Ensiling characteristics and feeding value of silage made from cattle waste and maize residues

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In this investigation, silage made from cattle waste being ensiled with maize residues (ECW), was evaluated with respect to ensiling characteristics and feeding value. Cattle waste was obtained from cows that were finished on a high-concentrate (80%) diet. It was collected together with maize residues which served as bedding material for animals housed on a concrete floor. The mixture consisted of approximately 70 parts of manure and 30 parts of maize residues. Effective preservation was indicated by the following measurements after an ensiling period of 2 months: pH 4,24; lactic acid content 7,8 g/100 g dry matter (DM); total volatile fatty acid content 4,6 g/100 g DM and butyric acid content 0,16 g/100 g DM. In a growth study, steers fed on ECW showed a daily mass gain of 0,20 kg/day in comparison to 0,46 kg/day by steers fed on maize residues ($P<0,01$). Organic matter intake for both treatments was the same. Apparent digestibility of organic matter however was found to be 61,7% for steers fed on ECW and 57,2% for steers fed on maize residues ($P<0,01$). When ECW was fed as the roughage component (30%) of a high-concentrate diet, however, it compared well with *Eragrostis curvula* hay as roughage component. Steers fed on a high-concentrate diet containing ECW showed a feed conversion of 6,50 kg DM intake/kg gain in comparison with a feed conversion of 7,39 for steers fed on a high-concentrate diet containing *Eragrostis curvula* hay as roughage component. Also, carcases of steers fed on the ECW-containing high concentrate ration tended to be of a better quality and scored 8,9 points out of 13 in comparison with steers fed on the *Eragrostis curvula*-containing high concentrate ration which scored 7,5 points (not significant).

In hierdie ondersoek is die inkuilingseienskappe en voedingswaarde van kuilvoer, gemaak van beesuitskeidings wat met mielie-oesreste ingekuil is, ondersoek. Beesmis en urine, afkomstig van koeie wat op 'n hoë kragvoerrantsoen (80%) afgerond is, is saam met mielie-oesreste wat as beddegoed op 'n betonoppervlak vir die diere gedien het, versamel. Die mengsel wat bestaan het uit ongeveer 70 dele nat mis en 30 dele reste, is vir 'n tydperk van 2 maande ingekuil. Ontledingsyfers het effektiewe preservering daarvan aangetoon. 'n Gemiddelde pH van 4,24, melksuurinhoud van 7,8 g/100 g droëmateriaal (DM), totale vlugtige vetsuurinhoud van 4,6 g/100 g DM en bottersuurinhoud van 0,16 g/100 g DM is gevind. In 'n groeistudie is gevind dat osse wat op die ingekuilde mengsel gevoer is, gemiddeld 0,20 kg/dag in massa toegeneem het in vergelyking met 0,46 kg vir osse wat op mielie-oesreste gevoer is ($P<0,01$). Die inname van organiese materiaal was dieselfde vir osse op die ingekuilde mengsel en osse op die mielie-oesreste terwyl die skynbare verteerbaarheid van organiese materiaal betekenisvol hoër was ($P<0,01$) vir osse op die ingekuilde mengsel (61,7% teenoor 57,2%). Waar die ingekuilde mengsel egter as ruvoerkomponent (30%) van 'n hoë kragvoerrantsoen gevoer is, het dit goed vergelyk met *Eragrostis curvula* hooi as ruvoerkomponent. Osse wat op eersgenoemde rantsoen gevoer is, het 'n voeromsetting van 6,50 kg DM-inname/kg massatoename getoon in vergelyking met 'n voeromsetting van 7,39 vir osse wat op die *Eragrostis curvula* bevattende kragvoer gevoer is. Verder het die karkasse van osse op kragvoer met die inkuilingsmengsel as ruvoerkomponent geneig tot 'n beter gradering naamlik, 8,9 punte uit 13 teenoor 7,5 punte vir karkasse van osse wat op die *Eragrostis curvula* bevattende kragvoer (nie betekenisvol) gevoer is.

Keywords: Silage, cattle waste, maize residues, feeding value

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Introduction

Demands for the production of more and cheaper food necessitate reutilization of some waste products, like cattle waste. At the same time, pollution which reaches alarming proportions in some feedlots can be counteracted.

