. Sodium metabisulfite has been shown to inhibit the formation of VFA but has less effect on lactic acid production (Murdoch et al., 1965).

Mineral Acids. Virtanen (1933) developed a method of preserving crops of higher moisture content by using mineral acids, 7 liters of 2 N HCl or H_2SO_4 per 100 kg of green fodder (AIV process). The main objective of using mineral acid was to lower the pH of forage to a level at which plant and microbial enzymes would be inhibited. He found that when the pH of material was reduced to 3.6 by HCl, no free mineral acid

remained in the fodder. He concluded that the acidity was not due to the presence of free HCl but due to protein bodies of acidic nature and weaker organic acids, such as oxalic, malic and citric, which are liberated by stronger mineral acids reacting with basic constituents of the fodder.

The effectiveness of the acid as a preservative depends on the dissociation constant (Pka) at which 50% of the total acid is dissociated. At this pH, which ranges from 3 to 5, the undissociated portion of the molecule is believed to be responsible for antimicrobial effect (Raa et al., 1983).

Divakaran (1987) preserved slaughter house by-products (blood and offals) by pickling with 3% sulfuric acid, which was later sundried. He found that acidulated sun dried blood had higher pepsin digestibility and available lysine value than commercial blood meal. Edin (1940) investigated the effect of H_2SO_4 preserved fish silage on the performance of chickens and reported that growth rates were identical to those on control basal diets.

Organic Acids. The antimicrobial effect of the short chain fatty acids has been well documented (Galbraith et al., 1971; Woolford, 1975). Wing et al. (1976) ensiled alfalfa containing 45% DM without additive, and with 1.25, 1.75 and 2.25% formic acid and 1 and 1.50% propionic acid, DM basis. They found higher values of NPN, soluble N and NH_3-N for the

alfalfa ensiled without additive, compared to silages containing formic and propionic acids. They stated that the decrease in NPN, soluble N and NH_3-N in the preserved silages may be due to binding properties of the acids to protein. Propionic acid and formic acid have been used extensively in the ensiling processes of plant products (Wing et al., 1976; Stallings et al., 1981), in the preservation of wet brewers grain (Allen et al., 1975), and crab waste (Abazinge et al., 1986; Ayangbile, 1989). The use of formic acid and commercial inoculant in grass silage with low DM (16%) and high water soluble carbohydrate (15%) has been reported by Haigh et al. (1987). The additives decreased silage pH and NH_3-N. There was an increase in residual soluble carbohydrate with addition of formic acid, when compared with inoculant or untreated silage. The formic acid was also effective against clostridial fermentation.

Singh-verna (1974) used the combination of formic and propionic acid, acetic and sorbic acid, 1:1 (v/v) at .65% (w/w) for preservation of soybean, mixed feed, barley and wheat with 30% moisture. Preservation was achieved for as long as 2 mo. He found that formic acid was more active than other acids. Woolford (1984) found that formic acid, sodium diacetate, propionic acid, ammonium isobutyrate and tributylephosphate were effective in reducing the microflora

of moist hay, and the antimicrobial properties of the additives were enhanced under acidic conditions. In another study Woolford (1974) found that salts of formic, acetic, and propionic acids and glutaraldehyde showed antimicrobial action against enterobacteria, clostridia and Bacilli, when used as silage additives, thereby creating a desirable fermentation. Yu et al. (1975) used .4% propionic acid and .5% ammonium isobutyrate on alfalfa hay. They found 40% reduction in fungal counts. Further reduction (75%) was achieved when doses were doubled. Paster (1979) found lower fungal population in poultry feed containing 13% moisture when stored for 53 d under summer conditions if .3% (w/v) propionic acid was used, compared to .5% (w/v) calcium propionate treated and untreated poultry feed.

Addition of 3% (w/w) of 98% formic acid to minced cod viscera yielded a stable silage with low microbial count (Backhoff, 1976). The use of 1.5% formic acid in preserving silage of cod viscera resulted in decreased soluble carbohydrates, increased pH and unpleasant odors of amines, with patches of mold growth (Gillerg and Raa, 1977). A mixture of propionic and formic acid at a concentration of 1.5 to 2% of each acid produced ensiled material with a pH of about 4.4 after 24 h. At this concentration, moldy fermentation was completely prevented (Raa et al., 1983). The mixture of

formic/propionic acid at a rate of 1.5% has been used to preserve the crab waste (Abazinge et al., 1988).

Stallings et al. (1981) ensiled the alfalfa haylage containing 40% DM without any additives, and with .2% formic acid and 1% propionic acid. The ensiling was done for 56 d with slight exposure to air. At d 56 the visible mold contamination was higher (75%) for formic acid-treated silage, compared to propionic acid-treated (15%) and untreated silage (40%). Formic acid-treated silage showed an increase in pH from 5 to 7 and insoluble N from 41 to 68%. Adding 1% propionic acid resulted in a reduction of pH and soluble N and NH_3 concentrations. They stated that the use of formic acid at the level of .2% for preserving the alfalfa haylage was ineffective. Handerson and McDonald (1971) had shown that up to 50% of formic acid used in silage making is lost through vaporization.

Muller et al. (1977) studied the effects of formaldehyde and propionic acid in preservation and fermentation of colostrum. They found that the chemicals were effective in retarding mold and yeast growth and degradation of protein. In another study, Muller et al. (1975) investigated the effect of a propionic/formic acid mixture and formaldehyde on preservation and fermentation of colostrum at 21, 32 and 39 C. Use of the formic/propionic acid mixture maintained low

pH after 18 and 23 d. However, formaldehyde maintained the initial pH of the colostrum. At temperatures of 21 and 32 C, the treatments reduced protein degradation, compared to the control. Lindahl (1974) found that the addition of 1 ml of 37% formaldehyde to 4 kg of reconstituted milk replacer retarded bacterial growth and prevented souring of the replacer for 24 h at 25 C, and 72 h at 7 C.

Ensiling of Slaughter House Waste. Ensiling of slaughter house waste has been shown to be a rapid and effective method of processing these wastes (El-Yassin and Fontenot, 1984; Raa and Fontenot, 1987).

Slaughter house wastes (blood and rumen contents) were ensiled by Raa and Fontenot (1987). The slaughter house wastes were ensiled with crop residues, with and without molasses. They reported low pH, and high lactic acid in all the ensiled mixture, which indicated that desirable fermentation had occurred. Alomar (1978) reported that ensiling of rumen contents with barley was a feasible way of preserving the rumen contents. El-Yassin and Fontenot (1984) ensiled whole blood and rumen contents with wheat straw untreated and treated with NaOH, with and without dry sugar cane molasses. They found that desirable fermentation occurred in all mixtures.

Crop Residues

Experiments have shown that some of these residues may fulfill the maintenance requirements of mature animals (Sundstol and Owen, 1984). In the USA 300 million metric tons of straw, stalk and stubbles are produced annually (USDA, 1979). Corn crop residue is estimated to be about 162 million tons of DM per year (Keys and Smith, 1981) which is over one half the total available residue supply. The estimated quantity of wheat straw (44 million tons) per year constitutes only about 15% of the total crop residue supply.

Nutritive Value of Wheat Straw. Brahman and Abe (1977) reported that untreated wheat straw contained 3% CP, 82% cell wall constituents and 4.3% ash, dry basis. Variation in nutritive value has been attributed to variety, cultural practices and time of harvesting (Jackson, 1979) irrigation and climate, and fertilization (Coxworth et al., 1981). Walker (1984) suggested that the fiber size, conformation and composition of straw limited the digestibility of cellulose and hemicelluloses polysaccharides. Coombe et al. (1979) demonstrated that chopped wheat straw alone has little value for feeding growing calves. Acock et al. (1979). have shown that feeding one third alfalfa hay with wheat straw can meet protein requirements of gestating beef cows.

Chemical Treatment of Crop Residues. The digestibility and voluntary intake of untreated straw is low, compared with animals fed high quality roughages (Harold, 1984). It has been well established that as plants mature, the lignin content increases (Theander and Aman, 1984), which decreases the digestibility of the plant. Digestibility and voluntary intake of straw can be increased by treating with chemicals (Jayasuriya and Perera, 1982; Dias-Da-Silva and Sundstol, 1986). The chemicals which have been routinely used are NaOH, $Ca(OH)_2$, KOH, urea and NH_3.

The mode of action for chemical treatment of crop residues has been established (Jackson, 1977). In general, the chemical treatment solubilizes some of the hemicelluloses without changing the cellulose. The reaction breaks the ether linkage between lignin and hemicelluloses (Hartley, 1981). There has also been suggestion of a swelling effect of chemical treatment on acetyl linkages of lignin and hemicellulose (Waller, 1976).

The use of urea as a NPN source and use of urea as a source of ammonia for straw treatment is well documented (Saadullah et al., 1981). Oji and Mowat (1977) treated maize stover with urea solution in polyethylene bags at room temperature. They found that after 2 d 70% of urea was decomposed. The wheat straw was low in urease enzyme, required

for hydrolysis of urea. Jackbean meal had to be added as a source of urease. The OM digestibility of the urea-treated straw was increased when jackbean meal was added. Azim and Ali (1985) analyzed various crop residues and animal wastes for their urease enzyme activity. The maximum activity was found in watermelon seeds, followed by soybean, pigeon pea, cattle manure and least in poultry litter and manure. Further, they stated that cattle manure appeared to be the most economical source of urease enzymes. Ibrahim (1983) found the treatment time for straw ensiled with urea could be reduced to 3 d by adding 8.5% soybean powder.

CHAPTER III

PROCESSING OF BROILER LITTER BY DEEP STACKING AT DIFFERENT MOISTURE LEVELS AND ENSILING WITH ADDITION OF WATER, MOLASSES AND RUMEN CONTENTS

ABSTRACT

The feasibility of processing broiler litter by deep stacking and ensiling was evaluated prior to use as feed ingredients. Fresh broiler litter was collected from the peri-urban area of Islamabad, Pakistan. Broiler litter was deep stacked at 15, 25 and 35% moisture; ensiled at 40% moisture, alone or with 5% added sugarcane molasses; and ensiled with rumen content at 60:40 and 50:50, wet basis. Deep stacking was in 1.2 x 1.2 x 1.2 m bins and ensiling was in 210 liter metal drums double lined with polyethylene. Litter, deep stacked at 15% moisture, showed a lower rise in temperature than litter deep stacked at 25 and 35% moisture. Maximum temperature was recorded at 40 cm depth for litter stacked with 25% moisture. Weekly data of stacked litter showed an increased ($P<.01$) concentration of DM. Overall, deep stacking had no effect on the chemical composition of broiler litter. Deep stacked litter was devoid of lactic acid, but the processing was effective in destruction of pathogens. Desirable fermentation was achieved in all the

silages, with significant reductions in pH and water soluble carbohydrates, and increases in lactic acid. The highest pH and lowest lactic acid concentration were recorded for silages containing broiler litter and rumen content 60:40, wet basis. Highest concentrations of total VFA, isovaleric and valeric acids, were found in broiler litter with rumen content 50:50, wet basis ($P<.05$). No pathogen microbes were observed in the ensiled mixtures.
(Key Words: Broiler litter, Rumen content, Deep stacking, Ensiling).

Introduction

In Pakistan, approximately 20 million metric tons of poultry litter are produced annually (Hasnain, 1983), most of which is not utilized. In the U.S. approximately 48 million tons of poultry waste are produced annually (Fontenot and Webb, 1974). Litter represents a waste product of the poultry industry which must be disposed of. Presently, poultry litter is disposed of by the traditional method of spreading on the land as a fertilizer. It has been shown that poultry litter is more valuable as a feed ingredient than as a fertilizer (Arndt, et al., 1979). Economic value of poultry litter as a feed component in balanced diets of

ruminants is three to four times greater than its value as plant nutrient (Smith and Wheeler, 1979).

Broiler litter has nutritional value (Fontenot et al., 1966). The CP content of broiler litter has averaged 30.81% or higher (NRC, 1983). In broiler litter 45% or more of the total N is in the form of protein (Bhattacharya and Fontenot, 1965, 1966). The main NPN constituent in poultry litter is uric acid (Bhattacharya and Fontenot, 1966). Other NPN fractions include NH_3, urea and creatinine. Nitrogen from poultry waste has been shown to be efficiently utilized by ruminants (Bhattacharya and Fontenot, 1965; Smith and Calvert, 1972). Poultry litter is an important source of energy as well as N for ruminants. Energy of autoclaved litter was efficiently used by ruminants (Bhattacharya and Fontenot, 1965, 1966).

When broiler litter was fed experimentally to beef cattle (Noland et al., 1955; Southwell et al., 1958; Fontenot et al., 1963; Drake et al., 1966) and sheep (Noland et al., 1955), satisfactory performance was obtained and no serious animal health problems were encountered. However, poultry litter was not sanctioned by FDA due to potential hazards of drugs and pathogenic organisms (Kirk, 1967). In 1984 the Association of American Feed Control Officials developed a model regulation which emphasizes testing, labeling and reg-

istration requirements for processed animal wastes as a feed ingredients (AAFCO, 1984). Due to the possible presence of harmful organisms in the broiler litter, the need for practical methods of processing the litter to alleviate the problem was emphasized by Fontenot et al. (1966). An experiment was conducted to: (a) develop a practical processing method(s) that will destroy the pathogenic organisms in broiler litter; and (b) study the effect of processing methods on nutritive value.

Experimental Procedure

This experiment was conducted at the Animal Nutrition Laboratories, National Agriculture Research Center, Islamabad, Pakistan. Broiler litter was collected from broiler houses near Islamabad shortly after removal of the birds. The broiler litter was transported from broiler houses and was spread and mixed on the floor. The broiler litter was transported from broiler houses to the experiment station soon after the collection. Broiler litter was accumulated in thin layer and was prevented from heating by turning the litter with shovels. Broiler litter was deep stacked with 15, 25 and 35% moisture levels and was ensiled with 40% moisture with or without 5% sugar cane molasses; or with rumen contents (40:60 and 50:50, wet basis).

Deep Stacking. The material was transferred to a horizontal mixer, allowed to mix for 30 min, and was stacled om 1.2 x 1.2 x 1.2 m bins with 15, 25 and 35% moisture levels. The bins were constructed of bricks and masonry in a covered building. Twelve bins were blocked according to location and the three treatments were assigned within blocks. Thermometers were placed at alternate depths of 40 and 80 cm from the surface of the stack. The temperature at these sites was monitored daily for 6 wk. Six cotton bags were filled with the sample collected from each mixer and were tied with thread. Bags were placed in each bin at the depth of approximately 80 cm and weekly samples were collected by pulling one bag each week. Initial and weekly samples were composited and frozen for later analysis.

Ensiling. Broiler litter was ensiled with water to achieve 40% moisture, with or without 5% sugarcane molasses; or with rumen contents in 40:60 and 50:50 ratios, wet basis. The broiler litter mixtures were mixed in a horizontal mixer for 30 min, and were transferred to 210-liter metal drums double lined with polyethylene bags. Each treatment consisted of three replicates. All mixtures were firmly packed by trampling and bags were individually sealed after exclusion of air. The material was allowed to ensile for 42 d. Initial samples of ingredients and mixtures were taken, com-

posited, subsampled and frozen for later analysis. Upon opening the silos, the top 5 cm were removed and samples were taken from several areas of each silo.

Chemical Analyses. Samples were prepared for analysis by homogenizing 25 g samples with 225 ml distilled water in .5 liter jars in a Waring blender at full speed for 2 min. The homogenate was filtered through four layers of cheesecloth and the extract was used for determining pH (electrometrically), lactic acid (Baker and Summerson, 1941, as modified by Pennington and Sutherland, 1956), water soluble carbohydrates (Dubois et al., 1956, as adapted by Johnson et al., 1966), and VFA (Erwin et al., 1961). Total (Anonymous, 1967) and fecal (Millipore Corp., 1973) coliforms were determined on the prepared samples. Kjeldahl N of the ingredients, initial and deepstacked samples, was determined on fresh basis (AOAC, 1984). Dry matter was determined by drying duplicate samples in a forced draft oven at a maximum of 60 C for 24 h. The samples were allowed to air equilibrate, composited and were ground through a 1 mm sieve. These samples were analyzed for DM, ash (AOAC, 1984), NDF (Van Soest and Wine, 1967), ADF (Van Soest, 1963), lignin, cellulose and hemicellulose (Van Soest and Wine, 1968).

Statistical Analyses. The data were treated by analysis of variance by the general linear model procedure of SAS

(1982). For the deep stacking study, block, treatment, week and treatment x block interaction were included in the model. Treatment effect was tested with treatment x block interactions. Then linear, quadratic, cubic, quartic and quintic orthogonal contrasts were used to test effect of week. Differences within treatments were also tested by orthogonal polynomials for linear and quadratic trends. In the ensiling study, the contrasts were litter ensiled alone vs litter ensiled with molasses and rumen contents; litter ensiled with molasses vs litter ensiled with rumen contents; litter ensiled with rumen contents, 60:40 vs 50:50, wet basis.

Results and Discussion

Composition of Broiler Litter. Dry matter content of the broiler litter averaged 85.27% (Table 1). The CP content of the litter averaged 24.3%, dry basis, lower than the values of 31% reported by Bhattacharya and Taylor (1975), 32.5% reported by Harmon et al. (1974), Bhattacharya and Fontenot (1965), Caswell et al. (1975) and 34% reported by El-Ashry (1987). These differences could be due to density of birds per unit area, length of rearing period or quantity of bedding material per surface unit.

Ash content of the waste averaged 19.79%, dry basis, which is similar to the ash values reported by Caswell et al.

Table 1. CHEMICAL COMPOSITION OF BROILER LITTER[ab]

Item	Percent
Dry matter	85.3
Crude protein	24.3
Ash	19.8
Neutral detergent fiber	40.9
Acid detergent fiber	31.1
Cellulose	18.2
Hemicellulose	9.8
Water soluble carbohydrates	2.7

[a]Each value represents the mean of four samples
[b]DM basis except DM.

(1975). Generally, ash contributes 13 to 15% of litter DM depending upon the nature and quantity of bedding material used (NRC, 1983). The higher value of NDF (40.9%) could be the result of high quantity of bedding material used compared to the value of 36% reported by Abdelmawla et al. (1988).

The value of 2.71%, dry basis, for the water soluble carbohydrates, is substantially lower than 4.40% reported by Harmon et al. (1975). The values agree with value of 2.6% reported by Caswell et al. (1978).

The initial DM values of deep stacked litter in the present study were 84.4, 77.9 and 69.2%, respectively (Table 2), which are slightly different from the calculated value of 85, 75 and 65%, respectively. The CP values were 24.6, 26.0 and 26.7% (P>.05), respectively.

Temperature of Deep Stacked Broiler Litter. Deep stacking affected the temperature of the litter (Figures 1, 2 and 3). Temperature of stacked litter at the depth of 80 cm from top remained higher from d 1 to 6 than at the depth of 40 cm. Maximum temperatures noted were 64 and 60 C on d 7 for 80 and 40 cm depth, respectively (Figure 1). After d 7 the temperatures at the depth of 40 cm were consistently higher than at 80 cm depth. In both cases, temperatures declined after the maximum was reached. However, the decline was more rapid at 80 cm depth. After d 21 the results dif-

Table 2. CHEMICAL COMPOSITION OF BROILER LITTER DEEP STACKED AT DIFFERENT MOISTURE LEVELS[ab]

Item	Moisture, %		
	15	25	35
	----------%----------		
Dry matter	84.4	77.9	69.2
Crude protein	24.6	26.0	26.7
Ash	21.0	21.7	21.8
Neutral detergent fiber	40.9	41.0	41.2
Acid detergent fiber	31.0	33.1	34.2
Cellulose	18.5	17.8	17.9
Hemicellulose	9.8	8.8	8.6

[a]Each value represents the mean of four samples (initial).
[b]DM basis except DM.

