Food Chemistry 48 (1993) 51–55

Fermentation characteristics and nutritive value of broiler litter ensiled with corn forage

S. M. Chaudhry, Z. Naseer & D. M. Chaudhry

Animal Nutrition Program, Animal Sciences Institute, National Agricultural Research Centre, Islamabad 45500, Pakistan

(Received 24 June 1992; revised version received and accepted 20 October 1992)

Fermentation characteristics and nutritive value of broiler-litter and corn-forage silages were determined. Corn forage was ensiled with and without broiler litter. Silages were prepared in 200-litre metal drums lined with double layers of polyethylene bags. Proportions of broiler litter and corn forage were 0 : 100, 20 : 80, 30 : 70 and 40 : 60 wet basis, respectively. After 45 days, silages were opened; all silages had desirable aromas and no mould growth was observed on the top of any silage. Addition of broiler litter to corn forage increased the crude protein linearly ($P < 0{\cdot}05$) from 8·64 to 10·8% on a dry-matter basis. The crude protein was increased linearly ($P < 0{\cdot}05$) with increase of broiler litter. The pH values of ensiled mixtures of corn forage and broiler litter were 4·19, 4·65, 5·09 and 5·47. All silages had substantial levels of lactic acid. In digestion trials, four wethers were fed corn-forage silage alone, and silages of corn forage and broiler litter mixed in the ratios of 20 : 80, 30 : 70 and 40 : 60, respectively. The experiment was designed as a 4 × 4 latin square and orthogonal polynomials were run to see the treatment effect. Digestibilities of dry matter, crude protein, ether extract and organic matter were higher ($P < 0{\cdot}05$) for the animals fed silages containing broiler litter compared to animals fed corn-forage silage alone. The results indicated that the broiler litter is a good source of protein and can be mixed with low-protein forages. Moreover, ensiling of broiler litter was effective for destruction of pathogenic organisms, and animals showed no ill health effect when silages were fed to sheep. It may be concluded from the study that the use of poultry waste as a feed ingredient will not only reduce waste disposal and pollution, but will also provide inexpensive feed components for ruminants.

INTRODUCTION

The two broad types of waste produced by poultry enterprises are: cage-layer manure, the waste from enterprises in which the birds, such as layers, are confined to wire cages, and poultry litter, the solid waste composed of bedding material and excreta. Poultry litter, the usual type of waste resulting from poultry reared on the floor, may be from one or more crops. Both kinds of waste may also contain wasted feed and feathers. Large-scale broiler operations experience problems in disposing of broiler litters. These problems focus on vast quantities of litter generated under such systems of production, proximity of those operations to metropolitan areas and suitability of land available for fertilization with litter. When litter is incorporated into rations for cattle and sheep, it contributes appreciable amounts of nitrogen, available energy and essential minerals (Bhattacharya & Fontenot, 1966; Fontenot *et al.*, 1971).

Although no serious health problems have resulted from feeding broiler litter, apprehension exists concerning potential hazards to human and animal health from various drugs and pathogenic organisms that could be transmitted through the use of litter as a feed ingredient (Kirk, 1967). However, recent research has indicated that ensiling litter with added water (Chaudhry, 1990), corn forage (Caswell *et al.*, 1975) or high-moisture corn (Caswell *et al.*, 1977) results in reduction or complete elimination of pathogens. Furthermore, Abdelmawla (1988) has reported satisfactory acceptance and performance by sheep, beef and dairy heifers (Cross & Jenny, 1975) when fed broiler- and turkey-litter silages.

The overall objective of the experiment reported here was (1) to study the feasibility of ensiling broiler litter and corn forage and (2) to assess the nutritive value of silages when fed to sheep.

MATERIALS AND METHODS

Wood-shaving broiler litter was collected immediately after the disposal of birds from a commercial broiler house. Broiler litter was strained through a metal strainer to remove any pieces of metal. Corn forage harvested at a stage having 40% dry matter was chopped. The broiler litter and corn forage were mixed in the ratios 0 : 100, 20 : 80, 30 : 70 and 40 : 60, respectively.

The corn forage for a particular batch of silage was weighed and spread on a concrete floor separately before mixing. The respective mixtures were allowed to blend in horizontal mixers for 30 min each. The silages were prepared in metal drums (200-litre capacity) lined with double layers of polyethylene. Packing was done by trampling on the drums. Samples of corn forage, broiler litter and initial mixtures were placed in polyethylene bags and were frozen for later analysis. The metal drums were stored in a covered shed for 42 days at room temperature. Some initial samples were stored at 5°C for microbial analysis.

