The utilization by domestic ruminants in Botswana of treatment diets containing cereal crop stovers treated with urea or urea and molasses

by

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Abstract

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The studies were aimed at examining the effects of treatment with urea or urea and molasses on the physical and chemical composition of stovers of sorghum, maize and millet and assessing the potential of these treated cereal crop stovers as additional feed for domestic ruminants in Botswana. The trials were carried out at Sebele, Botswana College of Agriculture (BCA), Botswana. Sebele is situated at 24º 33'S and 25º 57'E and is at an altitude of 994 m above sea level. Cereal crop stovers were ground in a hammer mill and treated with 10 g urea/kg stover (T1), 25 g urea/kg stover (T2) or 10 g urea + 10 g molasses/kg stover (T3) for 3 weeks. The experimental design for the treatment of the cereal crop stovers was a 3 x 4 completely randomized factorial design [3 cereal crop stovers *and* 3 treatment methods (T1, T2, T3) plus untreated]. Samples of cereal crop stovers untreated or treated with T1, T2 or T3 were obtained and analysed for dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and *in vitro* DM digestibility (IVDMD). The physical changes on the cereal crop stovers due to treatments were noted. Six steers, four of which were fitted with rumen cannulae, and six goats and six sheep were used in a crossover experiment to evaluate the utilisation of treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 or T3. The animals were kept in individual pens and fed a basal diet of veld grass hay plus a commercially available feed, namely Pen-feed. Each animal had unrestricted access to water

and a mineral lick and were adapted to the respective treatment diets for 14 days, followed by 7-day sampling periods The data collected included the feed intake and digestibility coefficients of DM, OM, CP, NDF and ADF. Data were also obtained on metabolisable energy (ME) intake, average daily gains and the pH and ammonia concentration of rumen fluid.

Treatment with T1, T2 and T3 increased the CP, NDF, ADF, ADL and IVDMD of the cereal crop stovers. The mean CP (g/kg DM) of cereal crop stovers increased from 69.75 (untreated) to 99.94, 112.63, and 110.50 when treated with T1, T2 and T3 respectively. Significant improvements in the total intake of DM and CP by steers compared to the Control diet were observed when feeding cereal crop stovers treated with T2 and T3. The improvements in the intake and nutrient digestibility coefficients when providing some treatment diets containing the treated stovers are comparable to those obtained when offering lucerne hay which implies that these treatment diets may be suitable replacements for lucerne hay. However, the treatment diets did not significantly improve the average daily gain and metabolic body weights of the steers, goats and sheep. Therefore, treatment diets containing stovers of sorghum, maize or millet treated with T1, T2 or T3 used in the present study are recommended for maintenance rather than production purposes.

Opsomming

Die benutting deur gedomestikeerde herkouers in Botswana van graanoesreste wat met ureum of ureum en melasse behandel is

deur

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Hierdie studies het ondersoek ingestel na die invloed van behandeling met ureum of ureum en melasse op die fisiese en chemiese samestelling van oesreste van sorghum, mielies en boermanna (millet) asook ‘n bepaling van die potensiaal van hierdie behandelde graanoesreste as bykomende voerbronne vir gedomestikeerde herkouers in Botswana. Die studie is op Sebele by die Botswana College of Agriculture (BCA) in Botswana uitgevoer. Sebele is geleë op 24º 33'S en 25º 57'E op ‘n hoogte van 994 m bo seevlak. Die graanoesreste is deur ‘n hamermeul gemaal en behandel met 10 g ureum/kg oesreste (T1), 25 g ureum/kg oesreste (T2) of 10 g ureum + 10 g melasse/kg oesreste (T3) vir drie weke. Die proefuitlag vir die behandeling van die graanoesreste was ‘n 3 x 4 volledige faktoriaal ontwerp [3 graanoesreste *en* 3 behandelingsmetodes (T1, T2, T3) plus onbehandeld]. Monsters van die onbehandelde graanoesreste en ook die wat behandel was met T1, T2 of T3 is versamel en ontleed vir droë materiaal (DM), organiese materiaal (OM), ruproteïen (RP), neutraalbestande vesel (NDF), suurbestande vesel (ADF), suurbestande lignien (ADL) en *in vitro* DM verteerbaarheid (IVDMD). Die fisiese verandering van die graanoesreste as gevolg van die drie behandelings is aangeteken. Ses osse, waarvan vier toegerus was met rumenkannules, en ses bokke en ses skape is in ‘n omslagproefontwerp gebruik vir die evaluering van die benutting van die proefdiëte wat graanoesreste van sorghum, mielies en boermanna (millet) wat met T1, T2 of T3 behandel is. Die diere is individueel in krale

gehuisves en die basale dieet van die diere het bestaan uit veldgrashooi plus ’n kommersieel beskikbare voerbron, naamlik “Pen-feed”. Elke dier het vrye toegang tot water en ’n mineralelek gehad en is oor ’n periode van 14 dae aangepas op die onderskeie behandelingsdiëte, gevolg deur ’n kolleksieperiode van sewe dae. Data is versamel ten opsigte van inname en verteerbaarheid koefisiënte van DM, OM, RP, NDF en ADF. Data is ook versamel ten opsigte van ME inname, gemiddelde daaglikse toenames en die pH en ammonium konsentrasies van rumenvloeistof.

