MINERAL ELEMENT PROFILES OF ANIMAL WASTES AND EDIBLE TISSUES FROM CATTLE FED ANIMAL WASTES

by

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INTRODUCTION

Approximately two billion metric tons of wastes are produced annually by farm animals in the United States. Much of this waste is produced under intensive conditions which require disposal or utilization. In the past, the wastes have been used mainly as fertilizer. At least, under certain economic situations, the plant nutrient value of the waste was not sufficient to cover the cost of hauling and spreading. Furthermore, in some instances insufficient land is available in close proximity to large concentrated livestock and poultry enterprises.

Another alternative would be recycling by feeding to animals. Within the past 10 to 15 years considerable interest and research has been directed toward feeding animal waste.

Many domestic animal species practice coprophagy. Research was conducted in the 1800's on the use of cattle waste by swine. It was a common livestock practice, particularly in the Midwest, for swine to voluntarily consume cattle feedlot waste which reduced the feed necessary for pork production.

The ruminant animal is the most adapted species for utilizing animal wastes. Recycling animal wastes through the ruminant provides a method of reducing waste disposal needs as well as utilizing the nutrients directly. Also, the energy of the waste would be of little value for soil application, except to provide organic matter if sufficient nitrogen is present.

Some apprehension exists concerning the feeding of animal wastes, due to potential hazards of residues from drugs, toxins, minerals and the possible transmission of disease organisms. Data are limited concerning mineral levels in animal wastes and the concomitant tissue levels when fed to the ruminant. With the increased use of animal wastes in the ruminant diet and limited data available the major thrust of the present study was to investigate mineral profiles in: 1) typical ruminant feedstuffs, 2) animal wastes, and 3) tissues from cattle fed animal waste compared to standard rations. Ration composition, performance, carcass characteristics and palatability traits of cattle fed waste were also evaluated.

REVIEW OF LITERATURE

Broiler Litter as a Feed Ingredient

Broiler litter, which includes bedding, excreta, wasted feed and feathers, has been used successfully as a feed for ruminants.

Composition and Nutritive Value. Crude protein content of 13 broiler litter samples taken in three major broiler producing areas of Virginia averaged 30.0 ± 2.6% (Fontenot *et al.*, 1971a), similar to the value of 31.3 ± 2.9% reported by Bhattacharya and Taylor (1975). Average crude protein content from a number of sources was 32.5% (table 1). Considerable variation exists in crude protein values. depending on bird density, amount and type of litter, feed composition, feed spillage and length of time from excretion to collection (Forsht *et al.*, 1974). This variation makes it necessary to analyze broiler litter by lot prior to being incorporated into the ration.

Brugman *et al.* (1964) reported digestion coefficients of 77.8, 44.4, 91.0 and 59.2%, respectively, for crude protein, ether extract, crude fiber, and gross energy for laying house litter fed to bulls.

Bhattacharya and Fontenot (1965) reported that protein nitrogen, non-protein nitrogen (NPN), uric acid nitrogen and ammonia nitrogen, expressed as a percentage of total nitrogen were, 44.4, 55.6, 28.8 and 15.4%, respectively, for woodshaving litter, and similar values for peanut hull litter. Average values for digestible protein, digestible energy, metabolizable energy and TDN for wood shaving and peanut hull

TABLE 1. PROXIMATE ANALYSES AND ENERGY VALUES OF BROILER LITTER[a]

Number of samples	Dry matter	Crude protein	Ether extract	Crude fiber	N.F.E.	Gross energy	Ash	Reference[b]
	%	%	%	%	%	cal/kg	%	
5	84.5	25.3	2.3	18.7	27.1		14.1	1
2	84.3	38.9	5.6	17.5	26.3		11.7	2
82							31.3	3
13	80.5	30.0	3.1	18.3	17.9		30.7	4
2	79.4	42.5	6.2	14.6	21.7	4250	15.1	5
33	75.2	28.4	2.5	27.0	29.6		12.5	6
3	89.1	32.0	2.8	15.1	31.8	3862	17.9	7
3	88.9	30.6	2.8	14.6	33.1	3748	19.0	8
2	85.5	32.6	3.0	13.1	34.0		17.4	9
Mean	83.4	32.5	3.5	17.4	27.7	3953	18.9	
Range	75.2	25.3	2.3	13.1	17.9	3748	11.7	
	89.1	42.5	6.2	27.0	34.0	4250	31.3	

[a] Dry matter basis.

[b] References: 1) Couch (1974); 2) Harmon *et al.* (1974); 3) Perkins and Parker (1971); 4) Fontenot *et al.* (1971a); 5) Fontenot *et al.* (1971b); 6) El-Sabban *et al.* (1969); 7) Bhattacharya and Fontenot (1966); 8) Hileman (1967); 9) Bhattacharya and Fontenot (1965).

litter fed at 25 and 50% of the diet were not significantly different between kinds and levels of litter fed (Bhattacharya and Fontenot, 1966). The average values were 22.7%, 2440 kcal/kg, 2181 kcal/kg and 59.8, respectively.

Ensiling broiler litter at 15 and 30% of the total dry matter with corn forage increased crude protein of the silage from 8.2% to 11.1% and 15.0%, respectively, dry basis (Harmon _et al._, 1975a). Dry matter digestibility was similar for all silages. Crude protein digestibility increased with litter level. Mean daily dry matter intakes by sheep were: control, 848 g; urea treated silage (.5%, wet basis), 925 g; 15% litter silage, 1445 g and 30% litter silage, 1464 g.

Digestibility of crude protein and nitrogen retention were significantly higher for sheep supplemented with citrus-pulp-poultry litter than a basal diet (Ammerman _et al._, 1966).

The ruminant can efficiently utilize the uric acid and NPN contained in poultry broiler litter. Belasco (1954) showed uric acid nitrogen supported rumen bacterial growth and _in vitro_ cellulose digestion. Oltjen _et al._ (1968) demonstrated more efficient utilization with high levels of uric acid fed to cattle, compared to urea, due to a slower breakdown of uric acid in the rumen. Looper and Stallcup (1958) reported ammonia from the litter is a potential source of nitrogen for ruminant. Bhattacharya and Fontenot (1965) reported positive nitrogen balance in lambs fed semi-purified diets in which 100% of the dietary nitrogen was supplied by broiler litter.

Fontenot _et_ _al_. (1971a) reported ash, calcium and phosphorus content of 13 unprocessed broiler litter samples taken in three major broiler producing areas of Virginia to be 30.7 ± 5.3%, 1.6 ± .2% and 1.5 ± 2%, respectively. The high ash content could limit the energy value of the broiler litter.

Broiler litter is an excellent source of crude protein, calcium and phosphorus for the ruminant and can compliment other feedstuffs deficient in these nutrients, such as corn forage.

Ensiling of Corn Forage and Broiler Litter. Barnett (1954) indicated that proper ensiling involves three phases: 1) respiration until all oxygen is removed, resulting in the production of heat and carbon dioxide; 2) organic acid production (principally lactic and acetic acids) caused by a rapid growth of anaerobic bacteria which are dependent on an available carbohydrate source; 3) cessation of bacterial activity caused by the acids produced which results in lowering the pH and inhibition of bacterial and enzymatic activity. The silage is in a preserved stage after approximately 21 days. Should the lactic acid level and pH not be optimal to stop bacterial activity, the resulting butyric acid producing bacteria may attack residual soluble carbohydrates, lactic acid and protein, resulting in nutrient decomposition and spoilage of the silage.

Corn forage is the major silage crop in the United States. According to the National Research Council (1976), well eared corn silage contains 40.0% dry matter, 2.53 cal, metabolizable energy/ kg, 70.0% TDN, 8.1% crude protein, .27% calcium and .20% phosphorus, dry basis. For growing and finishing cattle, corn silage is deficient in crude protein, calcium and phosphorus, making supplementation of these components necessary for optimum performance.

Harmon et al. (1975a) ensiled corn forage harvested at two stages of maturity with broiler litter at 15 and 30% of the total dry matter of the ensiled mixtures. All treatments underwent good fermentation.

The ensiling of broiler litter with corn forage appears to be a good method of processing, which is economical in many areas.

Performance of Ruminants. Noland et al. (1955) reported that gestating-lactating ewes fed a ration containing 23% ground chicken litter performed similarly to ewes fed a control ration with soybean meal. When energy intake was equalized, steers fed chicken litter performed as well as the control group fed cottonseed meal. Southwell et al. (1958) reported gains in steers fed a ration containing 30% corn cob broiler litter were similar to those of steers on a control ration. Fontenot et al. (1966) found that performance and carcass quality was similar for steers fed a fattening mixture containing 25% broiler litter as for those fed a conventional fattening mixture, plus a low level of long hay. Feed efficiency was higher for the litter ration resulting in 9% less feed per kilogram of gain. Based on performance of cattle fed corn silage supplemented with broiler litter, Stonestreet et al. (1966) concluded that 2.5 kg of broiler litter were equivalent to 1.0 kg of soybean meal.

Acceptable performance of cattle fed 25% litter was reported by Fontenot et al. (1971b), but rations containing 50% litter depressed intake and lowered performance. Growing lambs had a higher rate of gain and feed efficiency when fed 38, 58 or 68% rice hull litter, compared to an alfalfa hay ration (Galmez _et_ _al_., 1970). Average daily gains for dairy heifers fed ensiled turkey litter at 0, 15, 30 and 45%, dry basis, in combination with ensiled corn forage and concentrate were: .42, .58, .51 and .43 kg, respectively (Cross and Jenny, 1976). When rations were corrected for ash content feed efficiencies were similar for all treatments.

Webb _et_ _al_. (1978) have successfully wintered beef cows on a ration consisting of 80% broiler litter and 20% corn grain plus small quantities of coarse roughage over a 5-year period. Average daily gain, feed consumption, calving performance and calf weaning weight indicate no adverse effects on wintering cows with litter and corn grain compared to cows wintered on hay.

Fontenot _et_ _al_. (1963, 1966, 1971b), Cullison _et_ _al_. (1976) and El-Sabban _et_ _al_. (1970) reported the feeding of poultry wastes does not adversely affect taste of the meat.

Broiler litter has been successfully ensiled or fed with other feedstuffs. Feeding and digestibility studies indicate the ensiling and feeding of broiler litter to be an energy conserving process which compliments the nutritive value of the ensiled forage or feedstuff and improves the palatability of the litter.

Cattle Waste as a Feed Ingredient

Cattle waste is the major contributor to annual solid waste production by domestic animals. Wadleigh (1968) estimates 88% of the solid livestock waste produced is from cattle. According to Van Dyne and Gilbertson (1978) over 80% of livestock waste is produced by cattle. However, due to lower intensification of cattle in some of their production cycle, approximately 50% of the cattle waste is collectible. With such a significant contribution of waste from cattle, it would appear feasible to conduct studies on the composition, nutritive value and performance of cattle waste to optimize its use by refeeding.

Composition and Nutritive Value. Dowe et al. (1955) analyzed feces from steers fed varying corn to hay ratios (1:1, 2:1, 3:1, 4:1 and 5:1). They concluded that as the ratio of corn to hay in the diet of the steer increased, dry matter, crude protein and NFE increased. Crude fiber decreased as the ratio of corn to hay increased.

Lipstein and Bornstein (1973) reported chemical composition values of cattle waste for crude protein, ether extract, crude fiber, ash, NFE, and gross energy were: 13.1, 2.0, 24.2, 31.3, 29.5% and 3.27 kcal/gm, respectively, dry basis.

Lucas et al. (1975a) chemically analyzed waste collected from steers fed a 50% roughage ration. The steer waste contained 13.2% crude protein, 2.8% ether extract, 31.4% crude fiber, 5.4% ash, 47.2% NFE, dry basis.

Proximate and Van Soest analyses were conducted on waste from cattle fed a low or high roughage ration (Braman, 1975). Waste from cattle fed a low roughage ration was higher in dry matter, crude protein, ether extract and NFE and lower in ash, crude fiber, acid detergent fiber and neutral detergent fiber, compared to waste from cattle fed a high roughage ration.

Dry matter and crude protein of "wastelage", an ensiled mixture of 57 parts wet cattle waste and 43 parts hay were 52.9 and 10.6%, dry basis, respectively (Anthony, 1971b).

Anthony (1970) reported digestion coefficients for the following rations: 1) basal-concentrate mixture, 2) 40 parts cooked manure and 60 parts basal, wet basis; 3) 40 parts washed manure 60 parts basal, wet basis; 4) corn silage and ground ear corn supplemented with urea, cottonseed meal, minerals and vitamin A. Respective apparent digestion coefficients for dry matter, cellulose and crude protein were: Ration 1 - 62.9, 29.1, 49.8; Ration 2 - 67.4, 51.5, 56.2; Ration 3 - 61.0, 37.6, 50.0; Ration 4 - 68.2, 34.8, 35.3%. In a second experiment, dry matter digestibility was determined by the nylon bag technique. The dry matter digestibility values for rations consisting of: 1) basal; 2) basal with 40% wet manure; and 3) basal with 40% wet manure-autoclaved were 40.4, 46.6 and 45.6%, respectively. Dry matter digestion coefficients were higher for the rations containing manure, compared to the basal.

Digestibility of dry matter, nitrogen, ash and organic matter and TDN by sheep were significantly lower for a ration containing 31.5% dried dairy cattle feces, dry basis, compared to a control ration (Tinnimit _et al._, 1972). Nitrogen retention was also lower for the ration containing feces.

Nutritive value and digestibility coefficients for a cattle waste product called "cerola", a washed and fermented solid manure fraction, were reported by Ward _et_ _al_. (1973). Cerola had dry matter, crude protein, crude fiber, NFE and ash values of 54.0, 11.0, 14.0, 66.0 and 5.0%, respectively. Cerola was fed alone to six crossbred lambs in a digestion trial. The apparent digestibilities for dry matter, crude protein, crude fiber, NFE, crude fat were 76.0, 64.0, 50.0, 85.0 and 89.0%, respectively. The mean TDN value was 77.0%, dry basis.

Lucas _et_ _al_. (1975a) reported the following respective apparent digestibility values, calculated by difference, of heat treated dried steer feces for dry matter, organic matter, crude protein, ether extract, crude fiber and NFE: 16.6, 14.4, 24.4, 26.9, 17.3, 16.9, 18.6%. The TDN value was 18.6% and digestible and metabolizable energy values were 763 kcal/kg and 485 kcal/kg, dry basis. These values are considerably lower than values previously reported which may indicate the heat treatment (120 C) may have lowered the digestion coefficients.

Processing of Cattle Waste. Cattle waste has been processed by a variety of methods for use as a feed ingredient. Methods of principle interest include dehydrating, ensiling, washing, cooking, single cell protein production, chemical treatment and deep stacking.

Thomas _et_ _al_. (1970), McClure _et_ _al_. (1971), Bucholtz _et_ _al_. (1971), Smith _et_ _al_. (1971), Tinnimit _et_ _al_. (1972) and Lucas _et_ _al_. (1975a) have successfully dehydrated cattle waste by use of heat.

Drying by heat, due to high energy input, may be of limited value with the dramatic rise in energy costs. Methods which minimize energy input are the principle focus of processing research.

Anthony (1966) ensiled a combination of manure from cattle fed high energy rations with Coastal Bermuda grass hay. The ensiled combination, termed "wastelage", had a ratio of 57 parts cattle manure and 43 parts hay, wet basis. Wastelage contained 20% waste and 80% hay, dry basis. In two feeding trials with wastelage making up 63% of the ration, feed intake and palatability were similar for wastelage and control rations.

Vetter and Burroughs (1974) ensiled 20 to 27% cattle excreta with corn forage and corn grain and reported no differences in performance and palatability compared to basal rations. Ward and Beede (1973) and Ward _et al_. (1974) compared "cereco" silage, a fermented-processed waste from manure of finishing cattle consuming a 75 to 80% concentrate ration with corn silage. When fed at 25 and 50% of the ration, cereco silage was as acceptable as corn silage. Harpster _et al_. (1975) ensiled levels of 40 to 100% fresh cattle waste with grass hay. When 60% or less of cattle waste was ensiled, no differences were observed in dry matter intake, feed efficiency and daily gain.

Newton _et al_. (1977) compared digestibility and performance by cattle fed dehydrated and ensiled cattle waste. They found no difference in digestibility and performance. They concluded dehydrating cattle waste was counterproductive due to the additional energy input for drying.

Anthony (1970) fed washed, untreated and cooked cattle waste with concentrates to steers. Feeding trial data indicated cooking or washing did not improve performance.

Singh and Anthony (1968) and Moore and Anthony (1970) acid extracted the fiber portion of cattle waste and after neutralization, added the extract to the soluble portion, and innoculated with yeast cells. The innoculated waste contained 19% crude protein following fermentation at 40 C for 48 hours, compared to 7.4% crude protein for acid extracted residues.

Chemical treatment of cattle waste with sodium hydroxide (NaOH) to increase the apparent digestibility of fiber components has been investigated by Smith _et_ _al_. (1969), Smith _et_ _al_. (1970) and Lucas _et_ _al_. (1975b). These investigators concluded the digestibility of fiber components was significantly improved by treating the waste with an average of 3% NaOH, wet basis. This treatment is especially promising for low quality roughages and animal wastes. The digestion coefficients of the fiber components of waste from cattle fed a high roughage ration were increased by a larger magnitude with NaOH treatment than those of waste from cattle fed a low roughage ration (Lucas, 1975b).

Lamm _et_ _al_. (1978) ensiled 60% cattle waste, obtained from cattle fed a 70% concentrate ration, with 40% hay, wet basis. The mixture was treated with graduated levels of NaOH (0 to 12%, dry basis) prior to ensiling. Lactic acid production and pH were optimum at 0 and 2% NaOH. Digestibility of dry matter, crude fiber, NFE, organic matter and nitrogen retention were enhanced with 4% NaOH (dry basis) treatment.

Westing and Brandenburg (1974) and Albin and Sherrod (1975) collected cattle waste from open-soil surfaced commercial feedlots located in arid environments. Cattle waste was scraped from the pen surface and stockpiled for at least 30 days prior to grinding and feeding.

Performance of Cattle. Cattle waste from steers fed a high concentrate ration was washed (Anthony and Nix, 1962). The washed solids were fed at a level of 40% in a 54-day feeding trial. Average daily gains were 1.5 kg/day. Anthony (1970) fed rations containing 40% washed cattle waste solids either untreated or cooked, compared to a basal ration. Average daily gain (kg) and feed efficiency (feed/gain) for 1) basal, 2) basal with cooked manure, 3) basal with washed manure were: 1) 1.24, 8.14; 2) 1.23, 8.48; 3) 1.08, 9.0, respectively. Dry matter intake of manure containing rations was higher than that of basal, but intake of basal feed per unit gain was less for the manure containing rations.

Cattle fed wastelage outgained corn silage fed cattle (Anthony, 1968). Anthony (1971a), in a feeding trial in excess of 100 days, found that a mixture of 2 parts wastelage to 3 parts corn produced gains similar to a high concentrate ration, and less concentrate was needed for equivalent gain in cattle fed wastelage.

A feeding trial was conducted by Westing and Brandenburg (1974) to compare rations consisting of: 1) 14% composted cattle waste and 2) control. Average daily gain, daily feed intake and feed efficiencies were: 1) 1.1 kg, 8.66 kg, 7.87; 2) 1.11 kg, 8.25 kg, 7.43, respectively. More feed per kilogram of gain was required with the waste containing ration, but less concentrate per kilogram of gain was used in the waste ration. No differences were found in carcass quality and taste of the meat between dietary regimes.

Daily gains of heifers fed a basal ration containing 80% concentrate was 1.34 kg compared to 1.27 kg for those fed an ensiled combination of 60% basal and 40% wet cattle manure (Newton _et al._, 1975). Feed efficiencies were 5.65 and 8.71 feed/kg gain, respectively.

Schake _et al._ (1977) reconstituted sorghum grain with water or cattle excrement. Excrement was more effective than water as a reconstitution media if excrement to grain ratios did not exceed 1:1.6. The amount of grain dry matter required per kilogram of gain for control (dry), water reconstituted, and excrement reconstituted were 4.99, 4.46, and 4.36 kg, respectively. Reconstitution with excrement improved the utilization of sorghum grain by 12.6% over the control group. Excrement fed cattle had higher dressing percentages and more carcass fat than control cattle.

Regulatory Status of Animal Waste Feeding

The Food and Drug Administration (FDA) in a policy statement published in the Federal Register on September 3, 1967 (32 FR 12714) indicated the agency did not sanction the feeding of poultry litter to animals (Kirk, 1967). This policy has since been expanded to include wastes from other animal species (Taylor, 1971; and Taylor _et al._, 1974). The principle concerns from feeding animal wastes were the potential residues of drugs, toxins, toxic minerals and the possible transmission of pathogenic organisms.