After 45 days, each silo was weighed and opened. For microbial study, the samples were aseptically taken from the centre of the ensiled mass and immediately subjected to microbial analysis. After removing samples for microbial test and fermentation characteristics, the bags were immediately resealed. One silo from each treatment was reopened at the time of a digestion trial. Samples were taken at each feeding and composited for later analysis. During the digestion trial, samples of about 100 g from each silo taken at every feeding were frozen individually. Frozen silo samples were composited periodically after every eight days to give six samples of each material.

Digestibility trial

A digestion trial was conducted with four wethers with an average body weight of 35 kg. The animals were randomly allotted the following diets: (1) broiler litter : corn forage (0 : 100), (2) broiler litter : corn forage (20 : 80), (3) broiler litter : corn forage (30 : 70) and (4) broiler litter : corn forage (40 : 60). A 4 × 4 latin-square design was used in which treatments were randomly assigned to wethers. Each square consisted of 30 days, in which a period of 5 days was for the adaptation of animals to canvas bags followed by a 10-day transitional period, during which experimental rations were gradually introduced, a 10-day preliminary period during which experimental diets were fed and a 5-day collection period. Water was provided *ad libitum* except during feeding. The diets were fed twice daily in equal portions at 0800 and 2000 h. The sheep were fed at 2% body weight (DM). Samples of feed were obtained at each feeding 2 days prior to the beginning and 2 days prior to the end of collection period. All diet samples were immediately frozen in double-lined 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 faeces. Faeces 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 treatment, the dry faeces were composited in metal cans and loosely covered for moisture equilibration with atmospheric moisture. At the end of the trial, faecal composites were weighed, mixed and subsampled. At the completion of the trial, ruminal ingesta samples were collected 2 h post-feeding via a stomach tube and blood samples were taken 6 h post-feeding by Jugular puncture.

Chemical analyses

Samples of the ingredients, initial mixtures, silages, feed and faeces were analyzed for proximate components. Nitrogen was determined on wet samples of broiler litter, corn forage, initial mixtures and ensiled mixtures by the AOAC (1984) method. Dry matter of all the samples was determined by drying, in duplicate, 200-g samples of each material in a forced draught oven at 60°C for 48 h. Following equilibration with atmospheric moisture, the duplicate dried samples were composited, ground to pass a 1-mm sieve and subjected to analysis for crude fibre (Whitehouse *et al.*, 1945), DM, EE and ash (AOAC, 1984).

Extracts of poultry litter, corn forage, initial mixtures and silages were prepared by homogenizing 25 g wet material with 100 ml water in a blender for 2 min. The homogenate was filtered through four layers of cheese cloth and the filtrate used for measurement of pH (electrometrically), lactic acid (Baker & Summerson, 1945) as modified by Pennington and Sutherland (1956) and water-soluble carbohydrate content (Dubois *et al.*, 1956) as adapted to corn plant by Johnson *et al.* (1966).

Biological analyses

Total (Anon., 1967) and faecal (Millipore Corp., 1973) coliforms were determined on initial and ensiled mixtures. The aseptic samples collected for microbial analysis were prepared by homogenizing a 25-g sample with 225 ml of distilled water in a Waring blender at full speed for 1 min.

Statistical analyses

The data were treated by analysis of variance using the general linear model procedure of SAS (1982). For ensiling, treatment and block were included in the model. Linear, quadratic and cubic contrasts were used to test the treatment effect. Data collected from digestibility study, rumen fluid and blood analyses were analyzed using a latin-square design, and polynomials were run to test the treatment effect.

RESULTS AND DISCUSSION

Chemical composition and fermentation characteristics

The broiler litter was found lower in crude protein (CP) and ash content (Table 1) than the values

Table 1. Chemical composition of broiler litter and corn forage[a]

Item	Broiler litter[b]	Corn forage[b]
Dry matter	85·00	40·02
Composition of dry matter		
Crude protein	18·9	8·64
Ether extract	1·51	2·27
Crude fibre	37·2	25·2
Ash	17·8	4·8
NFE	24·6	59·1
Water-soluble carbohydrate	4·32	8·98

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

reported by NRC (1983) and higher in water-soluble carbohydrate than the material used by Chaudhry (1990). Corn forage was similar in CP, ash and crude fibre to the values reported by Harmon *et al.* (1975*a*,*b*). Chemical composition was similar for initial and ensiled mixtures. Initial and ensiled mixtures with broiler litter showed linear increases ($P < 0·05$) in DM, CP and ash with increased levels of broiler litter (Tables 2 and 3). Increased ash content with respect to litter addition might also be expected to supply some essential minerals, especially calcium, phosphorus and magnesium. Fontenot *et al.* (1971) reported that calcium, phosphorus and magnesium contents of litter collected from different locations in Virginia averaged 1·6, 1·5 and 0·3, respectively, on a dry basis.