Anthony and Nix (1962) indicated that manure collected from full-fed slaughter cattle has a high nutritive value. This was shown (Anthony, 1967) to have excellent palatability after being ensiled with hay in a ratio of 57 parts manure and 43 parts hay (wet basis). The ensiled product was referred to as ensiled cattle waste (ECW). During the process of ensiling most pathogens are killed (Vetter & Burroughs, 1974) and the maturation of parasitic nematodes inhibited (Anthony, 1974). This was corroborated by a feeding trial with breeding ewes and cattle (Anthony, 1967). The animals fed wastelage for approximately one year remained in good health and produced normal young and lactated normally.

Feeding trials in general indicated that ECW fed as the sole feed, contains enough feeding value to maintain body mass (Anthony, 1967; McClure, Preston & Klosterman, 1973; Harpster, Long, LaLonde & Saylor, 1975). ECW was also shown to be included successfully as roughage component of a high-concentrate diet (Bandel & Anthony, 1969). By inclusion of ECW approximately 20% of roughage was saved.

In the investigations carried out by Anthony, manure was ensiled mainly with coastal bermudagrass hay. Other sources of dry roughage, however, like straw (McClure, *et al.*, 1973), grass-legume hay (Harpster, Long & Wilson, 1978; Lamm, Webb & Fontenot, 1979)

and rye-straw (Cornman, Lamm, Webb & Fontenot, 1981) were also used successfully as dry roughage components. Corn stover was also used (McClure, *et al.*, 1973), but together with 10% ground-shelled corn. In a study carried out on laboratory scale (Snyman, Du Preez & Calitz, 1986) excellent fermentation characteristics were measured when manure was ensiled with maize residues. During the 1980 season, which can be regarded as a normal year of agriculture, 10,8 million tons of maize were produced in the RSA. (Report of the Maize Board, 1981). If the ratio of grain : residues is taken as 1 : 1, approximately 10 million tons of residues were produced. The larger part of these maize residues become available in the Highveld Region where feedlots have the capacity to finish 75 000 cattle each year. It can therefore be regarded as a relevant roughage component for the ensiling of cattle waste in the Highveld Region.

In this investigation the fermentation characteristics and feeding value of cattle waste ensiled with maize residues, were investigated. The feeding value of the ECW as a roughage ration was evaluated in a steer growth trial against maize residues. ECW was also evaluated as roughage component of a high-concentrate ration in a steer finishing trial.

Procedure

Collection and ensiling of manure

A system of collection and ensiling was followed which can also be used in practice. Manure was collected from Simmentaler cows being finished on a high-concentrate diet (maize, 73%; oil cake, 7%; maize silage, 20% on a DM basis). Four cows (550 kg each) were fed per kraal (15 m^2).

Maize residues, hammer-milled through a 25 mm sieve, were spread over the concrete surface of each kraal every morning after the residues of the preceding day had been collected together with manure and urine excreted by the cows. Ten kilograms of maize residues were spread out per cow, resulting into an estimated ratio of wet manure to maize residues of 70 : 30.

The mixture was collected daily after 2 kg of molasses syrup had been added to the mixture of each kraal. It was mixed and ensiled in a furrow (0,6 m wide and 1,2 m deep) lined with plastic sheet. Samples of both the maize residues and mixture were taken each day before ensiling and dried in a forced-draught oven for 48 h at 65°C. The material was ensiled for a period of 2 months.

Growth studies

Ensiled cattle waste as roughage diet

Twenty Simmentaler steers (15 months old), which were fed on *Eragrostis curvula* hay, were stratified according to body mass and allocated to two groups so that a comparable distribution of body mass between the two groups was obtained. The steers were fed individually for a period of 85 days, one group on ECW and the other group which served as a control, on maize residues plus 5% molasses syrup. All animals received a salt-dicalcium phosphate (1:1) lick (*ad lib.*) and a crude protein supplement (HPC-60), increasing the crude protein content by six percentage units. Because refusal of HPC-60 during the first 43 days of the experiment took place to some extent by steers on ECW, the crude protein supplement was replaced with an urea lick consisting of equal parts of urea, maize meal, salt (NaCl) and dicalcium phosphate, for the rest of the feeding period. This led to a more comparable intake of supplemented nitrogen between the two treatments. Body mass was measured after withholding feed and water overnight.