Behandeling met T1, T2 en T3 het die RP, NDF, ADF, ADL en IVDMD van die graanoesreste verhoog. Die gemiddelde RP (g/kg DM) van die graanoesreste is verhoog vanaf die 69.75 (onbehandelde materiaal) tot 99.94, 112.63 en 110.50 na behandeling met T1, T2 en T3 onderskeidelik. Betekenisvolle verhogings in die totale inname van DM en RP deur osse vergeleke met die Kontrole dieet is waargeneem wanneer die diëte graanoesreste bevat het wat met T2 en T3 behandel was. Die verhogings in inname en voedingstofverteerbaarheid wanneer sommige proefdiëte wat behandelde graanoesreste bevat het aan diere gevoer is, was vergelykbaar met lusernhooi. Dit dui daarop dat hierdie behandelde graanoesreste geskikte vervangings vir lusernhooi mag wees. Die proefdiëte het egter nie die gemiddelde daaglikse toename en metaboliese gewigte van die osse, bokke en skape betekenisvol verbeter nie. Derhalwe word aanbeveel dat die proefdiëte soos in hierdie studie gebruik deur graanoesreste van sorghum, mielies of boermanna (millet) met T1, T2 of T3 te behandel, vir onderhoud van diere eerder dan produksiedoeleindes gebruik word.

Declaration

I hereby declare that this dissertation submitted by me to the University of the Free State for the degree, **Philosophiae Doctor**, is my own independent work and has not previously been submitted by me at another University. I furthermore cede copyright of the dissertation in favour of the University of the Free State.

Signature ………………….. Date ……………………….

Moagi Letso (candidate)

Dedication

This work is dedicated to my wife, Shupiwe and our children; Moagi Jr., Moagisi and Sean for their constant prayers, love and encouragement.

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Finally and most importantly, acknowledgement is also due to the Gracious Great I AM for I can do all things through Him who strengthens me.

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List of abbreviations and symbols

%	=	percentage
ad lib.	=	*ad libitum* (to appetite)
ADF	=	acid detergent fibre
ADL	=	acid detergent lignin
ANOVA	=	analysis of variance
AOAC	=	Association of Official Analytical Chemists
APRU	=	Animal Production Research Unit
ARC	=	Animal Research Council
BAMB	=	Botswana Agricultural Marketing Board
BCA	=	Botswana College of Agriculture
BMC	=	Botswana Meat Commission
BR	=	bird resistant
BSE	=	bovine spongiform encephalopathy
CBPP	=	contagious bovine pleuro-pneumonia
cp	=	crude protein
CSM	=	cotton seed meal
CSO	=	central statistics office
DE	=	digestible energy
DM	=	dry matter
DMD	=	dry matter digestibility
DMI	=	dry matter intake
DOM	=	digestible organic matter
et al.	=	and others
EU	=	European Union
FAO	=	Food and Agricultural Organisation
FMD	=	foot and mouth disease
GC	=	gas chromatograph
GLM	=	general linear model
GSSA	=	Grassland Society of Southern Africa
H_2O	=	water
H_2O_2	=	hydrogen peroxide
H_2SO_4	=	sulphuric acid

HCl = hydrochloric acid
ILCA = International Livestock Centre for Africa
ILRI = International Livestock Research Institute
IVDMD = *in vitro* dry matter digestibility
JLSSC = joint local support study committee
KPa = kilopascals
LS = least squares
MaizeT1 = basal diet plus maize stover treated with 10 g urea/kg stover
MaizeT2 = basal diet plus maize stover treated with 25 g urea/kg stover
MaizeT3 = basal diet plus maize stover treated with 10 g urea and 10 g molasses/kg stover
ME = metabolisable energy
MilletT1 = basal diet plus millet stover treated with 10 g urea/kg stover
MilletT2 = basal diet plus millet stover treated with 25 g urea/kg stover
MilletT3 = basal diet plus millet stover treated with 10 g urea and 10 g molasses/kg stover
MJ = Mega joule
ml = millilitres
MoA = Ministry of Agriculture
Mt = metric tonnes
MTT1 = millet stover treated with 10 g urea/kg stover
MTT2 = millet stover treated with 25 g urea/kg stover
MTT3 = millet stover treated with 10 g urea and 10 g molasses/kg stover
MZT1 = maize stover treated with 10 g urea/kg stover
MZT2 = maize stover treated with 25 g urea/kg stover
MZT3 = maize stover treated with 10 g urea and 10 g molasses/kg stover
N = nitrogen
NBR = non bird resistant
NDF = neutral detergent fibre
NH_3 = ammonia
^oC = degrees Celsius
OM = organic matter
OMD = organic matter digestibility
P = probability

pH	=	power of the hydrogen atom
Psi	=	pounds per square inch
s.e.	=	standard error of the mean
SADC	=	Southern African Development Community
SAS	=	statistical analytical system
SASAS	=	South African Society of Animal Science
SGT1	=	sorghum stover treated with 10 g urea/kg stover
SGT2	=	sorghum stover treated with 25 g urea/kg stover
SGT3	=	sorghum stover treated with 10 g urea and 10 g molasses/kg stover
SLOCA	=	service to livestock to livestock owners in communal areas
SorghumT1	=	basal diet plus sorghum stover treated with 10 g urea/kg stover
SorghumT2	=	basal diet plus sorghum stover treated with 25 g urea/kg stover
SorghumT3	=	basal diet plus sorghum stover treated with 10 g urea and 10 g molasses/kg stover
T1	=	10 g urea/kg stover
T2	=	25 g urea/kg stover
T3	=	10 g urea and 10 g molasses/kg stover
TGLP	=	tribal grazing land policy
UNISWA	=	University of Swaziland
VFA	=	volatile fatty acid
WCAP	=	World Conference on Animal Production
ZSAP	=	Zimbabwe Society for Animal Production

1. Introduction

The contributions of livestock to national economies in Sub-Saharan Africa are substantially higher than generally perceived (Fitzhugh, 1993). Livestock commodities such as milk, meat, eggs, hides and fibres were worth nearly US$ 12 billion in 1988 (USDA, 1990 cited by Fitzhugh, 1993) and comprised roughly 8% of total GDP and 25% of agricultural domestic product for Sub-Saharan Africa. If the values of animal traction and manure (fertilizer, fuel) are included, it raises the livestock share of agricultural domestic product to 35% (Fitzhugh, 1993).