Crude fibre and ether extract for mixtures with broiler litter did not differ ($P > 0·05$) from those with corn forage alone. However, a decreasing trend in ether extract and increasing trend in crude fibre values was found with increased levels of broiler litter. These observations are in agreement with previously reported results of Bhattacharya and Fontenot (1966), Fontenot *et al.* (1966) and Harmon *et al.* (1975*a*).

All the silages had desirable aroma and even broiler litter odour was not detected. None of the silages showed evidence of surface moulds. The pH values of the initial and ensiled mixtures (Table 4) were higher ($P < 0·05$) for the mixtures containing broiler litter, compared to the mixture with corn forage alone. Ensiling decreased the pH for all the mixtures; the decrease was higher for corn forage ensiled alone than for the mixtures ensiled with broiler litter.

Table 2. Chemical composition[a] of initial mixtures of silages[b]

Item	Broiler litter : corn forage				
	0 : 100	20 : 80	30 : 70	40 : 60	SE
Dry matter[c]	40·02	49·6	53·8	58·3	0·172
Crude protein[c]	8·64	10·8	11·7	12·7	0·033
Ether extract	2·28	2·12	2·05	1·96	0·024
Crude fibre	24·4	25·5	25·7	25·7	0·110
Ash[c]	4·19	6·95	8·31	9·67	0·049

[a] Percent DM basis.
[b] Each value represents the mean of six samples.
[c] Linear effect of treatment ($P < 0·05$).

Table 3. Chemical composition[a] of ensiled mixtures of broiler litter and corn forage[b]

Item	Broiler litter : corn forage				
	0 : 100	20 : 80	30 : 70	40 : 60	SE
Dry matter[c]	41·09	48·5	54·4	57·6	0·11
Crude protein[c]	8·75	10·5	11·6	12·7	0·05
Ether extract	2·26	2·11	2·02	1·86	0·02
Crude fibre	24·3	25·2	25·6	25·7	0·08
Ash[c]	4·21	6·92	8·34	9·88	0·03

[a] Percent DM basis.
[b] Each value represents means of six values.
[c] Linear effect of treatment ($P < 0·05$)

The pH values of the litter silages were higher than those reported by Owens *et al.* (1970). Shirley *et al.* (1972) observed a pH of 4·1 for corn silage stored in an upright concrete stave silo, whereas Harmon *et al.* (1975*a*) observed pH values of 3·67 and 4·96 for corn forage ensiled alone and with litter respectively, and stored in upright silos. Thus the close agreement of the values obtained in the present study with the previously reported values indicates that normal ensiling had occurred.

The increase in lactic acid and decrease in water-soluble carbohydrate content after ensiling for all the treatments indicates that considerable fermentation was achieved. Lactic acid production in the silages increased ($P < 0·05$) with the increase in broiler litter. Buffers, such as ammonia from urea hydrolysis, have been shown to increase the final lactic acid concentration of ensiled corn forage (Owens *et al.*, 1969; Colenbrander *et al.*, 1971; Shirley *et al.*, 1972; Harmon *et al.*, 1975*a*). The lactic acid concentrations observed in this study generally agree with those studies.

Bacteriological determination

Total and faecal coliform for the initial mixtures varied from 0·5 to $8·15 \times 10^5$ and 0·1 to $1·81 \times 10^3$ counts g^{-1},

Table 4. Water-soluble carbohydrate (WSC), pH and lactic acid concentration of pre- and post-ensiled mixtures of broiler litter and corn forage[a]

Item	Broiler litter : corn forage				
	0 : 100	20 : 80	30 : 70	40 : 60	SE
Pre-ensiled					
WSC[b], %[c]	8·38	8·26	7·29	6·60	0·08
pH[b]	6·43	6·99	7·25	7·85	0·04
Post-ensiled					
WSC[d], %[c]	2·35	3·83	2·08	1·83	0·84
pH[b]	4·19	4·65	5·09	5·47	0·03
Lactic acid[b]	7·01	8·28	8·55	8·88	0·04

[a] Each value represents the mean of six samples.
[b] Linear effect of treatment ($P < 0·05$).
[c] Percent DM basis.
[d] Cubic effect of treatment ($P < 0·05$).