The FDA has indicated regulatory action will not be taken against the feeding of animal waste unless the waste is found in interstate commerce and contains harmful residues or disease producing organisms (Taylor and Geyer, 1977).

With the growing interest in animal waste feeding the FDA published in the Federal Register a document entitled "Recycled Animal Waste" (Federal Register 42, 1977). This document requests information and data from research already conducted, solicits ideas concerning regulatory controls necessary and invites suggestions on the identification of issues germane to waste feeding. These data will be reviewed by the agency to decide if changes should be made in its position on feeding animal waste.

Effects of Feeding Animal Waste on Health

Human Health. In a review of animal waste feeding research, Fontenot and Webb (1975) reported no harmful effects in humans who consumed animal products from animals fed animal wastes. As previously reported, organoleptic studies have conclusively shown consumers could not differentiate between products from animals fed animal wastes and products from animals fed standard rations.

Animal Health. Only one documented report has been published in which harmful effects were shown when feeding animal waste (Fontenot *et al.*, 1971a). Rations containing 0, 25 and 50% broiler litter were fed to ewes with no effect on performance, health and carcass characteristics of their lambs. The broiler litter contained 195 ppm copper, dry basis, as a result of the broilers receiving elevated levels of copper sulfate in their diet. One ewe fed 50% broiler litter ration died of copper toxicity after 137 days on trial. After 254 days on trial 64% of the ewes fed 25% broiler litter and 55% of the ewes fed 50% litter died of copper toxicity. Mean liver copper levels of ewes fed 0, 25 and 50% broiler litter at death or slaughter were 648, 1993 and 2671 ppm, dry basis, respectively. Liver copper levels of lambs for the respective treatments were 572, 891 and 961 ppm, dry basis. Underwood (1977) reports sheep are much more sensitive to high copper levels than cattle.

Webb _et al_. (1978) in a 6-year study has successfully fed beef cows on a diet of 80% broiler litter and 20% corn grain, plus a small amount of coarse roughage, with no deleterious effects. Mean copper level for the broiler litter was 200 ppm, dry basis. Cows were put on the following treatments in December and fed through April of each year: 1) hay; 2) 80% litter and 20% corn grain; 3) 80% litter, 20% corn grain and 160 ppm copper. Mean liver copper levels for the three treatments in December and April were: 1) 19.8, 53.6; 2) 154.3, 1263.9; 3) 186.3, 1726.7 ppm, dry basis. Liver copper levels increased in litter treatments over the wintering period but were reduced substantially during the grazing period in litter fed cows. No cases of copper toxicity were reported. Feed intake, average daily gain, calving percent, calf birth and weaning weights were not affected by elevated levels of dietary copper. Felsman _et al._ (1973) fed calves rations containing over 900 ppm copper, dry basis, for 98 days with no adverse effects on performance or signs of copper toxicity. In fact, daily gain tended to be higher for the copper supplemented calves.

Abortion was reported in brood cows fed low levels of broiler litter in a wintering ration and allowed to graze pastures that were fertilized with broiler litter (Griel _et al._, 1969). Broilers reared on the litter were fed dienestrol, a growth stimulant, and the litter was found to contain estrogenic activity equivalent to 10 μg of diethylstilbestrol (DES)/100 g litter. It was speculated that feeding dienestrol caused hormonal imbalances resulting in abortion. The authors did indicate DES had been fed at higher levels than the estrogen level these cows had received without causing abortion. Thus, the evidence is inconclusive in attributing abortions in cows to broiler litter.

Anthony (1969), in feeding trials over several years, has not shown any adverse effects on health and reproductive performance in cattle and sheep from feeding ensiled cattle waste.

Potential Problems from Feeding Animal Wastes

Pathogenic Organisms and Molds.

Standard feed ingredients contain significant levels of pathogenic organisms and molds (Singh, 1974). Chemical and/or heat treatment, properly used, can destroy and reduce these organisms below an effective dose level (McCaskey and Anthony, 1975; Fontenot and Webb, 1975; Bhattacharya and Taylor, 1975).

A trend for lower coliform counts in corn-litter silages, compared to control corn silage was reported by Harmon et al. (1975b). Litter silage tested negative for coliforms, salmonella and staphylococcus (Creger et al., 1973). Caswell et al. (1977) found lower coliform counts in silage containing 1 part broiler litter with 2 parts high moisture corn than in high moisture corn ensiled alone. Temperature and pH play a vital role in destroying salmonella in ensiled mixtures (McCaskey and Anthony, 1975). They suggest a minimum temperature of 25 C and a pH of 4.5 or below to destroy salmonella. Knight et al. (1977) reported destruction of coliforms in ensiled materials when the pH was 4.7 or lower. These studies indicate potential pathogens can be destroyed when the waste is properly processed.

Hormones. Estrogen is the hormone of principle interest in feeding animal waste. Products having estrogenic activity are used as growth stimulants in ruminants. At extremely high doses at least some estrogens are carcinogenic.

Mellin and Erb (1966) reported feces and urine to be rich sources of estrogens in cycling cows. Mathur and Common (1969) found that laying hens produced higher levels of estrogen metabolites than non-laying hens. Subcutaneous implants of 24 or 36 mg DES in growing heifers caused a significant increase in estrogen excretion for 60 days (Callantine et al., 1961). Lambs fed DES orally at levels of 1 and 2 mg daily excreted 76 and 84% of the intake dose daily (Story et al., 1957). Westing and Brandenburg (1974) reported no detectable levels of DES in livers of steers fed a 14% cattle waste ration.

Aflatoxins. Aflatoxins are metabolites of fungi which normally grow readily on animal feeds that meet their nutritional requirements. Aflatoxins are considered to be very potent carcinogens (CAST, 1978).

Hendrickson and Grant (1971) have shown aflatoxin formation to be much higher in fresh cattle waste than stockpiled waste. Westing and Brandenburg (1974) reported no aflatoxins in cattle waste which had been composted and stockpiled for 60 days. Lovett (1972) reported that mycotoxins in poultry litter are no more serious than in feed.

Medicinal Drugs. Elmund *et al.* (1971) indicated 75% of dietary chlortetracycline was excreted by cattle fed 70 mg chlortetracycline daily. Westing and Brandenburg (1974) assayed for antibiotic residues in cattle waste which was stockpiled for 60 days and found no residue. Fontenot and Webb (1975) analyzed broiler litter samples from several areas of Virginia and reported mean values of: oxytetracycline, 10.9 ppm; chlortetracycline, 12.5 ppm; nicarbazin, 81.2 ppm; amprolium, 27.3 ppm; penicillin, 12.2 units/g; neomycin, 0 ppm; zinc bacitracin, 7.2 units/g.

Webb and Fontenot (1975) conducted two trials, feeding steers rations containing 0, 25 and 50% broiler litter for 121 and 198 days. Broiler litter was withdrawn from the rations 5 days prior to slaughter. Loin eye muscle, kidney fat and liver tissue samples were assayed for levels of amprolium, nicarbazin and chlortetracycline. Tissue deposition of amprolium and nicarbazin did not occur. Chlortetracycline was detected at 34 to 41 ppb only in the kidney fat of three steers fed litter. A ration consisting of

14% cattle waste, dry basis, was fed to steers for 184 days and no antibiotics were detected in kidney tissue (Westing and Brandenburg, 1974).

Pesticides. Pesticides are used extensively in livestock production both on the animal and in the environment for the control of insects and external parasites. El Sabban *et al.* (1970) analyzed external fat (12th rib) of steers fed caged poultry waste for 139 days. No significant differences were found in DDE, DDT, TDE and Endrin between treatments. Fontenot *et al.* (1971a) analyzed 13 broiler litter samples from three major broiler producing areas in Virginia and reported mean DDT and DDT metabolite value of 0.095 ppm ± 0.011. Liver and omental fat from yearling steers fed 25 and 50% broiler litter for 121 days were assayed for pesticides (Fontenot *et al.*, 1971a). Feeding broiler litter at these levels did not affect pesticide level. Messer *et al.* (1971) detected DDE in only two samples of poultry litter at levels of .01 and .02 ppm in 10 samples evaluated.

Westing and Brandenburg (1974) reported total DDT levels in kidney fat of steers fed a 14% cattle waste and a control ration were .14 and .11 ppm, dry basis, respectively. Feeding Rabon (2-chloro-1 (2,4,5-trichlorophenyl) vinyl dimethyl phosphate), an orally administered pesticide used to control internal parasites and fly larvae in the feces, at levels up to 250 ppm did not affect dairy cow performance, and the pesticide did not accumulate in the milk (Miller and Gordon, 1973).

Mineral Elements. The Food and Drug Administration is concerned with the potential accumulation of toxic minerals in meat, milk and eggs destined for human consumption (Anonymous, 1977). Due to their toxic properties, arsenic, cadmium, lead, mercury and selenium are minerals of primary concern (Anonymous, 1977). Mineral profiles of animal wastes are related to the mineral content of feed ingredients consumed which in turn reflect the geological and environmental conditions under which the feed was grown, processed and stored (Church and Pond, 1975). Many minerals, such as cadmium, lead and mercury, are poorly absorbed from the digestive tract (Underwood, 1977). Coupled with the relatively high digestibility of dietary organic matter, some minerals are more concentrated in the excreta than in the diet.

Minerals can readily be quantified by chemical analyses but this is not necessarily a reliable indicator of mineral availability (Underwood, 1977). Most minerals are not in elemental form and mineral availability is dependent on chemical form, dietary level, conditions of administration, productive state of the animal, digestibility of carrier, mineral interactions, particle size, source of mineral, presence of chelating agents and method of processing the mineral source (Stake, 1977).

Required minerals can be toxic if fed in excessive amounts. The margin between required and toxic levels is small for some minerals. Caution must be practiced in feed formulation to meet requirements but not exceed tolerance levels.

Potential mineral toxicity can arise when feeding animal wastes across species. Fontenot et al. (1971a) reported copper toxicity in sheep. Ewes fed 25 and 50% broiler litter for 254 days had mortality rates of 64 and 55%, respectively, due to copper toxicity. Broilers can tolerate high levels of dietary copper due to lower absorption and a higher copper toxicity threshold than sheep (Underwood, 1977). When feeding animal waste, particularly across species, diet and medication regime of the animals producing the waste should be assessed as well as the tolerance of the species to be fed.

When absorbed, cadmium, lead and mercury accumulate, which can result in elevated levels in edible tissue (Ammerman, 1977). Arsenic and selenium do not accumulate and are rapidly depleted following a sufficient period of withdrawal.

The potential of mineral toxicity is variable between minerals so each, with its specific properties and interactions, must be considered individually.

Varghese and Flegal (1974) continuously recycled dehydrated poultry waste in laying hen rations at 12.5 and 25% of the diet for 33 recyclings to assess potential tissue mineral buildup. Muscle tissue, eggs and excreta were collected from the 25th through the 33rd cycle for analyses. Copper, mercury and zinc concentrations were not significantly increased due to recycling of the waste.

Smith and Lindahl (1977) reported elevated dietary ash diminishes the proportion of mineral absorbed in growing lambs. The ash content of most animal wastes is substantial. Feeding animal waste high in ash may reduce the amount of toxic or antagonistic minerals absorbed from dietary sources.

Currently, only a small amount of data are available on mineral profiles in feed ingredients and animal wastes and their effect on edible organ and tissue mineral profiles (Anonymous, 1977). A summary of the proximate analyses and mineral profile data appearing in the literature is shown in tables 1 through 8.

Feeds commonly fed to ruminants were surveyed and table 9 summarizes the concentrations of minerals of primary interest (arsenic, cadmium, copper, lead, mercury, selenium). The levels of minerals of primary interest in tissues from cattle and sheep, fed conventional rations and reported in the literature, are summarized in table 10. These tables indicate the paucity of data currently available for lesser researched, but important minerals receiving considerable attention from regulatory agencies.

The FDA has approved the use of several arsenicals in diets of poultry and swine but these are not approved for use in ruminants. Studies with broilers indicate a large portion of these arsenicals are excreted primarily in the feces (Smith and Calvert, 1976). Mean arsenic values for broiler litter, poultry waste and swine waste were 24, 2.3 and 5.6 ppm, dry basis, respectively (tables 2, 4 and 8).

Brugman *et al*. (1968) reported no accumulation of arsenic in tissues of sheep fed broiler litter. Webb and Fontenot (1975) in feeding trials of 121 days (trial 1) and 198 days (trial 2) fed broiler litter at 25 and 50%. Following 5-day withdrawal period, cattle were slaughtered and liver and longissimus muscle were

TABLE 2. MINERAL COMPOSITION OF BROILER LITTER[a]

	Cal-cium	Phos-phorus	Magne-sium	So-dium	Potas-sium	Alumi-num	Arse-nic	Barium	Boron	Cobalt	Copper	Iron	Manga-nese	Molyb-denum	Stron-tium	Zinc	Refer-ence
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
							40.4				214						1
							34.8										2
	2.5	1.6	0.35	0.42	1.77						23					343	3
	1.46	1.26															4
							18.1										5
							14.6										6
	1.97	1.07	0.37		1.7				33		29	1244	272	12.6		128	7
	1.64	1.46	0.31														8
	2.8	2.3	0.48														9
	1.9	1.6	0.46	0.58	1.9	305	12		41		105	490	242			253	10
	2.72	2.86															11
	2.48	2.26															11
	1.45	1.45	0.42	0.07	2.18	860		26	44	1	32	1000	225	4	64	125	12
	2.77	2.86															13
Mean	2.17	1.87	0.40	0.36	1.89	583	24	26	39	1	81	911	246	8.3	64	212	
Range	1.45	1.07	0.31	0.07	1.7	305	12		33		23	490	225	4		125	
	2.8	2.86	0.48	0.58	2.18	860	40.4		44		214	1244	272	12.6		343	

[a] Dry matter basis.

[b] References: 1) Webb and Fontenot (1975); 2) Fontenot (1975); 3) Couch (1974); 4) Harmon et al. (1974); 5) Calvert and Smith (1972); 6) Webb and Fontenot (1972); 7) Perkins and Parker (1971); 8) Fontenot et al. (1971a); 9) Fontenot et al. (1971b); 10) Ell-Sabban et al. (1969); 11) Bhattacharya and Fontenot (1966); 12) Hileman (1967); 13) Bhattacharya and Fontenot (1965).

TABLE 3. PROXIMATE ANALYSES AND ENERGY VALUES OF DRIED POULTRY WASTE[a]

Number of samples	Dry matter	Crude protein	Ether extract	Crude fiber	N.F.E.	Gross energy	Metabolizable energy	Ash	Reference[b]
	%	%	%	%	%	cal/kg	cal/kg	%	
10	92.1	33.1	2.0	16.5		3200		24.0	1
7		32.6	1.8	11.9			870	27.5	2
6	89.7	28.0	2.0	12.7	28.7	3533	1150	28.0	3
9	90.4	29.8	2.0	16.5	38.2		950	29.8	4
5	90.5	37.7	2.1	13.1	35.5			25.6	5
5	88.6	28.7	1.8	7.9	17.3		850	26.5	6
12		17.7	2.6	15.7	33.4			30.8	7
12	92.2	26.6	1.4	8.2	39.3			15.8	8
2								36.1	9
Mean	90.6	29.3	2.0	12.8	32.1	3367	955	27.1	
Range	88.6	17.7	1.4	7.9	17.3	3200	850	15.8	
	92.2	37.7	2.6	16.5	39.3	3533	1150	36.1	

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[a] Dry matter basis.

[b] References: 1) Evans *et al.* (1978); 2) Hodgetts (1971); 3) Bhattacharya and Taylor (1975); 4) Blair (1974); 5) Essig (1975); 6) Couch (1974); 7) Azevedo and Stout (1974); 8) Lowman and Knight (1970); 9) Benne *et al.* (1961).

TABLE 4. MINERAL COMPOSITION OF DRIED POULTRY WASTE[a]

	Calcium	Phosphorus	Magnesium	Sodium	Chlorine	Potassium	Arsenic	Boron	Bromine	Cadmium	Cobalt	Copper	Iron	Lead	Manganese	Molybdenum	Selenium	Zinc	Reference[b]
	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
	7.2	1.7	0.5	0.28		1.91						31	1216		232			276	1
	9.1									0.76		92	2740		394			399	2
	7.8	2.4	0.62		0.83							96	147		452			495	3
	8.8	2.5	0.67	0.94	0.94	2.33					0.001	150	2000		406			463	4
	8.3	2.4	0.75	0.4		1.5			19			66	2000		342			334	5
	8.5	2.1					2.34		16	1.2		49	1660	12.8			0.47	34	6
	7.8	2.2	0.63	0.42	0.93	1.37						61	630		291			325	7
	6.7	2.3	0.75	0.4		1.89													8
	4.8	1.5									1.0	29			245			431	9
	8.1	0.9	0.63			0.8		131				33	1014		196	12		196	10
Mean	7.7	2.0	0.65	0.49	0.9	1.63	2.34	131	17.5	0.98	0.5001	67	1426	12.8	320	12	0.47	328	
Range	4.8	0.9	0.5	0.28	0.83	0.8			16	0.76	.0001	29	630		196			34	
	9.1	2.5	0.75	0.94	0.94	2.33			19	1.2	1.0	150	2740		452			495	

[a] Dry matter basis.

[b] References: 1) Evans et al. (1978); 2) Calvert (1977); 3) Hodgetts (1971); 4) Bhattacharya and Taylor (1975); 5) Blair (1974); 6) Essig (1975); 7) Couch (1974); 8) Azevedo and Stout (1974); 9) Lowman and Knight (1970); 10) Benne et al. (1961).

TABLE 5. PROXIMATE ANALYSES AND ENERGY VALUES OF CATTLE WASTE[a]

Number of samples	Dry matter	Crude protein	Ether extract	Crude fiber	N.F.E.	Gross energy	Ash	Reference[b]
	%	%	%	%	%	cal/kg	%	
2	36.0	17.2	3.2	27.9	43.1	4736	8.6	1
2	90.0	16.6					7.6	2
3	91.6	13.2	2.8	31.4	47.2	4728	5.4	3
2	86.7	13.8	1.5	14.1			31.1	4
8	90.0	16.6					7.6	5
2		15.0					30.1	6
2		17.4	3.8	18.6	43.6		16.6	7
2	74.4	20.3					11.5	8
2		21.9					10.2	9
Mean	78.1	16.9	2.8	23.0	44.6	4732	14.3	
Range	36.0	13.2	1.5	14.1	43.1	4728	5.4	
	91.6	21.9	3.8	31.4	47.2	4736	31.1	

[a] Dry matter basis.

[b] References: 1) Harpster *et al.* (1978); 2) Essig (1975); 3) Lucas *et al.* (1975a); 4) Westing (1975); 5) Blair (1974); 6) Westing and Brandenburg (1974); 7) Azevedo and Stout (1974); 8) Anthony (1971b); 9) Benne *et al.* (1961).

TABLE 6. MINERAL COMPOSITION OF CATTLE WASTE[a]

	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Aluminum	Boron	Cadmium	Copper	Iron	Lead	Manganese	Molybdenum	Zinc	Reference[b]
		%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
	0.62	0.51	0.21	0.11	1.82	150	15		17	356		70		73	1
	1.56	0.75													2
	2.45	0.71						0.85			11.6				3
	1.6	0.75	0.27	0.36	0.72				16			89		112	4
	3.02	0.76		0.89				0.61			12.7				5
	2.91	0.92	0.58	0.19	0.56										6
	0.87	1.6	0.4		0.5				31	1340		147		242	7
	2.3	1.0	0.46		0.55		91		23	182		23	2	68	8
Mean	1.92	0.88	0.38	0.39	0.83	150	53	0.73	22	626	12.2	82	2	124	
Range	0.62	0.51	0.21	0.11	0.5		91	0.61	16	182	11.6	23		68	
	3.02	1.6	0.58	0.89	1.82			0.85	31	1340	12.7	147		242	

[a] Dry matter basis.

[b] References: 1) Harpster et al. (1978); 2) Essig (1975); 3) Westing (1975); 4) Blair (1974); 5) Westing and Brandenburg (1974); 6) Azevedo and Stout (1974); 7) Anthony (1971b); 8) Benne et al. (1961).

TABLE 7. PROXIMATE ANALYSES AND ENERGY VALUES OF SWINE WASTE[a]

Number of samples	Crude protein	Ether extract	Crude fiber	N.F.E.	Gross energy	Ash	Reference[b]
	%	%	%	%	cal/kg	%	
4	23.5	8.0	14.7	38.3	4570	15.3	1
21	18.9	6.6				18.1	2
24	19.0	5.0	18.2			17.0	3
3	16.5		17.9			16.3	4
6	12.5					28.8	5
Mean	18.1	6.5	16.9	38.3	4570	19.1	
Range	12.5	5.0	14.7			15.3	
	23.5	8.0	18.2			28.8	

[a] Dry matter basis.