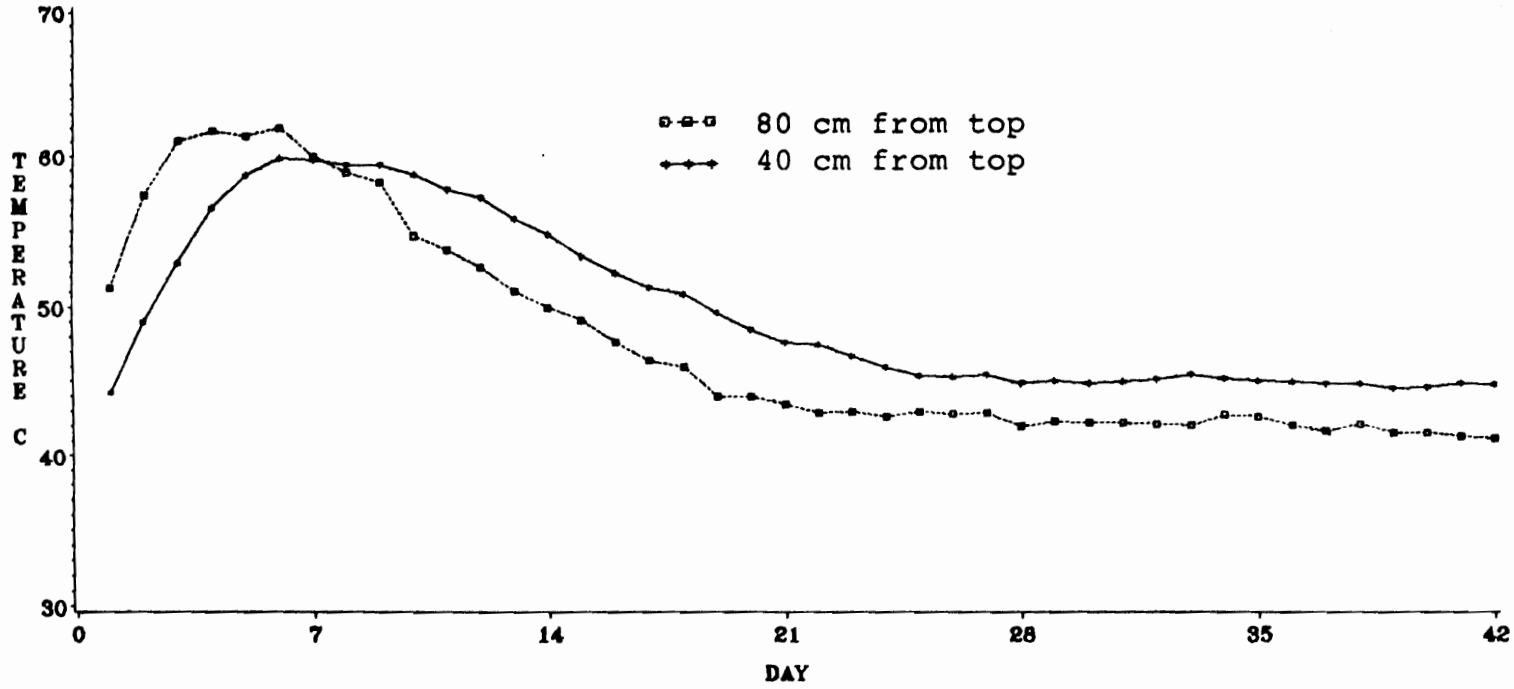


Figure 1. EFFECT OF DEPTH ON TEMPERATURE OF DEEP STACKED BROILER LITTER

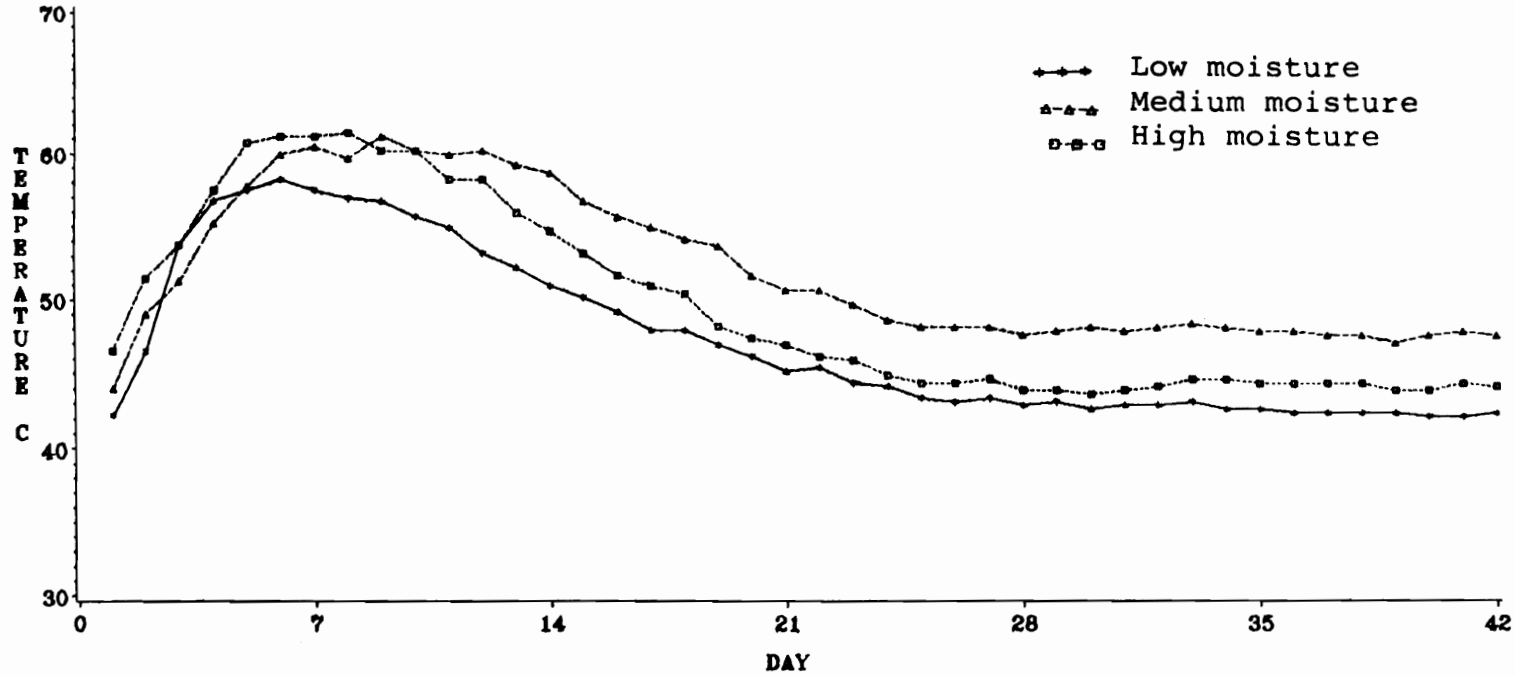


Figure 2. EFFECT OF MOISTURE LEVEL ON TEMPERATURE OF DEEP STACKED BROILER LITTER AT 40 CM DEPTH

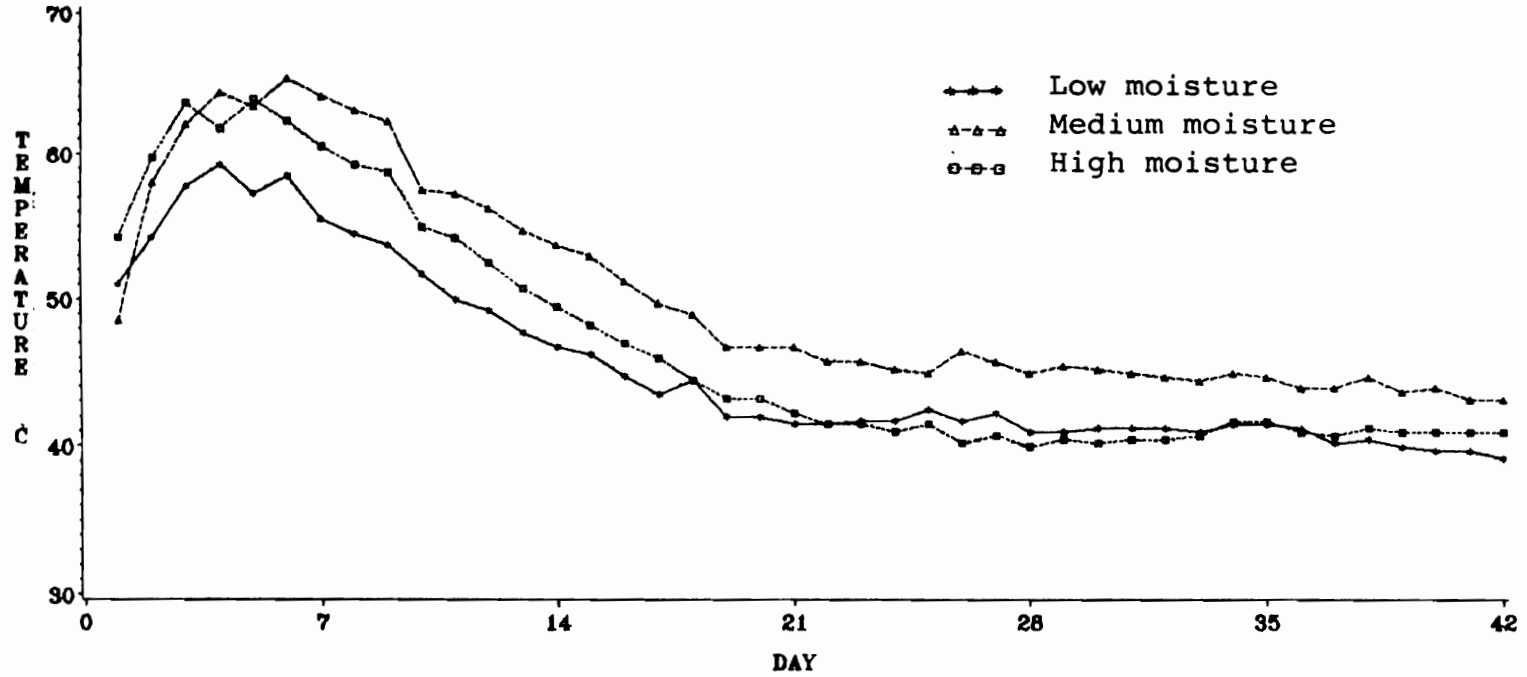


Figure 3. EFFECT OF MOISTURE LEVEL ON TEMPERATURE OF DEEP STACKED BROILER LITTER AT 80 CM DEPTH

fered from those reported by Dana et al. (1978). They found a maximum temperature of 54 C for 40 cm depth after 7 d. At 80 cm depth, 21 d were required to attain a maximum temperature of 46 C. They found that the decline was greater for 40 cm depth than 80 cm depth. In the present experiment the temperatures remained at 42 and 46 C for 80 and 40 cm depth, respectively, for the rest of the period, which was only slightly higher than ambient temperature.

Temperature changes in the stack at 40 cm showed that initially the temperature was higher for the 25% moisture stack than 15 and 35% moisture stack (Figure 2). The highest temperatures recorded for 15%, 25% and 35% moisture litter were 57.5, 61.2 and 60.2 C, respectively, on d 7. After d 7 the temperatures remained higher for 35% moisture stack than 15 and 25% moisture stacks. For all moisture levels, the temperature declined after the maximum was reached. Rate of decline was greater for the 15% moisture than the 25 and 35% moisture litter. However, the temperatures essentially stabilized for all moisture levels after d 21. Lowest temperatures were recorded for 15% moisture stack throughout the study.

Maximum temperatures of 55, 60 and 66 C were recorded at 80 cm for 15, 25 and 35% moisture stacks on d 7, after which temperatures declined (Figure 2). At 80 cm depth, 21

d were required to attain constant temperatures. Lowest temperatures were for the 15 and 25% moisture stacks. The decline pattern was similar for both depths. The temperature changes were similar to those reported by Dana et al. (1978). They also found that it took 7 d to reach maximum temperature.

Chemical Composition and Fermentation Characteristics of Deep Stacked Litter. Weekly DM content of broiler litter stacked with different moisture levels showed an increase in DM with time (Table 3). However, a greater increase ($P<.10$) was observed in litter stacked with 35% moisture. A quadratic effect ($P<.10$) was found, showing an average increase with time. It appears that maximum DM was reached at 5 wk. Dana et al. (1978) reported no change with time in DM of litter deep stacked at 30% DM. The increase in DM may be due to loss of moisture through evaporation in dry, hot weather through open stack. Ash contents of litter stacked with different moisture levels were not consistently affected by time, regardless of moisture level (Table 4). Ash was lower ($P<.05$) for the litter deep stacked at 15% moisture initially and this difference remained with time.

Lower CP values were observed in the litter with low moisture than litter with higher moisture (Table 5). There was a linear increase in CP with increase in moisture levels

Table 3. EFFECT OF DEEP STACKING ON DRY MATTER CONTENT OF BROILER LITTER[a]

Week	Moisture, %			SE
	15	25	35[b]	
	----------%----------			
0	84.40	77.87	70.71	1.78
1	86.85	82.35	73.19	1.78
2	87.68	82.74	78.68	1.78
3	87.00	83.06	77.06	1.78
4	85.55	81.66	78.86	1.78
5	88.73	85.16	81.36	1.78
6	86.42	85.15	83.03	1.78
Average[c]	86.66	82.55	77.13	.66

[a]Each value represents the mean of four samples.
[b]Quadratic effect of time (P<.10).
[c]Linear effect of treatment (P<.05).

Table 4. EFFECT OF DEEP STACKING ON ASH CONTENT OF BROILER LITTER[ab]

Week	Moisture, % 15	25[c]	35[c]	SE
	----------%----------			
0	20.95	21.66	21.84	.41
1	20.01	20.97	21.64	.41
2	20.85	21.22	21.13	.41
3	20.33	22.07	21.48	.41
4	20.55	20.59	21.13	.41
5	20.21	20.09	20.58	.41
6	21.65	21.11	21.93	.41
Average[d]	20.65	21.10	21.25	.85

[a]Each value represents the mean of four samples.
[b]DM basis.
[c]Quartic effect of time (P<.10).
[d]Linear effect of treatments (P<.05).

Table 5. EFFECT OF DEEP STACKING ON CRUDE PROTEIN CONTENT OF BROILER LITTER[ab]

Week	Moisture, %			SE
	15	25	35	
	----------%----------			
0	24.57	26.02	26.39	.45
1	25.48	26.64	26.60	.45
2	26.20	26.51	26.90	.45
3	26.09	27.32	28.03	.45
4	25.59	26.46	26.75	.45
5	25.53	26.00	26.81	.45
6	25.37	26.10	26.78	.45
Average[c]	25.55	26.44	26.75	.17

[a]Each value represents the mean of four samples.
[b]DM basis.
[c]Linear effect of treatments ($P<.05$).

(P<.05), although differences were not large. Duque et al. (1981) obtained similar value in litter ensiled at different moisture levels, and suggested the higher values may likely have been due to the concentration effect related to DM loss. However, in the present study the differences were likely due to differences in the litters initially. Crude protein values of litter stacked with 35% moisture increased with time until 3 wk, then decreased (quadratic effect, P<.10).

The pH was lower (6.63) in the initial samples of 35% moisture stacked broiler litter than in 25 and 15% moisture stacked litter (Table 6). A linear decrease was observed in pH values of litter stacked with 15% moisture level (P<.10). The pH of litter stacked with 25% moisture decreased until wk 1, increased until wk 5, then decreased sharply (cubic effect, P<.05).

Initial water-soluble carbohydrates were 2.71, 2.64 and 2.52%, DM basis, for low-, medium- and high-moisture deep-stacked litter, respectively (Table 7). A linear (P<.05) increase in the water-soluble carbohydrates was observed with increase in moisture. No significant effect of time of deep stacking was observed on water soluble carbohydrate values of litter stacked with low- and medium-moisture levels. However, litter stacked with high-moisture levels showed a cubic effect (P<.05) of time. Higher values of water-soluble

Table 6. EFFECT OF DEEP STACKING ON THE pH VALUE OF BROILER LITTER[a]

Week	MOISTURE, %			SE
	15[b]	25[c]	35	
0	7.49	7.25	6.63	.17
1	7.49	7.28	6.74	.17
2	7.16	6.99	6.86	.17
3	7.22	7.19	6.87	.17
4	7.11	7.42	6.63	.17
5	7.26	7.45	6.96	.17
6	6.85	6.60	6.65	.17
Average[d]	7.23	7.17	6.76	.07

[a]Each value represents the mean of four samples.
[b]Linear effect of time (P<.10).
[c]Cubic effect of time (P<.05).
[d]Linear effect of treatments (P<.05).

Table 7. EFFECT OF DEEP STACKING ON WATER SOLUBLE CARBOHYDRATES OF BROILER LITTER[ab]

Week	Moisture, %			SE
	15	25	35[c]	
	----------%----------			
0	2.71	2.64	2.52	.19
1	3.10	3.21	3.29	.19
2	2.77	2.81	3.42	.19
3	2.58	3.03	3.28	.19
4	2.83	3.08	3.33	.19
5	2.79	2.98	3.00	.19
6	2.85	3.06	3.51	.19
Average[d]	2.80	2.97	3.19	.07

[a]Each value represents the mean of four samples.
[b]DM basis.
[c]Cubic effect of time (P<.05).
[d]Linear effect of treatments (P<.05).

carbohydrates for the high-moisture litter may be due to the breakdown of hemicellulose during the anaerobic process. Similar results have been reported for water-soluble carbohydrates by Duque et al. (1980) during ensiling.

No lactic acid was observed in initial or weekly samples of stacked broiler litter. The process of deep stacking may result in the elimination of lactic acid producing organisms in the litter.

Total VFA concentrations for low-, medium- and high-moisture deep-stacked litter were 1.46, 1.25 and 1.52%, dry basis, respectively (Table 8). The major fatty acid in the stacked broiler litter was acetic, followed by butyric acid. However, no significant effect of treatments was observed.

No difference was observed in the cell wall components between initial and weekly deep-stacked litter (Table 9).

Total coliform counts of the initial mixtures ranged from 1.22×10^4 to 1.51×10^4 organism per gram, DM basis (Table 10). Fecal coliform counts on the initial mixture samples were 3.25×10^3 to 4.14×10^3 organisms per gram, DM basis. Deep stacking of litter resulted in complete elimination of total and fecal coliforms. Dana et al. (1978) and Chester-Jones et al. (1980) also reported that the deep stacking of litter completely eliminated pathogenic organisms.

Table 8. EFFECT OF DEEP STACKING OF BROILER LITTER ON VOLATILE FATTY ACID CONCENTRATION[ab]

Item	Moisture, %			SE
	15	25	35	
	----------%----------			
Total VFA	1.46	1.25	1.52	.41
Acetic acid	0.87	0.70	0.96	.23
Propionic acid	0.17	0.13	0.14	.03
Isobutyric acid	0.04	0.04	0.04	.01
Butyric acid	0.27	0.19	0.23	.08
Isovaleric acid	0.09	0.11	0.11	.03
Valeric acid	0.02	0.08	0.03	.03

[a]Each value represents the mean of four samples at each week up to 6 wk.
[b]DM basis.

Table 9. EFFECT OF DEEP STACKING ON CELL WALL COMPONENTS OF BROILER LITTER[ab]

Item	Moisture, %			SE
	15	25	35	
Neutral detergent fiber	39.88	39.64	39.60	.22
Acid detergent fiber	30.43	30.55	30.68	.20
Cellulose	17.43	17.21	17.43	.26
Hemicellulose	9.30	9.08	8.93	.32
Lignin	8.47	8.53	8.63	.17

[a]Each value represents the mean of four samples at each week up to 6 wk.
[b]Dry basis.

Table 10. MICROBIAL COUNTS IN DEEP STACKED BROILER LITTER[a]

Time	Moisture	Total coliform[b]	Fecal coliform[b]
	--%--	----10^4/g[c]--	--10^3/g[c]----
Initial	15	1.51	3.37
	25	1.22	3.25
	35	1.35	4.14
1 Week	15	0	0
	25	0	0
	35	0	0

[a]Each value represents the mean of four samples.
[b]Dry basis
[c]Counts /g of sample.

Ensiled Broiler Litter. No difference was found in the initial composition of litter used in silage and deep stacking (Tables 2 and 11).

Composition of Rumen Contents. Dry matter content of the rumen contents averaged 14.5% (Table 11). The CP content of the freshly collected rumen contents averaged 16%, DM basis, lower than the value of 18.4% reported by Rao and Fontenot (1987). However, the CP values were higher than the values reported by Ricci (1977) for rumen contents (12.2%, DM basis). The CP values were within the range established by Reddy and Reddy (1980) and Summerfelt and Yin (197) of 12 to 20%, DM basis, but agreed most closely with those determined by El-Yassin et al. (1984) when animals were fed finishing diets prior to slaughter.

Ash value of the rumen contents averaged 11.9%, dry basis, which is higher than values reported by Ricci (1977) and El-Yassin et al. (1984) in freshly collected rumen contents, but lower than the ash values reported by Reddy and Reddy (1980). The ash values agreed most closely with those reported by Jovanovic and Cuperlovic (1977). The higher values of cell wall components, NDF, ADF, cellulose and hemicellulose, compared to those reported by El-Yassin et al. (1984) reflected that in the present study the animals had been on high-fiber diets before slaughter.

Table 11. CHEMICAL COMPOSITION OF BROILER LITTER AND RUMEN CONTENTS[ab]

Item	Broiler litter	Rumen contents
	----------%	----------
Dry matter	85.27	14.50
Crude protein	24.33	15.95
Ash	19.79	11.86
Neutral detergent fiber	40.87	71.68
Acid detergent fiber	31.08	61.73
Cellulose	18.19	39.21
Hemicellulose	9.80	9.48

[a]Each value represents the mean for six samples.
[b]DM basis except DM.

Composition of Initial and Ensiled Mixtures. There was an increase ($P<.05$) in the DM content of initial and ensiled waste mixtures with the addition of molasses (Tables 12 and 13). The DM of initial and final silages was lower ($P<.05$) with the higher level of rumen contents, due to the high moisture in rumen contents.

Crude protein values for initial and final mixtures were highest for the litter alone than the litter mixed with molasses or rumen contents ($P<.05$). The ash contents of the initial and final mixtures of litter alone or with molasses were higher than litter rumen contents mixtures ($P<.05$), due to the higher ash content in the broiler litter than rumen contents. The ash values tended to decrease with the increase in level of rumen contents.

Higher NDF was observed for the litter-rumen contents than litter alone, or litter-molasses mixtures ($P<.05$), reflecting the higher NDF for rumen contents than litter. Among the litter-rumen contents mixtures, the higher values of NDF were for the 50:50 (wet basis) than 60:40 mixtures, wet basis ($P<.05$). The NDF values were higher ($P<.05$) for litter alone than litter with molasses mixtures, reflecting dilution with molasses. Acid detergent fiber and cellulose were lower ($P<.05$) for litter-molasses mixtures than mixtures containing rumen contents. Hemicellulose values were lower

Table 12. COMPOSITION OF INITIAL MIXTURES OF BROILER LITTER AND RUMEN CONTENTS[ab]

Item	Broiler litter		Broiler litter :rumen contents[c]		SE
	Alone	Molasses	60:40	50:50	
	----------%				
Dry matter[def]	68.38	70.97	59.17	53.59	.22
Crude protein[def]	27.00	26.51	25.81	23.15	.51
Ash[de]	22.45	21.89	20.28	19.18	.40
NDF[defg]	39.63	38.95	43.43	45.72	.54
ADF[eh]	33.80	32.51	34.11	34.59	.35
Cellulose[e]	17.96	16.06	18.61	18.99	.56
Hemicellulose[de]	5.83	6.44	9.31	11.31	.67
Lignin	8.71	8.69	8.97	9.46	.46

[a]Each value represents the mean of three samples.
[b]DM basis except DM.
[c]Proportion on wet basis.
[d]Broiler litter alone vs litter with molasses and with rumen contents differ (P<.05).
[e]Broiler litter with molasses vs broiler litter with rumen contents differ (P<.05).
[f]Rumen content silages differ (P<.05).
[g]Neutral detergent fiber.
[h]Acid detergent fiber.

Table 13. COMPOSITION OF ENSILED MIXTURES OF BROILER LITTER AND RUMEN CONTENTS[ab]

Item	Broiler litter		Broiler litter :rumen contents[c]		SE
	Alone	Molasses	60:40	50:50	
	----------%----------				
Dry matter[def]	68.84	71.49	59.44	53.33	.16
Crude protein[def]	26.99	26.51	25.80	23.15	.51
Ash[de]	21.42	21.44	20.81	19.67	.36
NDF[defg]	39.11	39.75	44.09	47.37	.24
ADF[fh]	33.08	33.08	32.61	34.97	.45
Cellulose[e]	16.52	16.01	18.86	19.44	.82
Hemicellulose[de]	6.03	6.67	11.48	12.39	.38
Lignin[ef]	7.51	7.40	7.63	8.69	.28

[a]Each value represents the mean of three samples.
[b]DM basis except DM.
[c]Proportion on wet basis.
[d]Broiler litter alone vs litter with molasses and rumen contents silages differ (P<.05).
[e]Broiler litter with molasses silages vs broiler litter with rumen contents silages differ (P<.05).
[f]Rumen contents silages differ (P<.05).
[g]Neutral detergent fiber.
[h]Acid detergent fiber.

(P<.05) for the litter alone than other mixtures. The hemicellulose values for the litter-molasses mixture were lower (P<.05) than for the litter-rumen contents mixtures. No significant differences were observed in the lignin values of mixtures.

Fermentation Characteristics of the Mixtures. The pH values of the initial mixtures were 6.21, 6.37, 6.43 and 6.87 for broiler litter alone, with molasses and with two levels of rumen contents, respectively, (Table 14). The pH of the ensiled mixtures vary from 5.35 to 5.63 (P>.05). The drop in pH after ensiling showed that fermentation took place. The pH value of the ensiled mixtures agreed with those of Caswell et al. (1975) when they ensiled litter with 40% moisture.

Initial values of lactic acid for waste silages averaged .40, .06, .13 and 0%, respectively, DM basis (Table 14). After ensiling an increase in lactic acid with a drop in water-soluble carbohydrates was noted in all silages, regardless of treatment. Similar trends of decreased water-soluble carbohydrates and increased lactic acid have been reported by Harmon et al. (1975) for corn forage-broiler litter and Caswell et al. (1975) for litter containing 40% moisture. Barnett (1954) reported that a low level of lactic

Table. 14 FERMENTATION CHARACTERISTICS OF SILAGES[a]

Item	Broiler litter		Broiler litter :rumen contents[b]		
	Alone	Molasses	60:40	50:50	SE
pH					
Pre-ensiled[c]	6.21	6.37	6.43	6.56	.06
Post-ensiled[d]	5.51	5.35	5.63	5.58	.03
Water soluble carbohydrates, %[e]					
Pre-ensiled[c]	4.41	6.02	3.93	4.02	.22
Post-ensiled[c]	3.26	4.08	2.40	2.74	.20
Lactic acid, %[e]					
Pre ensiled	0.40	0.06	0.13	0.00	.16
Post-ensiled[cdf]	1.47	2.06	0.41	0.79	.09

[a]Each value represents the mean of three samples.
[b]Proportion on wet basis.
[c]Silages of broiler litter with molasses vs litter with rumen contents differ (P<.05).
[d]Rumen contents silages differ (P<.05).
[e]DM basis.
[f]Silages of broiler litter alone vs litter with molasses and rumen contents differ (P<.05).

acid production in ensiled mass is an indication of poor ensiling.

The significant ($P<.05$) decrease in water soluble carbohydrates in all treatments is indicative of fermentation of sugars in these silages. The values of water soluble carbohydrates in the initial mixture was lower than the values (6%, dry basis) reported by Barnett (1954) for adequate ensiling, except for the litter-molasses mixture.

Volatile Fatty Acids. The total VFA concentration was highest ($P<.05$) for the waste silage containing 50% rumen contents (Table 15). Propionic acid was the major fatty acid for all the silages. Isovaleric concentration was higher ($P<.05$) in the silages containing rumen contents than litter alone or with molasses, which may be due to the rumen bacterial breakdown of amino acid to isovaleric acid (Van Soest, 1987).

Microbial Count. Total and fecal coliforms for the initial mixtures varied from 2.9 to 5.7 x 10^5 and .033 x 10^5 to .04 x 10^5, respectively (Table 16). Following ensiling, all silages tested negative for total and fecal coliforms. Complete elimination of organisms have been reported by Caswell et al. (1975) when broiler litter was ensiled with 40% moisture, Harmon et al. (1975) when broiler litter was

Table. 15 EFFECT OF ENSILING BROILER LITTER ALONE, WITH MOLASSES OR RUMEN CONTENTS ON VOLATILE FATTY ACID CONCENTRATION[ab]

	Broiler litter		Broiler litter :rumen contents[c]		
	Alone	Molasses	60:40	50:50	SE
	----------%[c]----------				
Total VFA[de]	4.33	4.39	4.99	7.74	1.12
Acetic acid	0.18	0.17	0.20	0.22	0.06
Propionic acid	2.75	2.51	2.42	3.17	0.32
Isobutyric acid	0.18	0.22	0.27	0.68	0.28
Butyric acid	0.13	0.11	0.07	0.25	0.08
Isovaleric acid[ef]	1.04	0.99	1.84	2.72	0.33
Valeric acid[df]	0.05	0.39	0.19	0.70	0.13

[a]Each value represents the mean of three samples.
[b]DM basis.
[c]Proportion on wet basis.
[d]Rumen contents silages differ (P<.05).
[e]Broiler litter ensiled alone vs litter ensiled with molasses and rumen contents differ (P<.05).
[f]Broiler litter ensiled with molasses vs litter ensiled with rumen contents differ (P<.05).

Table. 16 MICROBIAL COUNTS IN ENSILED MIXTURES OF BROILER LITTER ALONE OR WITH MOLASSES OR RUMEN CONTENTS[a]

Item	Time	Broiler litter		Broiler litter :rumen contents[b]	
		Alone	Molasses	60:40	50:50
		10^5/g			
Total coliform[c]	Initial	3.2	2.9	5.7	3.5
	Post ensiled	0	0	0	0
Fecal coliform[c]	Initial	0.04	0.04	0.036	0.033
	Post ensiled	0	0	0	0

[a]Each value represents the mean of three samples.
[b]Proportions on wet basis.
[c]Counts per gram of dry matter.

ensiled with corn forage and Samuels (1980) when cage layer waste was ensiled with corn forage or sugarcane bagasse.

Implications of these results for processing methods of broiler litter are twofold. First, complete elimination of pathogens may be obtained by deep stacking and ensiling. Secondly, both of these processing methods are very simple, effective and applicable directly to the farm levels, with low requirement of labor, investment and sophisticated machinery. Ensiling broiler litter with rumen contents can also enhance the utilization of both the wastes safely.

Literature Cited

A.A.F.C.O. 1984. Official Publication, Association of American Feed Control Officials, Inc. pp 63-65.

Abdelmawla, S. M., J. P. Fontenot and M. A. El-Ashry. 1988. Composted, deepstacked and ensiled broiler litter in sheep diets: chemical composition and nutritive value study. Virginia Polytechnic Institute and State University Anim. Sci. Res. Rep. No. 7:127.