Major constraints to improving livestock productivity include animal diseases, shortage of good quality livestock feeds, endangered forage and animal biodiversity, underdeveloped marketing structures and unresponsive policy environments (Raats, 1999). Livestock productivity in the tropics can be improved by developing and using improved feed resources. In the tropical developing world ruminants depend on a fluctuating supply of poor quality native pastures and crop residues for most of their feed, although these are increasingly supplemented with foliage from fodder trees (Raats, 1999).

1.1 The livestock industry in Botswana

Botswana is a landlocked country that lies directly to the north of South Africa. It is bordered on the north and west by Namibia and on the east by Zimbabwe. Botswana lies between latitudes 18º and 27º S and longitudes 20º and 28º W (Botswana Handbook, 1999). It is considered to be a high plateau of 581 730 km^2 (Aganga & Omphile, 2000). The climate is semi-arid to arid with average annual rainfall ranging from 250 mm in the southwest to 650 mm in the northeast (Monametsi, 2000). The hot summers, with temperatures ranging from 18 to 32.5ºC, last from September to March (Masokwane, 2000). Cool days with cold mornings and nights are experienced from April to July/August. This sometimes results in frost in parts of Botswana.

Sims (1981) categorised Botswana into two agro-climatic zones namely, the hardveld and the sandveld. Both arable and pastoral farming are practiced in the hardveld whereas in the sandveld, the dominant farming activity is the rearing of livestock due to the low fertility of the sandy soils and the climate that is unfavourable for crops (Ramolemana & Machacha, 2000).

The rainy season is during the summer months of October/November to March/April (Botswana Handbook, 1999). The rainfall supports a variety of short scrubby vegetation types including tropical savannah woodlands in the north and extensive savannah grasslands. According to Mosimanyana *et al.* (2000), the semi-arid environment makes extensive livestock production one of the few viable natural resource based industries. The low and erratic rainfall in Botswana results in minimal amounts of available surface water. This shortage of surface water limits the utilisation of pastures as well as the availability of drinking water to animals (Adogla-Bessa & Aganga, 2000). The interactions between soils and vegetation affect the nutrition of livestock that graze these areas. Generally, Botswana soils are low in minerals resulting in high incidences of phosphorus deficiency in livestock (Ramolemana & Machacha, 2000).

Pastoral farming is the mainstay of most rural economies (Mrema & Rannobe, 1996; Mosimanyana *et al.*, 2000). Domestic animals are kept for draught power, employment, risk aversion, ceremonial functions and as sources of income and dietary protein (Katongole *et al.*, 1996) and for tax evasion (Malope, 2000). At the time of independence in 1966, beef exports were Botswana's major source of foreign income. According to Raborokgwe (2000), export trade from beef alone is able to pay for all the basic food imports of Botswana. Although the contribution of agriculture to GDP is less than 5% (Aganga *et al.*, 2005), it is an important activity since, unlike diamonds, farming is a renewable resource (Malope, 2000).

1.1.1 Livestock numbers and distribution

The population of domestic ruminants in the country in 2002 was 3 060 000 cattle, 1 683 000 goats and 273 000 sheep (CSO, 2004). Ruminants constitute 79.68% of all the livestock in the country. More than 80% of these livestock is in the hands of traditional farmers (CSO, 2004). According to Raborokgwe (2000), a conservative estimate of the gross capital value of domestic ruminants in Botswana is P2 billion (P = Pula; about US$0.4 billion). This represents a substantial investment in this sector of the economy.

Most farming households in Botswana keep domestic ruminants, especially cattle and goats. About 65.6% and 69.3% of the 119 203 farming households keep cattle and goats respectively, whilst only 19.2% keep sheep (CSO, 2004). About 4 500 farming households which own goats do not own cattle (CSO, 2004). According to the CSO (2004), 92.1% of the cattle farms have 100 or fewer animals, yet they constitute 58.7% of the national herd. The majority of the goats (88.4%) and sheep (96.1%) are reared in farms with flock sizes of 40 or less animals. These farms contribute more than half (56.69% and 76% respectively) of the national flocks. Goat demographics show a shift towards the keeping of larger flocks. Although goat farms with 100 or more goats make up 18% of the national flock, they amount to only 2.7% of total farms.

Table 1.1 Distribution of cattle, goats and sheep in Botswana

	Cattle	Goats	Sheep
Mean herd/flock size (traditional sector)	38	20	12
Mean herd/flock size (commercial sector)	431	78	54
Traditional farms (%)	99.65	99.81	99.58
Livestock in traditional farms (%)	96.20	99.28	98.07
Female headed farms (%)	43.97	51.18	47.31

Source: Compiled from Central Statistics Office (CSO, 2004). 2002 Annual agricultural survey report.

From the data in Table 1.1, it is evident that the majority of cattle, goat and sheep farmers keep very few animals. Holdings owned by female farmers make a substantial portion of the cattle, goat and sheep farms in the country (Table 1.1). However, they contribute only 31.54%, 31.20% and 29.78% to the respective cattle, goat and sheep national herd/flocks. Just over 70% of cattle, 68% of goats and 66% of the sheep in Botswana are reared in the sandveld. This is especially true for most of the commercially reared domestic ruminants (82.49% cattle, 79.45% goats and 86.13% sheep).

1.1.2 Livestock production practices

Raborokgwe (2000) observed that despite the high contribution of beef in Botswana's economy, no significant changes have occurred in adopting better management practices for increased animal productivity. The ruminant livestock industry in Botswana is dominated by an inefficient extensive, communal management system (Raborokgwe, 2000). Characteristics of this system include poor management and performance resulting in inappropriate utilization of resources necessary to sustain the industry (Raborokgwe, 2000). Slow growth rates, high mortality, low birth rates, high prevalence of diseases and low off-take rates characterize production practices (CSO, 2004). This not withstanding, Pearce (1992) reported that in some semi-arid areas, there is increasing evidence that, where pastoral livestock systems are based on long established customs (such as in the Sahel), they remain the most sustainable form of agriculture.