[b] Reference: 1) Kornegay _et_ _al_. (1977); 2) Pearce (1977); 3) Hilliard (1977); 4) Robinson _et_ _al_. (1971); 5) Benne _et_ _al_. (1961).

TABLE 8. MINERAL COMPOSITION OF SWINE WASTE[a]

	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Aluminum	Arsenic	Boron	Cadmium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Selenium	Zinc	Reference[b]
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
	2.7	2.1	0.9		1.34						63							530	1
	3.2	2.5	0.8		1.2	544			1.0	6.0	249	1940	12.1	342	< 0.15	0.3	0.52	526	2
	3.5	2.6	0.7	0.3	1.0		5.57		0.77		280	2169	9.89					600	3
		1.8			0.06						354			189				1690	4
	2.0	0.6	0.29		1.5			143			18	1002		72		4.0		215	5
Mean	2.9	1.9	0.67	0.3	1.02	544	5.57	143	0.89	6.0	193	1704	11.0	201	< 0.15	2.2	0.52	712	
Range	2.0	0.6	0.29		0.06				0.77		18	1002	9.89	72		0.3		215	
	3.5	2.6	0.9		1.5				1.0		354	2169	12.1	342		4.0		1690	

[a] Dry matter basis.

[b] References: 1) Kornegay et al. (1977); 2) Pearce (1977); 3) Hilliard (1977); 4) Robinson et al. (1971); 5) Benne et al. (1961).

TABLE 9. LEVELS OF MINERALS OF PRINCIPLE INTEREST IN RUMINANT FEEDSTUFFS[a]

	Feed, ppm						
Element	Concentrate	Level	Protein supplement	Level	Roughage	Level	Reference
Arsenic	Cereal grain	.18 ± .05					Hamilton & Minski (1973)
			Fishmeal	2.7-9.7			Lunde (1968)
					Pasture,mix	< .5	Underwood (1971)
Cadmium	Corn	.035-.148					Garcia *et al.* (1974)
	Oats	.21					Maclean (1976)
			Soybean meal	< 1.			Jones *et al.* (1973)
					Clover	.02-.048	Williams & David (1973)
Copper	Oats	6.6					NRC (1976)
	Barley	8.6					NRC (1976)
			Fishmeal	9.1			NRC (1976)
			Soybean meal	40.8			NRC (1976)
					Alfalfa	14.4	NRC (1976)
					Bluegrass	14.1	NRC (1976)
Lead	Corn	< 1.					Underwood (1977)
	Corn	.27					Garcia *et al.* (1974)
			Soybean meal	4.0	Ryegrass	7.6	Jones & Clement (1972)
					Pasture,mix	.3-1.5	Mitchell & Reith (1966)
Mercury	Cereal grains	.005-.035	Fishmeal	.18			Underwood (1971)
Selenium	Oats	.2					
	Barley	.32	Salmon meal	1.9	Pasture,mix	.19	Miltmore *et al.* (1975)
	Corn	.032-.345	Soybean meal	.126			Ullrey *et al.* (1978)
					Hay, grass	.069	Perry *et al.* (1978)

[a] Dry matter basis.

TABLE 10. LEVELS OF MINERALS OF PRINCIPLE INTEREST IN RUMINANT TISSUES[a]

Element	Species	Type	Tissue, ppm						Reference
			Liver	Kidney	Muscle	Fat	Milk	Bone	
Arsenic	Cattle	Mature	.055						Becker (1976)
		Mature	< 1.	< 1.	.2	< 1.			Peoples (1964)
Cadmium	Cattle	Mature	.27±.04						Becker (1976)
							.003		Dorn et al. (1973)
							.02- .037		Murthy & Rhea (1968)
	Sheep	Lamb	1.69±.26	4.42±.5	.025±.001	.011±.001			Doyle et al. (1974)
Copper	Cattle	Mature	193.						Becker (1976)
		Calf	490.	13.8	4.6			1.2	Bingley & Dufty (1972)
							.086		Murthy et al. (1972)
Lead	Cattle	Mature	.34						Becker (1976)
			.68- 6.55						Hammond et al. (1956
					.1		.02- .08 .02- .04		Murthy et al. (1967)
	Sheep	Lamb	1.3±.24	1.0±.19				9.6±1.5[b]	Fick et al. (1976)
Mercury	Cattle	Mature	.016						Becker (1976)
			.01- .097	.01- .09					Prior (1976)
					< .1				Rancitelli et al. (1968)
							.003- .01		Mullen et al. (1975)
Selenium	Cattle	Mature	1.1						Becker (1976)
			.87- 1.72	5.70- 5.83	.29- .59	.021- .064			Ullrey et al. (1978)
							.06		Hadjimarkos (1968)
		Calf	.12	.85	.031				Perry et al. (1978)
			.91	2.7	.5				Kincaid et al. (1977)

[a] Dry matter basis.

[b] Ash weight basis.

assayed for arsenic. Values were similar, with the highest average arsenic value of .627 ppm, dry basis, found in liver of trial 2 cattle fed 50% litter. This is well below the FDA tolerance of 1 ppm, wet basis, for swine and poultry liver.

Mean liver arsenic in steers fed a ration containing poultry waste for 139 days was .3 ppm, dry basis (El-Sabban _et al._, 1970). Calvert (1973) fed rations containing 0 to 273.3 ppm arsenic, dry basis, to wethers for 28 days. Liver arsenic values for sheep fed the 0 and 273.3 ppm arsenic rations were < .01 and 29.2 ppm, respectively, after 28 days on trial. Following a 6-day withdrawal period liver arsenic values were < .01 and 5.0 ppm, respectively, indicating a rapid decline in tissue arsenic levels following withdrawal.

Copper is a widely used feed additive in diets of poultry and swine. In two successive feeding trials of 121 days (trial 1) and 198 days (trial 2) Webb and Fontenot (1975) fed copper containing broiler litter at 0, 25 and 50% of the ration to beef cattle. Litter copper levels were 230 ppm in trial 1 and 289 ppm for trial 2. Following a 5-day withdrawal period no significant differences were reported for muscle copper in both trials and liver copper in trial 1. Liver copper values in trial 2 were: control - 212 ppm; 25% ration - 434 ppm; and 50% ration - 542 ppm, dry basis, respectively.

Sheep were fed poultry waste at 0, 25 and 50% of the ration in an 88-day feeding trial and the respective copper values were 30, 24 and 35 ppm, dry basis (Thomas _et al._, 1972). At slaughter, liver and kidney copper values were not significantly different across treatments.

Calvert and Smith (1976) reported increases in liver copper when feeding poultry waste to cattle. The poultry waste contained 94 ppm copper, dry basis. Mean control liver copper levels were 158 ppm, compared to 333 ppm for liver from steers fed poultry waste. Blood, kidney and muscle copper values were similar between treatments.

Suttle _et al_. (1978), in a feeding trial of 112 days duration, assessed the accumulation of liver copper in lambs fed broiler litter or dried poultry waste at 15, 30, 45 and 60% of the ration. Liver copper values for increasing levels of waste for broiler litter were 686, 1009, 877, 874 and 269, 318, 379 and 411 ppm, dry basis, for dried poultry waste, respectively. Between the 10th and 15th week, 50% of the lambs on 45 and 60% broiler litter became sick and were slaughtered. Necropsy findings were dissimilar from those normally present with copper toxicity. One lamb fed 30% broiler litter did become jaundiced and indicated signs of copper toxicity after 98 days on trial.

Bruhn _et al_. (1977) and Calvert and King (1977) found no increase in copper content of milk from feeding 10 to 26% poultry waste in the diets of lactating cows.

Calvert and Smith (1976) reported no differences in cadmium and lead levels in steer rations containing 12% poultry waste, compared to controls. Tissue levels were similar with exception of kidney cadmium which was 1.7 ppm, dry basis, in steers fed poultry waste, compared to 5.0 ppm in control steers.

Cattle feedlot waste contained .61 ppm cadmium and 12.7 ppm lead, dry basis (Westing and Brandenburg, 1974). When fed at 14% of the diet there were no significant differences in liver cadmium and lead values between experimental and control steers. Levels of liver cadmium and lead were .062 and .567 ppm for control and .041 and .46 ppm, dry basis, for treated steers, respectively.

Bruhn et al. (1977) reported poultry waste contained 1.3 ppm cadmium, dry basis. Lactating cows fed poultry waste had mean cadmium values of 6.24 μg/kg raw milk, compared to 3.71 μg/kg for controls. These values were not significantly different. Lead content of poultry waste was 7 ppm, dry basis. Lead content of milk from lactating cows fed poultry waste and control ration were 49.4 and 56.2 μg/kg raw milk, respectively.

In perusing the literature, no reports appear on mercury and selenium in tissues of animals fed animal waste.

OBJECTIVES

Experiments were conducted to characterize mineral element levels in feedstuffs, animal wastes and cattle tissues.

The specific objectives were to:

1) Determine mineral element profiles of cattle tissues from cattle fed rations containing broiler litter or cattle waste;
2) Characterize mineral levels in animal wastes from several geographical areas and typical ruminant feedstuffs;
3) Assess performance of cattle fed rations containing broiler litter or cattle waste;
4) Evaluate carcass characteristics and taste of meat from cattle fed broiler litter.

EXPERIMENTAL PROCEDURE

Experiment 1 - Ensiled Corn Forage and Broiler Litter for Finishing Heifers

Forty-eight straightbred and crossbred weanling heifer calves (212 kg) were blocked by breeding and weight and randomly allotted within blocks to two sets of four pens of six head each for a 201-day feeding trial at the Shenandoah Valley Station, Steeles Tavern, Virginia. Four diets were fed to each of two pens of cattle. The negative control diet was composed of corn silage and the control diet consisted of corn silage and .9 kg soybean meal daily. The other two diets consisted of silage containing 70% corn forage and 30% broiler litter, dry basis, with and without .9 kg soybean meal daily. All silages were full fed and in each diet corn grain was fed at sufficient levels to provide a total concentrate (grain plus soybean meal) of 1% of body weight daily. Heifers were fed twice daily in protected feed bunks. Water and salt were provided free choice. Individual heifer weights were taken on commencement of the trial, at 28 day intervals during the trial and at termination. Intake of silage, corn grain and soybean meal was measured on a pen basis.

The litter was obtained from an indoor environmentally controlled broiler house at Rocco Feeds Inc., Harrisonburg, Virginia, and consisted of a wood shaving base and excreta from one group of broilers.

The broiler litter and corn forage contained 72 and 43% dry matter, respectively. To obtain 30% litter, dry basis, in the silage, 83% corn forage and 17% broiler litter were combined on an as fed basis. The litter was evenly distributed on top of each pre-weighed wagon load of corn forage with a front end loader which was pre-calibrated by weight with the litter to be used. Mixing of the corn forage and litter was accommodated as the wagon was emptied into the blower for introduction into the vertical silo for ensiling.

Most of the negative control heifers fed corn silage did not have sufficient finish to slaughter and were retained. Therefore, no carcass, sensory and tissue data will be presented on this group. Heifers were withdrawn from experimental rations 1 day prior to slaughter at Valleydale Packers, Roanoke, Virginia. At slaughter the liver, one kidney and omental fat samples were removed from each heifer, identified and frozen in double polyethylene bags. Following a 48-hour chill, yield and quality grade were placed on each carcass by a government grader and Dr. R. F. Kelly, and the data for each heifer were averaged. Quality grades were assigned using 1975 USDA standards. The left whole 6th-12th rib of each heifer was removed from the carcass and returned to the V.P.I.&S.U. Meat Laboratory for further analysis. The rib was divided into two sections: 6-7-8th for cooking, mechanical tenderness and sensory evaluation; 9-10-11th for separation and samples of lean and fat for neutron activation analysis. These rib sections, upon separation, were identified, double wrapped in freezer paper and frozen.

Prior to roasting, the 6-7-8th rib roast was thawed at room temperature for 16 hours. The roasts were weighed and roasted in a preheated oven (176 C) to an internal temperature of 70 C. Roasts were reweighed and cooking loss recorded. Samples of each cooked roast were scored by a trained eight-member sensory panel for tenderness (1 = very tender to 5 = very tough); juiciness (1 = very juicy to 5 = very dry); flavor (1 = very tasty to 5 = strong off-flavor); and overall acceptability (1 = very acceptable to 5 = very objectionable). Warner-Bratzler shear force measurements were made in duplicate on three 1.3 cm cores after the roasts were allowed to cool at room temperature to 3 C. Roasts were also subjected to Allo-Kramer shear press measurements.

The 9-10-11th rib was removed, weighed and separated into lean, fat and bone according to procedures developed by Hankins and Howe (1946). Upon separation, the respective tissues were weighed and the fat and lean portions were macerated in a Hobart food chopper. The liver, kidney and omental fat previously collected and frozen at slaughter were thawed and macerated. Two samples each of 9-10-11th rib muscle, external rib fat, liver, kidney, and omental fat from each carcass were randomly selected, placed in polyethylene bags which were placed in 1 liter waxed cylinder ice cream containers and frozen preparatory to neutron activation and atomic absorption analysis.

Experiment 2 - Dried Cattle Wastes as a Feed Ingredient for Finishing Steers

Trial I. Thirty-six crossbred yearling steers (321 kg) of British breeding and similar background, originating in Northern California, were blocked by frame size and weight, and randomly allotted within blocks to three pens of six head fed each of two diets (total of six pens). The 98-day feeding trial was conducted in open dry-lot pens with protected fence line feed bunks and cattle shades commencing in mid-spring at the Beef Unit at the California State Polytechnic University, Pomona. Cattle were allotted 27.9 sq m of area per head of which 9.3 sq m were under cover.

The ingredient composition of the control and 16% cattle waste (dry basis) rations are presented in table 21. Both rations were fed *ad libitum* and refusals collected and weighed back twice weekly. Water and iodized salt were provided free choice. Steers were implanted with 36 mg zeranol 30 days prior to initiation of the experiment. Individual steer weights were taken initially and at 28-day intervals during the trial between 0600 and 0700 hours. Feed intake was measured for each pen.

The cattle waste was obtained from open, unprotected dirt surface feedlot pens of the Roy Benton Feedyards, Walnut, California. Pens housing finishing cattle over the past 25 years, to whom high energy rations (70 to 80% concentrates) have been fed were scraped, leaving a manure layer in order to minimize contamination with dirt, and reduce ash content of the waste. The cattle waste was ground through a 1.9 cm screen, passed under a magnet and put into windrows

1.5 m in height. The waste was covered with a plastic tarp and aged for 45 days.

The control ration and cattle waste contained 86.6 and 86.7% dry matter, respectively. To blend the waste in the ration 16.0% waste, dry basis, and 84% control ration were combined. Rations were formulated with a Thompson and Gill continuous flow percentage mill equipped with a horizontal mixer. Random grab samples of the rations and cattle waste were taken weekly, stored and composited for analysis.

Steers were withdrawn from rations 24 hr prior to slaughter at Acme Meat Packing, Vernon, California. At slaughter a 400 g liver and 200 g kidney fat sample were removed from each steer, identified and immediately frozen in double polyethylene bags and stored.

Samples were thawed at room temperature prior to analysis and macerated in 200 ml stainless steel containers with a Waring blender. Random samples of the macerated tissue were lyophilized to obtain tissue dry matter. The dry samples were dry ashed preparatory to analysis by atomic absorption spectrophotometry for nickel and lead. Thawed, macerated tissues were randomly sampled for neutron activation analysis.

Trial II. Twenty crossbred yearling steers (316 kg) of British and exotic breeding and similar background were blocked by frame size and weight and allotted randomly within blocks to two diets with two pens of five head for each diet. The 93-day trial commenced in mid-June. All procedures, conditions and rations were similar to trial I with the following exceptions: a) cattle were allotted 33.5 sq m area per head, of which 11.2 sq m were under roof; b) a 400 g kidney sample was collected in addition to kidney fat and liver for mineral profile characterization.

Experiment 3 - Wintering Cows on Broiler Litter, Corn Grain and Supplemental Copper

In December 1972, 42 weanling heifers were blocked by breed and weight and randomly allotted within blocks to three lots of 14 head each (12 cows/treatment remained on 4/19/77) for a long term feeding trial at the Shenandoah Valley Station, Steeles Tavern, Virginia. During the fourth and fifth winters the rations were: lot 1 - hay (grass-legume mixture); lot 2 - 80% broiler litter; 20% ground shelled corn; lot 3 - 80% broiler litter, 20% ground shelled corn and 160 ppm supplemental copper. During the second and third winters the rations of lots 2 and 3 consisted of 75% litter and 25% ground ear corn. A small amount of long hay was fed the cattle in lots 2 and 3 when no dry coarse grazing was available. The litter was from the same source given in experiment 1. The litter was stacked in an open shed prior to combining with ground corn for feeding. Chemical composition, as per procedures reported previously, and copper levels of the rations are reported in table 30.

Liver samples were taken from all cows using the aspiration biopsy technique developed by Erwin _et_ _al_. (1956). Biopsy samples were obtained on December 28, 1976 and April 19, 1977, which coincided with the starting and ending dates of the wintering trial were used in the present study. Approximately 1 to 3 g of liver were obtained from each cow and immediately chilled in 10 ml vials. Initially, samples were assayed for copper level by atomic absorption. Due to the limited sizes of samples, only neutron activation analysis was conducted. Lead and nickel concentrations were not measured.

Experiment 4 - Chemical Composition and Mineral Profile Characterization of Animal Waste by Type

Twenty-eight waste samples from 15 different sources representing five waste types from four geographical regions were received as a result of soliciting some 20 individuals actively engaged in research or production involving animal waste.

Upon receipt, samples were dried for 48 hr in a forced air oven at 80 C. Dried samples were ground through a 1 mm sieve and retained in glass containers.

Proximate, neutron activation and atomic absorption analyses were run on all samples.

Procedures

Analytical and statistical procedures common to all experiments were as follows:

Proximate Analysis. Random grab samples of all feed ingredients were taken at intervals for analysis. Total kjeldahl nitrogen was determined by A.O.A.C. (1975). Dry matter for all silages was determined by drying duplicate samples of approximately 200 g each for 48 hr in a forced-air oven at 80 C. The duplicate dry matter samples were composited and ground through a 1 mm sieve. Samples were analyzed for crude fiber (Whitehouse et al., 1945), ash, dry matter and ether extract (A.O.A.C., 1975). NFE was calculated.

Mineral Classification. The 43 mineral elements profiled were classified according to a system reported by Huheey (1972). The classification was based on the specific chemical and physical properties of the elements and their periodicity. The five categories used were: Heavy Metals - Transition; Heavy Metals - Inner Transition; Light Metals; Metalloids; and Non-Metals. Arsenic and selenium are commonly referred to as heavy metals in periodicals and the literature. However, arsenic is a metalloid and selenium a non-metal based on chemical and physical properties.

Neutron Activation Analysis. Basically, Neutron Activation Analysis is a technique in which a stable isotope when immersed in a flux of neutrons undergoes a nuclear transformation producing a radioactive nuclide which emits gamma and X-radiation with characteristic energies and half lives (Lyon, 1964). Ledicotte (1968) reported 90 elements can be detected and accurately measured in concentrations ranging from 10^{-6} to 10^{-15} g in biological systems. Activation analysis allows the measurement of most elements heavier than neon (atomic weight = 20.183) with sensitivities up to 10^{-15} g (Kamen, 1951). The detection limits are dictated by the neutron flux and sensitivity of the measuring equipment. Several elements can be measured simultaneously (Battye et al., 1967). Neutron activation analysis is a nondestructive technique, a condition particularly important for in vivo studies and also where additional procedures need to be run on a limited amount of sample (Taylor *et al.*, 1967).

Tissue samples were thawed at room temperature for 12 hr prior to preparation for activation analysis. Approximately .5 to .7 g of tissue samples (wet basis) were weighed into pre-weighed pneumatic tubes. Pneumatic tubes were reweighed to obtain tissue weights by difference and placed into identified whirl pak polyethylene bags and refrigerated, in preparation for activation analysis. Duplicate samples of each tissue activated were weighed, lyophilized and reweighed to obtain dry matter values for reporting respective tissue mineral concentrations on a dry basis.

Composite samples of wastes, rations and separate feed ingredients were taken and ground in a Wiley micro mill through a 20 mesh screen. Due to higher concentrations of minerals in the feed and waste, compared to tissue, .06 to .1 g samples were weighed into pre-weighed penumatic tubes. Pneumatic tubes were reweighed to obtain weights by difference and placed in identified whirl pak polyethylene bags preparatory to activation analysis. Duplicate samples of each feed and waste activated were weighed and dried in a forced air oven at 80 C for 48 hours. Samples were reweighed to obtain dry matter values for reporting respective mineral concentrations on a dry basis.

All samples were activated in accordance with a procedure described by Furr (1971). Activated samples were removed from the reactor and placed on a lithium-germanium detector to record emissions from activated elements in the samples. Detector data were stored on magnetic tape and read into an IBM 360 computer for analysis. Mineral concentrations were reported in parts per million (ppm), dry basis.