Anonymous. 1967. Standard Methods for the Examination of Dairy Products (12th Ed.). Am. Public Health Assoc. Inc., New York.

AOAC. 1980. Official Methods of Analysis (13th Ed.). Assoc. of Official Anal. Chem., Washington, D.C.

Arndt, D. L., D. L. Day and E. E. Hatfield. 1979. Processing and handling of animal waste. J. Anim. Sci. 48:157.

Barker, S. B. and W. H. Summerson. 1941. The colorimetric determination of lactic acid in biological material. J. Biol. Chem. 138:535.

Barnett, A. J. G. 1954. Silage Fermentation. Academic Press, New York.

Bhattacharya, A. N. and J. P. Fontenot. 1965. Utilization of different levels of poultry litter nitrogen by sheep. J. Anim. Sci. 24:1174.

Bhattacharya, A. N. and J. P. Fontenot. 1966. Protein and energy value of peanut hull and wood shaving poultry litter. J. Anim. Sci. 25:367.

Bhattacharya, A. N. and J. C. Taylor. 1975. Recycling of animal waste as feedstuff: A review. J. Anim. Sci. 24:1174.

Caswell, L. F., J. P. Fontenot and K. E. Webb, Jr. 1975. Effect of processing treatment on pasteurization and nitrogen components of broiler litter and on nitrogen utilization by sheep. J. Anim. Sci. 40:750.

Caswell, L. F., J. P. Fontenot and K. E. Webb, Jr. 1978. Fermentation and utilization of broiler litter ensiled at different moisture levels. J. Anim. Sci. 46:547.

Chester-Jones, H., J. P. Fontenot, W. D. Lamm and K. E. Webb, Jr. 1980. Growing cattle fed different levels of ensiled and deepstacked broiler litter. Virginia Polytechnic Institute and State University Res. Div. Rep. 156:161.

Dana, G. R., J. P. Fontenot, J. A. Duque, W. Sheehan and K. E. Webb, Jr. 1979. Changes in characteristics of deepstacked broiler litter with time. Virginia Polytechnic Institute and State University Res. Div. Rep. 174:104.

Drake, C. L., W. H. McClure and J. P. Fontenot. 1965. Effect of levels and kind of broiler litter for fattening steers. J. Anim. Sci. 24:879. (Abstr.).

Dubois, M., K. A. Gilles, J. K. Hamilton, P. A. Rebers and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350.

Duque, J. A., J. P.Fontenot, K. E. Webb, Jr. and J. C. A. Berger. 1978. Fermentation and digestibility of broiler litter ensiled at different moisture levels by addition of whey or water. Virginia Polytechnic Institute and State University Res. Div. Rep. 174:108.

El-Ashry, M. A., H. M. Khattab, A. El-Sherafy, H. Solaiman and S. M. Abdelmoula. 1987. Nutritive value of poultry wastes for sheep. Biol. Wastes 19:287.

El-Yassin, F. A., J. P. Fontenot and H. Chester-Jones. 1984. Fermentation characteristics and nutritional value of rumen contents and blood ensiled with untreated or sodium hydroxide treated wheat straw. J. Anim. Sci. 59:453 (Abstr.).

Erwin, E. S., G. L. Macro and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

Fontenot, J. P. and H. A. Hopkins. 1965. Effect of physical form of different parts of lamb fattening rations of feedlot performance and digestibility. J. Anim. Sci. 24:62.

Fontenot, J. P., A. N. Bhattacharya, C. L. Drake and W. H. McClure. 1966. Value of broiler litter as a feed for ruminants. Proc. Natl. Symp. on Anim. Waste Management. Am. Soc. Agric. Eng. Publ. SP-0366:105.

Fontenot, J. P., W. H. McClure, R. F. Kelly and G. W. Litton. 1963. The value of poultry litter as feedstuffs for fattening beef steers. Va. Agric. Exp. Sta. Res. Prog. Rep. p. 9.

Fontenot, J. P., K. E. Webb, Jr., B. W. Harmon, R. E. Tucker and W. E. C. Moore. 1971. Studies of processing, nutritional value and palatability of broiler litter for

ruminants. Proc. Int. Symp. on Livestock Wastes. Am. Soc. Agric. Eng. Publ. Proc. 271:301.

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1974. The effect of processing method of broiler litter on nitrogen utilization of lambs. J. Anim. Sci. 39:942.

Harmon, B. W., J. P. Fonenot and K. E. Webb, Jr. 1975. Ensiled broiler litter and corn forage. II. Digestibility, nitrogen utilization and palatability by sheep. J. Anim. Sci. 40:156.

Hasnain, H. 1983. Feed - The key to more food in Pakistan. In: Least Cost Ration Formulation. Proc. FAO/PARC Workshop. p 4. Pakistan Agric. Res. Council, Islamabad, Pakistan.

Johnson, R. R., T. L. Balwani, L. J. Johnson, K. E. McClure and B. A. Dehority. 1966. Corn plant maturity. II. Effect on in vitro cellulose digestibility and soluble carbohydrate content. J. Anim. Sci. 25:617.

Jovanovic, M. and M. Cuperlovic. 1977. Nutritive value of rumen contents for monogastric animals. Anim. Feed Sci. Technol. 2:351.

Kirk, J. K. 1967. Use of poultry litter as animal feed. Fed. Register 32(171):12714.

NRC. 1983. Underutilized Resources as Animal Feedstuffs. National Academy Press, Washington, D.C.

Rao, N. M. and J. P. Fontenot. 1987. Ensiling of rumen contents and blood with wheat straw. Anim. Feed Sci. Technol. 18:67.

Reddy, M. R. and K. V. S. Reddy. 1980. A short note on the proximate composition of rumen digesta from bovine and ovine species and its utilization of rumen contents in broiler diets. Indian J. Poult. Sci. 20:27.

Ricci, R. 1977. A method of manure disposal for beef backing operation. First Interim Tech. Rep. EPA-600/2-77-103. Cited in NRC (1983).

Samuels, W. A. 1980. Fermentation, utilization and palatability of ensiled caged layer waste and sugarcane bagasse. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg.

Smith, L. W. and C. C. Calvert. 1972. Dehydrated poultry waste for sheep. J. Anim. Sci. 35:274.

Smith, L. W. and W. E. Wheeler. 1979. Nutritional and economical value of animal excreta. J. Anim. Sci. 48:144.

Southwell, B. L., O. M. Hale and W. C, McCormick. 1958. Poultry house litter as a nitrogen supplement in steer fattening rations. GA. Agric. Exp. Sta. Mimeo No. N.S. 55:6.

Summerfelt, R. C. and S. C. Yin. 1974. Paunch manure as a feed supplement in channel catfish farming. Proc. Fifth

Natl. Symp. Food Process. Wastes. EPA 660/2/74-046. pp 246-248. Cited in NRC (1983).

VanSoest, P. J. 1963. The use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Official Agric. Chem. 46:829.

VanSoest, P. J. 1987. Nutritional Ecology of the Ruminant. O and B Books, Inc., Corvallis, Oregon.

VanSoest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. The determination of plant cell wall constituents. J. Assoc. Official Anal. Chem. 50:50.

VanSoest, P. J. and R. H. Wine. 1968. Determination of lignin and cellulose in acid detergent fiber with permanganate. J. Assoc. Official Anal. Chem. 51:780.

CHAPTER IV

DIGESTIBILITY AND PALATABILITY OF DIETS CONTAINING DEEP STACKED BROILER LITTER AND BROILER LITTER ENSILED ALONE OR WITH MOLASSES OR RUMEN CONTENTS

ABSTRACT

A digestibility and palatability trial was conducted with 30 wethers allotted to five diets: 1) basal (20% corn grain, 23% wheat bran, 37% cotton seed cake, 18% wheat straw and 2% dicalcium phosphate) alone, basal and broiler litter processed by 2) deep stacking, 3) ensiling alone, 4) ensiling with 5% added molasses, and 5) ensiling with rumen contents (1:1, wet bais). For diets 2 to 5 ratio of basal and silages was 1:1, dry basis. The liter was deep stacked at 15% moisture and ensiled at 40% moisture (alone or with molasses). For the digestion trial, diets were fed at 2% body weight, dry basis. Feces were collected in canvas bags held by harnesses. In the palatability trial the sheep were fed the same diets ad-libitum and refusals were collected once daily. Apparent digestibilities of OM and CP were lower ($P<.05$) for the deep stacked litter diet, than for the other waste diets. Among the waste-containing diets, cellulose digestibility was higher ($P<.05$) for the diet with ensiled litter-rumen contents. No significant differences were found

in DM intake among diets containing broiler litter. The results indicate that different methods can be used to process broiler litter to be used as ruminant feed.
(Key Words: Broiler litter, Digestibility, Palatability, Rumen contents, Sheep, Processing).

Introduction

A major factor limiting animal production in developing countries is inadequate availability of feedstuffs. Animal production cannot be increased simply by moving to new land, since land suitable for growing food for human consumption is frequently limited, and production of human food should have priority over feed production.

Wastes can provide useful nutrients. Utilization of broiler litter as a source of N has been well documented by numerous researchers. Bhattacharya and Fontenot (1965) reported positive N balance in sheep fed a semi-purified diet in which up to 100% of the N was supplied by broiler litter. Bucholtz et al. (1971) reported a trend for higher N retention when sheep were fed poultry waste as only source of supplemental N, compared to soybean meal. Significantly higher N retention was reported for sheep fed a diet supplemented with citrus pulp base broiler litter than those fed a basal diet (Ammerman et al., 1966).

Apparent digestibility of N from poultry litter varied from 65 to 82% (Ammerman et al., 1966; Bhattacharya and Fontenot, 1966). Liebholz (1969) reported similar digestion coefficients for N in sheep fed diets supplemented with cage layer manure as for those fed a control diet.

Broiler litter ensiled with corn forage resulted in a sharp increase in CP content (Harman et al., 1973). Including 15 or 30% litter, dry basis, in silage resulted in increase in DM intake and N retention by sheep, and had no effect on digestibility of DM.

An experiment was conducted to determine the effect of processing methods on digestibility and palatability of broiler litter when fed to sheep.

Experimental Procedures

This experiment was conducted at the Animal Nutrition Laboratories, National Agriculture Research Center, Islamabad, Pakistan. Thirty wethers (Kajali breed of Pakistan) were assigned to six blocks of five animals, based on weight. Sheep within each block were randomly allotted to the following diets: 1) basal (20% corn grain, 23% wheat bran, 37% cotton seed cake, 18% wheat straw and 2% dicalcium phosphate) alone or basal and broiler litter processed by 2) deep stacking, 3) ensiling alone, 4) ensiling with 5% added

sugarcane molasses, 5) ensiling with rumen contents (50:50, wet basis). In diets 2 to 5 the ratio of basal and silage was 1:1, dry basis. The animals were given 500,000 IU of vitamin A and 75,000 IU of vitamin D i.m.

A 5 d adaptation period to canvas bags was followed by a 10-d transition to the experimental diets. Test diets were fed during the 10-d preliminary period followed by a 10-d collection period. Water was provided ad libitum except during feeding. The diets were fed twice daily in equal portions at 0600 h and 1800 h. Lambs were fed at 2% body weight (DM). Samples of feed were obtained at each feeding 2 d prior to the beginning and 2 d prior to the end of the collection period. All diet samples were immediately frozen in double thickness plastic bags and composited at the end of the trial.

Canvas bags held by harnesses as described by Fontenot and Hopkins (1965) were used to collect the feces. Feces were collected each morning and dried in a forced draft oven at a maximum of 60 C for a minimum of 24 h. For each animal, the dried feces were composited in metal cans, which were loosely covered to moisture equilibration. At the end of trial, fecal composites were weighed, mixed and subsampled. At the end of the trial ruminal ingesta samples were collected 2 h post feeding via stomach tube with a metal

strainer and blood samples were taken 6 h post feeding by jugular puncture.

Samples of the diet components and feces were ground in a Wiley mill and analyzed for DM, ash (AOAC, 1984), NDF (Van Soest and Wine, 1967), ADF (Van Soest, 1963), lignin and cellulose (Van Soest and Wine, 1968). Nitrogen was determined on wet feed and dry fecal samples (AOAC, 1984). The ruminal ingesta was strained through four layers of cheese cloth, and the filtrate was used for determination of pH (electromagnetic) and VFA (Erwin et al., 1961). Volatile fatty acids were determined with a Vista 6000 gas chromatograph (Erwin et al., 1961). Blood urea-N was determined by the method of Coulombe and Favreau (1963).

Following the digestion trial, a palatability trial was conducted on the same animals. Animals were given the same diets as for the digestion trial. Water was provided ad libitum and fresh feed was given to the sheep after every 12 hr. The trial consisted of an adaptation period during which feed offered was increased until all animals refused some feed, followed by a 10 d measurement period. During the measurement period, refusals were collected once daily, weighed and dried at 60 C in a forced draft oven.

The lambs were weighed before and at the end of palatability trial. The average of initial and final weights

were used to determine the metabolic size ($W^{.75}$) on which DM intake was calculated.

Statistical Procedure. The data were treated by analysis of variance by general linear model procedure of SAS (1982). Block and treatment were included in the model. In the digestibility and palatability trial, the contrasts were: control vs all waste containing diets; diets containing deep stacked litter vs ensiled litter; ensiled alone vs ensiled with molasses and rumen contents; ensiled with molasses vs ensiled with rumen contents.

Results and Discussion

Chemical Composition. Dry matter content was higher in the basal diet compared to the waste-containing diets (Table 17). Crude protein and ash were higher in the waste-containing diets than the basal diet. Neutral detergent fiber was higher in basal and deep stacked litter containing diets than other waste diets. Cellulose and hemicellulose were higher in the basal and deep stacked litter-containing diets.

Apparent Digestibility. The apparent digestibilities of DM, NDF and ADF were higher ($P<.05$) for the basal diet than the waste-containing diets (Table 18). Apparent digestibilities for DM, OM and CP were lower ($P<.05$) for the

Table 17. CHEMICAL COMPOSITION OF DIETS FED TO SHEEP[ab]

Item	Basal	Basal and broiler litter[c]				
		Deep stacked	Ensiled	Ensiled with molasses	Ensiled with rumen contents[d]	SE
	%					
Dry matter	90.15	88.94	78.69	80.02	67.27	2.40
Crude protein	12.94	17.58	19.46	18.71	18.17	1.12
Ash	9.04	14.30	15.99	15.05	15.55	1.22
NDF[e]	47.05	47.23	40.39	39.48	42.96	1.07
ADF[f]	26.68	28.73	24.59	27.14	28.42	1.01
Cellulose	19.75	19.13	16.89	19.21	18.48	0.95
Hemicellulose	20.37	18.50	15.80	12.39	14.54	1.25

[a]Each value represents the mean of six samples.
[b]DM basis except for DM.
[c]Ratio of basal and silages, 1:1, dry basis.
[d]Ratio of litter and rumen contents, 1:1, wet basis.
[e]Neutral detergent fiber.
[f]Acid detergent fiber.

Table 18. APPARENT DIGESTIBILITY OF DEEP STACKED AND ENSILED BROILER LITTER BY SHEEP[ab]

Item	Basal	Basal and broiler litter[c]				SE
		Deep stacked	Ensiled	Ensiled with molasses	Ensiled with rumen contents[d]	
			%			
Dry matter[ef]	62.57	49.62	52.59	52.59	52.89	1.21
Organic matter[ef]	66.66	55.91	57.87	58.29	59.41	1.08
Crude protein[f]	66.52	60.87	68.86	67.58	70.90	1.52
NDF[eh]	50.67	33.90	33.81	33.48	39.62	2.18
ADF[ej]	34.55	19.67	17.62	21.26	26.25	2.37
Cellulose[eg]	48.37	31.41	31.89	37.76	39.87	2.34
Hemicellulose	75.39	68.52	62.77	57.17	66.80	4.97

[a]Each value represents the mean of six samples.
[b]DM basis except DM.
[c]Ratio of basal and silages, 1:1, dry basis.
[d]Ratio of litter and rumen contents, 1:1, wet basis.
[e]Basal vs waste containing diets differ (P<.05).
[f]Deep stacked containing diets vs ensiled litter diets differ (P<.05).
[g]Litter ensiled with rumen contents vs litter ensiled alone differ (P<.05).
[h]Neutral detergent fiber.
[i]Acid detergent fiber.

deep stacked broiler litter diet than for the other waste diets. The difference was especially large for CP. Cellulose digestibility was higher ($P<.05$) for the diet with ensiled litter-rumen contents compared to litter ensiled with molasses. The apparent digestibility of CP for diets with ensiled litter generally agree with the ranges established by Bhattacharya and Fontenot (1966), Caswell et al. (1975) and Harmon et al. (1974) for conventional diets supplemented with broiler litter. However, the values were higher than the value of 57.5% of Smith and Calvert (1976) for a diet containing 38% broiler litter.

Ruminal Fluid pH and Blood Urea Nitrogen. Ruminal fluid pH was lower ($P<.05$) for sheep fed the basal diet, compared to those fed the processed waste-containing diets (Table 19). Among sheep fed the waste-containing diets, lower values were recorded for sheep fed the diet with deep stacked broiler litter, but differences were not significant.

Blood urea N (BUN) was higher ($P<.05$) for the sheep fed processed broiler litter compared to those fed the basal diet. The lower value for sheep fed the basal diet could be due to lower N intake. No significant difference was observed among waste-containing diets. The trend of low values of blood urea N for the animals fed deep-stacked litter may indicate high bypass N. Preston et al. (1965) reported a

Table 19. RUMINAL pH AND BLOOD UREA-N OF SHEEP FED DEEP STACKED AND ENSILED BROILER LITTER[a]

Item	Basal	Basal and broiler litter[b]				
		Deep Stacked	Ensiled	Ensiled with molasses	Ensiled with rumen contents[c]	SE
Rumen pH[d]	6.53	6.82	6.95	6.95	6.95	0.12
Blood urea-N[d], mg/100ml	22.18	29.11	35.90	33.64	30.83	1.97

[a]Each value represents the mean of six samples.
[b]Ratio of basal and silages, 1:1, dry basis.
[c]Ratio of litter and rumen contents, 1:1, wet basis.
[d]Basal vs waste containing diets differ (P<.05).

high correlation between N intake and BUN. Harmon et al. (1974) and Caswell et al. (1975) reported elevated BUN levels from inclusion of litter in diets of lambs.

Ruminal Volatile Fatty Acids. Total VFA concentration was not significantly different among the sheep fed the different diets (Table 20). Acetic acid tended to be lower for lambs fed the diet with deep-stacked litter than diets with ensiled broiler litter. Butyric acid tended to be higher for sheep fed the waste diets than those fed the basal diet.

Palatability. Dry matter intake by animals fed basal alone, basal with deep stacked litter and with ensiled litter were 1.70, 1.33, 1.33, 1.38 and 1.18 kg/day, respectively (Table 21). The values were higher ($P<.05$) for sheep fed the basal than those fed the waste-containing diets. Dry matter intake tended to be lower for sheep fed diets containing litter ensiled with rumen contents than for sheep fed the other waste diets. Dry matter intakes per kilogram of metabolic size were higher than the values of Caswell et al. (1978).

Implications of these results for feeding wastes to the animals are that broiler litter may be used as a source of protein and minerals (Bhattacharya and Taylor, 1975) and rumen contents as a source of fiber. Nutrient deficiencies in developing countries can be at least partly alleviated by

Table 20. RUMINAL VOLATILE FATTY ACIDS IN SHEEP FED DEEP STACKED AND ENSILED BROILER LITTER[a]

Item	Basal	Basal and broiler litter[b]				
		Deep stacked	Ensiled	Ensiled with molasses	Ensiled with rumen contents[c]	SE
Total VFA,umol/ml	39.75	44.58	44.58	44.50	55.54	8.93
Moles/100moles						
Acetic acid	41.22	39.65	42.84	45.17	41.95	3.90
Propionic acid	31.88	28.22	29.19	27.48	28.66	4.13
Isobutyric acid	3.57	2.04	1.65	1.23	1.30	1.11
Butyric acid	16.10	21.50	19.72	20.41	20.92	3.61
Isovaleric acid	3.59	3.62	2.54	3.00	2.88	0.94
Valeric acid	3.65	4.98	4.08	2.72	4.32	1.51

[a]Each value represents the mean of six samples.
[b]Ratio of basal and silages, 1:1, dry basis.
[c]Ratio of litter and rumen contents, 1:1, wet basis.

Table 21. DAILY DRY MATTER INTAKE BY SHEEP[a]

Item	Basal	Basal and broiler litter[b]				
		Deep stacked	Ensiled	Ensiled with molasses	Ensiled with rumen contents[c]	SE
DM intake.d^{-1}, g^{df}	1698	1326	1330	1378	1182	45
DM intake.$d^{-1}.BW^{.75}$, g^{df}	134	110	108	114	98	45
DDM intake.d^{-1}, g^{ef}	1062	658	695	729	641	45

[a]Each value represents the mean of six samples.
[b]Ratio of basal and silages, 1:1, dry basis.
[c]Ratio of litter and rumen contents, 1:1, wet basis.
[d]Dry matter.
[e]Digestible dry matter.
[f]Basal vs waste containing diets differ (P<.05)

successfully feeding up to 50%, DM basis, of processed broiler litter alone or with other agro-industrial wastes such as molasses and rumen contents. Utilizing these wastes as a feed ingredient will not only provide the nutrients for animals, but will also solve a pollution problem.

Literature Cited

Ammerman, C. B., P. W. Waldroup, L. R. Arrington, R. L. Shirley and R. H. Harms. 1966. Nutrient digestibility by ruminants of poultry litter containing dried citrus pulp. J. Agric. Food Chem. 14:279.

AOAC. 1984. Official Methods of Analysis. (14th Ed.). Assoc. of Official Anal. Chem., Washington, D.C.

Bhattacharya, A. N. and J. P. Fontenot. 1965. Utilization of different levels of poultry litter nitrogen by sheep. J. Anim. Sci. 24:1174.

Bhattacharya, A. N. and J. P. Fontenot. 1966. Protein and energy value of peanut hull and wood shaving poultry litters. J. Anim. Sci. 25:367.

Bucholtz, H. F., H. E. Henderson, J. W. Thomas and H. C. Zindel. 1971. Dried animal waste as a protein supplement for ruminants. In: Livestock Waste Management and Pollution Abatement. Proc. Int. Symp. on Livestock

Wastes. pp 185-187. Am. Soc. Agric. Eng., St. Joseph, MI.

Caswell, L. F., J. P. Fontenot and K. E. Webb, Jr. 1975. Effect of processing method on pastuerization and nitrogen components of broiler litter and on nitrogen utilization by sheep. J. Anim. Sci. 40:750.

Caswell, L. F., J. P. Fontenot and K. E. Webb, Jr. 1978. Fermentation and utilization of broiler litter ensiled at different moisture levels. J. Anim. Sci. 46:547.

Coulombe, J. J. and L. Favreau. 1963. A new semi-micro method for colorimetric determination of urea. Clin. Chem. 9:102.

Erwin, E. S., G. J. Marco and E. M. Emory. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

Fontenot, J. P. and H. A. Hopkins. 1965. Effect of physical form of different parts of lamb fattening rations of feedlot performance and digestibility. J. Anim. Sci. 24:62.

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1972. Digestibility and palatability of ensiled broiler litter and corn. J. Anim. Sci. 35:265. (Abstr.).

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1974. Effect of processing method of broiler litter on nitrogen utilization by lambs. J. Anim. Sci. 39:942.

Liebholz, J. 1969. Poultry manure and meat meal as a source of nitrogen for sheep. Aust. J. Exp. Agric. and Anim. Husb. 9:587.

Preston, R. L., L. H. Brewer and W. H. Pfander. 1961. Blood urea and rumen ammonia in sheep as affected by level and source of carbohydrate and protein. J. Anim. Sci. 20:947. (Abstr.).

SAS. 1982. SAS User's Guide. Statistical Analysis System Institute, Inc., Cary, NC.

VanSoest, P. J. 1963. The use of detergents in the analysis of fibrous feed: II. A rapid method for the determination of fiber and lignin. J. Assoc. Official Agric. Chem. 46:829.

VanSoest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. The determination of plant cell wall constituents. J. Assoc. Official Anal. Chem. 50:50.

VanSoest, P. J. and R. H. Wine. 1968. Determination of lignin and cellulose in acid detergent fiber with permanganate. J. Assoc. Official Anal. Chem. 51:780.

CHAPTER V

PRESERVATION OF RUMEN CONTENTS AND BLOOD AND FERMENTATION CHARACTERISTICS OF RUMEN CONTENTS-BLOOD-STRAW MIXTURES

ABSTRACT

Two experiments were conducted 1) To study the effect of 1% formic/propionic acid (w/w) or 10% molasses on preservation of rumen contents and blood; and 2) to study the fermentation characteristics of different combinations of fresh rumen contents and whole blood (1:1, 2:1 and 3:1) ensiled with or without 7.5% molasses and with or without urea-treated straw. The proportions of slaughter house waste and wheat straw were 40:60.