Table 1.2 Production indicators for cattle, goats and sheep in Botswana

Production indicator		Commercial sector	Traditional sector
Birth rate (%)	Cattle	45.8	55.9
	Goats	66.4	42.6
	Sheep	64.1	33.5
Mortality (%)	Cattle	4.8	5.4
	Goats	27.7	26.8
	Sheep	21.2	18.2
Off-take rate (%)	Cattle	15.0	6.8
	Goats	10.7	6.5
	Sheep	15.1	5.0
Income (Pula[1]/animal)	Cattle	1150.0	949.0
	Goats	264.0	246.0
	Sheep	243.0	211.0

Source: Compiled from Central Statistics Office (CSO, 2004). 2002 Annual agricultural survey report.
[1]Pula = about US$0.20 in 2005

Natural pasture is the main feed resource for livestock in Botswana (Aganga & Nsinamwa, 1997; Madibela *et al.,* 2000). Although crop residues are common in Botswana, they are available for only part of the year (Letso & Aganga, 1999). The country's rangelands are generally mismanaged resulting in overgrazing, bush encroachment, poor annual grass species and depletion and pollution of water sources (Makobo, 2000). Ørskov (1993) associated low growth rates, infrequent pregnancies and low milk yields with overgrazing of natural pastures. The production efficiency in the tropics and subtropics is one quarter of that in the developed regions (ILRI, 1999). Botswana is probably a typical example of these scenarios.

Indicators of domestic ruminant production in Botswana are low (Table 1.2). Factors that limit livestock production are poor nutrition, diseases, poor labour distribution, predators, uncontrolled breeding and inadequate distribution of research results to the farming community (Mrema & Rannobe, 1996; Masokwane, 2000). According to Senyatso (1999), the reproductive potential of Tswana smallstock is high; it was further stated that improved feeding and management could increase lambing/kidding rates.

1.1.3 Government policies in relation to animal production

The Botswana government pursues policies that promote the growth of the livestock sector. These policies have been criticised for encouraging the hoarding of livestock, thus leading to overstocking and range degradation. The policies are aimed at expanding the size of the national herd by improved animal husbandry practices so as to increase throughput at national abattoirs to meet the beef export quota to the EU market. However, Malope (2000) noted that the increase in the national herd did not result in a corresponding increase in off-take rates. The failure of these policies to achieve their objectives has been blamed on factors such as: a poor (undeveloped) domestic market for livestock products, lack of political will to enforce property rights, lenient taxation on livestock farmers (Malope, 2000) and lack of education (Raats, 1999; Masokwane, 2000).

1.1.4 Challenges faced by livestock farmers

The Botswana meat commission (BMC) is the sole entity that sells Botswana beef in external markets (Malope, 2000). Only about 6% of the BMC‘s beef is sold locally (BMC, 1998). Several authors (Ntshese & Moreki, 1998; Letsebe *et al.*, 1999; Malope, 2000) suggested that for this reason BMC has not contributed much to the development of a local market for its products. The marginal role of BMC in the domestic market has contributed to the market’s underdevelopment. Other constraints to the domestic ruminant meat market include complex marketing arrangements, poor road infrastructure, long distances to markets and high transport costs (Mrema & Rannobe, 1996; Ntshese & Moreki, 1998; Letsebe *et al.*, 1999). Other challenges faced by farmers include limited access to credit, land and appropriate technology (Tselaesele & Tladi, 1999). In this regard, Mrema and Rannobe (1996) also found that farmers are constrained by high costs of veterinary services, shortage of veterinary personnel and insufficient family labour coupled with unreliable hired labour.

Aganga and Nsinamwa (1997) and Aganga *et al.* (2000) noted that a lack of adequate feed throughout the year and proper nutrition is one of the challenges facing the livestock industry in Botswana. Since the outbreak of bovine spongiform encephalopathy (BSE), the FAO has banned the feeding of ruminants with feeds of ruminant origin (Hard, 2004). The BMC produces by-products such as blood meal and carcass meal that, as a result of BSE, cannot be used in ruminant diets. Poultry litter is excluded from livestock diets on grounds that it may contain animal protein or salmonella (Raborokgwe, 2000). Supplementary feeds such as lucerne and oilseed cakes are of limited availability and not affordable to most traditional farmers (Tsopito, 2002). This limits the choices of supplementary feeds available to farmers and calls for research into potential additional feeds that can be safely used by farmers.

1.2 Strategies for improving ruminant nutrition

1.2.1 Improvement of feed quality

Improving the quality of local feeds in Botswana increases the likelihood that farmers will provide it to animals and also reduces the need for imported and expensive energy supplements in diets (Goodchild *et al.,* 1998). Improvement of feed quality can be achieved by several means including feed management and alteration of the nutritive value of feeds.

1.2.1.1 Feed management

Natural pasture is an important feed resource for grazing livestock. The quality of feed from pasture can be improved by ensuring the continued existence of highly palatable or desirable plant species. This can be achieved by forage conservation, feed preservation and pasture re-seeding. Feed conservation entails relevant grazing systems, fencing rangelands and ensuring appropriate stocking rates. Feed preservation involves harvesting and storing forages as either hay or silage. Conserving and preserving feed in this manner requires expensive inputs such as putting up fences or equipment for harvesting forage materials.

The use of fertilisers can improve both the yield and quality of forage. Legwaila *et al*. (1998) reported that when fertiliser is applied to soils with low fertility, the dry matter (DM) production of *Cenchrus ciliaris* is about 5 to 10 tons/ha/year. Fertilisers are commonly used on cultivated pastures. The improvement of forage quality by fertilisation requires many inputs that are too costly and unavailable in smallholder systems, hence fertilisers are not commonly used on forage crops.