Roscoe and Furr (1976) reported results obtained by the Neutron Activation Laboratory at Virginia Polytechnic Institute and State University correlate very well with the National Bureau of Standards certified values for bovine liver (NBS-SRM 1577). Three bovine liver (NBS-SRM 1577) samples were analyzed along with liver samples from heifers and steers on experiment. Average mineral values are reported in table 3 of the appendix. The values are generally within the range of standard values (Becker, 1976) except for cadmium and uranium.

Atomic Absorption Spectrophotometry. Lead and nickel values for all tissue, feed and waste samples were obtained by atomic absorption due to interferences of these minerals when using neutron activation. Samples of approximately 10 g of tissue (wet basis) and 3 g feed and waste (air dry) were weighed into pre-weighed acid washed vitreous crucibles and dry ashed in a muffle furnace at 500 C for 10 hours. Temperature was gradually raised by 50 C increments starting at 300 C until reaching 500 C to prevent splattering and ash loss. Samples were cooled for 1 hour in glass desiccators and weighed. Each sample received aliquots of 3 ml hydrochloric acid and 3 ml nitric acid and allowed to stand for 12 hours. Samples were eluted into 10 ml volumetric flasks with deionized water and analyzed for lead and nickel by standard procedure using a Perkin-Elmer 403 Atomic Absorption Spectrophotometer.

Statistical Analysis. The least squares analysis of variance in the general linear model described by Barr *et al*. (1976) was used in analyzing all experimental data for statistical significance. Significant differences amont treatment means were tested using the multiple range test of Duncan (1955). An example of the least squares analysis of variance and mean separation is presented in table 1 of the appendix.

RESULTS AND DISCUSSION

Emphasis will be placed on minerals of primary interest (arsenic, cadmium, copper, lead, mercury, selenium), those minerals showing significance between treatments and minerals showing trends between treatments.

Experiment 1 - Ensiled Corn Forage and Broiler Litter for Finishing Heifers

Chemical composition of the beef heifer ration ingredients are presented in table 11. The corn forage-litter mixture ensiled quite well. When 30% broiler litter, dry basis, was ensiled with corn forage, the crude protein content was increased from 7.1 to 13.3%, which meets the protein requirement of finishing heifers.

Heifer performance data are shown in table 12. Heifers fed corn silage with no protein supplement gained .53 kg/day, which is less than all other treatments ($P < .01$). Heifers fed diets containing a protein supplement or corn-litter silage with no protein supplement had approximately 75% greater daily gain than the heifers receiving unsupplemented corn silage alone. Due to the very poor performance of the heifers fed corn silage and no protein supplement, these were not slaughtered because they lacked sufficient finish and quality grade. Hence, data will not be presented for on this group of cattle except feedlot performance.

The heifers fed corn-litter silage with protein supplement tended to have the highest level of gain, .98 kg/day, compared to

TABLE 11. CHEMICAL COMPOSITION OF BEEF HEIFER RATION INGREDIENTS

	Corn silage[a]	Corn-litter silage	Corn grain[b]	Soybean meal[c]
Dry matter, %	36.7	39.2	90.0	89.7
Composition of dry matter, %				
Crude protein	7.1	13.3	8.2	46.9
Crude fiber	21.4	20.8	4.0	10.2
Ether extract	2.9	2.9	4.4	1.5
Ash	2.8	6.6	1.4	6.4
NFE	65.8	56.4	82.0	35.0

[a] Corn, aerial pt, ensiled, dough stage, (3), IRN 3-08-153.
[b] Corn, dent yellow grain, grnd, (4), IRN 4-02-931.
[c] Soybean meal, solv-extd, grnd, (5), IRN 5-04-604.

TABLE 12. PERFORMANCE OF HEIFERS FED CORN SILAGE OR CORN-LITTER SILAGE

Item	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.	Corn silage	± S.E.
Number of heifers	12		12		11		12	
Days on trial	201		201		201		201	
Initial weight, kg	219.0	7.71	215.1	7.24	214.2	8.74	199.1	5.85
Final weight, kg	401.5^{a}	11.09	412.7^{a}	9.44	399.6^{a}	12.33	306.0^{b}	13.13
Daily gain, kg	.91^{a}	.03	.98^{a}	.03	.92^{a}	.04	.53^{b}	.04
Average daily feed intake, kg^{c}								
Silage	11.20		11.20		9.66		5.31	
Corn grain	3.67		2.86		2.63		3.13	
Soybean meal			.91		.91			
Feed/kg gain, kg^{c}								
Silage	5.58		5.13		4.67		4.50	
Corn grain	1.81		1.32		1.27		2.63	
Soybean meal			.41		.45			

[ab] Means in the same row with different superscripts are different ($P < .01$).

[c] As fed basis.

.92 kg for heifers fed corn silage and protein and .91 kg for those fed corn-litter silage with no protein supplement. Silage intakes were greater for the corn-litter silage groups, a definite indication that the litter silage was palatable. Concentrates required per kilogram of gain were greatest for the unsupplemented corn silage group. The amounts required for the other treatments were lower than the unsupplemented corn silage fed heifers.

In a subsequent feeding trial with finishing heifers reported by McClure et al. (1978) the corn litter silage group tended to outgain the corn silage plus protein heifers and gain was similar to corn-litter silage plus protein heifers, indicating that litter provided adequate supplementary protein. Daily feed intake was higher for the heifers on treatments receiving broiler litter than for the others.

Mean values for heifer carcass characteristics are presented in table 13. No significant differences among treatments were found for the major carcass characteristics such as USDA quality and yield grades which are of primary economic importance to the producer. Carcasses of heifers graded low to average choice and the yield grade averaged 3.7. Corn-litter silage fed heifers had a lower internal fat ($P < .05$) than those receiving the other treatments. Feeding of broiler litter did not affect the characteristics of principle interest to the producer and are congruent with results reported by Fontenot et al. (1966) and Cullison et al. (1976).

The results for organoleptic characteristics of the meat are

TABLE 13. COMPARISON OF MEAN VALUES FOR CARCASS CHARACTERISTICS OF HEIFERS

Trait	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.
Number of carcasses	12		12		11	
Carcass weight, kg	236.0	7.276	245.2	5.487	232.0	8.774
Dressing percent	58.74	.4285	59.49	.9199	57.94	.5339
Fat thickness, mm[a]	25.06	.1530	25.29	.1721	25.24	.1464
Kidney, pelvic, and heart fat, %	2.750^b	.1707	3.025^c	.1060	2.873^b	.1538
Longissimus muscle area, cm^2	63.71	2.246	65.70	1.917	63.99	2.965
USDA Yield Grade	3.790	.1997	3.792	.1835	3.760	.2228
USDA Quality Grade[d]	13.08	.4344	13.42	.3362	12.82	.4635
Composition of 9-10-11th rib, %						
Bone	15.97^b	.4505	14.78^c	.3790	14.52^c	.4072
Lean	42.69	.8210	41.62	1.042	42.25	1.276
Fat	41.34	1.112	43.60	1.175	43.23	1.586

[a] Fat thickness at the 12th rib - 3/4 measurement.

[bc] Means in the same row with different superscripts are different ($P < .05$).

[d] Code: 12 = Low Choice; 13 = Choice; etc.

given in table 14. No significant differences among treatments were found for flavor, juiciness, tenderness, and overall acceptability. In fact, there was a trend for meat from the corn-litter heifers to be more acceptable than that from the controls. This is in agreement with results reported by Fontenot _et_ _al_. (1963, 1966, 1971a) and Cullison _et_ _al_. (1976). Warner-Bratzler shear force values were lower ($P < .05$) for the meat from heifers fed corn-litter silage than the other treatments, indicating a higher degree of tenderness. Although not significantly different, the Allo-Kramer shear force values were very similar to the Warner-Bratzler shear force values, reflecting a trend toward more tenderness of the meat from litter-fed heifers. There were no differences in cooking loss. Results indicate the incorporation of broiler litter into rations did not adversely affect the acceptability or palatability of roasts as measured subjectively by a taste panel and objectively by mechanical means. In fact, litter fed heifers tended to be more tender.

Mineral profiles of feeds and broiler litter fed to the beef heifers are presented in table 15. Cadmium concentration of broiler litter was considerably higher than for the other feedstuffs used. Values for lead were slightly higher than those of other feedstuffs. The mercury content was low for all feedstuffs. Molybdenum and vanadium were highest for broiler litter. Copper content in litter (593 ppm) was much higher than for the other feedstuffs and was undoubtedly related to the use of copper sulfate in the chick diets. Arsenic was quite high in the litter (75.9 ppm) compared to the

TABLE 14. COMPARISON OF MEAN VALUES FOR PALATABILITY TRAITS OF HEIFERS

Parameter	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.
Flavor rating[a]	2.208	.0877	2.069	.0694	2.198	.0668
Juiciness rating[a]	2.402	.0777	2.279	.1722	2.318	.1018
Tenderness rating[a]	2.346	.1814	2.043	.1435	2.273	.2616
Overall acceptability rating[a]	2.318	.1205	2.043	.1162	2.241	.1575
Warner-Bratzler shear force value, kg	6.692[b]	.5010	5.575[c]	.3165	6.718[b]	.4346
Allo-Kramer shear value, kg	6.217	.7951	5.475	.5154	6.473	.5283
Cooking loss, %	34.24	.6485	33.56	.6210	33.78	.6643

[a] Code: 1 = very acceptable; 3 = acceptable; etc.

[bc] Means in the same row with different superscripts are different ($P < .05$).

TABLE 15. MINERAL PROFILES OF FEEDS AND BROILER LITTER FED TO BEEF HEIFERS[a]

	Corn silage	Corn-litter silage	Corn	Soybean meal	Broiler litter
Heavy metals - transition					
Aluminum	125.5	355.5	20.29	89.45	991.7
Cadmium	.8364	.0	.5232	.1684	6.072
Chromium	.3241	.9098	1.281	2.210	2.622
Cobalt	.4809	1.150	.4485	.5577	2.288
Copper	4.391	10.46	1.239	12.63	593.1
Gold	.0073	.0084	.0	.0	.0
Hafnium	.1673	.2196	.0	.0	.0694
Iron	188.2	334.6	267.0	1021.	1023.
Lanthanum	.1464	.8888	.1068	.3052	3.259
Lead	1.415	1.842	1.400	1.632	1.947
Manganese	81.55	146.4	8.863	51.56	371.0
Mercury	.0	.0105	.0534	.0	.0346
Molybdenum	1.004	1.987	.0000	1.789	9.186
Nickel	.0372	.1290	.0353	.5610	.7710
Scandium	.0209	.0627	.0	.0105	.1976
Tantalum	.0	.0	.1602	.0	.1421
Tin	.0	.0	.0	.0	16.66
Titanium	28.23	40.78	9.824	8.839	44.70
Tungsten	.0	.1778	.0534	.1684	.8564
Vanadium	.2823	1.569	.1922	.2631	5.721
Zinc	36.59	146.4	35.24	90.50	495.8
Light metals					
Barium	.8360	1.882	1.388	.0	39.52
Calcium	2404.	7947.	106.8	3262.	32241.
Cesium	.1882	.0	.0	.0	.1666
Magnesium	1986.	2823.	950.3	3367.	6344.
Potassium	10036.	16731.	4271.	33673.	36719.
Rubidium	7.318	11.50	.0	14.73	21.50
Sodium	25.10	1255.	12.00	91.00	6633.
Strontium	24.05	2.405	.0	17.89	87.39
Heavy metals - inner transition					
Cerium	.3764	2.301	.0	.0	5.581
Dysprosium	.0314	.3451	.0214	.0421	1.213
Europium	.0	.0209	.0054	.0210	.1664
Lutetium	.0042	.0314	.0107	.0	.0
Samarium	.0836	.6693	.0032	.0631	2.740
Thorium	.3973	.0627	.0	.1999	.7211
Uranium	.0209	.7215	.0	.0210	2.635
Ytterbium	.0314	.0	.0	.0842	.5998
Metalloids					
Antimony	.0941	.0	.3417	.3157	.0
Arsenic	.0418	15.69	.0534	.0211	75.93
Non-metals					
Bromine	6.168	5.961	.6620	4.525	11.09
Chlorine	2404.	3555.	469.8	221.0	8388.
Iodine	.3346	.1046	.1602	.6103	7.457
Selenium	.0	1.778	.0	.8103	1.086

[a] All values PPM, dry matter basis.

other feedstuffs. Selenium was a little higher in the litter than soybean meal and corn silage. The values for corn silage are strikingly high, since selenium in feeds in this area is usually below .1 ppm, dry basis.

When comparing the minerals of primary interest with values for feeds appearing in the literature (table 9) and with values for broiler litter (table 2), arsenic was considerably higher than values reported for corn silage and broiler litter. Cadmium was slightly higher than reported for corn silage and corn. Copper values of conventional feeds were lower than or similar to values of comparable feedstuffs in table 9. The broiler litter copper level of 593.1 ppm is very high compared to the range reported in the literature (23 to 105 ppm, dry basis). No lead values were reported for broiler litter but values for other feeds are within the ranges previously reported. Mercury values for corn and soybean meal are congruent with values previously reported.

Mineral profiles in the liver of beef heifers fed corn silage and corn litter silage are presented in tables 16 and 17. Although not significantly affected by treatment, cadmium was higher than the liver cadmium value reported in the literature. Liver cadmium values were 1.05, 1.228, 1.197 ppm, dry basis, respectively, for cattle fed corn-litter silage, corn-litter silage and protein supplement, and corn silage plus protein supplement. Liver copper values reflected the incorporation of broiler litter in the heifer rations. There were differences ($P < .01$) between the control

TABLE 16. MINERAL PROFILES IN LIVER OF BEEF HEIFERS FED CORN SILAGE AND CORN-LITTER SILAGE[a]

Heavy metals - transition	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.
Aluminum	8.646	.6131	7.844	.3526	8.759	.6232
Cadmium	1.050	.3039	1.228	.3125	1.197	.2646
Chromium	.6342	.2029	.4737	.2133	.3000	.1381
Cobalt	.4243	.0214	.3937	.0293	.3754	.0227
Copper	516.7^{d}	34.78	455.9^{d}	29.43	219.7^{e}	18.16
Gold	.0008	.0003	.0011	.0003	.0013	.0003
Hafnium	.0434	.0201	.0484	.0177	.0403	.0154
Iron	201.0	14.18	198.0	14.53	195.1	15.61
Lanthanum	.0793	.0131	.0695	.0145	.0677	.0151
Lead	.1361	.0126	.1532	.0119	.1484	.0133
Manganese	7.842^{c}	.3290	9.099^{b}	.2794	8.788^{b}	.3604
Mercury	.0664	.0228	.0620	.0274	.0226	.0119
Molybdenum	2.470	.1154	2.750	.1624	2.485	.2714
Nickel	.0351	.0052	.0395	.0047	.0538	.0078
Scandium	.0031	.0022	.0019	.0010	.0014	.0009
Tantalum	.0439	.0216	.0575	.0197	.0446	.0227
Tin	2.636	.8588	1.017	.3868	.9718	.4789
Titanium	2.888^{b}	.7025	1.184^{c}	.4636	1.343^{bc}	.5213
Tungsten	.1444	.0353	.1654	.0303	.1529	.0349
Vanadium	.0352	.0073	.0569	.0287	.0132	.0043
Zinc	161.3^{bc}	7.356	154.0^{b}	7.067	175.9^{c}	4.171

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

[de] Means in the same row with different superscripts are different ($P < .01$).

TABLE 17. MINERAL PROFILES IN LIVER OF BEEF HEIFERS FED CORN SILAGE AND CORN LITTER SILAGE[a]

	Corn-litter silage	$\pm$ S.E.	Corn-litter silage + protein	$\pm$ S.E.	Corn silage + protein	$\pm$ S.E.
Light metals						
Barium	1.956^{b}	.5040	.9369^{bc}	.4847	.4832^{c}	.2854
Calcium	94.81	20.23	115.3	19.32	130.7	18.84
Cesium	.0563	.0238	.0118	.1126	.0302	.0983
Magnesium	503.5^{bc}	27.76	545.3^{b}	30.98	432.1^{c}	55.90
Potassium	10271.	524.5	10334.	251.0	10201.	481.6
Rubidium	25.80	1.351	23.97	1.583	25.21	1.274
Sodium	1895.	106.6	1859.	62.67	1911.	85.59
Strontium	5.952	2.591	4.352	2.753	5.968	1.997
Heavy metals - inner transition						
Cerium	.1149^{bc}	.0552	.2811^{b}	.0995	.0532^{c}	.0285
Dysprosium	.0147	.0056	.0111	.0037	.0093	.0039
Europium	.0524	.0194	.1126	.0578	.0983	.0384
Lutetium	.0288	.0185	.0233	.0119	.0155	.0089
Samarium	.0215	.0133	.0182	.0057	.0808	.0718
Thorium	.2299	.0559	.2397	.0533	.2376	.0576
Uranium	.0003	.0003	.0055	.0055	.0031	.0031
Ytterbium	.0578	.0237	.0351	.0137	.0347	.0127
Metalloids						
Antimony	.0680	.0209	.0676	.0102	.3738	.2804
Arsenic	.1824	.0585	.1680	.0518	.3034	.2499
Non-metals						
Bromine	3.746^{b}	.2029	4.193^{bc}	.2236	4.711^{c}	.3037
Chlorine	2484.^{d}	90.81	2198.^{e}	45.82	2321.^{de}	47.78
Iodine	.1721	.0309	.1400	.0254	.1343	.0386
Selenium	.6104	.1337	.7340	.0829	.8988	.2266

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

[de] Means in the same row with different superscripts are different ($P < .01$).

ration and the litter-containing rations. Values for cattle fed corn-litter silage alone and supplemented with soybean meal were 516.7 and 455.9 ppm, dry basis, respectively, compared to 219.7 ppm for those not fed litter. No differences were found in lead, mercury or selenium content, nor did the liver mineral profiles exceed those reported in the literature (table 10).

The liver arsenic levels do not reflect arsenic levels in the litter. In fact, the heifers not receiving litter had a higher liver arsenic (.3034 ppm, dry basis) value than litter silage heifers (.1824 and .1680 ppm, dry basis). However, values for all treatments did not exceed the arsenic values for liver presented in table 10, which summarizes mineral levels in ruminant tissues from cattle and sheep fed conventional rations. Furthermore, the values are much lower than the value of 1 ppm, wet basis, allowed by the FDA for swine and poultry liver diets.

Magnesium and cerium were lower ($P < .05$) in the liver of heifers fed corn silage than in the liver of the corn-litter supplemented with soybean meal group, but not significantly different from the liver of corn-litter heifers. Livers of corn-litter heifers were lower ($P < .05$) in manganese than those of the other heifers. Liver bromine of the corn-litter silage heifers were lower ($P < .05$) than corn silage fed heifers. Zinc values were higher ($P < .05$) in the corn silage fed group than the corn-litter heifers fed soybean meal, but not significantly different from the corn-litter fed heifers. Chlorine and titanium were significantly lower in the soybean meal supplemented corn-litter group than the corn-litter group, but not significantly different than in the corn silage heifers.

Mean kidney mineral profile values for beef heifers are shown in table 18. Kidney mineral profiles across all treatments for arsenic, cadmium, copper, lead, mercury and selenium fall within the reported values in the literature presented in table 10. Kidney arsenic values were lowest ($P < .01$) for the corn silage fed heifers. This elevated arsenic value in litter fed heifers reflects the higher arsenic in litter resulting from the use of arsenicals in broiler production.

Zinc values were considerably higher ($P < .05$) in the kidneys of the control heifers than in either treatment receiving broiler litter. Control heifers tended to be higher in bromine than the other heifers. Cesium and uranium values were low in all heifers, but there were some differences among treatments.