Rumen contents and blood untreated or treated with 10% molasses had offensive odor, maggot infestation and production of NH_3 and H_2S. Hydrogen sulfide gas was highest in rumen contents on d 1, then decreased. Formic/propionic-treated blood and rumen content had no abnormal odors. The DM of molasses-treated rumen contents and blood was higher ($P<.05$), compared to control and formic/propionic acid treated. Total N for control and molasses-treated blood decreased linearly ($P<.05$) with time. Protein N was higher ($P<.05$) and NPN was lower for formic/propionic acid-treated blood, compared to the other treatments for blood. Pepsin

digestibility was lower (P<.05) for control and molasses-treated blood, compared to formic acid-treated blood. Protein N for control and formic acid-treated rumen contents increased (P<.05) and molasses-treated rumen contents decreased (P<.05) with time. Nonprotein nitrogen increased (P<.05) in molasses treated rumen contents with time. Pepsin digestibility values were higher (P<.05) in formic/propionic acid-treated rumen contents, compared to the other treatments.

The CP content of the mixtures increased from 9.26 to 22.63 when urea-treated straw used. Ash content increased (P<.05) due to the molasses. Proportion of rumen contents and blood had no significant P<.05) effect on CP and ash values. Desirable fermentation was achieved with significant reduction in pH and water-soluble carbohydrates, and an increase in lactic acid in silages made with untreated straw. High pH and low lactic acid concentration were recorded for silages with treated straw. Acetic acid concentration was higher (P<.05) for silages with urea-treated straw. Neutral detergent fiber tended to be lower for silages with urea-treated straw. The low pH in the silages with untreated straw and high pH in the urea-treated straw silages, resulted in complete elimination of total and fecal coliforms.

(Key Words: Blood, Rumen Contents, Ensiling, Preservation, Urea Treatment, Straw)

Introduction

In the United States, approximately 771 million kg of rumen contents and about .2 million kg of fresh whole blood are produced from 35 million cattle slaughtered annually (Withrow and Lammers, 1976). Rumen contents are poorly utilized and represent a disposal problem, especially for small plants. In the rumen, nutrients such as cellulose, NPN and part of dietary protein are converted to protein by microbes. Biological value of microbial protein obtained is sufficient to satisfy most of ruminant requirement for amino acids. The bulk amino acid composition of rumen is fairly constant and independent of the type of the diet given to the animal (Meyer et al., 1967). Abdo et al. (1964) and Bergen et al. (1968) found that rumen contents contained high concentrations of lysine and histidine and are a good source of B-vitamins. Heat drying of rumen contents may not be economically feasible, especially for small slaughter plants.

Blood from abattoirs has traditionally been dried for use as an animal feed, and the product is blood meal, which is a rich source of protein and most amino acids, particularly lysine. Conventional dried blood, was low in

palatability and availability of lysine when fed to pigs (Gutteridge and Trapnell, 1972). There has been interest in processing fresh blood. Ensiling with supplementary carbohydrates has been successful (Wilson and Maguire, 1973).

Ensiling of animal waste seems to be a feasible way of preserving. Mayer et al. (1984) and Alomar (1979) successfully ensiled rumen contents with barley, beet pulp or molasses. Rao and Fontenot (1987) also successfully ensiled rumen and blood with straw. However, before any successful fermentation can be achieved, the waste must be kept in a fresh condition prior to ensiling.

Various chemicals have been used extensively in preservation of highly degradable products (Rao et al., 1983). Backoff (1976) reported a fairly stable product and low microbial counts when 3% formic acid was added to minced cod viscera. Gillberg and Rao (1977) used .75% of propionic and .75% formic acid in achieving successful preservation of fish silage. Abazinge et al. (1986) successfully preserved crab waste treated with 1.5% propionic/formic acid. Ayangbile (1976) preserved the cage layer waste with 10% molasses.

Experiments were conducted to evaluate various chemicals to preserve rumen contents and blood, and fermentation characteristic of fresh rumen contents and whole blood when

ensiled in various proportions with or without molasses and with or without urea-treated straw.

Experimental Procedure

Preservation. This experiment was conducted at Virginia Polytechnic Institute and State University, Virginia. Fresh blood and rumen contents were obtained from a slaughter plant.[1] The materials were mixed separately to achieve homogenous mixture. The following chemicals were applied to fresh slaughter house waste (blood and rumen contents). 1) Control, (no treatment), 2) 1% propionic/formic acid (1:1, w/w), 3) 10% dry molasses. The treated materials were stored in 35 liter plastic buckets. An average of 30 kg of blood and 30 kg of rumen contents were put in each of six buckets per treatment. The chemicals were applied and mixed thoroughly by hand.

Initial samples were obtained for each treatment and stored in ice. The tops of the buckets were sealed with polyethylene. Two 1 m polyvinyl chloride (PVC) pipes (1.5 cm id) with several holes at the bottom were placed in each bucket in order to measure NH_3 and H_2S. The sheets were

---

[1] Valleydale Packing Co., Bristol, VA.

sealed tightly around the pipes and rubber stoppers were placed at the top openings. Small holes were made in the sheets to maintain partial aerobic conditions. The buckets were placed inside a building. Samples of the treated waste were taken on d 1, 3, 5 and 7. The volatile H_2S and NH_3 gases were measured with a gas sampler[2].

Kjeldahl N was determined on wet samples of preserved blood and rumen contents (AOAC, 1984). True protein N was determined on wet samples by precipitation with tungstic acid followed by N determination (AOAC, 1984). Non-protein N was determined by difference between total N and true protein N. Dry matter was determined by drying in a forced draft oven at a maximum of 39 C until a constant weight was reached. Following equilibration with atmospheric air, the duplicate dried samples were weighed, composited and ground in a Wiley mill with a 1 mm screen. Pepsin digestibility of preserved material was determined by AOAC (1984) procedures. Pepsin digestibility consisted of measuring the digestibility of .25 g of material at 45 C in 37.5 ml of a .2% pepsin solution in .75 N HCl. The difference between the initial weight of the sample and the amount of undigested residue retained by

---

[2] Gastec Precision Gas Detector System, Japan.

filtration was expressed as the percent digestibility of protein. Pepsin indigestible protein was determined by determining the Kjeldahl N on pepsin undigested residue.

Ensiling. In the small silo study the slaughter house wastes (rumen contents and blood) were mixed with wheat straw in 40:60 ratio. Ratios of 1:1, 2:1, and 3:1 rumen contents and blood were used. Other treatments were wheat straw, untreated and treated with 5% urea and ensiled with and without 7.5% dry sugarcane molasses. There were 12 treatments and the experiment was conducted as a 3 x 2 x 2 factorial.

Rumen contents and whole blood were collected immediately after slaughter at the meat laboratory of Department of Food Science and Technology at Virginia Polytechnic Institute and State University. The blood and rumen contents were placed in plastic garbage cans, and were stored at low temperature (5 C) for 24 h before ensiling. The ground wheat straw was treated with 5% urea 1 d before ensiling in large polyethylene bags.

Small silos were prepared by firmly packing the respective treatment mixtures into 4 liter capacity cardboard containers, double lined with polyethylene bags. Packing was done by hand to ensure maximum exclusion of air. After packing, each bag was sealed separately.

Approximately 16 kg of each mixture were prepared by separately weighing amounts of each component for the respective mixtures. The mixtures were prepared by adding known amounts of each component into a horizontal mixer and allowing to mix for 10 min. As blood, rumen contents and wheat straw were weighed, samples of each component were taken for chemical analysis. There were six silos per treatment, thus giving a total of 72 small silos. Each small silo had a total weight of approximately 2 kg.

After thorough mixing each mixture was sampled. The sampling for each treatment mixture was done at the beginning, midpoint and toward completion of filling the small silos. Samples for the microbial study were taken aseptically using sterile gloves in sterilized .5 liter mason jars. All microbial studies were done on the samples within 24 h. Samples for chemical analysis were taken at the same time as microbial samples except that the size of sample for chemical analysis was larger. The samples for chemical analysis were put in double polyethylene bags and frozen for later analysis.

The silos were opened after an average fermentation period of 60 d. One silo from each treatment was opened daily and microbial contents were determined. As the small silo was opened observations were made on appearance and odor of

silages. The top 4 to 5 cm material from each opened silo were discarded because of mold growth. Samples for microbial and fermentation characteristics were taken immediately from different locations of the silo.

Water extracts of initial and ensiled mixture were prepared by homogenizing duplicate 25 g samples with 225 ml of deionized water in a .5 liter jar in a Waring blender at full speed for 2 min. The homogenate was filtered through four layers of sterilized cheese cloth. The filtrate was collected in sterilized beakers and used for determining pH (electrometrically), lactic acid (Barker and Summerson, 1941, as modified by Pennington and Sutherland, 1956), water soluble carbohydrates (Dubois et al., 1956 as adapted to corn plant by Johnson et al., 1966), VFA (Erwin et al., 1961), and total (Anonymous, 1967) and fecal coliforms (Millipore Corp., 1973).

Kjeldahl nitrogen was determined on initial samples of blood, rumen content, straw, initial and ensiled mixtures of the small silos before drying (AOAC, 1984). Dry matter was determined on samples by drying duplicate 200 g samples in a forced draft oven at 60 C until a constant weight was reached. Following equilibration with atmospheric air, the duplicate dried samples were weighed, composited and ground in a Wiley mill with a 1 mm screen. The ground material of

large silos was then subjected to analysis of ADF (Goering and Van Soest, 1970), NDF (Van Soest and Wine, 1967), lignin and cellulose (Van Soest and Wine, 1968). Hemicellulose was determined by difference between NDF and ADF. Ash and DM wasdetermined by AOAC (1984).

The data for both experiments were tested by analysis of variance by general linear model procedures of SAS (1982). For the preservation study, day, treatment, block, day x treatment interaction and block x treatment interaction were included in the model. Treatment effect was tested by treatment x block interaction. Then linear, quadratic and cubic contrasts were made to test the effect of time in each period. For treatment means the following contrasts were made: control vs formic/propionic acid and molasses preserved; formic/propionic acid vs molasses preserved material. For the ensiling experiment urea, molasses, proportions of rumen contents and blood, urea x molasses, urea x proportions of rumen contents and blood, molasses x proportions of rumen contents and blood and molasses x urea x proportions of rumen contents and blood were included in the model. The linear and quadratic orthogonal contrasts were used to test the effect of different combinations of rumen contents and blood.

Results and Discussion

Preservation Experiment. Ammonia and H_2S were detected in control, formic/propionic acid and molasses preserved blood and rumen contents. Formic/propionic acid preserved rumen content had no odor while untreated and molasses preserved rumen content had the offensive odor. The highest values for NH_3 in control and chemicals added rumen contents were determined on d 1 (Figure 4). On d 3 and 5 no NH_3 gas was detected for any treatment. However, on d 7 small amounts of NH_3 were detected in rumen contents preserved without chemicals. Perhaps the NH_3 detected on d 1 may have been the result of the activity of ruminal proteolytic microbes that produced NH_3 from the breakdown of NPN and protein. The NH_3 detected on d 7 may have been the result of the aerobic bacterial breakdown of the protein.

Hydrogen sulfide detected was the same on d 1 for all treatments of rumen contents (Figure 5). The H_2S dropped more sharply on d 3 for control, compared to the formic/propionic acid and molasses preserved rumen contents. The H_2S detected on d 5 was lower for added preservative rumen contents than control. On d 7 H_2S was only detected for formic/propionic acid preserved rumen contents.

Blood preserved without any chemical and molasses preserved blood had an offensive odor, while formic/propionic

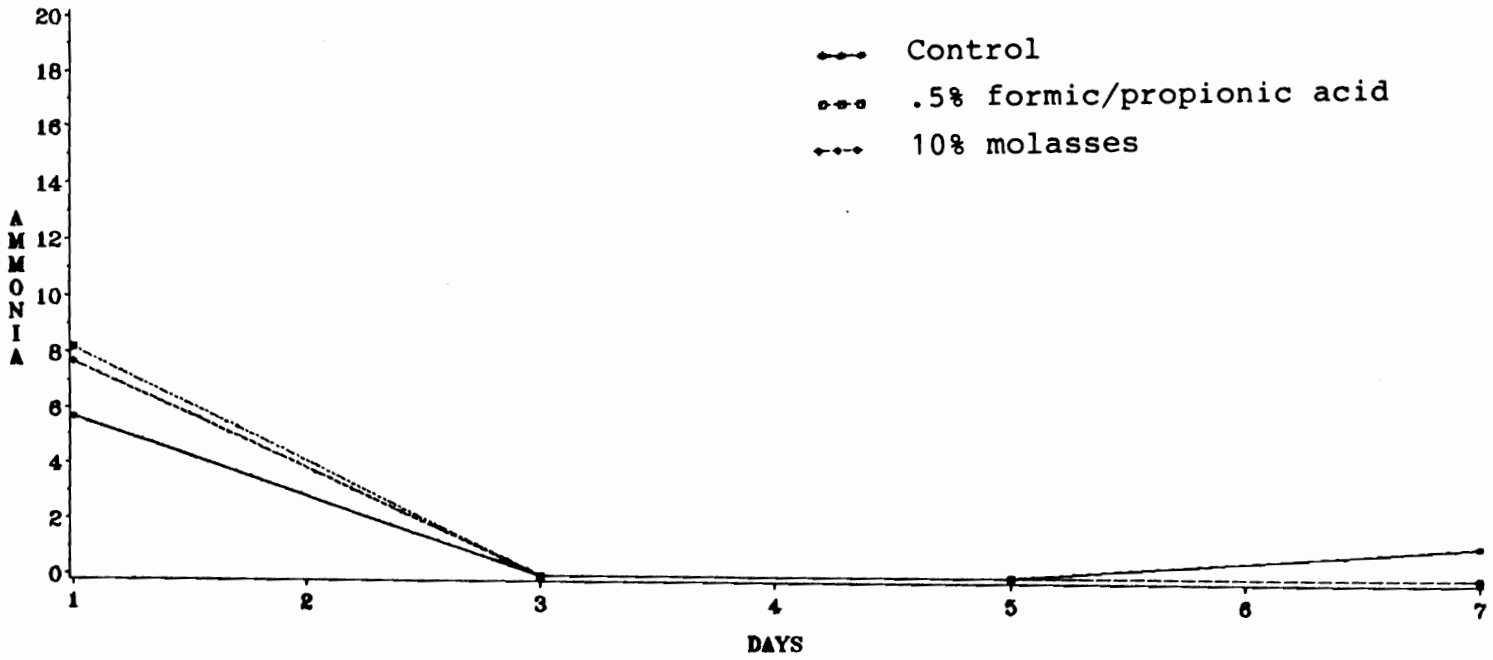


Figure 4. EFFECT OF CHEMICALS ON NH3 CONCENTRATION IN RUMEN CONTENTS, PPM, WET BASIS

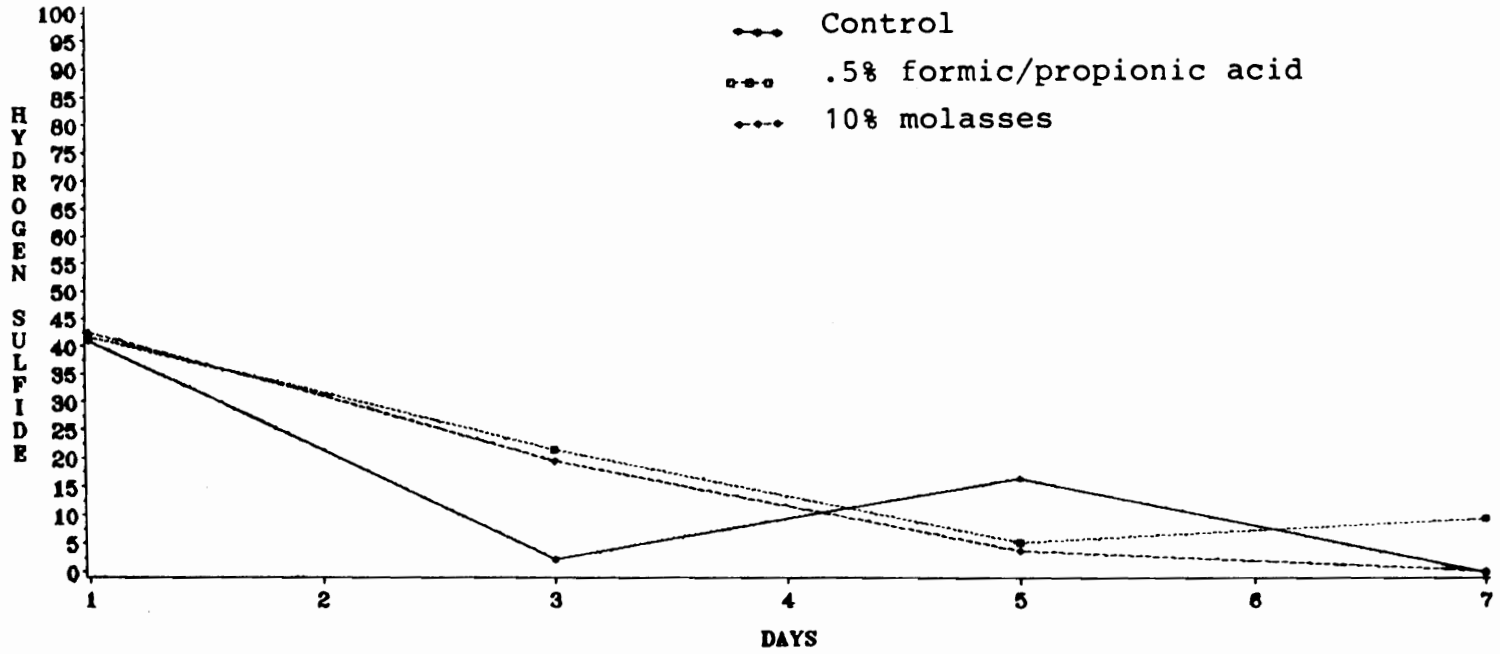


Figure 5. EFFECT OF CHEMICALS ON H2S CONCENTRATION IN RUMEN CONTENTS, PPM, WET BASIS

acid preserved blood had no objectionable odor. Ammonia was not detected in blood on d 1 for any treatment and on d 3, 5 and 7 for formic/propionic acid and molasses preserved blood (Figure 6). Maximum amount of NH_3 (1.75 ppm) was detected on d 5 for control samples. Hydrogen sulfide in blood was not detected for any treatment on d 1, 3 and 5 (Figure 7). Hydrogen sulfide was detected only in blood without any additive on d 7, which means that formic/propionic acid and molasses are effective against the H_2S producing bacteria in blood.

Total N of control blood showed a linear decrease ($P<.05$) with time throughout the storage period, probably due to loss of NH_3 (Table 22). The CP of molasses preserved blood was lower ($P<.05$) than for other treatments, reflecting difference in loss of N. The molasses-treated blood showed quadratic effect ($P<.05$) with time.

The final true protein values were higher ($P<.05$) for the formic/propionic acid-treated blood than control and molasses-treated blood (Table 23). The control blood showed no ($P>.05$) change in the true protein values over time. Formic/propionic acid-treated blood showed an increase (cubic trend) ($P<.05$) and molasses-treated blood showed a decrease (cubic trend, $P<.05$) during the storage period.

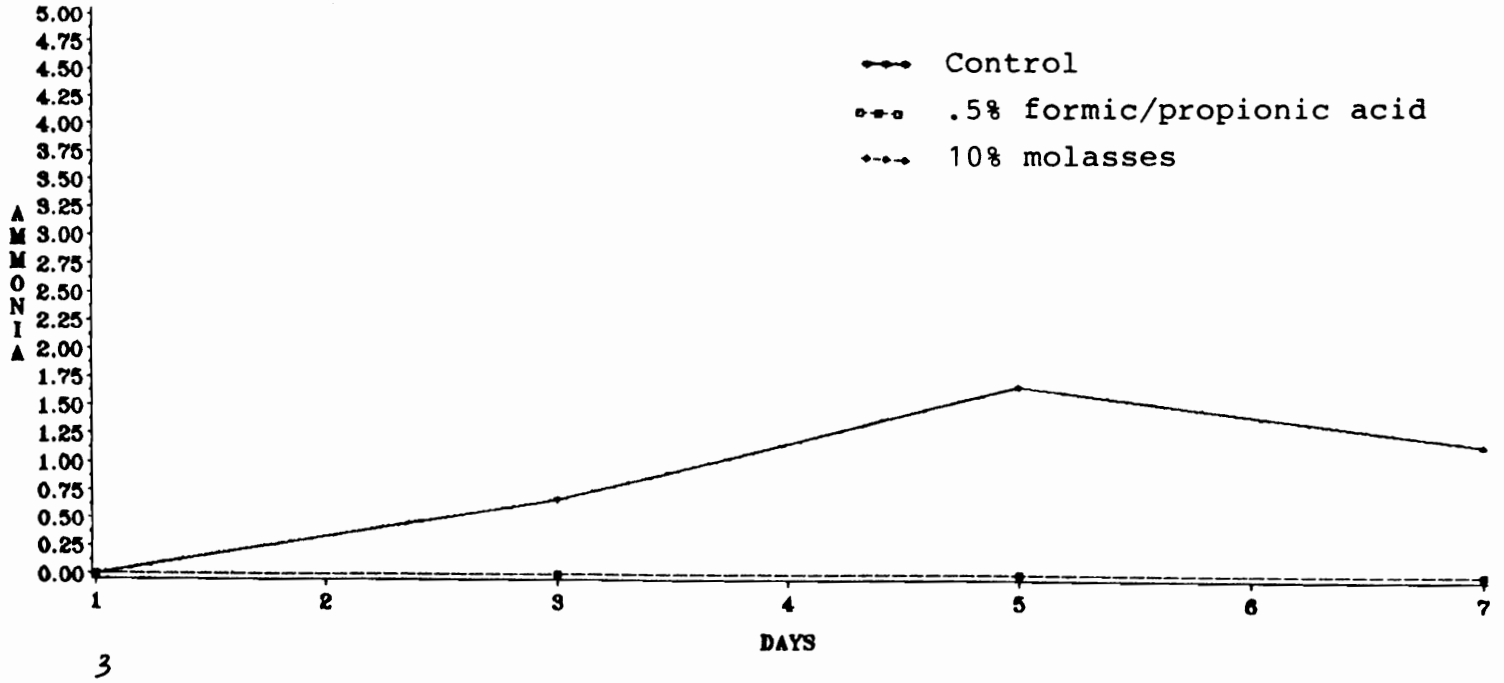


Figure 6. EFFECT OF CHEMICALS ON NH3 CONCENTRATION IN BLOOD, PPM, WET BASIS

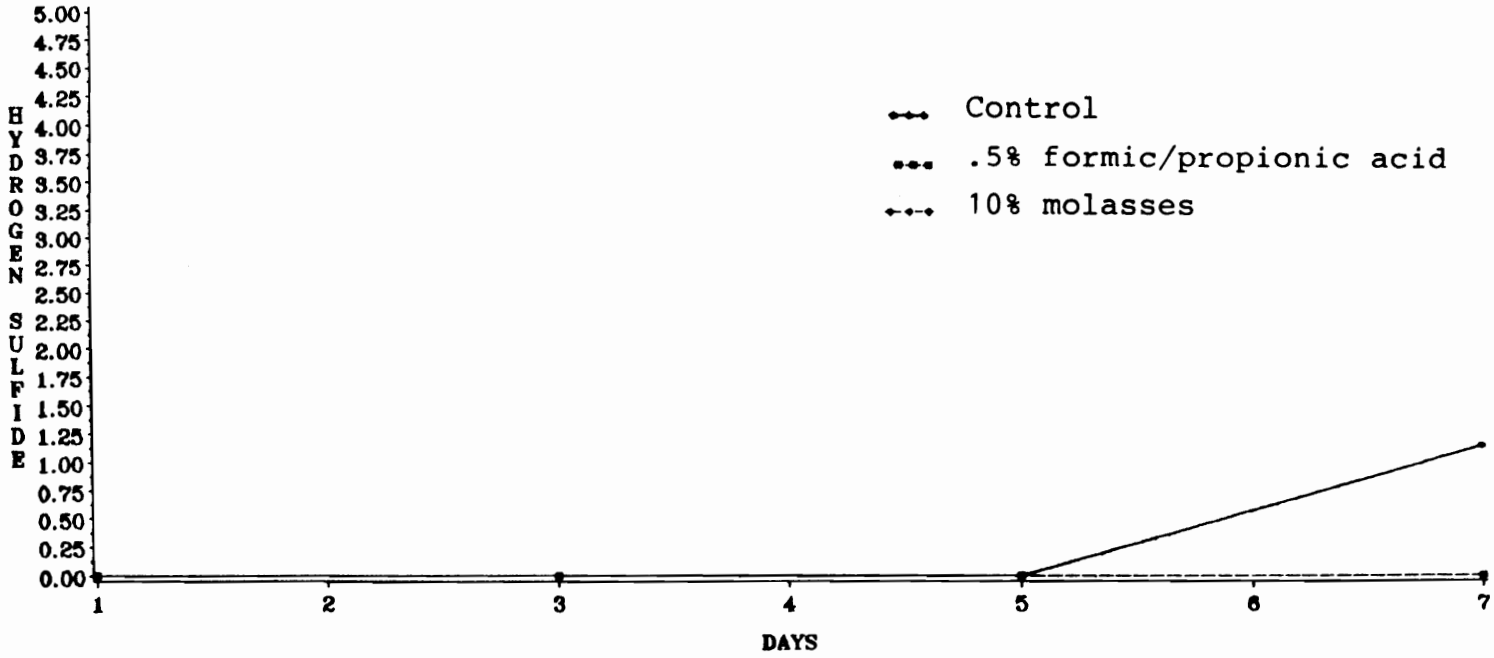


Figure 7. EFFECT OF CHEMICALS ON H2S CONCENTRATION IN BLOOD, PPM, WET BASIS

Table 22. EFFECT OF CHEMICALS ON DRY MATTER AND CRUDE PROTEIN CONTENTS OF PRESERVED BLOOD[a]

Days	Additives			SE
	None[b]	Formic/propionic acid	Molasses[c]	
Dry matter, %				
0	25.70	22.81	23.09	1.36
3	20.47	20.80	31.13	0.87
5	19.42	21.05	31.24	0.87
7	19.81	22.18	31.79	0.87
Average[de]	21.35	21.71	29.31	0.53
Crude protein, %[f]				
0	86.35	85.79	86.02	2.65
3	85.37	87.04	68.10	1.83
5	83.70	81.65	64.60	1.83
7	83.27	81.98	67.57	1.83
Average[de]	84.64	84.94	71.25	1.08

[a]Each value represents the mean of six samples.
[b]Linear effect of time for DM ($P<.05$).
[c]Quadratic effect of time for CP ($P<.05$).
[d]Treatment means of untreated vs treated blood differ ($P<.05$).
[e]Treatment means of formic/propionic acid vs molasses treated blood differ ($P<.05$).
[f]DM basis.