The quality of poor feed may also be improved by supplementation with concentrates. Poor quality roughages can be supplemented with limiting nutrients in the form of concentrates, minerals, proteins or green forages (Schiere & Nell, 1993). The supplements required must correct nutrient deficiencies and increase the balance between protein and energy available from digestion so that it more closely corresponds to the animal's requirements (Leng *et al.,* 1999). Akhtar *et al.* (1994) found that protein supplementation of winter range forage generally improved performance, DM intake and digestibility.

1.2.1.2 Altering the nutritive value

Altering the structural and/or chemical composition of poor quality forage materials by means of biological, mechanical or chemical treatments may be used to improve feed quality. Physical treatments such as chopping have an indirect effect on feed quality. A reduction in feed particle size leads to an increase in intake hence as more feed is consumed animal productivity may be enhanced (Ørskov, 1993).

Mechanical treatments are methods that use physical force to alter the form of the feed in order to increase its intake by animals and include chopping, grinding, pellet-making, soaking and steaming under pressure. Osafo *et al.* (1996) showed that chopped sorghum stover offered with minerals only is a sustainable feeding strategy for maintaining weight in sheep. Chopping of straw complements other treatment methods such as urea treatment. Methu *et al.* (1998) reported that treating un-chopped maize stover with urea resulted in severe mould formation which rendered the fodder unfit for use as feed.

Treating forages with chemicals such as ammonia (NH_3) or urea [$CO(NH_2)_2$] can positively influence forage quality (Harmon, 1996; Tabe *et al.,* 1995), intake and digestibility (Ørskov, 1993; Tabe *et al.,* 1995). Other chemicals used to improve feed quality include sodium hydroxide (NaOH) and calcium hydroxide [$Ca(OH)_2$]. Some of the chemical treatment methods used in the past became unpopular due to environmental hazards associated with the disposal of washing water (Sundstøl, 1988). Practical uses of physical and chemical treatments of crop residues may be limited by safety concerns, cost and potentially negative environmental consequences (Chen *et al.,* 1995).

Urea is the favoured chemical for treating forages. An obvious advantage of urea is that it is inert and therefore not as dangerous as other chemicals such as anhydrous NH_3 and NaOH (Harmon, 1996). Urea is also more readily available in the developing world than other chemicals used in the treatment of forages and treating forages with urea may be done on an industrial or a farm scale (Chenost & Kayouli, 1997). Although the feeding of treated straw instead of untreated straw increases individual animal production (Schiere & Nell, 1993), the magnitude of the increase depends on factors such as nutritive value of other components of the ration, age and type of livestock, level and type of product and disease incidence (Chenost & Kayouli, 1997). Straws treated with chemicals sometimes decrease DM intake (Brand *et al.,* 1990). Forages treated with urea offer the potential to improve productivity during dry periods. Ørskov (1993) stated that this method of improving feed quality is especially relevant where other options are lacking such as dry areas in which there is a vast excess of straw and stover.

1.3 The potential of crop residues as ruminant feeds

There was a 0.2% decrease in world rangelands between 1992 and 2002 (FAOSTAT, 2004a). The increasing need for land for crop production indicates that ruminants will continue using primarily crop residues, industrial by-products and pastures from relatively infertile rangelands as feeds. Such feeds have low digestibility, crude protein and mineral contents (Chen *et al.,* 1995; Leng *et al.,* 1999; Gertenbach & Dugmore, 2004). Globally, crop residues are second only to pasture in importance as feeds for ruminant livestock in the tropics (Bayer & Bayer, 1998). Stovers from sorghum, maize and millet are usually of better quality than fine straws from wheat or rice (Bayer & Bayer, 1998). Grain legumes provide residues that are better than cereal crop residues in nutritive value (Egan, 1997). However, crop residues have other uses besides animal feeding and the different uses may complement or compete with each other (Bayer & Bayer, 1998).

Table 1.3 Amounts (metric tonnes) of crop residues from the main crops in the world, Africa, the SADC region and Botswana

Crop residue	World	Africa	[1]SADC	Botswana
Millet	71 534 194	35 046 790	1 496 014	2 640
Barley	101 882 225	3 927 573	131 330	-
Fruits	115 259 880	15 025 824	2 529 582	2 544
Pulses	135 649 094	22 295 489	3 274 450	42 000
Sorghum	143 001 859	54 889 853	3 481 718	77 515
Wheat	333 809 176	11 779 278	1 187 310	330
Rice	459 518 158	14 882 413	993 793	-
Roots/Tubers	678 665 348	175 315 882	42 348 213	13 500
Maize	765 652 118	52 226 776	22 998 276	12 000
Coarse Grains	929 834 989	88 791 050	21 456 565	43 398

Calculated from FAO (2004) Production statistics. [1]SADC = Southern African Development Community

Quantitatively, the most important crop residue is straw from cereals and grain legumes (Schiere & Nell, 1993). World cereal production in 2002 was just over two thousand million metric tons (FAOSTAT, 2004b) of which nearly 6.5% was produced in Africa. This entails the production of large quantities of crop residues. Using the scheme (Appendix 1) of De Boer and Bickel (1988), the quantities of crop residues produced in the world in 2002 (FAOSTAT, 2004b) would appear as shown in Table 1.3. The most important cereal crop residues in Botswana in terms of abundance (Table 1.3) were stovers of sorghum, maize and millet comprising 84.11%, 13.02% and 2.86% respectively of the annual crop residue yield.