Use of ensiled cattle waste as roughage component of a high-concentrate diet

After a digestion trial that was carried out after the previously mentioned study, eight steers of each group were fed in a group on a high-concentrate diet consisting of 60% maize meal, 10% HPC-60 and 30% roughage. One group was fed ECW (*in vitro* dry matter digestibility (IVDMD) was 55,4%) as roughage component while the other group received *Eragrostis curvula* hay (IVDMD measured as 49%) as roughage component. A salt-dicalcium phosphate lick (1:1) was available *ad lib.*. Body mass was determined at days 42 and 85 after withholding food and water overnight and feed intake measured for this period. The animals were slaughtered after a feeding period of 92 days. The carcass mass was determined and the carcass quality evaluated on a 13-point scale based on the present grading system of the RSA.

Digestion study

Directly after the growth study on roughage, which also served as adaptation period for the digestion trial, had been completed, a digestion study was carried out on the same diets for a period of 10 days. Roughage was supplied on an *ad lib.* basis. Refusals were removed only after days 5 and 10 so that selection of specific plant particles was limited to a minimum. Forage samples for analysis were collected daily and faeces twice daily. Samples were dried in a forced-draught oven at 65°C for 48 h. A sample for measuring retention time according to the method of Balch (1950) as adapted by Pieterse, Lesch & van Schalkwyk (1963), was taken at the same time.

Chemical analyses

The following chemical analyses were performed on an extract obtained by shaking 40 g of ECW for a period of 6 h with 160 ml water and 2 ml solution of $HgCl_2$ (saturated) : pH, lactic acid (Barker & Summerson, 1941), total volatile fatty acids (Fenner & Elliot, 1963), acetic-, propionic-, and butyric acid (Clancy, Wangsness & Baumgardt, 1977), and ammonia-nitrogen (Clare & Stevenson, 1964). The gas chromatographic determination of fatty acids was carried out on the steam distillate (Fenner & Elliot, 1963) of the silage juice.

For determination of nitrogen and phosphorus, the forage, faeces and urine were digested by means of the micro-Kjeldahl method. Nitrogen and phosphorus were then determined by means of automatic flow systems according to the methods of Clare & Stevenson (1964) and Basson (1974) respectively. *In vitro* dry matter digestibility of the forage samples was determined according to

Tilley & Terry (1963) as adapted by Engels & van der Merwe (1967). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) content of the forages were determined according to the methods of van Soest (1963) and van Soest & Wine (1967) respectively. Water soluble carbohydrates (WSC) were determined by means of the automated orcinol method (Shannon, 1972) while true protein content was determined as for nitrogen after true proteins had been precipitated with trichloro-acetic acid (Agrawala, Duncan & Huffman, 1953). Calcium, magnesium, iron and aluminium were determined by atomic absorption spectrophotometry after the sample had been dry ashed and dissolved in dilute HCl.

Results and Discussion

Fermentation characteristics

The fermentation characteristics of the ECW are shown in Table 1. The data indicate that favourable fermentation took place. This is indicated by the relatively high ratio (1,7) of lactic acid to total volatile fatty acids and low content of butyric acid (0,16 ± 0,05 g/100 g DM). This may be the result of inoculation with large numbers of lactic acid-producing bacteria occurring in manure (Knight, McCaskey, Anthony & Walters, 1977). The somewhat high ratio of ammonia-nitrogen : total nitrogen (29,6%) is probably the result of inclusion of urine in the silage mixture together with pre-ensiling urease activity, rather than a result of unfavourable fermentation. A ratio of ammonia-nitrogen to total nitrogen of not more than 8% was obtained in an *in vitro* investigation (Snyman, *et al.*, 1986) where urine was not included in the mixture.

Table 1 Fermentation characteristics of ensiled cattle waste

Measurement	Number of samples analysed	Mean value ± *SE*
pH	14	4,24 ± 0,11
Lactic acid (g/100 g DM)	38	7,81 ± 1,47
Acetic acid (g/100 g DM)	14	2,19 ± 0,44
Propionic acid (g/100 g DM)	14	0,17 ± 0,04
Butyric acid (g/100 g DM)	14	0,16 ± 0,05
Total volatile fatty acids (g/100 g DM)	14	4,6 ± 0,80
Lactic acid : Total volatile fatty acids	–	1,7
Ammonia nitrogen (g/100 g DM)	38	0,62 ± 0,08
Ammonia nitrogen (% total N)	–	29,6

Chemical composition and IVDMD

The chemical composition and IVDMD of the maize residue-waste mixture (before and after ensiling) in comparison to that of maize residues are shown in Table 2. The crude protein value of the residue-waste mixtures, before and after ensiling, seems to be more than double the value of maize residues alone. A lot of the crude protein enrichment, however, was brought about by non-protein nitrogen, contributing nearly 50% of total nitrogen. Enrichment is also noticed for the ash content, including an increase in the content of phosphorus. Very high levels of iron and aluminium were measured in ECW. The difference in the contents before and after ensiling idicates contamination with soil during ensiling and/or removal of silage.