Table 23. EFFECT OF CHEMICALS ON TRUE PROTEIN AND NPN OF PRESERVED BLOOD[a]

Days	Additives: None	Formic/propionic acid[bc]	Molasses[bd]	SE
True protein, %[e]				
0	47.37	44.04	43.37	4.44
3	48.80	65.57	29.21	3.05
5	50.63	55.23	33.67	3.05
7	48.42	71.18	32.00	3.05
Average[f]	48.63	59.62	34.21	1.79
NPN, %[e]				
0	6.09	6.58	6.67	0.73
3	5.85	2.64	6.22	0.50
5	5.30	4.23	4.95	0.50
7	5.59	1.74	5.69	0.50
Average[fg]	5.75	3.72	5.93	0.30

[a]Each value represents the mean of six samples.
[b]Cubic effect of time for true protein (P<.05).
[c]Cubic effect of time for NPN (P<.05).
[d]Linear effect of time for NPN (P<.05).
[e]DM basis.
[f]Treatment means of formic/propionic acid vs molasses treated blood differ (P<.05).
[g]Treatment means of untreated vs treated blood differ (P<.05).

Initial NPN was similar among treatments (Table 23). The formic/propionic acid-treated blood showed, overall, more decrease in NPN value (cubic trend, $P<.05$) than any other treatment. The NPN values decreased from 6.58 to 1.74 from d 1 to d 7. The NPN values for molasses-treated blood showed a linear decrease ($P<.05$) from 6.68 to 5.69 over time.

Overall, pepsin digestibility was higher ($P<.05$) for formic/propionic acid preserved blood compared to control and molasses preserved (Table 24). There was a decrease in pepsin digestibility for all treatments over time (cubic effect, $P<.05$). However, the decrease was higher for control and molasses preserved blood than formic/propionic acid preserved blood. Divakaran (1987) found higher value of pepsin digestibility (97.9%) for acidulated preserved blood.

Percent N in the pepsin indigestible residue was lowest ($P<.05$) for the molasses-treated blood than other treatments (Table 24). Similar values were found for the control and formic/propionic acid-treated blood. These treatments showed an increase in N of pepsin indigestible residue (cubic effect, $P<.05$) over time. However, molasses-treated blood showed a decrease in N of pepsin indigestible residue over time (cubic trend, $P<.05$).

The DM content of molasses-treated rumen contents was higher ($P<.05$) than for other treatments (Table 25). This may

Table 24. EFFECT OF CHEMICALS ON PEPSIN DIGESTIBILITY AND PEPSIN INDIGESTIBILITY OF PRESERVED BLOOD[a]

Days	Additives			SE
	None[b]	Formic/propionic acid[b]	Molasses[b]	
Pepsin digestibility[c], %				
0	83.95	87.80	89.18	5.33
3	65.74	78.02	69.49	3.41
5	86.63	97.63	80.69	3.41
7	78.24	81.15	65.31	3.41
Average[de]	78.92	85.70	76.55	2.16
CP in indigestible residue[c], %				
0	61.92	68.18	69.94	7.27
3	80.76	80.17	66.63	5.01
5	69.85	63.82	46.92	5.01
7	79.81	84.06	63.02	5.01
Average[de]	74.12	73.89	60.87	2.96

[a]Each value represents the mean of six samples.
[b]Cubic effect of time for pepsin digestibility ($P<.05$).
[c]DM basis.
[d]Treatment means of untreated vs treated blood differ ($P<.05$).
[e]Treatment means of formic/propionic acid vs molasses treated blood differ ($P<.05$).

Table 25. EFFECT OF CHEMICALS ON DRY MATTER AND CRUDE PROTEIN OF PRESERVED RUMEN CONTENTS[a]

Days	Additives			SE
	None[b]	Formic/propionic acid[b]	Molasses[c]	
Dry matter, %				
0	18.34	18.62	19.69	.86
3	21.84	22.69	30.00	.55
5	22.64	23.56	27.85	.55
7	22.13	22.60	29.06	.55
Average[de]	21.43	21.85	26.76	.36
Crude protein, %[f]				
0	9.56	10.64	9.84	.50
3	10.71	10.26	9.50	.32
5	9.67	9.73	10.17	.32
7	9.65	10.72	9.72	.32
Average	10.00	10.23	9.80	.23

[a]Each value represents the mean of six samples.
[b]Linear effect of time for DM ($P<.05$).
[c]Cubic effect of time for DM ($P<.05$).
[d]Treatment means of untreated vs treated rumen contents differ ($P<.05$).
[e]Treatment means of formic/propionic acid vs molasses treated rumen contents differ ($P<.05$).
[f]DM basis.

be due to the added effect of dry molasses. The DM content for all treatments increased with time. However, DM contents of control and formic/propionic acid-treated rumen contents showed a quadratic effect ($P<.05$) with time, while molasses-treated rumen contents showed a cubic trend ($P<.05$).

Crude protein for treated rumen contents averaged 10.01% dry basis. No differences in CP values were observed during the storage period. Initial protein N was similar ($P>.05$) among treatments (Table 25). Average true protein of untreated rumen content was higher ($P<.10$) than the values of treated rumen contents (Table 26).

Untreated rumen contents and formic/propionic acid-treated rumen contents showed an increase in true protein (cubic trend, $P<.05$) with time, while molasses-treated rumen contents showed a decrease in true protein (cubic trend, $P<.05$) with time. Initial and average NPN values over time were similar in all treatments (Table 26). However, lower values were observed for untreated rumen contents than treated rumen content. Possible factors contributing to lower NPN may be the presence of fly (Musca domestica) eggs and maggots in the control treatment. Molasses-treated rumen contents showed an increase in NPN value (cubic trend, $P<.05$) with time. The NPN of formic acid/propionic acid-treated rumen contents tended to be higher. However, no significant

Table 26. EFFECT OF CHEMICALS ON TRUE PROTEIN AND NPN CONTENTS OF PRESERVED RUMEN CONTENTS[a]

Days	Additives: None[b]	Formic/propionic acid[b]	Molasses[bc]	SE
True protein, %[d]				
0	7.96	8.13	8.84	.53
3	9.55	8.87	6.75	.34
5	8.14	7.39	7.83	.34
7	8.24	9.04	7.27	.34
Average[de]	8.65	8.44	7.28	.20
Non protein nitrogen, %[b]				
0	0.28	0.58	0.16	.32
3	0.19	0.25	0.44	.20
5	0.25	0.37	0.38	.20
7	0.23	0.92	0.40	.20
Average	0.22	0.52	0.41	.13

[a]Each value represents the mean of six samples.
[b]Cubic effect of time for true protein ($P<.05$).
[c]Cubic effect of time for NPN ($P<.05$).
[d]DM basis.

(P>.05) difference was observed in the mean values of NPN for all treatments.

Pepsin digestibility for the control treatment decreased (cubic trend, P<.10) from 26.56 to 23.17% from d 1 to d 7 (Table 27). The molasses-treated rumen contents showed an increase (cubic trend, P<.05) in pepsin digestibility with time. The molasses-treated rumen contents showed the highest increase in pepsin digestibility.

Crude protein in pepsin indigestible residues was highest (P<.05) in control, compared to formic/propionic acid- and molasses-treated rumen contents (Table 27). Among treated rumen contents, CP of pepsin indigestible residue was higher (P<.05) for molasses-treated rumen contents than formic/propionic acid-treated rumen contents. The higher indigestibility values showed that the waste had not been preserved well.

Ensiling Experiments. Dry matter concentration of rumen contents averaged 15.85% (Table 28). Crude protein content of rumen contents averaged 13%, DM basis. The value of 9.59% for ash content is substantially lower than the value of 15.99% reported by Reddy and Reddy (1980). Level of N components generally was within the ranges established by Rao and Fontenot (1987), Reddy and Reddy (1980), Oshida et al. (1986), and Jovanovic and Cuperlovic (1977).

Table 27. EFFECT OF CHEMICALS ON PEPSIN DIGESTIBILITY AND PEPSIN INDIGESTIBILITY OF RUMEN CONTENTS[a]

Days	Additives			SE
	None[b]	Formic/propionic acid	Molasses[b]	
Pepsin digestibility, %[c]				
0	26.56	24.16	28.19	1.96
3	20.93	23.93	37.36	1.25
5	24.18	26.96	34.44	1.25
7	23.17	28.29	34.25	1.25
Average[de]	22.76	24.77	35.35	0.82
Crude protein in indigestible residue, %[c]				
0	54.65	55.13	54.83	6.77
3	65.90	54.70	65.75	4.31
5	59.35	48.09	46.63	4.31
7	65.27	52.62	51.53	4.31
Average[de]	63.50	51.81	54.64	2.37

[a]Each value represents the mean of six samples.
[b]Cubic effect of time ($P<.05$).
[c]DM basis.
[d]Treatment means of untreated vs treated rumen contents differ ($P<.05$).
[e]Treatment means of formic/propionic acid vs molasses treated rumen contents differ ($P<.05$).

Table 28. CHEMICAL COMPOSITION OF MATERIALS USED IN SMALL SILO STUDY[ab]

Item	Rumen Contents	Blood	Untreated Straw	Treated Straw
	----------%			
Dry matter	15.85	22.12	90.13	78.18
Crude protein	12.98	86.35	6.35	16.87
Ash	9.59	3.51	5.48	5.51
Neutral detergent fiber	65.31	N.D	77.32	75.92
Acid detergent fiber	42.01	N.D	47.09	46.89
Cellulose	29.30	N.D	34.34	32.28
Hemicellulose	23.30	N.D	30.23	29.03
Lignin	10.91	N.D	11.92	12.15

[a]Each value represents the mean of six samples.
[b]DM basis except DM.

Neutral detergent fiber, ADF, cellulose, hemicellulose and lignin values were similar to values obtained by El-Yassin et al. (1984).

Dry matter content of freshly collected whole blood averaged 22.1% (Table 28). The CP of whole blood averaged 86.4%, dry basis, lower than the value of 90.2% reported by Rao and Fontenot (1987). Ash content of the whole blood averaged 3.51%, dry basis, which is lower than ash value reported by El-Yassin et al. (1984).

The DM content of untreated and treated straw samples averaged 90.1% and 78.2%, respectively. Addition of urea increased the CP content of straw from 6.2% to 16.9%. No difference was observed in ash content of untreated and treated straw.

Neutral detergent fiber tended to be decreased from 77.3% to 75.9% due to the urea treatment. Acid detergent fiber, hemicellulose and lignin content were similar in the treated and untreated straw. However, cellulose decreased about 6% due to addition of urea to straw.

The values for the initial small silo mixtures represent an average of three replicates per treatment (Table 29). The DM content in the initial mixtures was similar for all treatments, ranging from 46.1% to 50.4%. Crude protein values were higher ($P<.05$) for the mixtures containing urea-

Table 29. COMPOSITION OF INITIAL MIXTURES OF BLOOD, RUMEN CONTENTS AND STRAW, SMALL SILO STUDY[ab]

RC[c]: blood	Straw[d]	Molasses %	DM	CP[ef]	Ash[g]	NDF[h]	ADF[i]	Hemi cellulose	Cellu- lose	Lignin
			----------	----------	----------	----------	----------	% ----------	----------	----------
1:1	T	5	47.55	24.25	4.24	76.48	48.57	27.91	33.05	10.36
1:1	T	0	46.98	25.06	3.45	77.78	48.61	29.17	30.49	10.71
1:1	U	5	46.09	10.77	4.15	74.42	48.19	26.23	30.61	11.61
1:1	U	0	46.53	10.10	3.43	77.29	48.73	28.58	30.73	12.30
2:1	T	5	46.74	24.74	4.17	75.20	48.29	26.91	30.62	10.48
2:1	T	0	49.13	24.77	3.39	72.34	48.61	23.73	31.10	10.88
2:1	U	5	49.16	8.68	4.10	73.62	49.13	24.49	30.96	10.85
2:1	U	0	48.94	8.24	3.39	75.38	49.15	26.23	31.14	11.95
3:1	T	5	46.54	24.38	4.43	72.34	48.28	24.06	31.31	11.39
3:1	T	0	46.53	25.44	3.38	77.93	48.71	29.22	31.00	10.58
3:1	U	5	49.03	7.81	4.12	73.17	49.93	23.24	30.61	11.88
3:1	U	0	50.42	7.64	3.36	72.49	48.50	23.99	30.67	12.46
SE			1.05	.57	.12	2.00	.52	1.48	0.41	0.41

[a]Each value represents the mean of three samples.
[b]DM basis except DM.
[c]Rumen contents.
[d]T=treated with 5% urea, U=untreated.
[e]Linear effect for combination of rumen contents and blood (P<.05).
[f]Effect of urea treatment (P<.05).
[g]Effect of molasses treatment (P<.05).
[h]Neutral detergent fiber.
[i]Acid detergent fiber.

treated straw, compared to mixtures containing untreated straw. No significant difference was observed in CP contents among the mixtures containing untreated straw. However, CP values decreased linearly ($P<.05$) with increases of rumen contents; in the mixtures. Addition of molasses had no effect on CP values.

Ash values were higher ($P<.05$) for the mixtures containing molasses, compared to mixtures without molasses. The CP values of ensiled mixtures decreased linearly ($P<.05$) with the increases of rumen contents in the mixture. Cell wall components were similar in the ensiled mixtures for all treatments (Table 30). The values for the ensiled mixtures represent an average of six replicates per treatment. Hemicellulose and NDF values for the urea-treated straw silages tended to be lower than for the untreated straw silages. The ADF, cellulose, and lignin values were similar for all silages.

The pH values of the initial mixtures containing urea-treated straw were higher ($P<.05$) compared to untreated straw mixtures, (8.66 vs 6.91) (Table 31). The pH of mixtures with untreated straw decreased from 6.91 to 4.53 after ensiling. The silages with urea-treated straw had an ammoniated odor and pH values remained about the same. The pH of the urea-

Table 30. COMPOSITION OF ENSILED MIXTURES OF RUMEN CONTENTS BLOOD-STRAW, SMALL SILO STUDY[ab]

RC[c]: blood	Straw[d]	Molasses %	DM	CP[ef]	Ash[g]	NDF[h]	ADF[i]	Hemi-cellulose	Cellu-lose	Lignin
			----------%----------							
1:1	T	5	47.45	23.64	4.66	68.88	49.02	19.86	36.65	11.39
1:1	T	0	47.49	23.70	3.63	68.84	49.88	18.96	38.52	10.93
1:1	U	5	48.89	10.97	4.60	70.94	47.72	23.22	36.41	10.76
1:1	U	0	48.82	10.51	3.49	72.43	52.64	19.79	36.70	11.52
2:1	T	5	48.55	22.64	4.61	71.58	48.60	22.98	36.47	10.88
2:1	T	0	47.08	22.71	3.58	70.35	51.25	19.10	38.71	10.33
2:1	U	5	50.22	8.63	4.52	72.27	49.54	22.73	37.24	12.03
2:1	U	0	49.96	8.26	3.61	73.08	48.47	24.61	39.24	11.31
3:1	T	5	46.52	21.20	4.38	69.90	48.83	18.68	33.82	11.64
3:1	T	0	47.54	21.89	3.55	69.18	51.22	17.96	34.59	10.34
3:1	U	5	51.53	8.31	4.22	72.27	48.24	24.03	36.31	10.79
3:1	U	0	50.18	8.86	3.78	72.23	46.92	25.31	33.83	9.76
SE			1.32	.65	.13	1.35	.87	.48	1.61	0.64

[a]Each value represents the mean of six sample.
[b]DM basis except DM.
[c]Rumen contents.
[d]T=treated with 5% urea, U=untreated.
[e]Linear effect of combination of rumen contents and blood (P<.05).
[f]Effect of urea treatment (P<.05).
[g]Effect of molasses treatment (P<.05).
[h]Neutral detergent fiber.
[i]Acid detergent fiber.

Table. 31 FERMENTATION CHARACTERISTICS OF RUMEN CONTENTS-BLOOD-STRAW SILAGES[a]

RC:blood[d]	Straw[e]	Molasses	pH		WSC[b], %[c]		Lactic acid, %[c]	
			Pre-ensiled[fgh]	Post-ensiled[f]	Pre-ensiled[g]	Post-ensiled[fg]	Pre-ensiled	Post-ensiled[fgi]
1:1	T	5	8.71	8.65	7.10	3.21	-	0.61
1:1	T	0	8.87	8.72	2.41	1.43	-	0.24
1:1	U	5	6.90	4.58	6.91	1.12	-	3.04
1:1	U	0	7.06	4.63	2.55	0.96	-	2.30
2:1	T	5	8.38	8.59	6.89	2.44	-	0.61
2:1	T	0	8.81	8.76	2.78	1.53	-	0.48
2:1	U	5	6.88	4.53	6.46	1.95	-	2.54
2:1	U	0	6.84	4.39	2.57	1.15	-	2.34
3:1	T	5	8.35	8.68	6.99	2.41	-	0.25
3:1	T	0	8.81	8.74	2.61	2.06	-	0.27
3:1	U	5	6.84	4.53	6.83	1.21	-	2.45
3:1	U	0	6.89	4.53	2.63	0.81	-	2.88
SE			0.09	0.07	0.21	0.24	-	0.22

[a]Each value represents the mean of six samples.
[b]Water soluble carbohydrates.
[c]DM basis.
[d]Rumen contents.
[e]T=treated straw with 5% urea, U=untreated.
[f]Effect of urea tratment (P<.05).
[g]Effect of molasses treatment (P<.05).
[h]Effect of urea and molasses treatment (P<.05).
[i]Effect of molasses and combination of rumen contents and blood (P<.05).

treated silages was higher (P<.05) than the silages containing untreated straw silages.

Water soluble carbohydrate levels in the mixtures reflected the amount of molasses added (Table 31). There was a decrease in water soluble carbohydrates after ensiling. Post ensiled water soluble carbohydrates were higher (P<.05) for mixtures with added molasses.

Substantial levels of lactic acid were observed only for ensiled mixtures with untreated straw (Table 31). Addition of urea-treated straw decreased (P<.05) lactic acid in the post ensiled mixtures, indicating that lactic fermentation was decreased by addition of urea. Addition of urea to the silage extended the fermentation period, increased pH and decreased lactic acid (Owen et al., 1970). The decrease in water soluble carbohydrates and no increase in lactic acid in urea-treated silages indicated that acetic acid producing bacteria dominated in the silage.

The total VFA concentration was highest for the silages with urea treated straw (Table 32). Acetic acid was the major fatty acid produced for all silages, however, higher (P<.05) values were found for silages with urea-treated straw. Butyric acid was the second major fatty acid produced in all silages, although lower (P<.05) values were found for silage with untreated straw. Isovaleric acid values showed differ-

Table 32. VOLATILE FATTY ACID CONCENTRATION IN RUMEN CONTENTS-BLOOD-STRAW SILAGES, SMALL SILO STUDY[ab]

RC:[c] blood	Straw[d]	Molasses %	Total VFA[efg]	Acetic acid[e]	Propionic acid[f]	Isobutyric acid[eg]	Butyric acid[eg]	Isovaleric acid[e]
			----------	----------	----------	%----------	----------	----------
1:1	T	5	1.12	0.92	0.13	0.013	0.03	0.03
1:1	T	0	1.42	1.12	0.08	0.041	0.02	0.07
1:1	U	5	0.69	0.56	0.10	0.092	0.01	0.02
1:1	U	0	0.53	0.32	0.08	0.016	0.11	0.01
2:1	T	5	1.54	1.29	0.07	0.037	0.08	0.06
2:1	T	0	1.53	1.32	0.08	0.041	0.04	0.07
2:1	U	5	0.40	0.27	0.08	0.036	0.01	0.01
2:1	U	0	0.44	0.34	0.08	0.003	0.02	0.01
3:1	T	5	1.87	1.55	0.10	0.028	0.14	0.06
3:1	T	0	1.25	1.01	0.12	0.025	0.06	0.04
3:1	U	5	0.36	0.23	0.09	0.019	0.02	0.01
3:1	U	0	0.65	0.50	0.10	0.015	0.02	0.01
SE			.14	.13	.02	.006	.02	.01

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Rumen contents.
[d]T=treated straw with 5% urea, U=untreated.
[e]Effect of urea treatment (P<.05).
[f]Effect of combinations of rumen contents and blood (P<.10).
[g]Effect of molasses and urea treatment (P<.05).

ences within urea-treated silages, with higher concentration for the silages containing molasses. No differences ($P<.05$) were found in propionic acid concentration for all silages.

Total and fecal coliforms for the initial mixtures was higher ($P<.05$) for silages containing untreated wheat straw, compared to silages containing urea-treated wheat straw (Table 33). This might be due to alkaline effect of urea. Antimicrobial effect can be achieved by the high buffer action and elevated pH due to the alkali (Greenhalgh et al., 1978). Ensiling eliminated the pathogenic organisms completely. Kodama (1952) reported that antibiotic-like substances are produced by some lactic acid-producing bacteria. Lactolin produced by L. plantarum may contribute to the inhibition of pathogens in fermented waste rations. Some lactobacilli produce hydrogen peroxide in sufficient amounts to inhibit the pathogenic organisms (Dahiya and Speck, 1968).

The results indicate that combinations of formic/propionic acids at 1% w/w (1:1 v/v) is effective in preserving the blood and rumen contents. However, ensiling soon after collection is the feasible means of preserving rumen contents and blood. Rumen contents have enough water soluble carbohydrates for ensiling bacteria to decrease the pH. Furthermore, results show that addition of urea increases the pH and acetic acid type fermentation.

Table 33. MICROBIAL COUNTS OF INITIAL AND ENSILED MIXTURES OF RUMEN CONTENTS-BLOOD-STRAW MIXTURES, SMALL SILO STUDY[a]

RC:blood[b]	Straw[c]	Molasses %	Total coliform 10^{5}[c]		Fecal coliform 10^{5}[d]	
			Pre-ensiled	Post-ensiled	Pre-ensiled	Post-ensiled
1:1	T	5	0.00	0.00	0.00	0.00
1:1	T	0	0.00	0.00	0.00	0.00
1:1	U	5	0.20	0.00	0.184	0.00
1:1	U	0	0.22	0.00	0.202	0.00
2:1	T	5	0.019	0.00	0.004	0.00
2:1	T	0	0.013	0.00	0.013	0.00
2:1	U	5	0.230	0.00	0.058	0.00
2:1	U	0	0.240	0.00	0.164	0.00
3:1	T	5	0.012	0.00	0.006	0.00
3:1	T	0	0.010	0.00	0.013	0.00
3:1	U	5	0.053	0.00	0.041	0.00
3:1	U	0	0.058	0.00	0.029	0.00

[a]Each value represents the mean of six samples.
[b]Rumen contents.
[c]T=treated straw with 5% urea, U=untreated.
[d]Counts per grams of dry matter.

Literature Cited

Abazinge, M. D. A., J. P. Fontenot and V. G. Allen. 1986. Effect of various additives on preservation and ensiling characteristics of crab waste. Virginia Polytechnic Institute and State Univ. Livestock Res. Rep. No. 5:107.

Abdo, K. M., K. W. King and R. W. Engel. 1964. Protein quality of rumen microorganisms. J. Anim. Sci. 23:734.

Alomar, C. D. 1979. Chemical evaluation of silage made from rumen content. Cited in Chem. Abstr. (1980). 92:145(2534).

Anonymous. 1967. Standad Methods for the Examination of Dairy Products (12th Ed.). Am. Public Health Assoc. Inc., New York.

AOAC. 1984. Official Methods of Analysis (14th Ed.). Assoc. of Official Anal. Chem., Washington, D.C.

Ayangbile, O. A. and J. P. Fontenot. 1986. Preservation of wet caged layer waste. Virginia Polytechnic Institute and State Univ. Livestock Res. Rep. No. 5:87.

Backhoff, H. P. 1976. Some chemical changes in fish silage. J. Food Tech. 11:353.

Barker, S. B. and W. H. Summerson. 1941. The determination of lactic acid in biological material. J. Biol. Chem. 138:535.

Bergen, W. G., B. D. Purser and J. H. Cline. 1968. Determination of limiting amino acid of rumen-isolated microbial protein fed to rat. J. Dairy Sci. 51:1698.

Dahiya, R. S. and M. L. Speck. 1968. Hydrogen peroxide formation by lactobacilli and its effect on staphlococcus aureus. J. Dairy Sci. 51:1568.

Divakran, S. 1987. An in vitro quality evaluation of slaughter house by-products preserved by pickling with sulphuric acid. Biol. Wastes 19:281.

Dubois, M., K. A. Gilles, J. K. Hamilton, P. A. Rebers and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350.