More than 150 000 Mt (DM) of crop residues were produced in Botswana in 2002 (Table 1.3). Almost one-third (92 485 Mt) was cereal crop residue. Assuming a DM intake of 2% of body weight per livestock unit[1] and assuming that it is properly used, this amount of crop residues can maintain about 42 000 livestock units for the whole year. In times of feed scarcity, Gertenbach and Dugmore (2004) suggested that feed availability takes precedence over feed quality. These crop residues are available during the months of May to July (harvest time). At this same time of the year (winter months), natural pastures deteriorate in

[1] Assuming a livestock unit to be an animal of 300 kg body weight

both quality and quantity. Crop residues could be harvested, treated with urea and used sparingly to supplement natural pastures instead of being grazed and trampled on the crop fields. Thus, it would be possible to maintain more animals in reasonable condition through the dry season without degrading the rangeland and crop residues would also be utilised more efficiently.

1.4 Objectives

Crop residues are both inexpensive and plentiful, but inappropriately and poorly utilised due to their low nutritive value. It is envisaged that more restrictions will be imposed on livestock movement, therefore, it may not be possible to move livestock to summer and winter grazing to escape drought. However, if available crop residues were harvested, treated with chemicals and properly utilised, ruminant livestock could be maintained in reasonable condition during drought periods.

The objectives of the present study were:

1.4.1 To evaluate and compare the effects of treatment with urea or urea and molasses on the composition and digestibility of sorghum, maize and millet crop stovers.

1.4.2 To evaluate the potential of sorghum, maize and millet crop stovers that were treated with urea or urea and molasses as additional ruminant feed during times of feed scarcity.

The specific objectives of the study were:

1.4.1.1 To assess the result of treatment with urea or urea and molasses on the dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) content of sorghum, maize and millet stovers.

1.4.1.2 To determine the effect of treating stovers of sorghum, maize and millet with urea or urea and molasses on the *in vitro* dry matter digestibility.

1.4.2.1 To quantify the intake of DM, OM, CP, NDF, ADF, metabolisable energy (ME) and water by steers, goats and sheep fed treatment diets containing stovers of sorghum, maize and millet treated with urea or urea and molasses.

1.4.2.2 To compute the coefficients of digestibility for DM, OM, CP, NDF and ADF by steers, goats and sheep fed treatment diets containing stovers of sorghum, maize and millet treated with urea or urea and molasses.

1.4.2.3 To gauge the influence of treatment diets containing stovers of sorghum, maize and millet treated with urea or urea and molasses on the changes in body weight of steers, goats and sheep.

1.4.2.4 To measure the pH and ammonia concentration of rumen fluid from steers, goats and sheep as influenced by treatment diets containing stovers of sorghum, maize and millet treated with urea or urea and molasses.

1.4.2.5 To assess the effect of treatment diets containing stovers of sorghum, maize and millet treated with urea or urea and molasses on the daily variation in pH and ammonia concentration of rumen fluid from steers.

2. Material and methods

2.1 Location of the study

The trials were carried out in the existing goat and sheep pens at Sebele, Botswana College of Agriculture (BCA), Botswana. New pens were constructed from gum poles with concrete floors and corrugated iron roofs to house the steers during the trials. Sebele is situated at 24º 33' S and 25º 57' E and is at an altitude of 994 m above sea level.

Although the study was conducted in pens with steers, goats and sheep, it is useful to provide a short description of the general area in south-eastern Botswana. Madibela *et al.* (2000) described the vegetation as a mixture of Acacia savannah with broad-leaved middle layer trees such as the red bush willow (*Combretum apiculatum*) and sand syringe (*Burkea africana*). Grasses consist of species of intermediate nutritive value such as Lehmann love grass (*Eragrostis lehmanniana*). The grass species rated as good in nutritive value include Guinea grass (*Panicum maximum*), Madagascar crab grass (*Digitaria milanjiana*) and Gonya grass (*Urochloa trichopus*). Tassel brittle grass (*Aristida congesta*) and Rose Natal grass (*Melinis repens*) are some of the grass species with poor nutritive value (Madibela *et al.*, 2000). De Wit and Nachtergaele (1990) classified the soil type of the area as moderately deep to very deep, imperfectly to moderately well drained, dark brown to red, sandy clay loams to clays. Mean annual rainfall is 513.6 mm and the minimum and maximum temperature is 12.8 and 28.6ºC, respectively (Madibela *et al.*, 2000).

2.2 Animals

Six steers, aged on average two years old and six one-year old female goats and six one-year old female sheep of relatively similar body condition scores were individually housed in pens. The condition scoring was done according to Nicholson and Butterworth (1986). Four of the steers were fitted with rumen fistulae (85 mm inner diameter). The steers, goats and sheep were sourced from the BCA farm at Sebele and were predominantly Tswana breeds. However, this could not be ascertained from farm records since the files for the animals had been accidentally erased from the farm manager’s computer. All animals were weighed and de-wormed at the beginning of the trials. Initial body weights varied from 165 kg to 225 kg for steers, 21.2 to 28.6 kg for goats and 26.5 to 32.2 kg for sheep. The animals were housed in individual pens that were large enough to allow freedom of movement for the animals to get up, lie down and turn around.

2.3 Basal diet

Veld grass hay is a poor quality feed resource for most livestock farmers in Botswana. In this study, veld grass hay (a random mixture of the species listed previously) was obtained from the BCA farm at Sebele and provided to the steers, goats and sheep as the main component of their basal diet. The veld grass hay was harvested from the BCA farm using a tractor drawn mower. It was pressed into bales of about 15 kg and then transported to the animal pens.

Pen-feed (a commercially available protein-energy concentrate for ruminants) was bought from Agrivet in Gaborone and provided to all the animals in addition to the veld grass hay. The Pen-feed was used in order to ensure that the minimum daily protein and energy requirements of the animals were met.