Muscle profile values of beef heifers fed corn silage and corn litter silage are presented in table 19. In comparing the minerals of primary interest, muscle cadmium was higher for all treatments, compared to literature values (table 10). Respective values for corn-litter, supplemented corn-litter and corn silage heifers and table 10 were .994, .734, .789 and .025 ppm, dry basis, respectively. Muscle copper values were strikingly higher for all treatments, compared to values in the literature (table 10). The elevated copper in the muscle of the litter fed heifers can be

TABLE 18. MINERAL PROFILES IN KIDNEY OF BEEF HEIFERS FED CORN SILAGE AND CORN-LITTER SILAGE[a]

	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.
Heavy metals - Transition						
Aluminum	6.895	.6341	6.439	.7379	7.540	.6113
Cadmium	2.114	.4731	1.076	.1439	1.525	.3559
Chromium	.6665	.1405	.5772	.1503	.6626	.1241
Cobalt	2.497	1.776	.9064	.5925	1.081	.8400
Copper	6.639	4.0954	2.698	1.275	4.275	1.793
Gold	.0020	.0007	.0023	.0007	.0016	.0004
Hafnium	.0444	.0139	.0350	.0135	.0295	.0190
Iron	243.9	15.77	239.4	11.08	236.4	14.40
Lanthanum	.0755	.0154	1.208	1.126	.0785	.0100
Lead	.5133	.0236	.4457	.0241	.4827	.0449
Manganese	4.091	.2888	4.228	.3460	4.349	.2805
Mercury	.1402	.0560	.0807	.0230	.0481	.0203
Molybdenum	1.448	.1052	1.294	.1030	1.201	.0654
Nickel	1.013	.0719	.8764	.0733	.7401	.1269
Scandium	.0022	.0008	.0027	.0007	.0010	.0005
Tantalum	.0859	.0249	.0727	.0220	.0819	.0206
Tin	4.822	1.051	3.107	.8412	3.702	1.007
Titanium	4.830	1.243	3.213	1.389	4.783	2.088
Tungsten	.2163	.0491	.3417	.1339	.3122	.0771
Vanadium	.1070	.0238	.0776	.0144	.0642	.0189
Zinc	85.94[b]	1.348	83.15[b]	1.937	92.62[c]	2.846
Light metals						
Barium	6.834	1.481	4.423	1.546	7.338	1.859
Calcium	226.6	32.67	205.9	34.28	132.5	37.64
Cesium	.0382[b]	.0150	.0938[c]	.0168	.0535[bc]	.0182
Magnesium	496.7	33.05	478.1	25.37	555.1	44.70
Potassium	9997.	510.4	10506.	1026.	10769.	826.9
Rubidium	15.16	.9451	23.08	8.128	16.21	.4966
Sodium	5263.	269.0	6377.	1045.	5945.	174.2
Strontium	16.65	4.437	12.21	4.039	14.60	5.055
Heavy metals - Inner transition						
Cerium	.3642	.0766	.2912	.0656	.2166	.0824
Dysprosium	.0498	.0353	.0143	.0024	.0485	.0360
Europium						
Lutetium	.0049	.0013	.0047	.0011	.0045	.0013
Samarium	.0337	.0069	.0285	.0101	.0188	.0027
Thorium	.1995	.0445	.1534	.0404	.1536	.0265
Uranium	.0872[b]	.0198	.0346[c]	.0177	.0381[bc]	.0112
Ytterbium	.0337	.0083	.0447	.0135	.0540	.0147
Metalloids						
Antimony	.2876	.2098	.1093	.0418	.1129	.0349
Arsenic	.4011[d]	.0458	.4256[d]	.0496	.1298[e]	.0370
Non-metals						
Bromine	13.00[b]	.7324	15.02[bc]	1.183	19.22[c]	2.283
Chlorine	6013.	253.0	7897.	1459.	5820.	321.2
Iodine	.2771	.0623	.2339	.0518	.2737	.1001
Selenium	4.076	.1266	4.061	.1469	4.091	.1634

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different (P < .05).

[de] Means in the same row with different superscripts are different (P < .01).

TABLE 19. MINERAL PROFILES IN RIB MUSCLE OF BEEF HEIFERS FED CORN SILAGE AND CORN-LITTER SILAGE[a]

	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.
Heavy metals - transition						
Aluminum	6.205	.2338	9.242	1.636	8.664	.9599
Cadmium	.9948	.2219	.7335	.1405	.7894	.2103
Chromium	.2239	.0608	.6722	.5067	.4000	.1431
Cobalt	.1851	.0115	.1983	.0118	.1933	.0147
Copper	49.26^{b}	1.149	42.06^{c}	2.273	45.07^{bc}	1.899
Gold	.0013	.0003	.0027	.0017	.0018	.0005
Hafnium	.0162	.0088	.0196	.0067	.0289	.0109
Iron	64.82	6.210	63.81	8.356	79.76	7.596
Lanthanum	.0655	.0188	.0513	.0116	.0469	.0074
Lead	.1484	.0107	.1327	.0075	.1293	.0057
Manganese	.3678	.0656	.3781	.0660	.6385	.2522
Mercury	.0393	.0227	.0106	.0055	.0057	.0030
Molybdenum	.1613	.0917	.0576	.0290	.1018	.0290
Nickel	.0884	.0094	.0851	.0085	.1157	.0126
Scandium	.0015	.0007	.0011	.0007	.0007	.0004
Tantalum	.0168	.0100	.0388	.0173	.0462	.0263
Tin	.4957	.2529	.8027	.3211	.3567	.1804
Titanium	1.214	.3554	1.369	.3925	1.860	.3671
Tungsten	.1781^{b}	.0424	.1552^{b}	.0139	.0518^{c}	.0220
Vanadium	.0113^{b}	.0031	.0027^{c}	.0010	.0123^{b}	.0031
Zinc	119.9	3.617	122.2	10.28	121.9	8.048
Light metals						
Barium	.7446	.2526	.7850	.3009	.9908	.3687
Calcium	135.4	9.738	131.0	20.78	99.35	10.29
Cesium	.0633^{d}	.0121	.0225^{e}	.0096	.0674^{d}	.0164
Magnesium	632.8	19.07	577.5	16.18	622.6	24.10
Potassium	12154.^{b}	222.0	11158.^{c}	302.9	11727.^{bc}	464.9
Rubidium	11.58	.5702	12.90	.0586	11.80	.6255
Sodium	1221.	41.76	1146.	51.11	1219.	41.15
Strontium	2.491	.9545	2.261	.8367	2.216	.9393
Heavy metals - inner transition						
Cerium	.1968	.0845	.1528	.0523	.1480	.0735
Dysprosium	.0083^{b}	.0031	.0015^{c}	.0009	.0055^{bc}	.0020
Europium	.0534	.0184	.0401	.0095	.0623	.0429
Lutetium	.0040	.0013	.0712	.0660	.0056	.0018
Samarium	.0232	.0103	.0131	.0049	.0077	.0033
Thorium	.1827^{b}	.0525	.1291^{bc}	.0349	.0539^{c}	.0240
Uranium	.0106	.0056	.0079	.0074	.0000	.0000
Ytterbium	.0306	.0098	.0336	.0158	.0376	.0075
Metalloids						
Antimony	.0334	.0111	.0602	.0125	.0354	.0082
Arsenic	.2923	.0380	.2013	.0408	.3042	.1363
Non-metals						
Bromine	1.959^{b}	.0922	2.177^{bc}	.1178	2.465^{c}	.1925
Chlorine	1103.	39.77	1039.	39.67	1103.	52.78
Iodine	.0604	.0219	.0721	.0160	.1442	.0891
Selenium	.1573	.0595	.3546	.1195	.2710	.0728

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[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

[de] Means in the same row with different superscripts are different ($P < .01$).

attributed to the presence of broiler litter in the ration, but there is no explanation for the rather high values of muscle copper in the control fed heifers. Significant differences were found in muscle copper between litter fed heifers with and without protein supplement. No other significant differences were noted in the minerals of primary interest. Arsenic, lead, mercury and selenium values fell within the range of those previously reported. Potassium and dysprosium were lower ($P < .05$) in the muscle of heifers fed corn-litter silage and protein supplement than the corn-litter silage heifers, but not significantly different from the control heifers. Heifers fed corn-litter silage plus soybean meal were lower in muscle vanadium ($P < .05$) and cesium ($P < .01$). Heifers fed corn silage were lower ($P < .05$) in muscle tungsten values than heifers fed broiler litter.

Mineral profiles of external fat samples taken at the 9-10-11th ribs and the data are presented in table 20. Cadmium values of external fat were elevated across all treatments, compared to literature values (table 10). Concentrations of arsenic, copper, lead, mercury and selenium all fell within the range of values for fat appearing in the literature. Arsenic was lower ($P < .05$) in control heifers compared to heifers fed litter silage, but all values were low. Tin was higher ($P < .05$) in the corn-litter treatment. Gold was higher ($P < .05$) for heifers fed corn-litter silage than those fed the silage plus soybean meal. Antimony and europium were highest ($P < .05$) in the fat of corn-litter silage

TABLE 20. MINERAL PROFILES IN FAT OF BEEF HEIFERS FED CORN SILAGE AND CORN LITTER SILAGE[a]

	Corn-litter silage	± S.E.	Corn-litter silage + protein	± S.E.	Corn silage + protein	± S.E.
Heavy metals - Transition						
Aluminum	1.931	.0259	1.950	.2142	1.810	.1317
Cadmium	.2465	.0379	.2645	.0941	.1717	.0770
Chromium	.0586	.0174	.0667	.0167	.0730	.0133
Cobalt	$.0358^{bc}$	.0058	$.0488^{b}$	.0029	$.0312^{c}$	.0079
Copper	.0000	.0000	1.016	.6913	.0080	.0080
Gold	$.0006^{b}$	.0001	$.0002^{c}$	.0001	$.0005^{bc}$	.0001
Hafnium	.0023	.0012	.0019	.0013	.0041	.0022
Iron	1.845	1.845	6.795	3.283	6.057	2.222
Lanthanum	$.0104^{bc}$	.0012	$.0132^{b}$	.0021	$.0076^{c}$	.0010
Lead	.0371	.0061	.0463	.0036	.0472	.0098
Manganese	.0267	.0118	.0851	.0400	.0215	.0065
Mercury	.0078	.0020	.0084	.0017	.0067	.0020
Molybdenum	.0374	.0144	.0226	.0062	.0353	.0081
Nickel	.0962	.0195	.0922	.0199	.5081	.1187
Scandium	.0000	.0000	.0002	.0001	.0000	.0000
Tantalum	.0000	.0000	.0028	.0020	.0000	.0000
Tin	$.2337^{b}$	.0313	$.1278^{c}$	.0353	$.0751^{c}$	.0247
Titanium	.3786	.0645	.3969	.0859	.2111	.0494
Tungsten	.0139	.0029	.0178	.0035	.0112	.0040
Vanadium	.0117	.0044	.0062	.0017	.0060	.0010
Zinc	4.086	.3081	3.746	.3454	3.782	.2774
Light metals						
Barium	.1630	.0461	.2370	.0679	.1334	.0483
Calcium	45.62	10.79	102.8	67.56	59.66	19.50
Cesium	.0047	.0026	.0010	.0010	.0010	.0010
Magnesium	18.15	2.155	18.49	2.143	18.70	2.313
Potassium	422.4	44.7	383.5	43.13	416.1	41.88
Rubidium	.2602	.0946	.1303	.0681	.2926	.1020
Sodium	156.7	6.594	304.5	135.4	175.1	10.77
Strontium	.4514	.1127	.7706	.1915	.5771	.1451
Heavy metals - Inner transition						
Cerium	.0284	.0101	.0319	.0101	.0446	.0180
Dysprosium	.0015	.0004	.0019	.0005	.0016	.0004
Europium	$.0034^{b}$	.0011	$.0162^{c}$	.0063	$.0028^{b}$	.0012
Lutetium	.0044	.0018	.0051	.0036	.0011	.0003
Samarium	.0029	.0010	.0027	.0008	.0050	.0019
Thorium	.0198	.0040	.0263	.0033	.0165	.0054
Uranium	.0084	.0031	.0063	.0021	.0087	.0029
Ytterbium	.0074	.0011	.0088	.0022	.0078	.0013
Metalloids						
Antimony	$.0106^{b}$	.0018	$.0233^{c}$	.0029	$.0140^{b}$	.0026
Arsenic	$.0126^{b}$	.0024	$.0131^{b}$	.0026	$.0043^{c}$	.0015
Non-metals						
Bromine	$.4234^{b}$	.0254	$.4932^{bc}$	.0302	$.5443^{c}$	.0273
Chlorine	198.8	6.538	211.8	11.51	194.7	21.72
Iodine	.1568	.0251	.1696	.0178	.1446	.0222
Selenium	.0460	.0049	.0451	.0077	.0479	.0117

[a] All values PPM dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

heifers supplemented with soybean meal.

In summary, liver copper in heifers fed broiler litter was substantially increased compared to control fed heifers which agrees with work previously reported by Webb *et al*. (1978). Arsenic in kidney and fat tissues of heifers fed litter were significantly higher than control heifers. Calvert (1972) reported tissue arsenic can be increased in a linear manner by the addition of dietary arsenic but tissue arsenic is rapidly depleted following withdrawal. Bromine was consistently and significantly higher in liver, kidney, loin and fat tissues of heifers fed a standard ration compared to litter fed heifers. Zinc profiles in the kidney and liver of control heifers were significantly higher than heifers fed litter.

Experiment 2 - Dried Cattle Waste as a Feed Ingredient for Finishing Steers

In comparing the composition of the beef waste (table 21) with the proximate analyses in the literature, values presented in table 5 the crude protein and crude fiber content are on the lower end of the range. The ash content of 31.1% is excessively high and is in the upper portion of the range reported (table 5). Such a high ash component definitely limits the energy value of the beef waste. The high ash resulted from contamination of the beef waste with the soil surface of the feedlot pens where the waste was collected. The nitrogen-free extract component is low and indicative of a relatively low energy value, compared to those presented in the literature (table 5).

TABLE 21. INGREDIENT COMPOSITION OF BEEF STEER RATIONS. TRIAL I AND TRIAL II.

Item	Control ration	Waste ration	Beef waste
Ingredient composition, %			
Alfalfa hay[a]	10.0	7.5	
Oat hay[b]	10.0	7.5	
Beet molasses[c]	10.0	10.0	
Mineral supplement[d]	2.0	1.5	
Cottonseed meal[e]	5.0	4.5	
Corn, rolled[f]	32.0	27.0	
Oats, rolled[g]	31.0	26.0	
Cattle fecal waste	-	16.0	
Chemical composition			
Dry matter, %	86.6	85.9	86.7
Composition of dry matter, %			
Crude protein	11.8	12.3	13.8
Crude fiber	13.1	13.9	14.1
Ether extract	4.7	3.6	1.5
Ash	8.4	10.4	31.1
NFE	62.0	59.8	39.5

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[a] Alfalfa, hay, s-c grnd, (1), IRN 1-00-111.

[b] Oats, hay, s-c grnd, (1), IRN 1-03-280.

[c] Beet, sugar, molasses, mm 48 invert sugar, mm 79.5 degree brix, (4), IRN 4-00-668.

[d] Commercial Feedlot Mineral Supplement supplied by Wilbur Ellis Inc., Heber, Ca.

[e] Cottonseed meal, solvent extracted, 41% protein, (5), IRN 5-01-621.

[f] Corn, dent yellow grain, steam flaked, (4), IRN 4-02-931.

[g] Oats, grain, Pacific Coast, steam flaked, (4), IRN 4-07-999.

Trial I. Performance of trial I steers fed cattle waste are presented in table 22. Average daily gain of the control steers tended to be higher ($P < .05$) compared to the cattle fed 16% waste. The values were 1.31 and 1.14 kg/day, respectively. Feed intake was similar for both groups. Feed efficiency favored the control group by a margin of 1.02 kg/kg of gain. The higher ash content of the waste undoubtedly lowered the caloric density of the waste ration. Lower average daily gain of the waste fed cattle can be attributed to lower total energy intake. Average daily gains obtained by both groups are similar to those obtained by Westing and Brandenburg (1974) from feeding 14% stockpiled cattle waste.

Mineral profiles of rations and cattle feedlot waste fed to beef steers for both trials are presented in table 23. Comparing the mineral profiles of primary interest with literature values (table 6), shows that the cadmium in waste was 7.21 ppm compared to the typical range for cadmium of .61 to .85, dry basis. Beef waste contained 221 ppm copper, compared to a range reported in the literature of 16 to 31 ppm, dry basis. Waste values for lead, mercury and selenium were within the ranges previously reported. Control and experimental ration mineral levels were compared with the average feedstuff values (table 9). Cadmium levels of the control and waste rations were 5 to 8.4 ppm, dry basis, compared to literature values of .035 to .21 ppm. Values for copper in the control and waste rations were 9.8 and 137.9 ppm, dry basis, respectively, compared to literature copper values from 6.6 to 40.8.

TABLE 22. PERFORMANCE OF BEEF STEERS FED CATTLE FEEDLOT WASTE. TRIAL I.

Item	Control ration	Waste ration
Number of steers	18	18
Days on trial	98	98
Initial weight, kg	326.0	315.0
Final weight, kg	454.0[b]	427.0[c]
Daily gain, kg	1.31[b]	1.14[c]
Daily feed intake, kg[a]	9.73	9.63
Feed/kg gain, kg[a]	7.43	8.45

[a] As fed basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

TABLE 23. MINERAL PROFILES OF RATIONS AND CATTLE FEEDLOT WASTE FED TO BEEF STEERS[a]. TRIAL I AND TRIAL II.

	Control ration	16% waste ration	Feedlot waste
Heavy metals - transition			
Aluminum	186.9	2334.	16846.
Cadmium	5.041	8.420	7.213
Chromium	2.244	1.861	14.74
Cobalt	.9456	1.379	4.580
Copper	9.793	137.9	221.1
Gold	.0044	.0015	.0024
Hafnium	.0434	.0904	1.569
Iron	346.8	1273.	8844.
Lanthanum	.4903	1.125	4.949
Lead	1.826	1.238	1.889
Manganese	43.38	67.36	247.4
Mercury	.1194	.0	.0053
Molybdenum	2.753	1.934	2.443
Nickel	.1948	.2762	.5940
Scandium	.0330	.2387	1.895
Tantalum	.1520	.0370	.2053
Tin	2.946	11.64	3.843
Titanium	18.16	77.44	931.8
Tungsten	.3294	.4187	.4896
Vanadium	.8017	3.766	26.32
Zinc	64.41	68.40	101.6
Light metals			
Barium	4.126	51.43	145.0
Calcium	5655.	4722.	34219.
Cesium	.2094	.1701	.6844
Magnesium	2748.	3130.	11003.
Potassium	15951.	19411.	20024.
Rubidium	9.042	15.92	44.22
Sodium	2900.	4170.	6003.
Strontium	36.03	54.01	352.7
Heavy metals - inner transition			
Cerium	1.039	3.129	21.06
Dysprosium	.1317	.1588	1.948
Europium	.0	.0957	.0
Lutetium	.0056	.0265	.0158
Samarium	.3289	.7588	2.743
Thorium	.3517	1.050	5.633
Uranium	.3082	.2598	.0368
Ytterbium	.1966	.0849	.3264
Metalloids			
Antimony	.2095	.1169	.3422
Arsenic	.2009	.0	.1211
Non-metals			
Bromine	23.66	25.99	19.48
Chlorine	5933.	5409.	9739.
Iodine	.3149	.5847	.5107
Selenium	.8124	.7974	1.948

[a] All values PPM, dry matter basis.

Arsenic, lead, mercury and selenium are all within the ranges reported for conventional feedstuffs in table 9.

Liver mineral profiles of steers are presented in table 24. Liver cadmium values for all steers were higher than values reported in the literature (table 10, .27 ppm). The values were 1.06 and 1.39 ppm, dry basis, respectively, for waste fed and control cattle. Arsenic, copper, lead and mercury liver values for all steers were within the ranges presented in table 10. Selenium was higher ($P < .05$) in the livers of waste-fed steers than conventionally-fed steers. The respective values were 2.08 and 1.21 ppm, dry basis. Aluminum, manganese, magnesium, uranium and chlorine were higher ($P < .05$) in the livers of control cattle than steers fed waste. Bromine ($P < .01$) and thorium ($P < .05$) were significantly higher in the livers of waste fed steers.

Mineral profiles in fat taken from the kidney knob are presented in table 25. Only cadmium was elevated above the range presented in the literature (table 10). Mean cadmium values for fat were: waste ration, .256; control, .234; and table 10, .011 ppm, dry basis. No significant differences were found in the 43 minerals profiled in the fat tissue between treatments.

Trial II. Steer performance data are presented in table 26. Daily gain was .13 kg/day higher and feed intake 2.5 kg/day greater for waste-fed steers, compared to conventionally-fed steers. Feed efficiency favored the control steers. However, the amount of concentrate per kilogram of gain, corrected for waste would be less for

TABLE 24. MINERAL PROFILES IN LIVER OF BEEF STEERS FED CATTLE FEEDLOT WASTE[a]. TRIAL I.