Gilberg, A. and J. Rao. 1977. Properties of a propionic acid/formic acid preserved silage of cod viscera. J. Food Technol. 28:647.

Goering, H. K. and P. J. VanSoest. 1977. Forage fiber analysis. Agric. Handbook 379. ARS, USDA, Washington, D.C.

Greenhalgh, J. F., D. R. Pirie, H. T. Shin and C. S. Stewart. 1978. Alkali tratment of straw for ruminants. II.

Nutritive value of straw ensiled after alkali treatment. Anim. Feed Sci. Technol. 3:289.

Gutteridge, J. S. and M. Trapnell. 1972. Feeding of pigs. Aust. J. Agric. 70:115.

Jovanovic, M. and M. Cuperlovic. 1977. Nutritive value of rumen contents for monogastric animals. Anim. Feed Sci. Technol. 2:351.

Kodama, R. 1952. Studies on lactic acid bacteria. II. Lactolin, a new antibiotic substance produced by lactic acid bacteria. J. Antibiot. 5:72.

Meyer, H., M. Coenen and C. Schunemann. 1984. Use of rumen contents of slaughtered cattle as feed. 3. Use of rumen contents for feeding pigs. Berliner und Murchener Tierarztliche Wochenschrift 97:239. Cited in Nutr. Abstr. Rev. (1985). 55:9 (4570).

Meyer, H., G. Amtsberg, H. J. Burger, M. Coenen and H. R. Frey. 1984. Use of rumen contents of slaughtered cattle as feed. 1. Preservation of partly dehydrated rumen contents with urea and composition of the product. Berliner und Munchener Tierarztliche Wochenschrift 4:123. Cited in Nutr. Abstr. Rev. (1985). 55:9(4480).

Millipore Corporation. 1973. Biological Analysis of water and waste water. Catalog No. LAM 302B, Milliporre Corp., Bedford, MA.

Owens, F. N., J. C. Meiske and R. D. Goodrich. 1970. Corn silage fermentation. 1. Effect of crude protein sources and sodium bisulfite on energy constituents. J. Anim. Sci. 30:455.

Oshida, T., K. Aikawa, T. Fukuyasu and K. Tanaka. 1986. Fermentation of slaughter house residuum and palatability of fermented slaughter house residuum for pigs. Jap. J. of Zootech. Sci. 57:808. Cited in Nutr. Abstr. Rev. (1987). 57:3(967).

Pennington, R. J. and T. M. Sutherland. 1956. Ketone body production from various substrates by sheep-rumen epithelium. Biochem. J. 63:353.

Raa, J., A. Gildberg and T. Strom. 1983. Silage production; Theory and practice. In D. A. Ledward, A. J. Taylor and R. A. Lawrie (Ed.). Upgrading Waste for Feeds and Food. pp 83-101. Butterworths, Boston.

Reddy, M. R. and K. V. S. Reddy. 1980. A short note on the proximate composition of rumen digesta from bovine and ovine species and its utilization as a component of livestock feed. Indian Vet. J. 57:429.

Rao, N. M. and J. P. Fontenot. 1987. Ensiling of rumen contents and blood with wheat straw. Anim. Feed Sci. Technol. 18:67.

SAS. 1982. SAS User's Guide. Statistical Analysis System Institute, Inc., Cary, NC.

VanSoest, P. J. 1963. The use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Official Agric. Chem. 46:829.

VanSoest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feed. IV. The determination of plant cell wall constituents. J. Assoc. Official Anal. Chem. 50:50.

VanSoest, P. J. and R. H. Wine. 1968. Determination of lignin and cellulose in acid detergent fiber with permanganate. J. Assoc. Official Anal. Chem. 51:780.

Wilson, R. K. and M. F. Maguire. 1973. Preservation of blood and fish offal. An Foras Taluntais. Anim. Prod. Res. Rep. p. 51.

Witherow, J. L. and S. Lammers. 1976. Paunch and viscera handling. Environ. Prot. Technol. Ser. EPA-600.2-76. Cited in NRC (1983).

CHAPTER VI

DIGESTIBILITY AND NUTRIENT UTILIZATION BY SHEEP FED ENSILED BLOOD-RUMEN CONTENTS-STRAW MIXTURE

ABSTRACT

Blood and rumen contents were preserved with 1% formic/propionic acid. Treated rumen contents and blood were ensiled with wheat straw in a ratio of 45:15:40, wet basis. The mixture was allowed to ensile for a minimum of 10 wk. A reduction in pH and water-soluble carbohydrates and a high concentration of lactic acid (3.18%, dry basis) indicated that desirable fermentation had occurred. The silage was used in a metabolism trial with 18 wethers with an average weight of 42 kg. Diets were 1) basal (46% orchardgrass, 46% corn grain, 7% soybean meal and 1% limestone), 2) a 75:25 mixture, dry basis, of basal and silage, 3) a 50:50 mixture, dry basis, of basal and silage. The digestibility of 100% silage was calculated by regression equation. Apparent digestibility of DM, OM, NDF, ADF, cellulose and hemicellulose decreased linearly ($P<.05$) with increased silage in the diet. The calculated DM and OM digestibility of 100% silage was 36% lower than the basal diet. No difference was observed in the CP digestibility for different diets. However, the calculated CP digestibility of 100%

silage was 8% higher than the basal diet. Nitrogen retention decreased linearly ($P<.05$) with level of rumen contents-blood-straw silage. Ruminal total VFA concentration and pH were highest for sheep receiving 50% silage. Ruminal NH_3-N and blood urea-N increased linearly with level of silage.
(Keywords: Rumen contents, Blood, Straw, Digestibility, Absorption, Silage).

Introduction

The byproducts of large slaughter houses are efficiently utilized in the developed countries. However, byproducts from small plants in developed countries and all plants in the developing countries are not well utilized due to the lack of knowledge, thus causing a public nuisance and even the danger of spreading disease. The proper utilization of undigested food in forestomach of herbivores, and of blood can lead to healthier and more productive livestock. These materials are highly perishable, hence, need to be processed immediately after collection.

Kamphues (1981) reported improved palatability of rumen contents when ensiled with molasses and sugar beet pulp. Messersmith et al. (1974) found that feeding 5, 7.5 10 and 15% dried rumen contents to ruminants resulted in no significant reduction in body weight gain, feed intake and feed

efficiency. Meyer (1984) found 51 and 44% apparent digestibility of N and CF, respectively, when sheep were fed silage of rumen contents and sugar beet pulp.

Reggiardo et al. (1981) reported that feeding 10 or 20% of digestible protein from blood meal to sheep had no significant effect on weight gain and carcass yield. Pedgett et al. (1978) showed that substituting peanut meal with 0, 5, 10, 14, and 18% whole blood resulted in equal TDN, ME, digested N retained and apparent absorption of S, P and Ca.

This experiment was conducted to determine the digestibility and nutritional value of rumen contents-blood-straw silage when fed to sheep.

Experimental Procedure

Blood and rumen contents were obtained from a commercial meat packing plant[3]. The blood and rumen contents were treated individually with 1% propionic/formic acid (1:1, w/w) and 10% molasses. After the preservation period, the blood and rumen contents were evaluated for appearance, odor and overall quality. The untreated and molasses-treated blood and rumen contents appeared unacceptable, and were discarded.

---

[3] Valleydale Packing Co., Bristol, VA.

The blood and rumen contents preserved with 1% propionic/formic acid were ensiled with wheat straw. The straw used in this study was ground in a tub grinder through a 2-cm screen. The treated rumen contents, blood and straw were ensiled in proportions of 45:15:40, wet basis, respectively. The appropriate amounts of treated rumen contents, blood and straw were weighed into a horizontal mixer and mixed for 10 min. As the rumen contents, blood and straw were transferred into the mixer, samples were taken. After thorough mixing, the mixtures were emptied into 210-liter metal drums double lined with polyethylene bags (.08 mm). As the mixtures were put into each of the drums, samples were taken at intervals. Drums were packed by trampling and each bag was sealed separately after expelling the air. The mixtures were allowed to ensile for a minimum of 10 wk before the metabolism trial began. Initial samples of ingredients and mixtures were taken, composited, subsampled and frozen for later analysis. Upon opening the silos, the top 5 cm were removed and samples were taken from several areas of each silo. Samples of initial and ensiled mixtures were prepared for analysis by homogenizing 25 g samples with 225 ml distilled water in .5 liter jars in a waring blender at full speed for 2 min. The homogenate was filtered through four layers of cheesecloth and the extract was used for determin-

ing pH (electrometrically), lactic acid (Baker and Summerson, 1941, as modified by Pennington and Sutherland, 1956), water-soluble carbohydrates (Dubois et al., 1956, as adapted by Johnson et al., 1966), and VFA (Erwin et al., 1961). Kjeldahl N of the ingredients, initial and ensiled samples was determined on fresh basis (AOAC, 1984). Dry matter was determined by drying duplicate samples in forced draft oven at a maximum of 60 C for 24 h. The samples were allowed to air equilibrate, composited and were ground through a 1-mm sieve. These samples were analyzed for DM, ash (AOAC, 1984), NDF (VanSoest and Wine, 1967), ADF (VanSoest, 1963), lignin and cellulose (VanSoest and Wine, 1968).

Eighteen crossbred (1/2 Dorset x 1/4 Finn x 1/4 Rambouillet) wethers with an average weight of 42 kg were assigned to six blocks of three animals each based on body weight. Sheep within each block were randomly allotted to the following diets: 1) basal, consisting of 46% orchardgrass hay, 46% corn grain, 7% soybean meal and 1% limestone, 2) 25:75, dry basis, of basal and rumen contents-blood-straw silage, and 3) 50:50, dry basis, of basal and silage rumen contents-blood-straw silage.

The sheep were placed in false metabolism stalls similar to those described by Briggs and Gallup (1949) which allowed for separate collection of feces and urine. All animals were

treated for internal parasites with Ivermectin[4] and given 500,000 I.U. of vitamin A and 75,000 I.U. of vitamin D i.m. All animals were fed 786 g of DM of the respective diets daily. The diets were fed twice daily, one half at 0700 h and the second half at 1900 h.

The metabolism trial consisted of a 5-d adaptation period to the metabolism stalls, 10-d transition period to experimental diets, a 10-d preliminary period followed by a 10-d collection period. Water was available to the animals throughout the feeding trial except during feeding.

Samples of feed were obtained at each feeding 2 d prior to the beginning and 2 d prior to the end of the collection period. Samples of feed were obtained at each feeding, placed in double plastic bags and frozen for later analysis. At the end of the trial the feed samples were thawed, composited and subsampled for later analysis.

Feces were collected daily and dried in a forced draft oven at a maximum temperature of 60 C for a minimum of 24 h. For each animal the dried feces were composited in metal cans which were double lined with plastic bags and loose fitting lids to equilibrate with atmospheric moisture. At the end

---

[4] MSDAGNET, Div. of Merck & Co., Rahway, NJ.

of the collection period the total fecal collections were weighed, mixed, subsampled and ground in a Wiley mill through a 1 mm screen. Urine was collected in a 4 liter plastic jar containing 15 ml of 1:1 (w/w) solution of concentrated H_2SO_4 and water plus approximately 500 ml water. Total urine was collected once daily and diluted to constant volume (3000 ml) with water and a 2% sample was taken and placed in tightly capped bottles and refrigerated. The samples were subsampled at the end of the trial and frozen for N analysis.

On the last day of the collection period ruminal fluid samples were taken 2-h postfeeding, using a stomach tube, with a metal strainer on the end. The samples were strained through four layers of cheese cloth and used for determination of pH (electrometrically), VFA (Erwin et al., 1961) and NH_3-N (Beecher and Whitten, 1970). Blood samples were taken 6-h postfeeding by puncturing jugular vein, and analyzed for urea N (Coulombe and Favreau, 1963).

Samples of diets and feces were analyzed for DM, ash (AOAC, 1984), NDF (VanSoest and Wine, 1967), ADF (Goering and VanSoest, 1970), lignin, and cellulose (VanSoest and Wine, 1967). Hemicellulose was determined by difference between NDF and ADF. Nitrogen was determined on wet feed ingredients, dry fecal samples and urine (AOAC, 1984). The

digestibility of 100% silage was calculated by regression equation ($y = a + bx$).

a = intercept, b = slope

x = independent variable

y = dependent variable

Statistical Analyses

The data was treated by analysis of variance by general linear model procedure of SAS (1982). Block and treatment was included in the model. Linear and quadratic contrasts were made to test the data obtained for each treatment.

Results and Discussion

Chemical Composition. The DM of the 1% formic/propionic acid preserved rumen contents and blood was 22.60 and 22.18%, respectively (Table 34). The DM of rumen contents was slightly lower than the value of 25% reported by Ebers (1983), but higher than the value of 12.3% reported by Shcherbakov et al. (1986). The DM value of whole blood is lower than the values reported by Rao and Fontenot (1987) and El-Yassin et al. (1984). Crude protein of blood, straw and rumen contents were 81.98, 6.53 and 10.72%, DM basis, respectively. The CP content of blood was lower than the value of 85% reported by Aranda (1980) for blood preserved with H_2SO_4; and 90.7% reported by Walker (1977) for formalin-

Table 34. CHEMICAL COMPOSITION OF RUMEN CONTENTS, BLOOD AND STRAW, LARGE SILO STUDY[ab]

Item	Blood	Straw	Rumen contents
	----------%	----------	
Dry matter	22.18	90.01	22.60
Crude protein	81.98	6.53	10.72
Ash	3.87	5.42	8.95
Neutral detergent fiber	-	75.19	68.13
Acid detergent fiber	-	46.09	45.22
Cellulose	-	36.01	27.01
Hemicellulose	-	29.10	22.91
Lignin	-	11.20	11.78

[a]Each value represents the mean of six samples.
[b]DM basis except DM.

treated blood. The CP content of preserved rumen contents was lower than the value of 18.40% reported by Rao and Fontenot (1987) and value of 21.8% CP reported by Javanovic and Cuperlovic (1977). Ash value of blood, wheat straw and rumen contents were 3.87, 5.42 and 8.95%, respectively.

Chemical composition was similar for initial and ensiled mixtures (Table 35). The DM of silage was 46%. Crude protein content and ash were 9.6 and 4.77%, respectively.

Silage had desirable aroma and no offensive odor was detected. The pH of the mixture dropped from 6.51 to 4.50 after ensiling (Table 36). Decreases in pH and water-soluble carbohydrates (2.89 to 1.02%) and the increase in lactic acid concentration (0.54 to 3.18%) indicated that good fermentation was achieved. Rao and Fontenot (1987) and El-Yassin et al. (1984) reported similar values for pH, water-soluble carbohydrates and lactic acid. The main VFA, 60% of the total, was acetic acid (Table 37), followed by propionic acid (32% of the total VFA). Traces of isobutyric, isovaleric and valeric acid were detected in the silage. Butyric acid contributed 5.3% of the total VFA.

The CP of the basal diet averaged 10.47%, dry basis (Table 38). Respective values for the diets containing 25 and 50% slaughter house waste-straw silage were 10.25 and 10.03%.

Table 35. CHEMICAL COMPOSITION OF INITIAL AND ENSILED MIXTURES OF RUMEN CONTENTS-BLOOD-STRAW, LARGE SILO STUDY[abc]

Item	Initial mixture	Ensiled mixture
	----------%----------	
Dry matter	46.34	46.21
Crude protein	9.60	9.58
Ash	4.76	4.77
Neutral detergent fiber	75.15	74.56
Acid detergent fiber	45.01	44.73
Cellulose	31.39	33.98
Hemicellulose	30.14	29.98
Lignin	9.34	9.25

[a]Each value represents the mean of six samples.
[b]Rumen contents-blood-straw (45:15:40, wet basis).
[c]DM basis except DM.

Table 36. FERMENTATION CHARACTERISTICS OF RUMEN CONTENTS-BLOOD-STRAW MIXTURES, LARGE SILO STUDY[ab]

Item	Silage	SE
pH		
Pre-ensiling	6.51	.05
Post-ensiling	4.50	.04
Water soluble carbohydrates, %[c]		
Pre-ensiling	2.89	.02
Post-ensiling	1.02	.03
Lactic acid, %[c]		
Pre-ensiling	0.54	.02
Post-ensiling	3.18	.02

[a]Each value represents the mean of six samples.
[b]Silage of rumen contents-blood-straw (45:15:40, wet basis).
[c]DM basis.

Table 37. EFFECT OF ENSILING RUMEN CONTENTS-BLOOD-STRAW UPON VOLATILE FATTY ACID CONCENTRATION, LARGE SILO STUDY[ab]

Item	Silage[c]	SE
	------%------	
Total VFA	2.63	.12
Acetic acid	1.59	.06
Propionic acid	0.84	.12
Isobutyric acid	0.002	.001
Butyric acid	0.14	.04
Isovaleric acid	0.04	.003
Valeric acid	0.03	.007

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Rumen contents:blood:straw (45:15:40, wet basis).

Table 38. CHEMICAL COMPOSITION OF DIETS FED TO SHEEP

Item	Basal	Basal:Silage[a] 3:1	Basal:Silage[a] 1:1
	----------%----------		
Dry matter	92.50	80.94	69.37
Crude protein[a]	10.47	10.25	10.03
Ash[a]	4.81	4.80	4.79
Neutral detergent fiber[a]	50.60	56.52	62.58
Acid detergent fiber[a]	22.06	27.73	33.40
Cellulose[a]	16.91	21.18	25.45
Hemicellulose[a]	28.54	28.87	29.19
Lignin[a]	3.91	5.25	6.59

[a]DM basis.

Cell wall constituents increased with increasing level of silage in the diets.

Apparent Digestibility. Apparent digestibility of DM and OM was highest ($P<.05$) for the basal diet (Table 39). Apparent digestibilities of OM, DM, NDF, ADF, cellulose and hemicellulose decreased linearly ($P<.05$) with increased levels of rumen contents-blood-straw silage in the diet. Apparent digestibility of CP was similar ($P>.05$) for the basal diet and the diets containing 25 and 50% silage. However, CP digestibility tended to be higher for the sheep fed basal and silage 1:1 dry basis. Kamphues (1981) ensiled slaughter house waste with molasses and sugar beet pulp and DM digestibility of the silage was 40%.

The calculated DM and OM apparent digestibilities for silage were 45.53 and 45.84%, respectively. These values were approximately 25 percentage units lower than OM and DM digestibilities of the basal diet. When fed to bulls, Coenan et al. (1985) found similar apparent digestibility of rumen contents as in our study. The apparent digestibilities of NDF, ADF, hemicellulose and cellulose of the silage were lower also than the values for basal diet.

Nitrogen Utilization. Nitrogen intake tended to decrease with level of silage (Table 40). Fecal N excretion follows a similar trend as N intake. Urinary N excretion

Table 39. APPARENT DIGESTIBILITY OF DIETS FED TO SHEEP[ab]

Item	Rumen contents-Blood-straw Silage ,%[c]				
	0	25	50	100[d]	SE
	%[c]				
Dry matter[e]	71.38	64.78	58.64	45.53	0.98
Organic matter[e]	71.95	65.28	58.92	45.84	0.98
Crude protein	64.05	64.94	66.63	69.12	1.28
Acid detergent fiber[e]	52.83	46.25	45.15	36.54	1.76
Neutral detergent fiber[e]	61.43	54.43	50.31	38.69	1.36
Hemicellulose[e]	68.08	62.29	56.21	44.39	1.49
Cellulose	54.76	51.69	50.69	46.27	1.63
Lignin[e]	36.60	21.65	18.43	-1.69	2.74

[a]Each value represents the mean of six samples.
[b]Rumen contents-blood-straw silage (45:15:40, wet basis).
[c]DM basis except DM.
[d]Calculated by regression. Not included in statistical analysis.
[e]Linear effect (P<.05).

Table 40. NITROGEN UTILIZATION BY SHEEP FED DIETS WITH DIFFERENT LEVELS OF RUMEN CONTENTS-BLOOD-STRAW SILAGES[a]

Item	Rumen contents-blood-straw silages, %[bc]			
	0	25	50	SE
Intake, g/d	13.17	12.90	12.62	0.00
Excretion, g/d				
Fecal	4.65	4.52	4.21	0.16
Urinary[d]	6.95	6.99	7.52	0.19
Total	11.59	11.51	11.73	0.21
Retention,				
G/d[d]	1.58	1.39	0.89	0.21
% of intake[d]	11.99	10.77	7.03	1.59
% of absorbed[d]	18.36	16.63	10.53	2.30

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Rumen contents-blood-straw (45:15:40, wet basis).
[d]Linear effect (P<.05).

increased linearly with level of silage in the diet. Total N excretion tended to be higher for animals fed the 1:1 basal and silage as compared to basal alone or 3:1 basal and silage, DM basis.

Nitrogen retention, expressed as g/d, % of intake and % of absorbed decreased linearly with the level of rumen contents-blood-straw silage. The trend of these values is in agreement with the previous study by El-Yassin et al. (1984).

Ruminal and Blood Parameters. Final ruminal pH tended to be higher for animals fed basal and silage (1:1, DM basis). Ruminal NH_3 and blood urea N increased linearly ($P<.05$) with increased amount of rumen contents-blood-straw silage fed (Table 41). Preston et al. (1965) reported that level of blood urea is related to the concentration of the ruminal NH_3.

Total VFA tended to be higher for sheep fed basal and rumen contents-blood-straw silage (1:1, dry basis) than sheep fed other diets (Table 42). Chappell and Fontenot (1968) reported a tendency for the total VFA concentration in the rumen to be higher when a high level of readily-available carbohydrates was fed. In the present study acetic acid concentration increased linearly with level of silage ($P<.10$). Propionic acid decreased with the 25% level of

Table 41. RUMINAL pH, AMMONIA-N AND BLOOD UREA-N OF SHEEP FED RUMEN CONTENTS-BLOOD-STRAW SILAGE[a]

Item	Blood-Rumen contents-Straw silage, %[bc] 0	25	50	SE
Ruminal pH				
Initial	6.45	6.72	6.48	.13
Final	6.40	6.46	6.75	.12
Ruminal NH3-N, mg/100ml				
Initial	18.00	21.48	19.87	.81
Final[d]	19.50	23.08	23.52	.72
Blood urea-N, mg/100ml				
Initial	10.34	11.99	10.69	.13
Final[d]	10.50	13.00	15.70	.12

[a]Each value represents the means of six samples.
[b]DM basis.
[c]Rumen contents-blood-straw, silage (45:15:40, wet basis).
[d]Linear effect ($P<.05$).

Table 42. RUMINAL VOLATILE FATTY ACIDS IN SHEEP FED RUMEN CONTENTS-BLOOD-STRAW SILAGE[ab]

Item	Rumen contents-blood-straw silage, %[c]			
	0	25	50	SE
Total VFA, umol/ml	98.86	99.38	101.28	6.85
Moles/100 moles				
Acetic acid[d]	47.84	50.92	49.14	0.76
Propionic acid[e]	29.58	27.33	27.36	1.24
Isobutyric acid[e]	5.50	5.76	7.28	0.29
Butyric acid[e]	7.36	5.75	4.80	0.45
Isovaleric acid[e]	6.24	7.04	8.12	0.41
Valeric acid	3.36	3.05	3.53	0.28

[a]Each value represents the mean of six samples.
[b]Rumen contents-blood-straw silage (45:15:40, wet basis).
[c]DM basis.
[d]Quadratic effect (P<.05).
[e]Linear effect (P<.10).

silage, then leveled off (quadratic effect, P<.05). Butyric acid decreased and isobutyric acid concentration increased linearly (P<.10) with increased proportion of silage mixture in the diet. The increased production of isobutyrate may indicate an increased proteolysis and/or deamination (Leng, 1973). Isovaleric acid tended to increase with level of silage.

These results indicate that preserved slaughter house by-products ensile satisfactorily. Rumen contents and blood ensiled with crop residues such as straw can be used as a protein and roughage supplement for ruminants. Ensiling of rumen content and blood with straw has higher nutritive value than straw alone. It seems that slaughter house by-products can be used as feed ingredients to fill the nutrient deficiency gap.

Literature Cited

AOAC. 1984. Official Methods of Analysis (4th Ed.). Assoc. of Official Anal. Chem., Washington, D.C.

Barker, S. B. and W. H. Summerson. 1941. The colorimetric determination of lactic acid in biological material. J. Biol. Chem. 138:535.

Beecher, G. P. and B. K. Whitten. 1970. Ammonia determination. Reagent modification and interfering compound. Anal. Biochem. 36:243.

Briggs, H. M. and W. D. Gallup. 1949. Metabolism stalls for wethers and steers. J. Anim. Sci. 8:479.

Chappell, G. L. M. and J. P. Fontenot. 1968. Effect of level of readily available carbohydrates in purified sheep rations, cellulose digestibility and nitrogen utilization. J. Anim. Sci. 61:661.

Coulombe, J. J. and L. Favreau. 1963. A new semi-micro method for colorimetric determination of urea. Clin. Chem. 9:102.

Coenen, M., M. Meyer and A. Ebers. 1984. Use of rumen contents of slaughter cattle as feed. 2. Rumen contents preserved with urea in the diet of cattle. Berliner and munchener Tierarztliche Wochenschrift 97:155. Cited in Nutr. Abstr. Rev. (1985). 55:9(4481).

Dubois, M., K. A. Gilles, J. K. Hamilton, P. A. Rebers and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350.

Ebers, A. 1981. Studies on conservation and feeding value of compressed rumen contents from slaughtered cattle. Thesis, Tierarztliche Hochschule Hannover, GFR. pp 72. Cited in Nutr. Abstr. Rev. (1983). 53:5(1886).