The veld grass hay plus Pen-feed constituted the basal diet of the animals. The veld grass hay was provided to steers in equal amounts thrice daily due to the size of the feeding troughs. This procedure reduced the amount of feed wasted. Veld grass hay was given to the goats and sheep twice daily. The amount of veld grass hay offered varied between 115 and 125% of the forage intake for the previous three days. The Pen-feed was provided once in the morning in quantities shown in Table 2.1 to all animals. The animals consumed all the Pen-feed offered to them.

Table 2.1 The average quantities (as-provided) of the basal diet (veld grass hay + Pen-feed) and water offered daily to the steers, goats and sheep

	Steers	Goats	Sheep
Veld grass hay (kg)	9 to 12	1	1
Pen-feed (kg)	1	0.15	0.15
Water (litres)	40	5	5

Water was made available to each animal *ad libitum* (Table 2.1) and the voluntary water intake was calculated as the difference between what was offered and what remained after 24 hours (Jurgens, 1997; McDonald *et al.,* 2002). Evaporation of water from the troughs was not determined. The water consumed as part of the feed intake was calculated as the difference between the weight of the consumed feed (as-provided) and the DM intake (Adogla-Bessa & Aganga, 1999). Each animal also had *ad libitum* access to a mineral block (Table 2.2). The intake of the mineral supplement was not quantified.

Table 2.2 Composition of the phosphate salt-trace element supplement for ruminants used in the trials

Macro elements	Content (g/kg)	Trace elements	Content (mg/kg)
Calcium	120	Manganese	1200
Phosphorus	60	Copper	300
Sulphur	39	Cobalt	3
Magnesium	30	Iron	750
Potassium	19	Iodine	15
Sodium chloride	180	Zinc	1200
		Selenium	3

Source: Phosphate block. Reg. No. V10264 ACT 36/1947. Namibia N-F.F 0430 (Voermol Feeds)

2.4 Amelioration of sorghum, maize and millet stover with urea or urea and molasses

Cereal crop stovers are important sources of feeds in Botswana but are also poorly utilised by ruminants due to their poor nutritive value. Ameliorating forages with non-protein nitrogen (NPN) sources such as ammonia or urea can have a positive influence on forage quality (Egan, 1997). In this study, three cereal crop stovers namely, sorghum (*Sorghum bicolour var. segaolane*), maize (*Zea mays var. kalahari early pearl*) and millet (*Pennisetum americanum var. Serere* 6A) were obtained from the BCA farm at Sebele. These three types of cereal crop stovers are the most common in terms of distribution and abundance in Botswana. The order in which they are listed shows their abundance in Botswana.

Previously, satisfactory results were achieved in Botswana when maize stover was treated with urea and molasses at a rate of 10 g urea + 100 g molasses/kg maize stover (MoA, 1990).

Molasses is expensive and in liquid form is difficult to handle at the farm level. For this reason, a smaller amount (10 g molasses/kg stover) was used in this study. In the present study, ten bales (about 100 kg) of each of the three cereal crop stovers (sorghum, maize and millet) were coarsely ground in a hammer mill to pass through an 18 mm sieve and assigned to the three treatments as shown in Table 2.3. The objectives of this study were to evaluate the effect of treatments on the chemical composition and *in vitro* DM digestibility of the cereal crop stovers and to use the ameliorated cereal crop stovers as supplementary feeds for steers, goats and sheep receiving a basal diet of veld grass hay plus Pen-feed (Table 2.1).

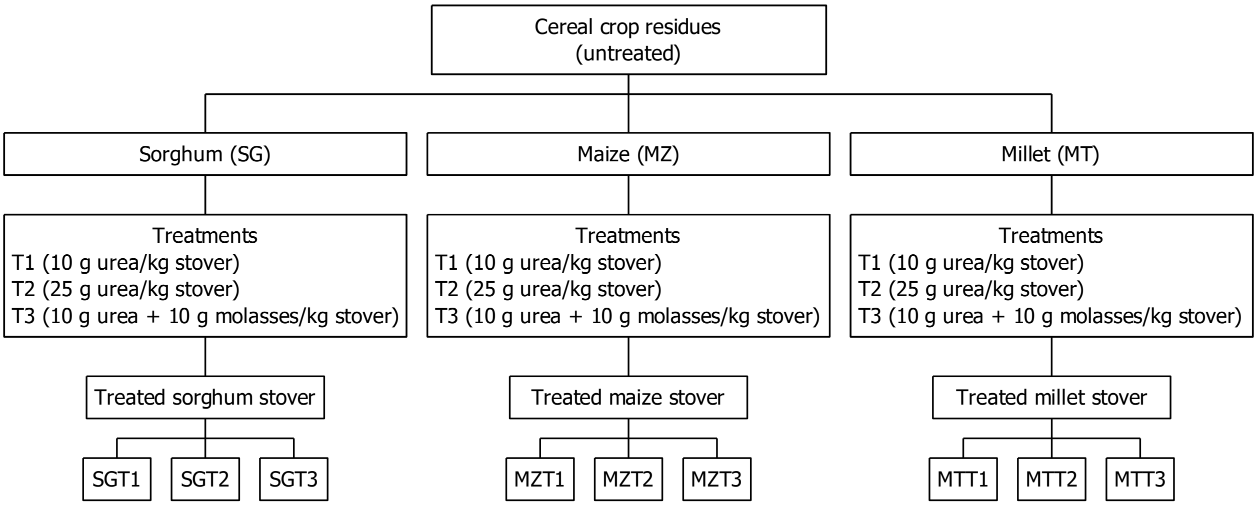
Table 2.3 Ameliorants used in this study to treat the three cereal crop stovers

Treatment	Cereal crop stover plus ameliorant treatments
T1	Cereal crop stover plus 10 g urea/kg stover
T2	Cereal crop stover plus 25 g urea/kg stover
T3	Cereal crop stover plus 10 g urea + 10 g molasses/kg stover