The IVDMD of the residue-waste mixture before ensiling is the same as that of maize residues alone which can be interpreted that the IVDMD of maize residues will not be influenced by the waste component. This conclusion, however, applies under the present experimental conditions. Measurements performed on both cattle manure and maize residues (Snyman, unpublished data) indicate great variation in IVDMD for both these components. This means that the IVDMD of the mixture will be determined primarily by the values of the individual components and their mixing. Ensiling of the mixture did not influence IVDMD negatively. On the contrary, it is improved by a small amount (2%).

The decrease in the content of water soluble car-

Table 2 Chemical composition and *in vitro* dry matter digestibility values (mean ± *SD*) of ensiled cattle waste and maize residues

Component	Maize residues	Maize residues — cattle waste mixture	
		Before ensiling	After ensiling (ECW)
Crude protein (g/100 gDM)	3,9 ± 0,2	10,0 ± 0,5	9,9 ± 0,4
NPN (% total N)	0,0 ± 0,0	47,7 ± 8,8	48,2 ± 4,8
IVDMD (g/100 gDM)	53,4 ± 1,3	53,4 ± 2,0	55,4 ± 1,1
ADF g/100 gDM)	55,7 ± 1,8	41,6 ± 1,4	43,2 ± 1,6
NDF (g/100 gDM)	87,1 ± 0,8	70,3 ± 1,1	64,4 ± 1,1
WSC (g/100 gDM)	3,91 ± 0,25	2,63 ± 0,22	1,48 ± 0,12
Phosphorus (g/100 gDM)	0,10 ± 0,01	0,30 ± 0,01	0,32 ± 0,01
Calcium g/100 gDM)	0,23 ± 0,02	0,27 ± 0,03	0,33 ± 0,01
Iron (μg/g)	179 ± 38	480 ± 88	1625 ± 415
Aluminium (μg/g)	150 ± 30	360 ± 50	1308 ± 391
Ash (g/100 gDM)	4,9 ± 0,8	9,4 ± 1,1	9,9 ± 0,9

bohydrates (WSC) during ensiling is a consequence of fermentation. The favourable type of fermentation that was obtained despite the very low content of WSC before ensiling once again demonstrates the effectiveness with which fermentation took place. The lower content of NDF in ECW indicates that hemicellulose was probably also involved in the fermentation process. ADF content was not influenced by ensiling.

Apparent digestibility and mean retention time

The apparent digestibility and mean retention time (MRT) of ECW and maize residues are shown in Table 3. A significantly higher ($P<0,01$) apparent digestibility for DM and organic matter (OM) was measured for ECW (58,4 and 61,7%) in comparison with maize residues (53,4 and 57,2%). No significant difference in intake, however, was found, especially when expressed in terms of OM. These findings were accompanied by a tendency of a shorter MRT for steers fed on ECW (71 h vs 81 h, not significant). This coincides with the higher apparent digestibility measured for ECW and also the much leaner appearance observed for steers fed on ECW. These findings suggest that rumen capacity of steers fed on ECW was not fully utilized.

Table 3 Intake, apparent digestibility and mean retention time of steers fed ensiled cattle waste and maize residues

Item	Maize residues	Ensiled cattle waste	Significance of difference
Number of steers	10	10	
Intake			
Dry matter (kg/day)	4,76	5,41	NS
Organic matter (kg/day)	4,53	4,87	NS
Apparent digestibility			
Dry matter (%)	53,4	58,4	$P<0,01$
Organic matter (%)	57,2	61,7	$P<0,01$
Mean retention time (h)	81	71	NS

NS — Not significant, $P>0,05$

Growth study with ECW as roughage diet

In Table 4, the intake and growth data of steers fed on ECW are compared with those of steers fed on maize residues. A significantly higher intake of DM was measured for steers fed on ECW (4,59 vs 4,19 kg/day; ($P<0,01$). However, when intake was corrected for ash content and expressed as OM, intake was found to be the same (3,98 vs 4,13 kg).