El-Yassin, F. A., J. P. Fontenot and H. Chester-Jones. 1984. Fermentation characteristics and nutritional value of rumen contents and blood ensiled with untreated or sodium hydroxide treated wheat straw. J. Anim. Sci. 59:453 (Abstr.).

Erwin, E. S., G. J. Marco and E. M. Emory. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

Jovanovic, M. and M. Cuperlovic. 1977. Nutritive value of rumen contents for monogastric animal. Anim. Feed Sci. Technol. 2:351.

Kampheus, J. 1980. Investigation of the possibilities of preservation and of the nutritive value [composition, slaughtered animals (cattle, pigs)]. Thesis, Tierarrztliche Hochscuhule Hannover, GFR. Cited in Nutr. Abstr. Rev. (1981). 51:12(7008).

Leng, R. A. 1973. Salient features of the digestion of pastures by ruminants and herbivores. In G. W. Butler and R. W. Baily (Ed.). Chemistry and Biochemistry of Herbage. pp 105-110. Academic Press, New York.

Messersmith, T. L., W. R. Fulton and T. J. Klopfenstein. 1974. Dried paunch feed as a roughage source in beef finishing rations. J. Anim. Sci. 39:246 (Abstr.).

Meyer, H., G. Amstsberg, H. J. Burger, M. Coenen and H. R. Frey. 1984. Use of rumen contents of slaughtered cattle as feed. 1. Preservation of partly dehydrated rumen contents with urea and composition of the product. Burliner und Munchener Tierarztlichle Wochenschrift 4:123. Cited in Nutr. Abstr. Rev. (1985). 55:9(4480).

Padgett, D. G., R. L. Shirley and J. F. Easley. 1978. Nutrient digestibility in diets fed steers in which whole cattle blood was substituted for peanut meal on protein basis. J. Anim. Sci. 46:746.

Rao, N. M. and J. P. Fontenot. 1987. Ensiling of rumen contents and blood with wheat straw. Anim. Feed Sci. Technol. 18:67.

Reggiardo, S., F. Lierena and G. Pardoi. 1976. Use of blood meal in the intensive fattening of sheep at po. Anales Cientificos 14:139. Cited in Nutr. Abstr. Rev. (1981). 51:5(3123).

Shcherbakov, A. A., A. G. Polishchuk, M. L. Faivishevskh, V. N. Khomenkov, M. I. Pakosh and B. Kravchuk. 1985. A new feed containing forestomach contents. Myasnaya Industriya USSR 12:26. Cited in Nutr. Abstr. Rev. (1986). 56:5(2378).

VanSoest, P. J. 1963. The use of detergents in the analysis of fibrous feeds. II. A rapid method for the determi-

nation of fiber and lignin. J. Assoc. Official Agric. Chem. 46:829.

VanSoest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. The determination of plant cell wall constituents. J. Assoc. Official Anal. Chem. 50:50.

VanSoest, P. J. and R. H. Wine. 1968. Determination of lignin and cellulose in acid detergent fiber with permanganate. J. Assoc. Official Anal. Chem. 51:780.

Walker. 1977. The composition of processed Abattoir blood and its use in finishing-pig diets. Anim. Feed Sci. Technol. 2:21.

CHAPTER VII

GENERAL DISCUSSION

In Pakistan and other developing countries millions of tons of underutilized feed resources, such as poultry waste and slaughter house waste are produced annually. These are either utilized inefficiently or not utilized at all. Poultry-house waste (broiler litter) and slaughter house waste (blood and rumen contents) are wasted through the lack of knowledge of how to use them. These wastes are valuable resources, which have potential feeding value for ruminants (Fontenot, 1977 and Rao and Fontenot, 1987). In order to utilize broiler litter as a feed ingredient, it has to be processed to render it pathogen free. The most feasible and economical methods for processing the broiler litter are ensiling and deep stacking. On the other hand slaughter house wastes (blood and rumen contents), being highly perishable, must be processed soon after the collection,

Results indicated that broiler litter deep stacked with 15% moisture levels showed lowest rise in temperature, but deep stacking of litter with all moisture levels tested was effective in destruction of pathogens. Hovatter et al. (1979) reported that significant amount of heat is generated

in deep stacked broiler litter, which kills the pathogens of broiler litter and makes deep stacking an inexpensive potential processing method. Duque et al. (1978) reported that the heat generated in deep stacked broiler litter kills the pathogens of litter and lactic acid producing bacteria as well. These results were confirmed and extended in the present study.

Decreases in pH and water soluble carbohydrates and increase in lactic acid in broiler litter ensiled alone, with molasses and with rumen contents showed that desirable fermentation occurred. Broiler litter has been successfully ensiled alone, with molasses and with corn forage (Harmon et al., 1975; Caswell et al., 1978; and Abdelmawla et al., 1988). Initial mixtures of broiler litter were highly contaminated with total and fecal coliform. Ensiling of broiler litter completely eliminated total and fecal coliforms. Kodema (1952) reported that antibiotic-like substances are produced by some lactic acid producing bacteria, which can kill coliform bacteria. Dahiya and Speck (1968) reported that lactobacilli produced H_2S in sufficient amounts to inhibit the growth of pathogenic organisms. McCaskey and Anthony (1975) reported that ensiling animal waste results in the improvement of palatability, reduction of nutrient

loss, elimination or reduction of pathogenic organisms and decreased energy cost.

Our results indicated lower OM and CP digestibilities for the deep stacked litter diet than for other waste diets, but differences were small. Abdelmawla et al. (1988) also reported lower values of CP digestibilities for animals fed deepstacked and composited broiler litter compared to those fed ensiled broiler litter. Intakes of diets containing broiler litter processed by different methods show that this waste product is not unpalatable to ruminants.

Desirable fermentation was achieved with significant reduction of pH, water soluble carbohydrates and increased lactic acid in the silages containing slaughter house wastes and untreated wheat straw. However, the destruction of pathogens in ensiled mixtures containing urea-treated wheat straw indicated that such silages can be fed safely. The digestibility of such silages is enhanced, compared to silages with untreated straw (El-Yassin et al., 1984). Owens et al. (1970) reported that addition of urea in the silage extends the fermentation time, increases pH and NPN. Ensiling seems to be a feasible way to preserve fresh rumen content and blood.

The major limitation to the use of slaughter house waste (blood and rumen contents) is the fact that it has to be

ensiled soon after collection or it must be refrigerated to avoid deterioration. It seems to be impractical to collect and ensile the waste daily. The preservation of the waste with additives will permit storage for several days prior to ensiling. Molasses and formic/propionic acids have been investigated as preservatives. The results of preservation indicated that the combination of formic/propionic acid at 1% w/w (1:1, wet basis), but not molasses, was effective in preserving the waste for 15 d. It is apparent from this study that a combination of formic/propionic acid may result in a stable product which can be stored for several days prior to ensiling. Gillberg and Raa (1977) successfully preserved cod viscer with 1.5% w/w formic acid for several days.

In a digestion trial with sheep fed 0, 25 and 50% rumen contents-blood-straw silage, dry basis, no difference in CP digestibility was found. Calculated CP digestibility of 100% rumen contents-blood-straw silage was higher than that of a basal diet. The digestibility of the OM of the silage indicates that ensiled blood-rumen contents-straw can be used as a source of protein and roughage in ruminants.

In conclusion, deep stacking and ensiling of broiler litter were equally effective in eliminating the pathogenic organisms. Both the processing methods are inexpensive, feasible and practical to do on the farm levels. Digestion

and palatability studies indicate that deep stacked and ensiled products are consumed readily by ruminants. Daily DM intake was similar for the animals fed ensiled or deepstacked broiler litter diets.

Satisfactory ensiling of rumen contents-blood with untreated wheat straw was achieved. The preservation of blood and rumen contents with 1% w/w of formic/propionic acid was achieved for 15 d. Further studies need to be conducted to lower the concentration, or possibly study use of other less expensive additives to achieve similar or greater effects. Fermentation characteristics and intake of silages by animals appeared satisfactory when preserved blood and rumen contents were used. Rumen contents-blood-straw silage can be used as a protein and roughage supplement for ruminants.

In developing countries there is an acute shortage of nutrients during winter and severe drought conditions. On the other hand, poultry waste and slaughter house wastes, which have high nutritive value, are wasted, causing nuisance and disposal problems. The poor nutritive value of crop residues fails to meet even maintenance requirements of the animals. In developed countries the poultry industry and small meat processing plants are forced to reduce their disposal of waste through land application and landfills. Thus, the prospect of recycling waste as feed ingredients become

more attractive. Current data indicate that these wastes (blood and rumen contents) ensile very well with crop residues and are safe for feeding and pose no health problem when fed to sheep.

LITERATURE CITED

A.A.F.C.O. 1984. Official Publication, Association of American Feed Control Officials, Inc. pp 63-65.

Abazinge, M. D. A., J. P. Fontenot and V. G. Allen. 1986. Effect of various additives on preservation and ensiling characteristics of crab waste. Virginia Polytechnic Institute and State University Anim. Sci. Res. Rep. No. 5:107.

Abazinge, M. D. A., J. P. Fontenot and V. G. Allen. 1986. Digestibility, nitrogen utilization and palatability of ensiled crab waste-wheat straw mixtures fed to sheep. Virginia Polytecninc Institute and State University Anim. Sci. Res. Rep. No. 5:100.

Abdelmawla, S. M., J. P. Fontenot and M. A. El-Ashry. 1988. Composted, deepstacked and ensiled broiler litter in sheep diets: chemical composition and nutritive value study. Virginia Polytechnic Institute and State University Anim. Sci. Res. Rep. No. 7:127.

Albin, R. C. and L. B. Shersod. 1975. Nutritional value of cattle feedlot waste for growing-finishing beef cattle. Am. Soc. Agric. Eng. Pub. Proc. 275:211.

Abou-Raya, A. K., E. M. Omar, M. A. Rafaat and A. S. El-Ghoneimy. 1971. Evaluation of animal protein supple-

ments, locally produced by analytical and comparative feeding studies with growing chicks. United Arab Republic Journal of Animal Production 11:41. Cited in Nutr. Abstr. Rev. (1973). 43:2(1022).

Acock, C. W., J. K. Ward, I. G. Rush and T. J. Klopfenstein. 1979. Wheat straw and sodium hydroxide treatment in beef cow rations. J. Anim. Sci. 49:354.

Alexander, D. C., J. A. J. Carriore and K. McKay. 1968. Bacteriological studies of poultry litter fed to livestock. Can. Vet. J. 9:127.

Allen, W. R., K.R. Stevenson and J. Buchanan-Smith. 1975. Influence of additives on short-term preservation of wet brewer's grain stored in uncovered piles. Can. J. Anim. Sci. 55:609.

Alomar, C. D. 1979. Chemical evaluation of ensiled rumen contents. Inst. Prod. Anim. Univ. Aust. De Chile Casilla 567, Valdivia Chile, Agronom. Surv. 7(2):89 cited in Chem. Abstr. (1980). 92(9):145253.

Ammerman, C. B., P. W. Waldroup, L. R. Arrington, R. L. Shirley and R. H. Harms. 1966. Nutrient digestibility by ruminants of poultry litter containing dried citrus pulp. J. Agric. Food Chem. 14:279.

Andrighetto, I., G. B. Bittante and M. Ramanzin. 1987. Effect of using molasses and organic acids in ensiling

lolium multiflorum on qualitative and quantitative changes during storage. Zootech Nutr. Anim. 3:425.

Anonymous. 1970. Municipal Refuse Disposal. Institute of Solid Wastes, American Public Works Association. 3rd Ed. Chicago, Ill. Cited in Feeding Animal Waste; 1978. CAST Rep. No. 75.

Antongiovanni, M., A. Giorgetti and B. M. Poli. 1973. Valore nutritive del contenuto ruminale disidrato. Aliment. Anim. 17:47. From Jovanovic and Cuperlovic (1977).

Aranda, E. 1980. The use of sulfuric acid as a preservative of animal feedstuffs in the tropics. Tropical Anim. Prod. 5:285.

Ayangbile, O. A. and J. P. Fontenot. 1986. Preservation of wet caged layer waste. Virginia Polytechnic Institute and State University Anim. Sci. Res. Rep. No. 5:87.

Azim, A. and A. Ali. 1985. Studies on the natural urease activity in various substances. In Proc. 3rd Asian Aust. Assoc. Anim. Prod. Cong. Vol. 2, pp 755-758. Seoul, Korea.

Backhoff, H. P. 1976. Some chemical changes in fish silage. J. Food. Technol. 11:353.

Barbosa, H. P., E. T. Fialho, V. Costa, C. R. V. M. Pacheco and J. F. Protas. 1982. Blood meal as source of pro-

tein in feeds for pigs. Comunicado Technico. Empresa Brasileira de pesquisa Agropecuaria 36:3. Cited in Nutr. Abstr. Rev. (1983). 53:1 (423).

Belasco, I. J. 1954. New nitrogen feed compounds for ruminants - A laboratory evaluation. J. Anim. Sci. 13:601.

Beutling, D. 1983. Problems in collection and transport of slaughter house offal. Biol. Abstr. 74:8555 (Abstr.).

Bhattacharya, A. N. and J. C. Taylor. 1975. Recycling animal waste as a feedstuff: A review. J. Anim. Sci. 41:1438.

Bhattacharya, A. N. and J. P. Fontenot. 1965. Utilization of different levels of poultry litter nitrogen by sheep. J. Anim. Sci. 24:1174.

Bhattacharya, A. N. and J. P. Fontenot. 1966. Protein and energy value of peanut hull and wood shaving poultry litter. J. Anim. Sci. 25:367.

Bolsen, K. K., M. A. Hinds, H. J. Ilg, G. Milliken and J. Hoover. 1984. Effects of rapid and delay silo filling and 1177 inoculant on performance of calves fed corn and sorghum silages. J. Anim. Sci. 59(Suppl. 1):288 (Abstr.).

Braman, W. L. and R. K. Abe. 1977. Laboratory and in vivo evaluation of the nutritive value of NaOH-treated wheat straw. J. Anim. Sci. 46:496.

Briggs, H. M. and W. D. Gallup. 1949. Metabolism stalls for wethers and steers. J. Anim. Sci. 8:479.

Bruggeman, J., J. Schole and J. Tiews. 1963. Are animal feed additives hazardous to human health? J. Agric. Food. Chem. 11:367.

Brugman, H. H., H. C. Dickey, B. E. Plummer and B. R. Poulton. 1964. Nutritive value of poultry litter. J. Anim. Sci. 23:869.

Bruhn, J. C., G. D. Reif, H. Toone and J. H. Evans. 1977. Influence of feeding dehydrated poultry waste on composition and organoleptic quality of milk. J. Food Prot. 40:29.

Bull, L. S. and J. T. Reid. 1971. Nutritive value of chicken manure for cattle. In: Livestock Waste Management and Pollution Abatement. Proc. Int. Symp. on Livestock Wastes. pp 271-297. Am. Soc. Agric. Eng., S. Joseph, MI.

Burrows, W. 1968. Textbook of Microbiology. W. B. Saunders Co., Philadelphia.

Calvert, C. C. and L. W. Smith. 1976. Heavy metal differences in tissues of dairy steers fed either cottonseed

meal or dehydrated poultry excreta supplements. J. Dairy Sci. 59:127 (Abstr.).

Calvert, C. C., L. W. Smith and T. R. Wrenn. 1978. Hormonal activity in poultry excreta processed for livestock feed. Poult. Sci. 57:265.

Caswell, L. F., J. P. Fontenot and K. E. Webb, Jr. 1975. Effect of processing treatment on pasteurization and nitrogen components of broiler litter and on nitrogen utilization by sheep. J. Anim. Sci. 40:750.

Caswell, L. F., K. E. Webb, Jr. and J. P. Fontenot. 1977. Fermentation, nitrogen utilization, digestibility and palatability of broiler litter ensiled with high moisture corn grain. J. Anim. Sci. 44:803.

Chester-Jones, H., J. P. Fontenot, W. D. Lamm and K. E. Webb, Jr. 1980. Growing cattle fed different levels of ensiled and deep stacked broiler litter. Virginia Polytechnic Institute and State University Res. Div. Rep. 156:161.

Coenen, M., M. Meyer and A. Ebers. 1984. Use of rumen contents of slaughter cattle as feed. 2. Rumen contents preserved with urea in the diet of cattle. Berliner and Munchener Tierarztliche Wochenschrift 97:155. Cited in Nutr. Abstr. Rev. (1985). 55:9(4481).

Colenbrander, V. F., L. D. Muller. J. A. Wassou and M. D. Cunningham. 1971. Effects of added urea and ammonium polyphosphate to corn stover silage on animal performance. J. Anim. Sci. 33:1091.

Cooke, J. A. and J. P. Fontenot. 1985. Utilization of phosphorous and other minerals from swine waste and broiler litter. Virginia Polytechnic Institute and State University Anim. Sci. Res. Rep. No. 4:5.

Coombe, J. B., D. A. Dinius, H. K. Goering and R. R. Oltjen. 1979. Wheat straw urea diets for beef steers: Alkali treatment and supplement with protein, monensin and a feed stimulant. J. Anim. Sci. 48:1223.

Coser, A. M. L., L. Jokl and E. C. Viera. 1977. Effects of temperature of processing and of isoleucine fortification on the nutritive value of blood meal. Archives Latino Americanos de Neutricion 27:297. Cited in Nutr. Abstr. Rev. (1979). 49:1(109).

Coulombe, J. J. and L. Favreau. 1963. A new semi-micro method for colorimetric determination of urea. Clin. Chem. 9:102.

Coxworth, E., J. Kernan, J. Knipfel, O. Thorlacius and L. Crowle. 1981. Review: Crop residues and forages in western Canada; Potential for feed use either with or

without chemical or physical processing. Agric. Environ. 6:245.

Cullison, A. E., H. C. McCampbell, A. C. Cunningham, R. S. Lowrey, E. P. Warren, B. D. McClendon and D. H. Sherwood. 1976. Use of poultry manure in steer finishing rations. J. Anim. Sci. 42:219.

Dana, G. R., J. P. Fontenot, J. A. Duque, W. Sheehan and K. E. Webb, Jr. 1979. Changes in characteristic of deep stacked broiler litter with time. Virginia Polytechnic Institute and State University Res. Div. Rep. 174:104.

Davis, G. K., R. B. Becker, T. Dix Arnold, C. L. Comar and S. P. Marshall. 1944. Urea in sorghum silage. J. Dairy Sci. 27:649.

Dias-Da Silva, A. A. and F. Sundstol. 1986. Urea as a source of ammonia for improving the nutritive value of wheat straw. Anim. Feed Sci. Technol. 14:67.

Divakaran, S. 1982. Animal blood processing and utilization. FAO Agric. Services Bull. No. 32. FAO, Rome.

Divakran, S. 1987. An in vitro quality evaluation of slaughter house by-products preserved by pickling with sulfuric acid. Biol. Wastes 19:281.

Donefer, E., I. O. A. Adeleye and A. O. C. Jones. 1969. Effects of urea supplementation on the nutritive value of sodium hydroxide treated oat straw. In R. F. Gould

(Ed.). Cellulases and Their Application. pp 328-342. Advances in Chem. Series No. 95. Am. Chem. Soc., New York.

Duque, J. A., J. P. Fontenot, K. E. Webb, Jr. and J. C. A. Berger. 1978. Fermentation and digestibility of broiler litter ensiled at different moisture levels by addition of whey or water. Virginia Polytechnic Institute and State University Res. Div. Rep. 174:108.

Edin, H. 1940. Undersokningar angaande importavstengningens aggviteproblem. Nord. Jordbr. Torsk. 22:142. From Raa and Gilberg (1982).

El-Sabban, F. F., T. A. Long, R. F. Gentry and D. E. H. Frear. 1969. The influence of various factors on poultry litter composition. In: Animal Waste Management. Proc. Cornell Conf. on Agric. Waste Management. pp 340-345. Syracuse, New York.

El-Sabban, F. F., J. W. Bratzler, T. A. Long, D. E. H. Frear and R. F. Gentry. 1970. Value of processed poultry waste as a feed for ruminants. J. Anim. Sci. 31:1071.

El-Yassin, F. A., J. P. Fontenot and H. Chester-Jones. 1984. Fermentation characteristics and nutritional value of rumen contents and blood ensiled with wheat straw. J. Anim. Sci. 59:453 (Abstr.).

Fitzpatrick, D. W. and H. S. Bayley. 1977. Evaluation of blood meal as a protein source for young pigs. Can. J. Anim. Sci. 57:745.

Flegal, C. J. and H. C. Zindel. 1971. Dehydrated poultry waste as a feedstuff in poultry rations. In: Livestock Waste Management and Pollution Abatement. Proc. Int. Symp. on Livestock Wastes. pp 305-309. Am. Soc. Agric. Eng., St. Joseph, MI.

Flipot, P., M. McNixen and J. D. Summers. 1975. Poultry wastes as a feedstuff for sheep. Can. J. Anim. Sci. 55:291.

Fontenot, J. P. 1977. Broiler litter as a feed ingredient for ruminants. In Conference on Alternate Nitrogen Sources for Ruminants. Athens, Ga. p. 34.

Fontenot, J. P., A. N. Bhattacharya, C. L. Drake and W. H. McClure. 1966. Value of broiler litter as a feed for ruminants. Am. Soc. Agric. Eng. Pub. SP 0366:105.

Fontenot, J. P. and V. Jurubescu. 1979. Processing of animal waste by feeding to ruminants. In: Y. Ruckebusch and P. Thivend (Ed.). Digestive Physiology and Metabolism in Ruminants. p. 641. AVI Pub. Co., Inc., Westport, CT.

Fontenot, J. P., W. H. McClure, R. F. Kelly and G. W. Litton. 1963. The value of poultry litter as feedstuffs for

fattening beef steers. Va. Agric. Exp. Sta. Livestock Res. Prog. Rep. p. 9.

Fontenot, J. P. and K. E. Webb, Jr. 1971. Feed intake and feedlot performance of cattle fed different levels of broiler litter. Virginia Polytechnic Institute and State University Res. Div. Rep. 135:137.

Fontenot, J. P. and K. E. Webb, Jr. 1975. Health aspects of recycling animal wastes by feeding. J. Anim. Sci. 40:1267.

Fontenot, J. P., K. E. Webb, Jr., B. W. Harmon, R. E. Tucker and W. E. C. Moore. 1971. Studies of processing, nutritional value and palatability of broiler litter for ruminants. Proc. Int. Symp. on Livestock Wastes, Am. Soc. Agric. Eng. Pub. 271:301.

Goyan, J. F. 1980. Recycled Animal Waste. Fed. Register 45(251):86272.

Forsht, R. G., C. R. Burbee and W. M. Crosswhite. 1974. Recycling poultry waste as feed: Will it pay? U.S. Dept. Agric. Econ. Rep. 254.

Galbrith, H., T. B. Miller, A. M. Patton and J. K. Thompson. 1971. Antibacterial activity of long chain fatty acids and reversal with calcium, magnesium, ergocalciferol and cholesterol. J. Appl. Bacteriol. 34:803.

Galmez, J., E. Santisteban, E. Haardt, C. Crempian, L. Vaillalta and D. Torell. 1970. Performance of ewes and lambs fed broiler litter. J. Anim. Sci. 31:241 (Abstr.).

Gilberg, A. and J. Raa. 1977. Properties of propionic/formic acid preserved silage of cod viscera. J. Food Technol. 28:647.

Golobyatnikov, V., A. Melnik and V. Pshenichnyi. 1984. A feed additive in diets for pigs. Svinoredstvo, No. 1. USSR. Cited in Nutr. Abstr. Rev. (1984). 51:12 (3293).

Griel, L. C., Jr., D. C. Kradel and E. W. Wickersham. 1969. Abortion in cattle associated with the feeding of poultry litter. Cornell Vet. 59:226.

Haigh, P. M., M. Appleton and S. F. Clench. 1987. Effect of commercial inoculant and formic acid +/- formalin silage additives on silage fermentation and intake and on liveweight change of young cattle. Grass and Forage Sci. 42(4):405.

Halbrook, E. R., A. R. Winter and T. S. Sutton. 1951. The microflora of poultry house litter and droppings. Poult. Sci. 30:381.

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1974. The effect of processing method of broiler litter on nitrogen utilization of lambs. J. Anim. Sci. 39:942.

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1975a. Ensiled broiler litter and corn forage. II. Digestibility, nitrogen utilization and palatability by sheep. J. Anim. Sci. 40:156.

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1975b. Ensiled broiler litter and corn forage. I. Fermentation characteristics. J. Anim. Sci. 40:144.

Harry, E. G., W. B. Brown and G. Goodship. 1973. The influence of temperature and moisture on disinfecting activity of methyl bromide on infected poultry litter. J. Appl. Bacteriol. 36:343.

Hartley, R. D. 1981. Chemical constitution, properties and processing of lignocellulosic wastes in relation to nutritional quality for animals. Agric. Environ. 6:91.

Henderson, A. R. and P. McDonald. 1971. Effect of formic acid on the fermentation of grass of low dry matter content. J. Sci. Food Agric. 22:157.

Hertelendy, F., T. G. Taylor, R. S. Mathur and R. H. Common. 1965. Isolation of estradiol-17β from hens urine and its characterization as the crystalline 3-methyl ether. Can. J. Biochem. 43:1379.

Hileman, L. H. 1967. The fertilizer value of broiler litter. Univ. Ark. Agric. Exp. Sta. Rep. Series 158.

Hodgetts, B. 1971. The effects of including dried poultry waste in the feed of laying hens. In: Livestock Waste Management and Pollution Abatement. Proc. Int. Symp. on Livestock Wastes. pp 271-311. Am. Soc. Agric. Eng., St. Joseph, MI.