Table 5. Microbial counts[a] of pre- and post-ensiled mixtures of broiler litter and corn forage

Item	Broiler litter : corn forage			
	0 : 100	20 : 80	30 : 70	40 : 60
Total coliform ($\times 10^5$)				
Pre-ensiled	0·50	3·81	7·94	8·15
Post-ensiled	—	—	—	—
Faecal coliform ($\times 10^3$)				
Pre-ensiled	0·10	1·02	1·21	1·81
Post-ensiled	—	—	—	—

[a] Counts g^{-1}.

Table 6. Digestibility of broiler litter–corn forage silage when fed to sheep

Item	Broiler litter : corn forage				
	0 : 100	20 : 80	30 : 70	40 : 60	SE
Dry matter[a]	50·9	57·3	59·5	61·2	0·42
Crude protein[b]	50·4	59·5	64·2	61·4	2·36
Crude fibre[b]	47·8	52·3	55·7	52·8	2·20
Ether extract[b]	51·9	60·0	63·4	62·0	2·37
Ash[a]	53·1	50·3	51·1	50·1	0·55

[a] Linear effect of treatment ($P < 0·05$).
[b] Quadratic effect of treatment ($P < 0·05$).

respectively (Table 5). Following ensiling, all the silages tested were negative for total and faecal coliforms. Complete elimination of the organisms has been reported by Caswell *et al.* (1975) when broiler litter was ensiled with 40% moisture, by Harmon *et al.* (1975*a*) when broiler litter was ensiled with corn forage and by Samuels (1980) when caged-layer waste was ensiled with corn forage or sugar-cane bagasse.

McCaskey and Anthony (1979) reported that the bacteria isolated from ensiled animal waste rations inhibits the growth of salmonella, streptococci and staphylococci by a mechanism other than acid production. Anaerobic conditions (Chung & Goepfert, 1970) and heat production during fermentation also contribute to the inhibition of coliform organisms (McCaskey & Anthony, 1979). Some lactobacilli produce sufficient hydrogen peroxide to inhibit coliform and salmonella organisms (Dahiya and Speck, 1969).

Digestibility analyses

Differences in composition of diets containing different proportions of broiler litter reflected the composition of silages. All diets were readily accepted by lambs and no digestion disturbances were noted. Among the diets containing silages, average digestibilities of DM, CP, CF and EE were lower ($P < 0·01$) for the silages containing corn forage alone, compared to silages containing corn forage and broiler litter (Table 6). However, the digestibilities of DM and ash increased linearly ($P < 0·05$) with the increase of broiler litter in the silage. Feeding diets contained ensiled corn forage with broiler litter up to 70 : 30 increased ($P < 0·05$) apparent digestibilities of all components and decreased digestibilities of CP, CF and EE when the level of broiler litter was increased from 30 to 40%. Adding nitrogen sources like broiler litter in the corn-forage silages increases the apparent digestibilities of all components (Harmon *et al.*, 1975*b*).

Colovos *et al.* (1970) observed a slight depression in silage DM digestibility with advancing maturity of corn forage for steers, but wethers showed a slight decrease in DM digestibility. Saylor and Long (1972) reported that in-vitro organic matter digestibility of poultry manure in crop residues was higher than for similar mixtures containing cattle manure.

On the basis of ensiling and feeding studies it appears that ensiling broiler litter with corn forage may be a feasible means of preserving and converting broiler litter, a solid waste, into a palatable and nutritious feed for ruminants. In addition to improving the nutrient content of corn forage, this method of disposing of waste provides a means of stretching feed supplies and increasing the production of meat for human consumption.

REFERENCES

Abdelmawla, S. M., Fontenot, J. P. & El-Ashry, M. A. (1988). Composted, deepstacked and ensiled broiler litter in sheep diet: Chemical composition and nutritive value study. Virginia Polytechnic Institute and State University Animal Science Research Report No. 7, p. 127.

Anon. (1967). Standard methods for the examination of dairy products—microbial and chemical (12th edn). American Public Health Association Inc., New York, USA.

AOAC (1984). Official Methods of Analysis (14th edn). Association of Official Analytical Chemists, Washington DC, USA.