A mass increase of 0,05 kg/day was measured for steers fed ECW in comparison to 0,39 kg/day for steers fed on maize residues. However, when mass increase was calculated from day 15 of the growth trial, mass increases of 0,20 and 0,46 kg/day were measured for steers fed on ECW and maize residues respectively. The higher growth rate when calculated over the last 70 days of the trial, was most probably due to the fact that the negative effect of adaptation during the first 15 days of the trial was eliminated. In the case of steers fed on ECW, a decrease in body mass initially took place during this period. Besides the possible influence of adaptation to the new diet, a decreased mass of rumen contents due to a possible decrease in mean retention time, could also have contributed to this.

Table 4 Intake and daily gain means of steers fed on ensiled cattle waste and on maize residues

Item[a]	Roughage fed: Maize residues	Roughage fed: Ensiled cattle waste	Significance of difference
Number of steers	10	10	
Dry matter intake (kg/day)	4,19	4,59	$P<0,01$
Organic matter intake (kg/day)	3,98	4,13	NS
Beginning mass (kg)	229,4	231,4	NS
Mass at day 15 (kg)	230,2	221,0	NS
Final mass, day 85 (kg)	262,7	235,3	$P<0,01$
Average daily gain (kg)			
Total period, 85 days	0,39	0,05	$P<0,01$
Last 70 days	0,46	0,20	$P<0,01$

[a] Measurement of the different items were performed over the total period of 85 days

NS — Not significant, $P>0,05$

The lower mass increase of steers fed ECW in comparison to steers fed on maize residues (0,2 vs 0,46 kg/day), despite a somewhat higher digestibility, can only be explained by negative factors associated with the utilization of silage (Thomas, Kelly & Chamberlain, 1980). Probably the abnormally high content of iron might also have contributed to this (Standish, Ammerman, Simpson, Neal & Palmer, 1969), although they also indicated a depressed intake which was not found in this experiment.

Growth study with ECW as roughage component of a high-concentrate diet

The intake, average daily gain and carcass characteristics of steers fed on high-concentrate diets containing ECW and *Eragrostis curvula* hay (hammermilled, 25 mm screen) respectively as roughage components, are shown in Table 5.

According to the data in Table 5 performance with ECW tended to be somewhat better than with *Eragrostis curvula* hay as roughage component. Although a slightly higher intake of dry matter was measured for the high-concentrate diet containing *Eragrostis curvula* hay as roughage (12,20 vs 11,12 kg/day), a tendency for a higher average daily gain (1,72 vs 1,65 kg/day; NS) was observed for steers fed the diet containing ECW as roughage. Also, tendencies for higher carcass mass (221,1 vs 211,3; NS) and carcass scoring (8,9 vs 7,5; NS) as evaluated in Table 6 were found. In this evaluation, however, the *Eragrostis curvula* hay was of a somewhat

Table 5 Intake, daily gain and carcass characteristics of steers fed on high concentrate rations containing ensiled cattle waste and *Eragrostis curvula* hay respectively as roughage components

Item[a]	Roughage component		
	Eragrostis curvula hay	Ensiled cattle waste	Significance of difference
Number of steers	8	8	
Dry matter intake (kg/day)	12,20	11,12	-
Beginning mass (kg)	312	309	NS
Final mass (kg)	383	383	NS
Average daily gain (kg)	1,65	1,72	NS
Dry matter intake/kg gain	7,39	6,50	-
Carcass mass (kg)	211,3	221,1	NS
Carcass scoring (points out of 13)	7,5	8,9	NS

[a] Animals were fed over a period of 85 days. Measurement of the different items, however, only took place over the last 43 days
NS — Not significant, $P>0,05$

lower *in vitro* digestibility (IVDMD = 49,0%). The results, however, still indicate that ECW with maize residue as dry roughage component, can be included successfully as roughage component of a high-concentrate diet. This is confirmed by a feed conversion of 6,50 .

Conclusion

The fermentation characteristics of ECW showed clearly that waste, collected from cattle being fed a high-concentrate diet, can be ensiled successfully on a large scale with maize residues. ECW was shown to be of a lower feeding value than maize residues alone when fed as roughage, supplemented with a nitrogen-phosphate containing lick, to steers. ECW can be included successfully as roughage component in a high-concentrate diet, saving on roughage while at the same time counteracting pollution.

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