	Cattle waste	± S.E.	Control	± S.E.
Heavy metals - transition				
Aluminum	7.646^{b}	.1593	8.319^{c}	.2322
Cadmium	1.058	.2641	1.394	.2506
Chromium	.7397	.2308	.3962	.0967
Cobalt	.4125	.0157	.4158	.0143
Copper	145.4	9.387	173.6	12.11
Gold	.0010	.0002	.0007	.0002
Hafnium	.0364	.0132	.0579	.0147
Iron	172.9	9.367	187.0	7.272
Lanthanum	.0691	.0111	.0980	.0136
Lead	.1650	.009	.2110	.032
Manganese	8.758^{d}	.3456	10.05^{e}	.2123
Mercury	.0220	.0114	.0174	.0086
Molybdenum	2.840	.2309	2.950	.1117
Nickel	.5750	.123	.6330	.096
Scandium	.0030	.0007	.0016	.0005
Tantalum	.0756	.0188	.0473	.0203
Tin	2.104	.8336	1.401	.5130
Titanium	1.535	.4243	1.059	.3720
Tungsten	.1935	.0327	.2068	.0222
Vanadium	.0392	.0110	.0146	.0056
Zinc	122.2	1.337	121.0	2.485
Light metals				
Barium	1.421	.4111	.7384	.3794
Calcium	137.4	18.77	152.6	17.19
Cesium	.0429	.0120	.0500	.0175
Magnesium	490.1^{b}	14.23	580.0^{c}	22.32
Potassium	10539.	128.3	10084.	269.9
Rubidium	20.04	.6430	20.22	.7025
Sodium	2194.	59.89	2271.	74.56
Strontium	5.501	1.361	8.336	1.718
Heavy metals - inner transition				
Cerium	.2307	.0924	.2753	.0733
Dysprosium	.0068	.0021	.0072	.0027
Europium	.0728	.0328	.1545	.0664
Lutetium	.0265	.0206	.0052	.0017
Samarium	.0118	.0029	.0203	.0119
Thorium	$.3014^{b}$	.0680	$.1519^{c}$	.0269
Uranium	$.0000^{b}$	.0000	$.0358^{c}$	.0116
Ytterbium	.0354	.0083	.0237	.0071
Metalloids				
Antimony	.0557	.0085	.0445	.0091
Arsenic	.0625	.0227	.1151	.0586
Non-metals				
Bromine	11.13^{d}	.2192	9.531^{e}	.2753
Chlorine	$2300.^{b}$	49.00	$2595.^{c}$	71.11
Iodine	.0982	.0202	.1492	.0312
Selenium	2.078^{b}	.2609	1.210^{c}	.1634

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

[de] Means in the same row with different superscripts are different ($P < .01$).

TABLE 25. MINERAL PROFILES IN KIDNEY FAT OF BEEF STEERS FED CATTLE FEEDLOT WASTE[a]. TRIAL I.

	Cattle waste	± S.E.	Control	± S.E.
Heavy metals - Transition				
Aluminum	1.116	.1284	1.351	.1328
Cadmium	.2561	.0580	.2341	.0487
Chromium	.0431	.0201	.0561	.0168
Cobalt	.0465	.0040	.0410	.0059
Copper	2.115	.7376	2.272	.7420
Gold	.0002	.0001	.0002	.0001
Hafnium	.0014	.0008	.0016	.0009
Iron	4.178	1.901	4.169	1.894
Lanthanum	.0083	.0012	.0121	.0015
Lead	.0063	.0037	.0092	.0067
Manganese	.0203	.0046	.0271	.0099
Mercury	.0084	.0020	.0140	.0028
Molybdenum	.0210	.0068	.0321	.0099
Nickel	.0332	.006	.0352	.002
Scandium	.0001	.0001	.0001	.0001
Tantalum	.0000	.0000	.0000	.0000
Tin	.1790	.0543	.1750	.0661
Titanium	.2864	.0506	.4403	.0793
Tungsten	.0206	.0035	.0198	.0024
Vanadium	.0032	.0007	.0027	.0008
Zinc	1.815	.1858	2.217	.1350
Light metals				
Barium	.1620	.0343	.1972	.0433
Calcium	4.275	1.648	3.499	1.458
Cesium	.0045	.0021	.0039	.0021
Magnesium	7.250	1.197	8.748	.6872
Potassium	135.0	8.414	144.7	11.91
Rubidium	.0247	.0247	.0349	.0349
Sodium	180.2	11.14	188.3	13.71
Strontium	.4832	.1397	.4475	.1161
Heavy metals - Inner Transition				
Cerium	.0176	.0070	.0325	.0113
Dysprosium	.0013	.0005	.0012	.0004
Europium	.0061	.0019	.0114	.0034
Lutetium	.0013	.0003	.0014	.0003
Samarium	.0016	.0003	.0014	.0004
Thorium	.0248	.0048	.0292	.0079
Uranium	.0057	.0018	.0029	.0015
Ytterbium	.0095	.0028	.0125	.0023
Metalloids				
Antimony	.0224	.0106	.0183	.0030
Arsenic	.0106	.0025	.0185	.0073
Non-metals				
Bromine	1.0450	.0428	.9412	.0533
Chlorine	177.8	16.18	209.3	10.35
Iodine	.0180	.0031	.0398	.0177
Selenium	.0555	.0122	.0599	.0098

[a] All values PPM, dry matter basis.

TABLE 26. PERFORMANCE OF BEEF STEERS FED CATTLE FEEDLOT WASTE. TRIAL II.

Item	Control ration	Waste ration
Number of steers	10	10
Days on trial	93	93
Initial weight, kg	320.0	311.0
Final weight, kg	451.0	454.0
Daily gain, kg	1.41	1.54
Daily feed intake, kg[a]	10.5	13.0
Feed/kg gain, kg[a]	7.42	8.48

[a] As fed basis.

the waste-fed cattle.

Liver mineral profiles of steers on their respective rations are presented in table 27. The cadmium level for both treatments was considerably higher than the value of .27 ppm previously reported (table 10). Respective liver cadmium values for control and waste fed steers were 1.72 and 1.23 ppm, dry basis, respectively. Arsenic, copper, lead, mercury and selenium values for liver fall within ranges presented in table 10. Liver copper was significantly ($P < .05$) higher in the control steers, compared to experimental steers. Respective values were 126.3 and 96.6 ppm, dry basis. No other significant differences were found between treatments in minerals of primary interest. Zinc, sodium and bromine were significantly higher in the livers of conventionally-fed steers.

Mineral profiles of kidney tissue are presented in table 28. Minerals of primary interest in both treatments were within the range reported in table 10 for kidney tissue. No significant differences were found between treatments in arsenic, cadmium, copper, lead, mercury and selenium. Kidney calcium was higher ($P < .05$) in conventionally-fed steers. The kidney potassium level of waste fed steers was higher ($P < .05$) than conventionally-fed steers. No other differences between treatments were noted in the 43 minerals profiled.

Kidney fat samples were profiled and the levels are reported in table 29. Samples from both treatments were considerably higher in cadmium and selenium than literature values (table 10). Lead

TABLE 27. MINERAL PROFILES IN LIVER OF BEEF STEERS FED CATTLE FEEDLOT WASTE[a]. TRIAL II.

	Cattle waste	± S.E.	Control	± S.E.
Heavy metals - transition				
Aluminum	8.119	.5175	7.675	.5957
Cadmium	1.233	.2046	1.720	.1739
Chromium	.4344	.1273	.1569	.1152
Cobalt	.5213	.1425	.9566	.2319
Copper	96.58 [b]	4.709	126.3 [c]	9.362
Gold	.0003	.0002	.0011	.0003
Hafnium	.0338	.0093	.0415	.0174
Iron	197.5	11.63	184.6	15.22
Lanthanum	.0612	.0093	.0644	.0119
Lead	.1846	.017	.2120	.021
Manganese	7.481	.2586	6.659	.5018
Mercury	.0052	.0052	.0216	.0116
Molybdenum	2.573	.1754	2.631	.1402
Nickel	.2430	.040	.2121	.022
Scandium	.0005	.0004	.0017	.0007
Tantalum	.0333	.0176	.0254	.0173
Tin	1.046	.4629	2.238	.6589
Titanium	1.244	.3845	2.752	1.215
Tungsten	.1693	.0314	.1937	.0846
Vanadium	.0189	.0056	.0204	.0048
Zinc	125.3 [b]	1.406	142.9 [c]	7.159
Light metals				
Barium	1.407	.4926	2.782	1.146
Calcium	149.4	20.26	106.9	16.41
Cesium	.0362	.0139	.0216	.0127
Magnesium	542.1	24.05	476.9	27.23
Potassium	10421.	156.1	9857.	291.4
Rubidium	19.79	.6554	17.40	.9921
Sodium	1745. [b]	64.94	2029. [c]	100.2
Strontium	4.757	2.018	8.567	2.270
Heavy metals - inner transition				
Cerium	.0672	.0324	.1323	.0844
Dysprosium	.0052	.0026	.0044	.0023
Europium	.1715	.0721	.0676	.0453
Lutetium	.0033	.0012	.0024	.0013
Samarium	.0186	.0101	.0115	.0047
Thorium	.0862	.0385	.0803	.0238
Uranium	.0132	.0080	.0062	.0062
Ytterbium	.0195	.0074	.0230	.0096
Metalloids				
Antimony	.0337	.0080	.0318	.0052
Arsenic	.0644	.0494	.2551	.1798
Non-metals				
Bromine	14.16 [d]	.6310	17.80 [e]	.7003
Chlorine	2083.	46.84	2193.	107.9
Iodine	.1266	.0446	.0455	.0221
Selenium	.7122	.1614	.8818	.1266

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different (P <.05).

[de] Means in the same row with different superscripts are different (P < .01).

TABLE 28. MINERAL PROFILES IN KIDNEY OF BEEF STEERS FED CATTLE FEEDLOT WASTE^{a}. TRIAL II.

	Cattle waste	± S.E.	Control	± S.E.
Heavy metals - Transition				
Aluminum	7.697	.6852	7.581	.8384
Cadmium	.6553	.1565	1.3650	.3926
Chromium	.3789	.1174	.2922	.1087
Cobalt	.1808	.0255	.2205	.0269
Copper	.0000	.0000	.0000	.0000
Gold	.0038	.0018	.0021	.0003
Hafnium	.0055	.0055	.0188	.0131
Iron	130.8	10.03	124.0	8.441
Lanthanum	.0836	.0816	.0616	.0110
Lead	.1368	.0198	.1684	.0180
Manganese	.7266	.1030	.9943	.5628
Mercury	.0293	.0125	.0239	.0129
Molybdenum	.1547	.0460	.2601	.1609
Nickel	.2492	.0187	.2171	.0374
Scandium	.0026	.0010	.0014	.0007
Tantalum	.0000	.0000	.0000	.0000
Tin	1.276	.4444	1.206	.6109
Titanium	2.160	.7804	2.952	.8178
Tungsten	.0848	.0259	.1468	.0179
Vanadium	.1256	.0740	.0659	.0254
Zinc	173.6	9.642	151.1	11.71
Light metals				
Barium	2.027	.7317	1.650	.6020
Calcium	18.87^{b}	12.92	85.64^{c}	19.36
Cesium	.0677	.0207	.0481	.0221
Magnesium	1288.	629.8	588.1	45.15
Potassium	11448.^{b}	596.6	9324.^{c}	719.5
Rubidium	12.77	.6172	11.31	1.025
Sodium	2345.	140.9	2235.	203.5
Strontium	6.292	1.918	4.792	2.383
Heavy metals - Inner transition				
Cerium	.2201	.0874	.2337	.0668
Dysprosium	.0071	.0011	.0253	.0210
Europium	.1327	.0431	.1490	.0286
Lutetium	.0053	.0010	.0059	.0007
Samarium	.0073	.0015	.0054	.0025
Thorium	.1647	.0400	.1296	.0278
Uranium	.0068	.0068	.0099	.0051
Ytterbium	.0248	.0119	.0368	.0121
Metalloids				
Antimony	.0321	.0073	.0539	.0230
Arsenic	.0658	.0246	.0735	.0315
Non-metals				
Bromine	15.01	.7662	17.04	1.493
Chlorine	1933.	238.7	2317.	177.4
Iodine	080.8	.0241	.0770	.0293
Selenium	.5884	.0622	.5600	.0674

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

TABLE 29. MINERAL PROFILES IN KIDNEY FAT OF BEEF STEERS FED CATTLE FEEDLOT WASTE[a]. TRIAL II.

	Cattle waste	± S.E.	Control	± S.E.
Heavy metals - Transition				
Aluminum	3.467	.6945	4.154	.9741
Cadmium	.2587	.0581	.2248	.1048
Chromium	.1556	.0404	.1078	.0665
Cobalt	.1153	.0189	.1134	.0175
Copper	.1305	.0940	.3704	.1391
Gold	.0013	.0002	.0017	.0003
Hafnium	.0080	.0044	.0076	.0037
Iron	28.12	5.345	35.73	8.276
Lanthanum	.0254	.0059	.0255	.0038
Lead	.0889^{b}	.0167	.0441^{c}	.0119
Manganese	.0335	.0100	.1263	.1002
Mercury	.0161	.0075	.0080	.0037
Molybdenum	.1134	.0614	.0901	.0277
Nickel	.0569	.0075	.0537	.0102
Scandium	.0007	.0003	.0006	.0003
Tantalum	.0000	.0000	.0000	.0000
Tin	.0822	.3641	.7025	.2173
Titanium	.6357	.2287	.3549	.2430
Tungsten	.0585	.0152	.0518	.0132
Vanadium	.0670	.0026	.0070	.0021
Zinc	19.23	9.116	9.947	1.955
Light metals				
Barium	.6611	.3264	.4871	.2447
Calcium	27.69	8.101	8.720	6.764
Cesium	.0201	.0051	.0127	.0066
Magnesium	59.08	4.509	48.43	7.284
Potassium	1553.	79.85	1407.	188.6
Rubidium	1.061	.2702	1.296	.3447
Sodium	751.6	124.3	586.2	74.27
Strontium	1.243	.4441	.3611	.3611
Heavy metals - Inner transition				
Cerium	.0722	.0232	.0369	.0197
Dysprosium	.0037	.0018	.0038	.0015
Europium	.0287	.0198	.0315	.0144
Lutetium	.0081	.0061	.0027	.0008
Samarium	.0105	.0014	.0102	.0036
Thorium	.0338	.0081	.0483	.0112
Uranium	.0114	.0043	.0097	.0059
Ytterbium	.0226	.0077	.0306	.0154
Metalloids				
Antimony	.0185	.0036	.0265	.0061
Arsenic	.0267	.0126	.0469	.0109
Non-metals				
Bromine	7.283	1.284	6.130	.7497
Chlorine	915.8	167.2	675.9	87.59
Iodine	.0677	.0173	.0362	.0130
Selenium	.1096	.0233	.1633	.0344

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

was higher ($P < .05$) in the kidneys of waste-fed steers, compared to controls. Respective values for waste-fed and control steers were .089 and .044 ppm, dry basis. No other significant differences were found in the minerals profiled.

In summary, the high copper level in the waste ration (138 ppm) can be attributed to the waste (221 ppm) incorporated into the ration. Liver, kidney and fat tissues did not reflect the elevated dietary copper intake. Liver selenium values were significantly higher in waste-fed steers in trial I. Kidney fat of steers fed waste was significantly higher in lead content in trial II. Cadmium values were high across all treatments, compared to reported values (table 10). This could be a location effect as five major freeways encircle the area where these experiments were conducted and the roughages grown. With the burning of large volumes of hydrocarbons, considerable amounts of lead and cadmium are airborne and settle on forage plants. The roughage source may contribute significant amounts of cadmium to the animal.

Experiment 3 - Wintering Cows on Broiler Litter, Corn Grain and Supplemental Copper

The chemical composition of the beef cow ration ingredients fed during the winter are presented in table 30. Values for crude protein, crude fiber, ether extract, ash and NFE for litter were within the ranges reported (table 1). Cow and calf performance reported by Webb *et al*. (1978) indicate there are no differences between lots in number of calves born and birth weight of calves over three calving periods. The average weaning weights of lot 1 (hay), lot 2 (80%

TABLE 30. CHEMICAL COMPOSITION OF BEEF COW RATION INGREDIENTS - DECEMBER, 1976 TO APRIL, 1977

Item	Hay[a]	Corn[b]	Litter	Litter + corn	Litter, corn and copper
Dry matter, %	92.0	88.9	80.9	80.5	80.0
Composition of dry matter, %					
Crude protein	12.8	8.6	32.8	29.8	30.0
Crude fiber	33.6	3.9	19.9	17.7	15.5
Ether extract	3.2	4.1	3.4	2.5	2.1
Ash	6.9	1.5	21.2	18.3	17.6
NFE	43.7	82.1	22.8	32.0	35.0
Copper, ppm[c]	15.9	7.6	463.9	412.6	595.6

[a] Grass-legume, aerial pt, s-c, (1), IRN 3-02-303.
[b] Corn, dent yellow grain, grnd, (4), IRN 4-02-931.
[c] Dry matter basis.

litter and 20% corn) and lot 3 (80% litter, 20% corn and supplemental copper) were 147, 143, and 155 kg, respectively. The lot receiving the highest level of dietary copper had the heaviest weaning weight. Thus, cow and calf performance was not impaired by elevated levels of dietary copper and the use of 80% broiler litter as a wintering feed.

The litter copper value (table 31) was considerably higher (431 ppm, dry basis) than the reported range of 23 to 105 ppm, dry basis (table 9). Ration copper levels were: lot 1 - 15.9; lot 2 - 412.6; and lot 3 - 595.6 ppm, dry basis (table 30). Mineral values of corn for arsenic, cadmium and selenium of 13.6, 7.38 and 3.41 ppm, dry basis, were higher than literature values (table 9). Hay was higher in cadmium, mercury and selenium than values reported.

Liver mineral values for the December biopsy are shown in tables 32 and 33 and those for April biopsy are shown in tables 34 and 35. At the end of the winter feeding period liver arsenic values were lower ($P < .01$) for cows wintered on hay, compared to litter rations, but there were no differences prior to the period (tables 32 and 34). Liver arsenic levels for litter fed cows increased dramatically over the wintering period. Respective liver arsenic values for December and April were: hay, .697 and .158; litter and corn, .295 and 6.35; litter, corn and copper, .355 and 6.79 ppm, dry basis. Liver copper levels were lower ($P < .01$) from cows fed hay, compared to litter regimes. The respective copper levels in liver for cows wintered on hay, litter plus corn, and litter plus

TABLE 31. MINERAL PROFILES IN FEEDS FED TO BEEF COWS WINTERED ON BROILER LITTER AND CORN - WINTER 1976-77

	Corn	Hay	Litter + corn	Litter + corn + copper	Litter
Heavy metals - Transition					
Aluminum	32.10	129.2	977.8	1009.	1008.
Cadmium	.0000	3.229	8.614	14.91	8.281
Chromium	.0000	4.736	3.958	5.276	7.081
Cobalt	.0000	1.615	3.725	3.556	4.201
Copper	6.704	14.34	336.2	505.0	430.9
Gold	.0000	.0000	.0081	.0000	.0084
Hafnium	.2325	.0000	.0000	.8946	.0000
Iron	.0000	.0000	1164.	1835.	1440.
Lanthanum	.0332	1.507	3.259	3.941	3.841
Lead					
Manganese	14.39	93.64	337.6	401.4	480.1
Mercury	.3322	.4951	.6053	.2867	.5401
Molybdenum	.3100	2.583	9.196	11.35	11.64
Nickel					
Scandium	.0111	.0646	.2328	.1606	.1920
Tantalum	.0000	.0000	.8032	.0000	.0000
Tin	3.765	5.059	2.095	32.11	.0000
Titanium	6.530	26.91	98.94	73.40	114.0
Tungsten	.1218	.5919	4.656	1.262	1.560
Vanadium	.0000	1.722	5.936	6.079	8.641
Zinc	47.61	107.6	442.3	401.4	516.1
Light metals					
Barium	.0000	20.45	33.76	32.26	.0000
Calcium	.0000	8718.	4656.	14910.	25204.
Cesium	.0000	1.184	1.036	.0000	.5281
Magnesium	642.2	2583.	5005.	4932.	7081.
Potassium	4651.	20500.	34920.	36702.	39606.
Rubidium	.0000	.0000	.0000	33.26	.0000
Sodium	57.60	2153.	4540.	4817.	5401.
Strontium	7.750	48.43	.0000	71.11	37.21
Heavy metals - Inner Transition					
Cerium	1.041	3.875	8.730	4.702	12.00
Dysprosium	.0332	.4413	1.630	1.950	2.280
Europium	.0022	2.583	.9894	1.950	1.440
Lutetium	.0044	.0215	.1513	.1032	.0000
Samarium	.0443	1.292	3.492	3.785	3.961
Thorium	.4208	.4628	1.630	2.064	1.680
Uranium	.2768	1.615	3.376	4.129	4.441
Ytterbium	.5869	.1507	.6053	.5047	.7441
Metalloids					
Antimony	.5869	.4305	.9545	1.124	2.040
Arsenic	.1218	1.076	.6635	52.76	54.41
Non-metals					
Bromine	1.772	7.320	9.894	11.47	12.00
Chlorine	808.3	4628.	3259.	4588.	5761.
Iodine	.3322	.0753	2.328	4.473	8.281
Selenium	.6865	.6889	6.402	3.211	3.121

[a] All values PPM, dry matter basis.