Holter, J. B. and T. D. Kaleuga. 1974. Urea versus soybean meal as supplements for corn silage fed to heifers and dry cows. J. Anim. Sci. 39:1180.

Horsfield, B. 1975. Drying dairy waste with solar energy. Managing livestock wastes. Proc. 3rd Int. Symp. on Livestock Wastes. p. 478-488. Am. Soc. Agric. Eng., St. Joseph, MI.

Hovatter, M. D., W. Sheeham, G. R. Dana, J. P. Fontenot, K. E. Webb, Jr. and D. L. Lamm. 1979. Different levels of ensiled and deep stacked broiler litter for growing cattle. Virginia Polytechnic Institute and State University Res. Div. Rep. 175:77.

Huber, J. T. and J. W. Thomas. 1971. Urea-treated corn silage in low protein rations for lactating cows. J. Dairy Sci. 54:224.

Huber, J. T. and O. P. Santana. 1972. Ammonia-treated corn silage for dairy cattle. J. Dairy Sci. 55:489.

Ibrahim, M. N. M. and G. R. Pearce. 1983. Effects of chemical pretreatments on the composition and in vitro

digestibility of crop by-products. Agric. Wastes 5:135-156.

Ivey, M. C., R. A. Hoffman and H. V. Claborn. 1968. Residues of Gardena in the body tissue of cattle sprayed to control hypoderma spp. J. Econ. Entomol. 61:1647.

Jackson, M. G. 1977. The alkali treatment of straws: Review article. Anim. Feed Sci. Technol. 2:105.

Jackson, M. G. 1978. Treating straw for animal feeding - an assessment of its technical and economic feasibility. World Anim. Rev. 28:38.

Jasiorowski, H. A. 1976. The developing world as a source of beef for world markets. In A. J. Smith (Ed.). Beef Cattle Production in Developing Countries. University of Edinburgh, UK. pp 2-28. Cited in Minson (1985). Fiber as a Limit to Animal Production. Proc. 3rd Asian Aust. Assoc. Anim. Prod. Congr. Vol 1, pp 108-119. Seoul, Korea.

Jayasuriya, M. C. N. and H. G. D. Perera. 1982. Urea-ammonia treatment of rice straw to improve its nutritional value for ruminants. Agric. Wastes 4:143.

Jeroch, H., A. Hemig, K. Weber and W. Helwig. 1969. Feeding value of broiler deep litter. Jahrb. Tierernahrung Futterung 7:457. Cited in Bhattacharya and Taylor (1975).

Jovanovic, M. and M. Cuperlovic. 1974. Mogucnosti Koriscenja Nekih Klanicnih otpadaka u Ishrani Zivotinja. Krimva (Zagreb), XVI:241. Cited in Jovanovic and Cuperlovic (1977).

Jovanovic, M. and M. Cuperlovic. 1977. Nutritive value of rumen contents for monogastric animals. Anim. Feed Sci. Technol. 2:351.

Jurtshuk, P., R. N. Doetsh and J. C. Shaw. 1958. Anaerobic purine dissimilation by washed suspension of bovine rumen bacteria. J. Dairy Sci. 41:190.

Kampheus, J. 1980. Investigation of the possibilities of preservation and of the nutritive value [composition, slaughtered animals (cattle, pigs)]. Thesis, Tierarrztliche Hochscuhule Hannover, GFR. Cited in Nutr. Abstr. Rev. (1981). 51:12 (7008).

Keys, J. E. and L. M. Smith. 1981. Effect of dried poultry excreta on growth, intake and digestion of corn stover silage diets by yearling dairy heifers. J. Dairy Sci. 64:211.

King, R. H. and R. G. Campbell. 1978. Blood meal as a source of protein for grower/finisher pigs. Anim. Feed Sci. Technol. 3:191.

Kirk, J. K. 1967. Use of poultry litter as animal feed. Fed. Register 32(171):12714.

Kirov, N. 1962. A study of the effects of bacterial ferments on quality of silages made from forages, easy and difficult to ensile. Herbage Abstr. 33:233.

Koenig, D. E., E. E. Hatfield and J. W. Spears. 1978. Animal performance and microbial adaptation of ruminants fed formaldehyde treated poultry waste. J. Anim. Sci. 46:490.

Kohler, G. O. and R. E. Hellwig. 1985. Dehydration and processing of forages. In: M. E. Heath, R. F. Barnes and D. S. Metcalfe (Ed.). Forages: The Science of Grassland Agriculture. pp 470-478. Iowa State University Press, Ames, Iowa.

Kraft, D. J., C. Olechowski-Gerhardt, J. Berkowitz and M. S. Finstein. 1969. Salmonella in wastes produced at commercial poultry farms. Appl. Microbiol. 18:703.

Kramer, S. L., P. E. Waibel, B. R. Behrends, and S. M. El Kandelgy. 1978. Amino acids in commercially produced blood meals. J. Agric. Food Chem. 26:979.

Kubena, L. F., F. N. Reece, J. D. May and T. W. Deaton. 1973. Nutritive properties of broiler excreta. Poult. Sci. 52:1700.

Lanigan, G. W. 1961. Studies on ensilage. I. Comparative laboratory study of molasses and sodium metabisulfite

as aids to the conservation of lucerne. Aust. J. Agric. Res. 12:1023.

Lesins, K. and F. H. Shultz. 1968. Some effects of bacterial inoculation on silage making. Can. J. Anim. Sci. 48:15.

Lindahl, I. L. 1974. Formaldehyde as a bacterial growth retardant in reconstituted artificial ewe milk. J. Anim. Sci. 39:638.

Long, T. A., J. W. Bratzler and D. E. H. Frear. 1969. The value of hydrolyzed and dried poultry waste as a feed for ruminant animals. Proc. Cornell Waste Management Conf. pp 340-342. Cornell Univ., Ithaca, N.Y.

Lovett, J., J. W. Messer and R. B. Read, Jr. 1971. The microflora of southern Ohio poultry litter. Poult. Sci. 50:746.

Lowman, B. G. and D. W. Knight. 1970. A note on the apparent digestibility of energy and protein in dried poultry excreta. Anim. Prod. 12:525.

Mann, I. 1962. Processing and utilization of animal by-products. In: FAO Animal Production and Health Paper. pp 4-5. FAO, Rome.

Mann, I. 1978. High-protein feed from blood and ruminal contents using a solar drier. World Anim. Rev. 50:24.

Mathur, R. S. and R. H. Common. 1969. A note on daily urinary excretion of estradiol-17β and estrone by the hen. Poult. Sci. 48:100.

McCaskey, T. A. and W. B. Anthony. 1975. Health aspects of feeding animal waste conserved in silage. In: Managing Livestock Wastes. Proc. 3rd Int. Symp. on Livestock Wastes. pp 230-235. Am. Soc. Agric. Eng., St. Joseph, MI.

McClure, W. H., J. P. Fontenot and K. E. Webb, Jr. 1979. Ensiled corn forage and broiler litter and zeranol implant for finishing heifers. Virginia Polytechnic Institute and State University Res. Div. Rep. 156:69.

McCullough, M. E. 1978. Fermentation of silage, a review. Natl. Feed Ingredients Assoc., Des Moines, IA.

McCullough, M. E. and W. E. Neville, Jr. 1960. Factors affecting heifer performance on silage rations. J. Dairy Sci. 43:444.

McDonald, P. 1981. The Biochemistry of Silage. John Wiley and Sons, New York.

McDonald, P. and R. Wittenbury. 1973. The ensiling process. In: G. W. Butler and R. W. Bailey (Ed). Chemistry and Biochemistry of Herbage. pp 110-120. Academic Press, New York.

McInnes, P., P. J. Austin and D. L. Jenkins. 1968. The value of poultry litter and wheat mixture in the drought feeding of weaner sheep. Aust. J. Exp. Agric. Anim. Husb. 8:401.

Meiske, J. C., R. M. Prouty, L. M. Schuman and J. V. Scaletti. 1965. Effect of sodium bisulfite addition to corn silages. J. Anim. Sci. 24:705.

Messer, J. W., J. Lovett, G. K. Murthy, A. J. Wehby, M. L. Shafer and R. B. Read, Jr. 1971. An assessment of some public health problems resulting from feeding poultry litter to animals. Microbiological and chemical parameters. Poult. Sci. 50:874.

Messersmith, T. L., W. R. Fulton and T. J. Klopfenstein. 1974. Dried paunch feed as a roughage source in beef finishing rations. J. Anim. Sci. 39:246 (Abstr.).

Meyer, H. 1984. Investigations about conserving and feed value of rumen contents of slaughtered cattle and pigs. In: Animals as Waste Converters. 1983. Proc. Int. Symp., pp 99-100. Wageningen, Netherland.

Meyer, H., G. Amtsberg, H. J. Burger, M. Coenen and H. R. Frey. 1984. Use of rumen contents of slaughtered cattle as feed. 1. Preservation of partly dehydrated rumen contents with urea and composition of the product.

Berliner und Munchener Tierarztliche Wochenschrift 4:123. Cited in Nutr. Abstr. Rev. (1985). 55:9 (4480).

Meyer, H., M. Coenen and C. Schunemann. 1984. Use of rumen contents of slaughtered cattle as feed. 3. Use of rumen contents for feeding pigs. Berliner und Munchener Tierarztliche Wochenschrift 97:239. cited in Nutr. Abstr. Rev. (1985). 55:9(4570).

Morrison, J. L. 1969. Distribution of arsenic from poultry litter in broiler chickens, soil and crops. J. Agric. Food Chem. 17:1288.

Muller, L. D. and D. R. Syhre. 1975. Influence of chemicals and bacterial cultures on preservation of colostrum. J. Dairy Sci. 58:957.

Muller, L. D. and J. Smallcomb. 1977. Laboratory evaluation of several chemicals for preservation of excess colostrum. J. Dairy Sci. 60:627.

Muller, Z. O. 1980. Feeding animal wastes. In: Feed from Animal Wastes. In: FAO Animal Production and Health Paper. pp 45-48. FAO, Rome.

Murdoch, J. C., M. C. Holdsworth and M. Wood. 1956. The chemical composition and loss of nutrients in silage made with the addition of sodium metabisulfite and halogenated acetate of glycol. J. Br. Grassl. Soc. 11:16.

Murthy, G. K. 1969. Status of iodine in milk preserved with sodium metabisulfite and formaldehyde. J. Dairy Sci. 52:124.

Noland, P. R., B. F. Ford and M. L. Ray. 1955. The use of ground chicken litter as a source of nitrogen for gestating lactating ewes and fattening steers. J. Anim. Sci. 14:860.

NRC. 1983. Underutilized Resources as Animal Feedstuffs. National Research Council. National Academy Press, Washington, D.C.

Ohyama, Y., S. Masaki and T. Morichi. 1973. Effects of inoculation of lactobacillus plantarum and addition of glucose of ensiling on the silage quality of aerated silages. J. Sci. Food Agric. 26:1001.

Oji, U. I. and Mowat, D. H. 1977. Breakdown of urea to ammonia for treating corn stover. Can. J. Anim. Sci. 57:828 (Abstr.).

Oltjen, R. R. and D. A. Dinius. 1976. Processed poultry waste compared with uric acid, sodium urate, urea and biuret as nitrogen supplements for beef cattle fed forage diets. J. Anim. Sci. 43:201.

Oltjen, R. R., L. L. Slyter, A. S. Kozak and E. E. Williams, Jr. 1968. Evaluation of urea, biuret, urea phosphate

and uric acid as NPN sources for cattle. J. Nutr. 94:193.

Oshida, T., K. Aikawa, T. Fukuyasu, K. Tanaka. 1986. Fermentation of slaughter house residuum and palatability of fermented slaughter house residuum for pigs. Japanese Journal of Zootechnical Science 57:808. Cited in Nutr. Abstr. Rev. (1987). 57:3(967).

Ostrander, C. E. 1975. Techniques that are solving pollution problems for poultry men. In: Livestock Wastes. Proc. 3rd Int. Symp. on Livestock Wastes. pp 71-72. Am. Soc. Agric. Eng., St. Joseph, MI.

Owens, F. N., J. C. Meiske and R. D. Goodrich. 1970. Corn silage fermentation. I. Effects of crude protein sources and sodium bisulfite on energy constituents. J. Anim. Sci. 30:455.

Padgett, D. G., R. L. Shirley and J. F. Easley. 1978. Nutrient digestibility in diets fed steers in which whole cattle blood was substituted for peanut-meal on protein basis. J. Anim. Sci. 46:746.

Parigi-Bini, R., M. R. Volpato, G. Xiccato and M. Ginetto. 1987. Research on the preparation, digestibility and utilization of maize stover silage and molasses in fattening bull calves. Zootech. Nutr. Anim. 12:91.

Paster, N. 1979. A commercial scale study of the efficiency of propionic acid and calcium propionate as fungistates in poultry feed. Poult. Sci. 58:572.

Pelczar, M. J., Jr. and R. D. Reid. 1965. Microbiology (2nd Ed.). McGraw-Hill Book Co., New York.

Petkov, S., O. Kacerovsky, Z. Sova, J. Kallous, L. Slavik, F. Bouska, Z. Jedlicka, M. Stradal and L. Parizkova. 1980. Possible part or complete replacement of animal meals by spray-dried blood from preserved or nonpreserved blood in feeds from broilers. Sbornik Vysoke Skoly Zemedelse V Praze, Fakulta Agronomicka 31:33. Cited in Nutr. Abstr. Rev. (1981). 51:9(5527).

Petkov, S., O. Kacerovsky, Z. Sova, L. Slavik, F. Bouska and L. Parizkova. 1980. Effect of part or complete replacement of animal meals by spray-dried blood preserved or nonpreserved in fresh condition on digestibility, biological value and net protein utilization in broilers. Sbornik Vysoke Skoly Zemedelske V Praze, Fakulta Agronomicka 31:51. Cited in Nutr. Abstr. Rev. (1981). 51:9(5528).

Poelma, H. R. 1974. Aeration of liquid manure and forced recirculation of aerated manure. In Proc. 8th Int. Congress of Agric. Eng. pp 499-520. Elberg. The Netherlands.

Pratt, A. D., R. G. Washburn and C. F. Rogers. 1958. Comparative palatability of silages. Ohio Agric. Exp. Sta. Res. Bull. 814.

Prokop, M. J., T. J. Klopfenstein and T. Messersmith. 1974. Blood and paunch meal in ruminant rations. J. Anim. Sci. 39:250 (Abstr.).

Raa, J., A. Gildberg and T. Strom. 1983. Silage production, Theory and Practice. In D. A. Ledward, A. J. Taylor and R. A. Lawrie (Ed.). Upgrading Waste for Feeds and Food. pp 83-101. Butterworths, Boston.

Rao, N. M. and J. P. Fontenot. 1987. Ensiling of rumen contents and blood with wheat straw. Anim. Feed Sci. Technol. 18:67.

Ray, M. L. and J. R. Cate. 1966. Chicken litter as a roughage in finishing beef steers. Anim. Farm. Res. 15:5.

Reddy, M. R. and K. V. S. Reddy. 1980. A short note on the proximate composition of rumen digesta from bovine and ovine species and its utilization as a component of livestock feed. Indian Vet. J. 57:429.

Reddy, V. R., C. V. Reddy and V. R. Reddy. 1985. Nutritive value and utilization of rumen contents in broiler diets. Indian J. Poult. Sci. 20:27.

Reed, D. E. and J. B. Fitch. 1971. Alfalfa silage. Kansas Agric. Exp. Sta. Bull. 217.

Reed, W. N. 1969. An experimental investigation of the thermophilic composting characteristics of sawdust-poultry manure mixtures. Thesis, North Carolina State Univ., Raleigh. Cited in CAST (1978).

Reggiardo, S., F. Lierena and G. Parodi. 1976. Use of blood meal in the intensive fattening of sheep at pono. Anales Cientificos 14:139. Cited in Nutr. Abstr. Rev. (1981). 51:5(3123).

Ricci, R. 1977. A method of manure disposal for beef packing operation. First Interim Tech. Rep. EPA-600/2-77-103. Cited in NRC (1983).

Saadullah, M., M. Hague and F. Dolberg. 1981. Effectiveness of ammonification through urea in improving the feeding value of rice straw in ruminants. Trop. Anim. Prod. 6:30.

SAS. 1982. SAS User's Guide. Statistical Analysis System Institute, Inc., Cary, NC.

Scaletti, J. V., R. F. Klay and C. A. Lane. 1961. Effect of sodium bisulfite on toxic silage gasses. Minn. Nutr. Conf. p. 46.

Shannon, D. W. F. and w. O. Brown. 1969. Losses of energy and nitrogen on drying poultry excreta. Poult. Sci. 48:41.

Shebata, M. A., N. Allen and R. D. Goodrich. 1984. Evaluation of dried rumen liquor as a feed ingredient for poultry. Archiv fur Geflugelkunde 48:89. Cited in Nut. Abstr. Rev. (1985). 55(9):4307.

Singh-Verna, S. B. 1974. The effect of different organic acids in the preservation of moist grains and feeding stuff from the microbiological point of view. Biol. Abstr. 36:7690 (Abstr.).

Skrede, A. and I. F. Ness. 1988. Slaughter house by-products preserved by lactobacillus plantarum fermentation as feed for mink and foxes. Anim. Feed Sci. Technol. 20:287.

Smith, L. W. and C. C. Calvert. 1972. Dehydrated poultry waste in rations for sheep. J. Anim. Sci. 35:274.

Smith, L. W. and C. C. Calvert. 1976. Dehydrated broiler excreta versus soybean meal on nitrogen supplements for sheep. J. Anim. Sci. 43:1286.

Smith, D. T., N. F. Conant and J. R. Overman. 1964. Zinsser Microbiology (13th Ed.). Appleton-Century Crafts, New York.

Smith, M. S. and L. B. Danials. 1977. Nutritional value of ensiled broiler litter. Ark. Farm Res. 3:16.

Southwell, B. L., O. M. Hale and W. C. McCormick. 1958. Poultry house litter as a nitrogen supplement in steer fattening rations. GA. Agric. Exp. Sta. Mimeo No. N. S. 55:6.

Stallings, C. C., R. Townes, B. W. Jesse and J. W. Thomas. 1981. Changes in alfalfa haylage during wilting and ensiling with and without additives. J. Anim. Sci. 53:765.

Stock, R., N. Merchen, T. Klopfenstein and M. Poos. 1981. Feeding value of slowly degraded proteins. J. Anim. Sci. 53:1109.

Summerfelt, R. C. and S. C. Yin. 1974. Paunch manure as a feed supplement in channel catfish farming. Fifth Natl. Symp. Food Process. Wastes. pp 246-257. EPA-660/2-74-046. From NRC (1983).

Sundstol, F. and Owen, E. 1984. Straw and Other Fibrous By-products as Feed. Elsevier, New York.

Surbrook, J. C., C. C. Sheppard, J. S. Boyd, H. C. Zindel and C. J. Flagel. 1971. Drying poultry waste. In: Livestock Waste Management and Pollution Abatement. Proc. Int. Symp. on Livestock Wastes. pp 192-193. Am. Soc. Agric. Eng., St. Joseph, MI.

Tagari, H., M. Silanikove and S. Hurwitz. 1981. Availability of phosphorus contained in poultry litter for lambs. J. Nutr. 111:405.

Taylor, J. C., D. A. Bagle, G. Graber and E. W. Lucas. 1974. Health criteria for processed wastes. Fed. Proc. 33:1945.

Taylor, S. J., D. J. A. Cole and D. Lewis. 1977. An interaction of leucine, isoleucine and valine in the diet of the growing pig. Proc. Nutr. Soc. 36:36A (Abstr.).

Theander, O. and Aman, P. 1984. Anatomical and chemical characteristics. In: F. Sundstol and E. Owen (Ed.). Straw and Other Fibrous By-products as Feed. pp 45-59. Elsevier, New York.

Thomas, J. W. 1978. Preservatives for conserved forage crops. J. Anim. Sci. 47:721.

Thomas, J. W., P. Tinnimitt and H. C. Zindel. 1972. Dehydrated poultry waste as a feed for milking cows and growing sheep. J. Dairy Sci. 55:1261.

Thomas, J. W., Y. Yec and J. A. Huefer. 1970. Digestibility of paper and dehydrated feces. J. Anim. Sci. 31:255 (Abstr.).

Underwood, E. J. 1977. Trace Elements in Human and Animal Nutrition. 4th Ed. Academic Press, New York.

USDA. 1979. Agricultural Statistics. Washington, D. C.

Virtanen, A. I. 1933. The A.I.V. method of preserving fresh fodder. Emp. J. Exp. Agric. 1:143.

Walker, H. G. 1984. Physical treatment. In: F. Sundstol and E. Owen (Ed.). Straw and Other Fibrous Byproducts as Feed. pp 79-105. Elsevier, New York.

Waller, J. C. 1976. Evaluation of sodium, calcium and ammonium hydroxides for treating residues. J. Anim. Sci. 41:424 (Abstr.).

Walker, N. 1977. The composition of processed Abattoir blood and its use in finishing-pig diets. Anim. Feed. Sci. Technol. 2:21.

Watson, S. J. and M. J. Nash. 1960. The Conservation of Grass and Forage Crops. Oliver and Boyd, Edinburgh.

Webb, K. E., Jr. and J. P. Fontenot. 1975. Medicinal drug residues in broiler litter and tissues from cattle fed litter. J. Anim. Sci. 41:1212.

Webb, K. E., Jr., J. P. Fontenot and W. H. McClure. 1979. Performance and liver copper levels of beef cows fed broiler litter. Virginia Polytechnic Institute and State University Res. Div. Rep. 175:109.

Whittenberg, K. H., J. R. Ingalls and T. J. Devlin. 1983. The effect of lactobacteria inoculation on corn silage preservation and feeding value for growing beef animals and lambs. Can. J. Anim. Sci. 64:2378.

Wieringa, G. W. 1960. Some factors affecting silage fermentation. Proc. 8th Int. Grassl. Congr. p. 497.

Wiley, J. S. 1962. Pathogen survival in composting municipal wastes. J. Water Pollution Control Fed. 34:8.

Wing, P. D., R. D. Goodrich, J. G. Linn and J. C. Meiske. 1976. Effect of chemical additives on the preservation and digestibility of alfalfa haylage. J. Anim. Sci. 42:469.

Wise, G. H., J. H. Mitchell, J. P. LaMaster and D. B. Boderick. 1944. Urea treated corn silage versus untreated corn silage as feed for lactating dairy cows. J. Dairy Sci. 27:649.

Witherow, J. L. 1974. Paunch handling and processing techniques. Nat. Provis. 10:14.

Witherow, J. L. and S. Lammers. 1976. Paunch and viscera handling. Environ. Prot. Technol. Ser. EPA-600/2-76-214. From NRC (1983).

Wittenbury, R. 1961. An investigation of lactic acid bacteria. PhD Thesis. Univ. of Edinburg. From McDonald. (1981).

Woodward, T. E. and J. B.Shepard. 1944. Corn silage made with the addition of urea and its feeding value. J. Dairy Sci. 27:648.

Woolford, M. K. 1972. Some aspects of the microbiology and ammonium isobutyrate on the preservation and nutritive value of alfalfa haylage. J. Anim. Sci. 41:1458.

Woolford, M. K. 1975. Some aspects of the microbiology and biochemistry of silage making. J. Sci. Food Agric. 26:219.

Woolford,M. K. 1984. The antimicrobial spectra of some organic acids and glutaraldehyde in response to their potential as silage additives. Biol. Abstr. 78:2773 (Abstr.).

Woolford, M. K. 1984b. The antimicrobial spectra of organic compounds with respect to their potential as hay preservatives. Biol. Abstr. 78:2774 (Abstr.).

Yu, Y. and Y. W. Thomas. 1975. Effect of propionic acid and ammonium isobutyrate on the preservation and nutritive value of alfalfa haylage. J. Anim. Sci. 41:1458.

Zelter, S. Z. 1960. Fermentation behaviour of lucerne ensiled by different methods. In: Proc. 8th Int. Grassl. Congr., p. 505-509. Reading, UK.

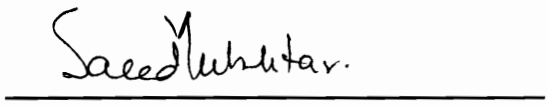
Zindel, H. C. 1970. Bacteriological procedures. Mich. State Univ. Agric. Exp. Sta. Res. Rep. 117:45.

Ziolecki, A., E. Kwiatkowska and H. Laskowska. 1984. The effect of stabilized rumen extracts on growth and development of calves. 2. Digestive activity in rumen

and development of microflora in the rumen and faeces. Zeitschrift fur Tierphysiologie. Tierernahrung und Futtermittelkunde 51:21. Cited in Nutr. Abstr. Rev. (1984). 54:10(5200).

VITA

Saeed Mukhtar Chaudhry, son of Mukhtar Hassan Chaudhry, was born on November 1, 1958, in Village 171-G.B., Faisalabad, Pakistan. He attended Government College Civil Line Multan. He received his Doctor of Veterinary Medicine degree from University of Agriculture, Faisalabad, in 1981. He received his Master of Science degree in Animal Nutrition from University of Agriculture, Faisalabad, in 1984. He worked as scientific officer in Pakistan Agriculture Research Council, Islamabad, from April, 1984, to October, 1985. He entered Virginia Polytechnic Institute and State University in October, 1985. He is a member of Pakistan Veterinary Medicine Society.



Saeed Mukhtar Chaudhry