Baker, S. B. & Summerson, W. H. (1945). The colorimetric determination of lactic acid in biological material. *J. Biol. Chem.*, **138**, 535.

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

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

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

Chaudhry, S. M. (1990). Processing and nutritional value of broiler litter and slaughter house by-products. PhD Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Chung, L. C. & Goepfert, J. M. (1970). Growth of Salmonella at low pH. *J. Food Sci.*, **35**, 326.

Colenbrander, V. F., Muller, L. D. & Cunningham, M. D. (1971). Effects of added urea and ammonium polyphosphate on fermentation of corn stover silages. *J. Anim. Sci.*, **33**, 1097.

Colovos, N. F., Holter, J. B., Koes, R. M., Urban, W. E., Jr & Davis, H. A. (1970). Digestibility, nutritive value and intake of ensiled corn plant (*Zea mays*) in cattle and sheep. *J. Anim. Sci.*, **30**, 819.

Cross, D. L. & Jenny, B. F. (1975). Efficacy of turkey litter silage for dairy heifers. *J. Anim. Sci.*, **41**, 240 (abstr).

Dahiya, R. S. & Speck, M. L. (1969). Hydrogen peroxide formation by lactobacilli and its effects on *Staphylococcus aureus*. *J. Dairy Sci.*, **51**, 1568.

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

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

Fontenot, J. P., Bhattacharya, A. N., Drake, C. L. & McClure, W. H. (1966). Value of broiler litter as feed for ruminants. Proc. Nat. Symp. on Management of Farm Animal Wastes. A.S.A.E. Publ. SP-0366, p. 105.

Fontenot, J. P., Webb, K. E. Jr, Harmon, B. W., Tucker, R. E. & Moore, W. E. C. (1971). Studies of processing nutritional value and palatability of broiler litter for ruminants. Proc. Int. Symp. on Livestock Wastes. A.S.A.E. Pub. SP-271, p. 301.

Harmon, B. W., Fontenot, J. P. & Webb, K. E. Jr (1975*a*). Ensiled broiler and corn forage. I. Fermentation characteristics. *J. Anim. Sci.*, **40**, 144.

Harmon, B. W., Fontenot, J. P. & Webb, K. E. Jr (1975*b*). Ensiled broiler and corn forage. II. Digestibility nitrogen utilization and palatability by sheep. *J. Anim. Sci.*, **40**, 1256.

Johnson, R. R., McClure, K. E., Johnson, L. J., Klostermnan, E. W. & Triplet, G. B. (1966). Corn plant maturity. I. Changes in dry matter and protein distribution in corn plants. *J. Anim. Sci.*, **25**, 617.

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

McCaskey, T. A. & Anthony, W. B. (1979). Human and animal health aspects of feeding livestock excreta. *J. Anim. Sci.*, **48**, 163.

Millipore Corp. (1973). Biological Analysis of Water and Waste Water. Catalog NO. LAM 302b, Millipore Corp., Bedford, MA, USA.

NRC (1983). *Underutilized Resources as Animal Feedstuffs*. National Academy Press, Washington DC, USA.

Owens, F. N., Meiske, J. C. & Goodrich, R. D. (1969). Effect of calcium sources and urea on corn silage fermentation. *J. Dairy Sci*, **52**, 1817.

Owens, F. N., Meiske, J. C. & Goodrich, R. D. (1970). Effects of crude protein sources and sodium bisulfite on energy constituents. *J. Anim. Sci.*, **30**, 455.

Pennington, R. J. and Sutherland, T. M. (1956). Ketone body production from various substrate by sheep-rumen epithelium. *Biochem. J.*, **63**, 353.

SAS (1982). *SAS User's Guide*. Statistical Analysis System Institute, Inc., Cary, NC, USA.

Samuels, W. A. (1980). Fermentation, utilization and palatability of ensiled caged layer waste and sugarcane bagasse. MS thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Saylor, W. W. & Long, T. A. (1972). Nutritive value of ensiled animal wastes. *J. Anim. Sci.*, **35**, 288 (abstr.).

Shirley, J. E., Brown, L. D., Toman, F. R. & Stroube, W. H. (1972). Influences of varying amounts of urea on the fermentation pattern and nutritive values of corn silage. *J. Dairy Sci.*, **55**, 805.

Whitehouse, K. A., Zarow, A. & Shay, H. (1945). Rapid method of determining 'crude fiber' in distillers and grains. *J. Assoc. Offic. Agric. Chem.*, **28**, 147.