TABLE 32. MINERAL PROFILES IN LIVER OF BEEF COWS WINTERED ON BROILER LITTER AND CORN - DECEMBER[a]

	Hay		Litter + corn		Litter + corn + copper	
	Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Metalloids						
Antimony	.2347	.0394	.2348	.0443	.2965	.0522
Arsenic	.6965	.5560	.2946	.0756	.3552	.0755
Non-Metals						
Bromine	8.799	.2408	9.597	.7705	10.62	1.066
Chlorine	4603.	210.3	4749.	383.3	5548.	419.0
Iodine	4.170	.9324	4.564	.9700	5.054	1.185
Selenium	1.267	.2375	1.378	.1942	1.469	.5712
Heavy Metals - Transition						
Aluminum	26.03	2.018	23.88	3.511	28.25	3.723
Cadmium	2.826	.7939	4.390	1.593	3.541	1.325
Chromium	2.824	1.262	1.860	.4355	2.909	.9060
Cobalt	1.163	.0847	1.142	.0954	1.263	.1422
Copper	27.00^{d}	5.340	195.7^{e}	27.70	218.9^{e}	11.29
Gold	.0080	.0030	.0046	.0012	.0039	.0012
Hafnium	.1160	.0336	.1119	.0581	.1806	.0965
Iron	566.4	55.50	495.9	85.96	707.4	84.74
Lanthanum	.3709^{d}	.0261	.2849^{d}	.0412	.1612^{e}	.0279
Manganese	17.91	.6750	18.12	.8038	19.69	.9004
Mercury	.2367	.0784	.1828	.0587	.1982	.0505
Molybdenum	3.958	.3884	3.865	.3425	3.947	.3163
Scandium	.0027	.0016	.0022	.0015	.0014	.0014
Tantalum	.0000^{d}	.0000	.0575^{e}	.0328	.0000^{d}	.0000
Tin	.4317	.1189	.3527	.1141	.4116	.1323
Titanium	4.427	.9174	5.578	1.472	8.512	2.284
Tungsten	.2473	.0697	.3952	.0789	.3194	.1010
Vanadium	.0850	.0209	.0959	.0277	.1164	.0211
Zinc	214.6	10.82	214.3	16.03	228.8	20.03

[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

[de] Means in the same row with different superscripts are different ($P < .01$).

TABLE 33. MINERAL PROFILES IN LIVER OF BEEF COWS WINTERED ON BROILER LITTER AND CORN - DECEMBER[a]

	Hay		Litter + corn		Litter + corn + copper	
	Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Light Metals						
Barium	7.571	1.294	5.010	1.361	7.646	2.482
Calcium	138.5	51.79	103.4	38.12	189.1	48.85
Cesium	.0528^{bc}	.0403	.1666^{b}	.0701	.0097^{c}	.0097
Magnesium	814.6	55.75	828.7	55.36	836.0	47.35
Potassium	14942.	614.3	15206.	813.7	14830.	1028.
Rubidium	14.84	2.626	11.84	2.200	13.39	2.705
Sodium	3851.	193.6	4069.	471.1	3516.	444.8
Strontium	6.349	3.580	7.396	4.243	5.422	2.437
Heavy Metals - Inner Transition						
Cerium	1.535^{b}	.3592	.5238^{c}	.2284	1.102^{bc}	.2920
Dysprosium	.0156	.0051	.0176	.0090	.0226	.0056
Europium	.0923	.0439	.0920	.0376	.1818	.0665
Lutetium	.0311	.0077	.0251	.0051	.0398	.0119
Samarium	.0944	.0151	.0635	.0108	.0845	.0213
Thorium	.7388	.1769	.6216	.1726	.6537	.1646
Uranium	.0519	.0309	.0425	.0289	.0979	.0492
Ytterbium	.2133	.0403	.1240	.0383	.2023	.0772

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[a] All values PPM, dry matter basis.

[bc] Means in the same row with different superscripts are different ($P < .05$).

TABLE 34. MINERAL PROFILES IN LIVER OF BEEF COWS WINTERED ON BROILER LITTER AND CORN - APRIL[a]

	Hay		Litter + corn		Litter + corn + copper	
	Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Metalloids						
Antimony	$.1554^{b}$	.0234	$.2335^{bc}$	.0451	$.2731^{c}$	.0389
Arsenic	$.1577^{e}$	.0691	6.345^{f}	1.015	6.785^{f}	1.616
Non-Metals						
Bromine	9.789^{e}	.7480	13.20^{f}	.7480	13.94^{f}	.4976
Chlorine	4499.	230.8	4043.	201.9	4368.	149.0
Iodine	2.767	.5157	22.42	13.72	11.41	8.482
Selenium	.9743	.1364	1.418	.2834	1.317	.2973
Heavy Metals - Transition						
Aluminum	20.76	.8812	18.71	2.012	18.21	1.137
Cadmium	3.086	.5579	4.467	1.145	2.666	.4917
Chromium	2.815	1.421	1.877	.4724	1.701	.4709
Cobalt	.8371	.0548	.8829	.0821	.9032	.0618
Copper	34.54^{e}	5.260	757.3^{f}	51.24	964.4^{g}	104.2
Gold	.0059	.0036	.0058	.0020	.0041	.0007
Hafnium	.0838	.0320	.0619	.0292	.1100	.0258
Iron	411.8^{bc}	33.60	449.4^{b}	42.99	306.1^{c}	33.96
Lanthanum	2.643^{e}	.1722	1.198^{f}	.1588	1.893^{g}	.2235
Manganese	16.61^{b}	.9573	13.60^{c}	.7806	15.18^{bc}	.7654
Mercury	.0896	.0288	.1892	.0411	.1813	.0709
Molybdenum	3.753	.3278	3.580	.3969	3.944	.1940
Scandium	.0012	.0009	.0011	.0009	.0009	.0009
Tantalum	.0042	.0042	.0000	.0000	.0000	.0000
Tin	.5069	.1369	.3989	.1625	.5544	.1583
Titanium	5.557	1.250	3.244	1.272	5.553	1.238
Tungsten	.3673	.0675	.3176	.0795	.3924	.0618
Vanadium	.0475	.0138	.1057	.0384	.0915	.0118
Zinc	210.8	27.77	197.8	25.51	180.8	14.57

[a] All values PPM, dry matter basis.

[bcd] Means in the same row with different superscripts are different ($P < .05$).

[efg] Means in the same row with different superscripts are different ($P < .01$).

TABLE 35. MINERAL PROFILES IN LIVER OF BEEF COWS WINTERED ON BROILER LITTER AND CORN - APRIL[a]

	Hay		Litter + corn		Litter + corn + copper	
	Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Light Metals						
Barium	3.113	1.066	5.861	1.775	5.858	2.266
Calcium	134.8	42.57	103.8	40.04	95.45	41.63
Cesium	.1376	.0437	.1020	.0393	.0700	.0379
Magnesium	662.9	52.68	583.5	42.18	638.3	49.31
Potassium	14633.	881.8	14628.	1284.	15471.	528.3
Rubidium	28.29	2.221	30.97	2.879	24.21	3.001
Sodium	3291.	367.0	3124.	270.9	3758.	194.1
Strontium	12.74	3.974	8.929	2.961	5.232	2.879
Heavy Metals - Inner Transition						
Cerium	.5756	.1513	.7828	.2768	.2320	.1022
Dysprosium	.0141	.0048	.0173	.0094	.0223	.0060
Europium	.1737	.0835	.1127	.0536	.4329	.2712
Lutetium	.0091	.0021	.0115	.0034	.0133	.0035
Samarium	.0629	.0091	.2245	.1611	.0354	.0089
Thorium	.4065	.1057	.4226	.1336	.4228	.1211
Uranium	.0893	.0275	.1005	.0407	.0355	.0202
Ytterbium	.1021	.0277	.0798	.0202	.1161	.0564

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[a] All values PPM, dry matter basis.

corn with supplemental copper were 27.0, 195.7 and 218.9 ppm, dry basis, in December and 34.5, 737.3 and 964.4 ppm, dry basis, in April. The liver copper values indicate a considerable buildup in litter treatments over the wintering period. These values are linear in their reflection of dietary copper levels. Liver antimony values in April were lower ($P <.05$) in cows on hay compared to the litter plus copper. Iron values were lower ($P <.05$) in the liver of cows supplemented with copper compared to cows fed litter and corn. Generally, the values were also lower than for the cows fed hay. Bromine was lower in the liver of cows wintered on hay, compared to litter fed cows, and the difference was significant in April. Lanthanum and manganese were significantly higher in the cows wintered on hay compared to cows on litter plus corn, but differences were not always significant.

Liver biopsy samples taken in December were considerably higher in liver cadmium and mercury for all treatments than levels previously reported (table 10).

In summary, liver copper levels directly reflect the elevated dietary intake of copper. Liver cadmium levels were substantially elevated by dietary cadmium. Hay and corn were the principle contributors of dietary cadmium.

In comparing the mineral profiles between April and December (tables 32 to 35) liver arsenic apparently is depleted in cows grazed on pasture. Liver copper levels were increased by three to five fold in the livers of cows fed broiler litter during the winter.

Over the wintering period, liver levels of arsenic and copper undergo buildup and when cows are withdrawn from wintering rations and allowed to graze, liver copper and arsenic are rapidly depleted. Liver copper levels have not reached a toxicity threshold in litter fed cows as there have been no reported cases of jaundice or copper toxicity syndrome.

As reported by Webb *et al*. (1978), wintering cows on litter is a feasible and economical way to provide a low cost maintenance ration and not impair performance or have contraindications.

Experiment 4 - Chemical Composition and Mineral Profile Characterization of Animal Waste by Type

Values for chemical composition and mineral profiles for poultry and livestock waste are presented in tables 36, 37 and 38.

Broiler Litter. The chemical composition values for broiler litter (table 36) closely parallel those of Couch (1974) and El-Sabban *et al*. (1969) (table 1). The average crude protein of 26.7% is below the 32.5% reported in the literature (table 1). Arsenic (54 ppm) and copper (441 ppm) litter values presented in tables 37 and 38 are much higher than values reported (table 2) but agree with values reported by Webb and Fontenot (1975). Elevated litter arsenic and copper may be the result of the diet of the chicks.

Dried Poultry Waste. Ash content of the dried poultry waste (34.3%) is higher than the mean value (27.1%) reported in table 3 but similar to values reported by Essig (1974) and Azevedo and Stout (1974). NFE value of 19.9% is markedly lower than the

TABLE 36. MEAN PROXIMATE ANALYSES BY WASTE TYPE (CHEMICAL COMPOSITION)[a]

Waste type	No. of samples	Dry matter %	± S.E.	Crude protein %[a]	± S.E.	Crude fiber %	± S.E.	Ether extract %	± S.E.	Ash %	± S.E.	NFE %	± S.E.
Broiler litter	5	80.81	4.95	26.72	3.29	23.25	2.17	2.40	.25	19.01	2.43	29.00	1.56
Dried poultry waste	13	92.91	.5	32.14	1.96	12.61	.59	1.01	.12	34.33	2.39	19.91	1.15
Swine waste	4	93.74	.58	23.17	1.28	15.98	.76	5.49	2.04	23.64	3.31	31.72	.89
Cattle feedlot waste	4	92.86	.5	14.15	1.81	20.43	3.18	1.29	.37	28.59	8.1	35.55	6.11

[a] Dry basis.

TABLE 37. COMPOSITE MINERAL PROFILES OF POULTRY WASTE BY WASTE TYPE[a]

	Broiler litter	± S.E.	Dried poultry waste	± S.E.	Swine waste	± S.E.	Cattle waste	± S.E.
Number of samples	5		15		4		4	
Heavy metals - Transition								
Aluminum	2225.	1035.	2657.	954.1	4782.	3099.	11073.	5773.
Cadmium	3.640	2.230	3.496	1.157	1.000	.9998	8.805	1.595
Chromium	3.660	1.070	9.104	1.464	10.44	1.865	10.76	3.945
Cobalt	2.180	.1896	5.022	1.287	4.565	1.215	4.365	.2150
Copper	441.3	129.1	178.2	18.59	157.4	42.35	193.9	27.25
Gold	.0000	.0000	.0041	.0011	.0020	.0005	.0042	.0018
Hafnium	.3057	.2168	.4548	.0610	.6407	.1094	1.013	.5568
Iron	1489.	396.0	2694.	886.5	3575.	525.0	5793.	3051.
Lanthanum	3.530	.8892	2.253	.2341	4.795	1.045	3.685	1.265
Lead	1.638	0.501	1.709	.374	2.035	.6290	1.919	.0301
Manganese	409.9	46.10	429.7	45.38	494.0	47.15	199.1	48.35
Mercury	.0208	.0208	.1381	.0481	.1250	.1249	.1295	.1242
Molybdenum	6.970	1.420	7.091	1.252	6.310	1.160	2.405	.0349
Nickel	0.672	0.087	.7433	.0837	.8900	.0430	.5555	.0385
Scandium	.2542	.0607	.4009	.1853	.3971	.0028	1.202	.6978
Tantalum	.1328	.0244	.1705	.0529	.3628	.1371	.1531	.0522
Tin	9.990	9.990	14.61	4.613	8.550	8.550	1.920	1.920
Titanium	108.1	48.00	154.8	78.89	147.2	94.68	543.3	388.6
Tungsten	.8433	.1738	.7436	.0986	.8010	.3490	.5241	.0344
Vanadium	5.500	.6972	10.38	2.154	7.510	3.869	16.46	9.843
Zinc	476.0	23.70	398.1	39.85	729.5	243.0	119.6	17.95
Heavy metals - Inner transition								
Cerium	7.590	2.390	5.095	.8694	12.90	1.300	16.05	5.050
Dysprosium	.8351	.2464	.8180	.0883	2.140	.4900	1.001	.9494
Europium	.4126	.2662	.1021	.0438	.1973	.0026	.1269	.1268
Lutetium	.0184	.0143	.0265	.0061	.0781	.053	.0079	.0078
Samarium	3.220	1.090	2.949	.5137	4.700	1.400	2.380	.3600
Thorium	1.940	1.030	1.983	.2347	3.615	.9348	4.130	1.500
Uranium	1.750	.5702	4.042	1.359	.7665	.0835	.4471	.4103
Ytterbium	.6459	.2124	.3521	.0388	.4697	.2197	.3072	.0192

[a] All values ppm, dry matter basis.

TABLE 38. COMPOSITE MINERAL PROFILES OF POULTRY WASTE BY WASTE TYPE[a]

	Broiler litter	± S.E.	Dried poultry waste	± S.E.	Swine waste	± S.E.	Cattle waste	± S.E.
Number of samples	5		15		4		4	
Light metals								
Barium	37.10	10.70	85.63	20.90	166.7	106.8	72.55	72.55
Calcium	28091.	3289.	74306.	5640.	50786.	20820.	17299.2	16919.
Cesium	.2580	.1106	.5351	.0988	.4553	.1447	.8722	.1877
Magnesium	6137.	487.7	7484.	690.6	7394.	2543.	7476.	3527.
Potassium	34495.	2748.	28518.	1396.	13312.	3511.	21090.	1066.
Rubidium	27.10	4.900	29.84	2.358	12.60	3.200	35.70	8.499
Sodium	6352.	932.7	4239.	410.8	3183.	1232.	5784.	536.5
Strontium	52.40	23.20	327.6	106.9	319.6	140.1	176.4	176.4
Metalloids								
Antimony	.1904	.1191	.5747	.0754	.6159	.4840	.9111	.5689
Arsenic	54.10	14.90	4.555	1.395	2.755	.7552	.8155	.6944
Non-metals								
Bromine	14.10	3.900	17.94	2.575	6.645	2.755	16.65	2.850
Chlorine	6036.	1122.	5427.	520.4	2746.	1616.	12114.	2375.
Iodine	5.840	1.850	4.839	.7606	5.305	4.195	3.103	2.620
Selenium	1.270	.4869	1.557	.3132	1.525	1.525	1.308	.6422

[a] All values PPM, dry matter basis.

average literature value of 32.1% (table 3). Couch (1974) reported a similar NFE value of 17.3% for dried poultry waste. Copper values were high (table 37) in all samples analyzed and agree with levels reported by Bhattacharya and Taylor (1975). Cadmium and selenium values were in the upper range of literature values reported in table 4.

Swine Waste. Chemical composition values of swine waste (table 36) closely parallel average literature values reported in table 7. Aluminum, iron and manganese average values (table 37) were 4782, 3575 and 494 ppm, dry basis, compared to considerably lower reported values (table 8) of 544, 1704 and 201 ppm, respectively.

Cattle Waste. Average ash and NFE values were 28.6 and 35.6%, respectively (table 36). These values differ considerably from respective literature values of 14.3 and 44.6% (table 5). The majority of these samples were taken from open soil-surfaced feedlot pens which would account for the high ash content and lower NFE values (Westing and Brandenburg, 1974). Average aluminum, cadmium and copper values for both locations were 10500, 8.8 and 198 ppm, respectively, compared to literature values (table 6) of 150, .73 and 22 ppm, dry basis.

It is interesting to note that cadmium and selenium were elevated in waste samples originating in areas of high population density compared to waste from rural areas. Chemical and mineral composition values of waste by type and geographical origin are presented in tables 4 to 8 of the appendix.

The wide range of values encountered in chemical and mineral composition of wastes (Forsht et al., 1974) make the characterization of livestock and poultry waste necessary prior to using them as feed ingredients.

SUMMARY

Experiments were conducted to determine mineral element levels in feedstuffs, animal wastes and tissues from cattle fed broiler litter or cattle waste.

Heifers fed 30% broiler litter ensiled with corn forage performed as well as heifers fed corn silage and soybean meal but performance tended to be lower than for heifers fed corn-litter silage and soybean meal in a 201-day feeding trial. No differences were found in carcass quality and yield grades. Feedlot performance was very low for cattle fed corn silage and no protein supplement. Feeding broiler litter to heifers did not adversely affect the eating quality of roasts from these heifers as measured subjectively by a taste panel and shear devices.

Copper (593 ppm) and arsenic (75.9 ppm) levels were high in broiler litter, compared to other ruminant feedstuffs. Following a 24-hour withdrawal, heifers were slaughtered and liver, muscle, fat and kidney samples were taken. Liver copper reflects high dietary copper intakes in litter fed heifers ($P < .01$). Arsenic in the kidney and fat was higher in litter-fed heifers. Bromine was lower ($P < .05$) in liver, kidney, muscle and fat of litter-fed heifers.

In two successive cattle finishing trials, a 16% cattle waste ration was compared to a conventional feedlot ration. Control

steers in trial I outgained (1.31 kg/day) waste fed steers (1.14 kg/day), but in trial II gains were higher for the waste fed steers (1.41 _vs_ 1.54 kg/day). In trial I selenium was higher ($P < .05$) in livers of steers fed waste. In trial II lead content was higher ($P < .05$) in fat of waste fed cattle and liver copper was higher ($P < .05$) in conventionally-fed steers.

In a long term experiment, currently in its sixth year, cows were wintered on hay, 80% litter and 20% corn grain with and without supplemental copper. Liver biopsies of the cows were taken in December and April, the beginning and end of the wintering period. Average copper levels in the wintering rations were 15.9, 412.6 and 595.6 ppm, dry basis, respectively. Liver biopsies taken in December and April for litter-fed cattle were higher ($P < .01$) in copper than livers of cows fed hay. Respective April and December liver copper values were: hay, 34.5 and 27.0; corn-litter, 757.3 and 195.7; corn-litter-copper, 964.4 and 218.9 ppm, dry basis. Liver arsenic levels were similar after the grazing season but increased dramatically over the wintering period.

Waste samples from broilers, caged layers, cattle and swine from several regions in the United States were analyzed. Litter arsenic and copper values were 54 and 441 ppm, respectively. Dried poultry waste varied in ash, crude protein, cadmium and selenium. Aluminum, cadmium and copper content of cattle waste was higher for all samples than values reported in the literature. Swine waste had an average crude protein content of 23% and varied in cadmium and selenium.

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APPENDIX

TABLE 1. EXAMPLE OF ANALYSIS OF VARIANCE AND DUNCAN'S MEAN SEPARATION FOR MINERALS PROFILED

General Linear Models Procedure

Dependent variable: CL

Source	DF	Sum of squares	Mean square	F value	PR > F
Model	5	920010.49947555	184002.09989511	4.48	0.0038
Error	29	1190996.86837716	41068.85753025		
Corrected total	34	2111007.36785271			

Duncan Mean Separation

Duncan's Multiple Range Test for Variable CL

Means with the same letter are not significantly different.

Alpha level = .05 DF = 29 MS = 41068.9

Grouping				Treat
	A	2483.887553	12	1
	A			
B	A	2321.023621	11	3
B				
B		2197.760263	12	2

TABLE 2. MINERAL CONTENT OF REFERENCE MAN[1]

	Tissue levels, ppm					Intake			Excretion %	
	Total body	Adipose	Kidney	Liver	Skeletal muscle	Unit[2]	Food + fluid	Airborne	Feces	Urine
Heavy metals - Transition										
Aluminum	.88	.35	.27	.67	.2	mg	45.	.1	95.50	.22
Cadmium	.71	.047	.94	2.22	.61	μ	150.	<1.	33.33	66.67
Chromium	.094	.021	.01	.009	.012	μ	150.	.1	53.33	46.67
Cobalt	.021	.024	.013	.061	.007	μ	300.	<.1	30.00	66.67
Copper	1.03	.24	1.29	6.67	.893	mg	3.5	.02	97.14	1.43
Gold	.14	.01	.097	.128	.121					
Iron	60.	24.	74.2	177.8	39.3	mg	16.	.03	93.75	1.56
Lead	1.71	.04	1.1	1.72	.061	mg	.44	.01	66.67	10.00
Manganese	.17	.03	.9	1.39	.054	mg	3.7	.002	97.30	.81
Mercury		.3	2.81	.3	.15	μ	15.	1.	62.50	25.00
Molybdenum	.14	.006	.035	1.	.046	μ	300.	<.1	40.00	50.00
Nickel	.14	.035	.055	.07	.061	μ	400.	.6	92.50	2.75
Tin	.24	.047	.19	.32	.061	mg	4.	.0003	87.5	.5
Titanium	.21	.031	.055	.067	.061	mg	.85	.001	61.18	38.82
Vanadium	.43	1.47	.011	.013	.0012	mg	2.	.0002	99.25	.75
Zinc	32.9	1.8	48.4	47.2	53.6	mg	13.	<.1	84.62	3.85
Light metals										
Barium	.31	.03	.015	.003	.005	mg	.75	.0002	92.00	6.67
Calcium	14286.	22.67	93.55	50.	31.07	g	1.1	-	67.27	16.36
Cesium	.021	-	.0074	.01	.02	μ	10.	.025	8.00	90.00
Magnesium	271.4	.20	129.0	172.2	189.3	g	.3	-	61.40	38.23
Potassium	2000.	320.	1903.2	2500.	3000.	g	3.3	-	10.91	84.85
Rubidium	9.71	-	8.71	30.56	6.07	mg	2.2	-	13.50	86.16
Sodium	1428.6	506.7	2000.	1000.	750.	g	4.4	-	2.27	75.00
Strontium	4.57	.025	.058	.018	.015	mg	1.9	-	78.95	17.90
Heavy metals - Inner transition										
Uranium	.001	.0006	.023	.0003	.0002	μ	1.9	.007	84.21	14.47
Metalloids										
Antimony	.11	-	.3	.2	-	μ	50.	.05	18.00	80.00
Arsenic	.26	-	.03	.1	-	mg	1.	.0014	80.00	5.00
Non-metals										
Bromine	2.86	.43	5.48	2.61	4.29	mg	7.5	-	.93	93.33
Chlorine	1357.1	1200.	2387.1	2000.	785.7	g	5.2	-	.96	84.62
Iodine	.19	-	-	.189	.011	μ	200.	.42	10.00	85.00
Selenium	.19	-	.094	.67	.179	μ	150.	-	13.33	33.33

[1] Snyder *et al.* (1975), dry matter basis.

[2] mg = milligram; μ = microgram; g = gram.

TABLE 3. COMPARISON OF VALUES REPORTED FOR NATIONAL BUREAU OF STANDARDS BOVINE LIVER (NBS-SRM 1577)[a]

Element	National Bureau of Standards			
	Range of results[b]	Certified or interim value	Mean value[c]	Difference, %[d]
Antimony	<.1-.14(2)	.014	.03[e]	114.3
Arsenic	.05-.059(1)	.055	.07	27.3
Bromine	4.3-9.3(3)		8.8[e]	
Cadmium	.024-.32(3)	.8	.53	196.0
Cesium		.013	.014[e]	7.7
Chlorine	2533-2656(1)	2610.	2285.	12.4
Chromium	.05-1.57(8)	.2	.5[e]	150.0
Cobalt	.15-.29(3)	.18	.26[e]	44.4
Copper	180-204(3)	193.	f	
Iron	259-299(2)	270.	210.	22.2
Magnesium	600-611(1)	605	600.[e]	8.3
Manganese	9.2-11.3(2)	10.3	9.2[e]	10.7
Mercury	.014-.017(2)	.016	.04	150.0
Molybdenum	3.08-3.34(1)	3.2	2.5	21.9
Potassium	9300-10100(2)	9700.	8240.	15.1
Rubidium	17.5-19.2(2)	18.3	17.	7.1
Selenium	1.05-1.17(2)	1.1	1.2[e]	9.1
Sodium	2230-2670(2)	2430	1890.	22.2
Strontium	.136-.142(1)	.14	.0	
Uranium	.00055-.0009(1)	.0008	.0055	677.5
Zinc	120-134(3)	130.	130.[e]	.0

[a] All values PPM, dry matter basis.

[b] Range is of individual values reported for National Bureau of Standards. Results and mean values reported for other laboratories (Becker, 1976). Numbers in parentheses refer to total number of laboratories reporting values.

[c] Determined by Neutron Activation Laboratory, Virginia Polytechnic Institute and State University.

[d] Calculated as follows: $\frac{\text{certified value - mean value}}{\text{certified value}} \times 100$

[e] Value is within reported range.

[f] No values were reported.

TABLE 4. MEAN PROXIMATE ANALYSES BY WASTE TYPE AND GEOGRAPHICAL REGION (CHEMICAL COMPOSITION)[a]

Waste type	Region	No. of samples	Dry matter %	± S.E.	Crude protein %[a]	± S.E.	Crude fiber %	± S.E.	Ether extract %	± S.E.	Ash %	± S.E.	NFE %	± S.E.
Broiler litter	Va	3	72.73	.49	32.0	.70	20.64	.95	2.73	.19	18.4	.07	26.89	1.08
Broiler litter	Miss	2	92.93	.004	18.8	1.29	27.18	3.51	1.91	.27	19.93	6.18	32.18	1.65
Caged layer waste	Calif	8	93.93	.72	29.65	2.62	12.97	.93	.86	.16	37.82	3.06	18.73	.82
Dried poultry waste	Calif	4	92.35	.95	31.24	4.46	10.82	.67	1.08	.32	36.29	4.51	20.60	3.74
Dried poultry waste	Miss	3	91.66	.29	38.33	.52	14.28	.24	1.24	.17	24.74	.08	21.41	.50
Swine waste	Calif	2	94.61	.26	21.02	.59	17.12	.31	1.95	.07	29.38	.12	30.54	.32
Swine waste	Va	2	92.87	.65	25.34	.28	14.85	.89	9.02	.06	17.91	.14	32.89	1.36
Cattle feedlot waste	Calif	2	92.03	.07	14.91	.10	16.52	.34	.79	.02	39.19	.06	28.61	.29
Cattle feedlot waste	Fla	2	93.71	.23	13.39	4.30	24.34	5.46	1.79	.55	17.99	13.00	42.50	11.29

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[a] Dry basis.

TABLE 5. COMPOSITE MINERAL PROFILES OF POULTRY WASTE BY WASTE TYPE AND GEOGRAPHICAL REGION[a]

	Broiler litter Va	± S.E.	Broiler litter Miss	± S.E.	Caged layer waste Cal	± S.E.	Dried poultry waste Cal	± S.E.	Dried poultry waste Miss	± S.E.
Number of samples	3		2		8		4		3	
Heavy metals - Transition										
Aluminum	991.7	105.7	4075.	2232.	1626.	352.7	5940.	3054.	1030.	24.80
Cadmium	6.072	3.043	.0	.0	5.290	1.800	2.180	1.260	0	0
Chromium	2.622	1.047	5.213	2.041	5.230	2.290	12.40	1.930	8.960	1.940
Cobalt	2.288	.1582	2.029	.4940	2.920	.4819	12.20	1.520	1.130	.0525
Copper	593.1	156.8	213.7	80.68	186.1	21.60	199.2	51.70	129.2	3.320
Gold	.0	.0	.0	.0	.0057	.0018	.0003	.0003	.0052	.0013
Hafnium	.0694	.0694	.6598	.4961	.3871	.0239	.7297	.1433	.2697	.0383
Iron	1022.	67.13	2189.	859.1	2465.	1140.	4009.	2415.	1551.	115.8
Lanthanum	3.259	.3484	3.926	2.698	1.930	.7180	1.930	.7180	2.140	.1905
Lead	2.013	.408	1.263	.594	2.182	0.577	2.148	0.305	0.798	0.241
Manganese	371.0	18.56	468.3	120.4	474.0	77.80	449.0	41.40	295.3	8.860
Mercury	.0346	.0346	.0	.0	.0914	.0500	.1319	.1319	.1326	.0878
Molybdenum	9.186	.5377	3.642	.9815	6.280	1.900	3.630	1.270	11.50	.6319
Nickel	.7860	.1060	.5580	.0680	0.784	0.071	1.042	0.067	0.404	0.113
Scandium	.1976	.0160	.3391	.1549	.1848	.0535	.9235	.6498	.2806	.0036
Tantalum	.1421	.0385	.1188	.0490	.1028	.0512	.2155	.0757	.2907	.2019
Tin	16.66	16.66	.1000	.0020	23.80	6.660	.0000	.0000	9.700	3.850
Titanium	44.70	22.35	203.3	80.54	57.80	17.70	385.6	246.5	53.20	25.10
Tungsten	.8564	.2523	.8236	.3323	.6133	.1659	.8351	.1619	.1843	.1155
Vanadium	5.721	.3149	5.162	2.092	6.470	1.980	12.00	7.290	11.70	.4833
Zinc	495.8	30.52	446.4	37.13	439.5	66.50	395.4	35.80	291.7	9.860
Heavy metals - Inner transition										
Cerium	5.580	2.247	10.60	5.172	3.880	.8376	4.540	1.880	9.080	.9948
Dysprosium	1.213	.1254	.2675	.1519	.7440	.1227	.8124	.2080	.9523	.0291
Europium	.1664	.0433	.7819	.6898	.0519	.0340	.1904	.1300	.1181	.0966
Lutetium	.0	.0	.0460	.0276	.0311	.0085	.0138	.0138	.0313	.0066
Samarium	2.740	.8169	3.950	2.988	2.330	.5800	1.900	.6028	5.390	.6775
Thorium	.7211	.2301	3.764	2.228	1.670	.3570	1.820	.6849	1.330	.6751
Uranium	2.635	.1941	.4100	.4098	3.460	1.850	.5711	.2355	10.20	.7656
Ytterbium	.5998	.3317	.7149	.3363	.3357	.0245	.4307	.1345	.2918	.0337

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[a] All values ppm, dry matter basis.

TABLE 6. COMPOSITE MINERAL PROFILES OF POULTRY WASTE BY WASTE TYPE AND GEOGRAPHICAL REGION[a]

	Broiler litter Va	± S.E.	Broiler litter Miss	± S.E.	Caged layer waste Cal	± S.E.	Dried poultry waste Cal	± S.E.	Dried poultry waste Miss	± S.E.
Number of samples	3		2		8		4		3	
Light metals										
Barium	39.52	9.660	33.42	29.01	53.10	12.90	169.00	52.00	20.30	10.20
Calcium	32241.	603.5	21865.	6516.	16824.	12437.	30892.	21184.	73824.	1745.
Cesium	.1665	.1665	.3952	.0882	.6054	.1624	.5088	.0876	.3829	.1979
Magnesium	6344.	394.4	5825.	1323.	7964.	726.0	7274.	2480.	3988.	360.3
Potassium	36719.	3849.	31158.	3531.	29570.	2139.	27206.	2144.	27306.	1976.
Rubidium	21.50	1.403	35.41	10.85	22.90	4.450	25.00	8.570	37.70	3.310
Sodium	6898.	393.8	5532.	2667.	4332.	400.6	5542.	756.7	2546.	161.6
Strontium	87.39	16.30	.0	.0	69.30	33.90	490.3	305.0	144.0	16.90
Metalloids										
Antimony	.0	.0	.4759	.0765	.6283	.1290	4858.	.0751	.4613	.0363
Arsenic	75.93	2.226	21.31	20.64	5.560	2.320	4.390	2.130	2.100	.2764
Non-metals										
Bromine	11.09	.3417	18.55	10.88	21.00	2.790	18.60	6.770	9.010	.4277
Chlorine	8387.	1013.	7507.	3004.	5737.	862.2	5811.	1554.	5685.	118.4
Iodine	7.457	2.047	3.417	3.417	4.760	.9345	7.690	3.120	2.920	1.220
Selenium	1.086	.8625	1.555	.0824	2.140	.3597	1.100	.6359	.6119	.3852

[a] All values PPM, dry matter basis.

TABLE 7. COMPOSITE MINERAL PROFILES OF SWINE AND CATTLE FEEDLOT WASTE BY TYPE AND GEOGRAPHICAL REGION[a]

	Swine waste Calif.	± S.E.	Swine waste Va.	± S.E.	Cattle feedlot waste Calif.	± S.E.	Cattle feedlot waste Fla.	± S.E.
Number of samples	2		2		2		2	
Heavy metals - Transition								
Aluminum	7881.	350.0	1682.	4.510	16846.	3158.	5300.	5091.
Cadmium	2.000	2.000	.0000	.0000	7.210	7.210	10.40	7.490
Chromium	12.30	5.150	8.570	1.970	14.70	2.110	6.810	.2540
Cobalt	3.350	.2500	5.780	.2258	4.580	.2630	4.150	2.100
Copper	115.0	13.00	199.7	9.980	221.1	210.7	166.6	162.2
Gold	.0015	.0015	.0026	.0005	.0024	.0018	.0061	.0010
Hafnium	.7501	.2500	.5313	.1328	1.570	.5369	.4562	.1490
Iron	4100.	310.0	3050.	218.5	8844.	1052.	2741.	2131.
Lanthanum	3.750	.5501	5.840	.1734	4.950	4.950	2.420	2.020
Lead	2.664	0.405	1.406	0.621	1.889	0.303	1.949	0.881
Manganese	541.1	19.00	446.8	4.060	247.4	26.30	150.7	35.00
Mercury	.2500	.0500	.0000	.0000	.0053	.0053	.2537	.0489
Molybdenum	5.150	1.850	7.470	.5457	2.440	1.450	2.370	2.370
Nickel	0.933	0.050	0.847	0.207	0.594	0.035	0.517	0.380
Scandium	.4000	.0000	.3943	.0063	1.900	.2105	.5044	.5044
Tantalum	.5000	.5000	.2257	.1413	.2053	.0158	.1099	.1009
Tin	.0000	.0000	17.10	7.140	3.840	3.840	.0000	.0000
Titanium	52.50	5.250	241.8	9.870	931.8	78.90	154.7	127.8
Tungsten	1.150	.1500	.4520	.0303	.4896	.4896	.5586	.0466
Vanadium	3.450	.0500	11.57	1.080	26.30	4.210	6.610	5.690
Zinc	486.5	24.50	972.5	2.650	101.6	1.570	137.5	33.00
Heavy metals - Inner transition								
Cerium	11.60	.7501	14.20	.4876	21.10	2.110	11.00	8.350
Dysprosium	1.650	.3500	2.630	.1122	1.950	.2633	.0512	.0512
Europium	.2000	.2000	.1947	.0689	.0000	.0000	.2537	.0489
Lutetium	.0250	.0250	.1312	.0785	.0158	.0158	.0000	.0000
Samarium	3.300	.5000	6.100	.2266	2.740	2.730	2.020	1.710
Thorium	4.550	.3500	2.680	.1649	5.630	.1582	2.630	1.400
Uranium	.8501	.2500	6.830	.2286	.0368	.0369	.8575	.8575
Ytterbium	.2500	.0500	.6895	.3225	.3264	.3264	.2880	.2164

[a] All values ppm, dry matter basis.

TABLE 8. COMPOSITE MINERAL PROFILES OF SWINE AND CATTLE FEEDLOT WASTE BY TYPE AND GEOGRAPHICAL REGION

	Swine waste Calif.	± S.E.	Swine waste Va.	± S.E.	Cattle feedlot waste Calif.	± S.E.	Cattle feedlot waste Fla.	± S.E.
Number of samples	2		2		2		2	
Light metals								
Barium	273.5	123.5	59.90	5.100	145.1	139.3	.0000	.0000
Calcium	71607.	16802.	29965.	606.0	34219.	3683.	379.4	379.4
Cesium	.6001	.6001	.3105	.1428	.6844	.1368	1.060	.4494
Magnesium	4851.0	3920.0	9937.	499.8	11003.	1631.	3948.	1429.
Potassium	9801.	1600.	16822.	45.10	20024.	19988.	22155.	13758.
Rubidium	9.400	9.400	15.80	1.090	44.20	2.100	27.20	27.20
Sodium	1950.	250.0	4415.	11.84	6320.	6315.	5247.	4841.
Strontium	459.6	64.50	179.5	93.10	352.7	352.7	.0000	.0000
Metalloids								
Antimony	1.100	.4000	.1318	.1318	.3422	.3106	1.480	1.080
Arsenic	3.510	.3500	2.000	.0054	.1211	.1211	1.510	1.510
Non-metals								
Bromine	9.400	.2000	3.890	.0947	19.50	19.50	13.80	8.180
Chlorine	1130.	20.00	4363.	40.90	9739.	474.3	14490.	11940.
Iodine	9.500	4.400	1.110	1.110	.5107	.5107	5.750	5.750
Selenium	3.050	3.050	.0000	.0000	1.950	.5792	.6656	.6656

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[a] All values PPM, dry matter basis.

VITA

Thomas Warren Westing, son of Paul A. and Lucia W. (deceased) Westing, was born on February 24, 1937 in Madera County, California.

He attended Lincoln Elementary School and was graduated from Madera Union High School in June, 1954. He was in the Submarine Service of the United States Navy from April, 1955 to January, 1959. He received his Bachelor of Science Degree in Animal Science from California Polytechnic State University, San Luis Obispo, California, in 1962. He received his Master of Science Degree in Animal Science from Purdue University, West Lafayette, Indiana, in 1964.

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Thomas Warren Westing

MINERAL ELEMENT PROFILES OF ANIMAL WASTES AND EDIBLE TISSUES FROM CATTLE FED ANIMAL WASTES

by

Thomas Warren Westing

(ABSTRACT)

Experiments were conducted to determine mineral element levels in feedstuffs, animal wastes and tissues from cattle fed broiler litter or cattle waste.

Heifers fed 30% broiler litter ensiled with corn forage performed as well as heifers fed corn silage and soybean meal but performance tended to be lower than for heifers fed corn-litter silage and soybean meal in a 201-day feeding trial. No differences were found in carcass quality and yield grades. Feedlot performance was very low for cattle fed corn silage and no protein supplement. Feeding broiler litter to heifers did not adversely affect the eating quality of roasts from these heifers as measured subjectively by a taste panel and shear devices.

Copper (593 ppm) and arsenic (75.9 ppm) levels were high in broiler litter, compared to other ruminant feedstuffs. Following a 24-hour withdrawal, heifers were slaughtered and liver, muscle, fat and kidney samples were taken. Liver copper reflects high dietary copper intakes in litter fed heifers ($P < .01$). Arsenic in the kidney and fat was higher in litter-fed heifers. Bromine

was lower ($P < .05$) in liver, kidney, muscle and fat of litter-fed heifers.

In two successive cattle finishing trials, a 16% cattle waste ration was compared to a conventional feedlot ration. Control steers in trial I outgained (1.31 kg/day) waste fed steers (1.14 kg/day), but in trial II gains were higher for the waste fed steers (1.41 *vs* 1.54 kg/day). In trial I selenium was higher ($P < .05$) in livers of steers fed waste. In trial II lead content was higher ($P < .05$) in fat of waste fed cattle and liver copper was higher ($P < .05$) in conventionally-fed steers.

In a long term experiment, currently in its sixth year, cows were wintered on hay, 80% litter and 20% corn grain with and without supplemental copper. Liver biopsies of the cows were taken in December and April, the beginning and end of the wintering period. Average copper levels in the wintering rations were 15.9, 412.6 and 595.6 ppm, dry basis, respectively. Liver biopsies taken in December and April for litter-fed cattle were higher ($P < .01$) in copper than livers of cows fed hay. Respective April and December liver copper values were: hay, 34.5 and 27.0; corn-litter, 757.3 and 195.7; corn-litter-copper, 964.4 and 218.9 ppm, dry basis. Liver arsenic levels were similar after the grazing season but increased dramatically over the wintering period.

Waste samples from broilers, caged layers, cattle and swine from several regions in the United States were analyzed. Litter arsenic and copper values were 54 and 441 ppm, respectively. Dried poultry waste varied in ash, crude protein, cadmium and selenium. Aluminum, cadmium and copper content of cattle waste was higher for all samples than values reported in the literature. Swine waste had an average crude protein content of 23% and varied in cadmium and selenium.