The appropriate amounts of urea or urea and molasses were dissolved in tap water before being applied to the cereal crop stovers. Each of the coarsely ground cereal crop stovers was added to a 220 litre airtight plastic drum in four amounts of about 15 kg. Grab samples of the untreated cereal crop stovers were obtained before each addition to the drums and bulked by cereal crop stover type namely: sorghum, maize and millet and stored in plastic honey jars with screw tops pending analysis. After each addition of cereal crop stover, a predetermined amount of the urea or urea and molasses solution was added to the drum. A clean gum pole (100-125 mm diameter) was used to mix and compact the cereal crop stover and urea or urea and molasses solution after each consecutive addition until the required amount had been reached. On average, about 65 kg of stover was pressed into each drum. When a drum was filled with treated cereal crop stover, a labelled paper in a plastic envelope was put on top of the cereal crop stover for identification. This was a precautionary measure since four drums were filled with different cereal crop stovers or different stover/treatments combinations at a time.

The experimental design was a 3 x 4 completely randomized factorial design (3 cereal crop stovers *and* 3 treatment methods (T1, T2, T3) plus untreated).

The following abbreviations were used for the cereal crop stovers: SG for sorghum stover, MZ for maize stover and MT for millet stover. The full complement of cereal crop stovers and treatments are shown in Figure 2.1.



Where SGT1 = sorghum stover treated with 10 g urea/kg stover, SGT2 = sorghum stover treated with 25 g urea/kg stover and SGT3 = sorghum stover treated with 10 g urea + 10 g molasses/kg stover.
MZT1 = maize stover treated with 10 g urea/kg stover, MZT2 = maize stover treated with 25 g urea/kg stover and MZT3 = maize stover treated with 10 g urea + 10 g molasses/kg stover.
MTT1 = millet stover treated with 10 g urea/kg stover, MTT2 = millet stover treated with 25 g urea/kg stover and MTT3 = millet stover treated with 10 g urea + 10 g molasses/kg stover.

Figure 2.1 Schematic diagram showing cereal crop stovers and ameliorant treatments.

According to Chenost and Kayouli (1997) a treatment time of about 2-3 weeks is sufficient to allow the process to be completed at ambient temperatures ranging from 15-30ºC. Average daily temperatures for Gaborone during this time of the year (May-June) range between 22 and 26ºC (CSO, 2004). The sealed drums were therefore stored for 21 days to allow the decomposition of urea to NH_3. After the three weeks, the drums were opened for about 30 minutes to allow the excess NH_3 and CO_2 to escape and then closed again. The drums containing the treated cereal crop stovers were kept tightly closed when not in use in order to minimise spoilage due to excessive exposure.

The treated cereal crop stovers were intended to supplement the basal diet comprised of veld grass hay and Pen-feed in digestibility studies. Since veld grass hay has a low digestibility and N content, the different cereal crop stovers treated with urea or urea and molasses would provide additional N that is deficient in veld grass hay. At the same time, by treating cereal crop stovers and using it as supplementary feed, the availability and use of these important feed sources could be extended over the dry season since it could be stored effectively.

It is common practice for some farmers in Botswana to use lucerne hay (*Medicago sativa*) and cottonseed (*Glycine max*) oil cake meal (CSM) as supplementary feed during the dry season and in times of drought. However, these feeds are expensive and most traditional farmers do not provide any supplementary feed to their livestock. Therefore, lucerne hay and CSM were also evaluated as supplementary feeds to the basal diet of veld grass hay plus Pen-feed. These two supplements (lucerne hay and CSM) were provided alongside and not in addition to the cereal crop stovers treated with urea or urea and molasses. The combination of these two supplements (lucerne hay and CSM) and the basal diet formed the 10^{th} and 11^{th} treatment diets. A control diet (Control) consisting of the basal diet (veld grass hay plus Pen-feed) only served as the 12^{th} treatment diet. The other treatment diets were the nine cereal crop stovers treated with urea or urea and molasses (Figure 2.1) in addition to the basal diet. The amounts of lucerne hay, CSM and the cereal crop stovers treated with urea or urea and molasses were provided daily to the steers, goats and sheep as shown in Table 2.4.

Table 2.4 The quantities (as-provided) of supplements (lucerne hay and CSM) and cereal crop stovers treated with urea or urea and molasses provided daily to steers, goats and sheep

	Steers	Goats	Sheep
Supplement and ameliorated cereal crop stovers (kg)	1	0.15	0.15

Lucerne hay was sourced from the BCA farm at Sebele while CSM was bought from the Botswana Agricultural Marketing Board (BAMB). The chemical composition and *in vitro* DM digestibility of the treatment diets, veld grass hay and Pen-feed offered to the steers, goats and sheep are shown in Table 2.5.

Table 2.5 The chemical composition (means±s.e.[1]) of the feeds used in the study

528.17	Chemical composition						
546.82	**[2]DM**	**OM**	**CP**	**NDF**	**ADF**	**ADL**	**IVDMD**
652.72	**(g/kg)**	**(g/kg DM)**					
Sorghum stover (SG) treated with:							
10 g urea/kg (SGT1)	453.1±29.88	856.4±16.47	88.2.6±0.13	670.3±18.10	439.7±13.41	48.4±4.88	505.4±31.82
25 g urea/kg (SGT2)	484.9±54.98	850.3±13.25	114.9±20.38	658.1±15.84	447.7±7.66	36.8±6.62	577.9±56.50
10 urea + 10 g molasses/kg (SGT3)	431.5±31.88	854.0±15.94	105.7±3.69	576.0±24.02	441.1±13.71	29.0±2.76	603.1±21.42
Maize stover (MZ) treated with:							
10 g urea/kg (MZT1)	407.1±13.42	836.2±21.72	122.9±11.38	614.0±14.88	401.1±6.99	39.6±8.03	561.6±9.84
25 g urea/kg (MZT2)	410.1±17.68	843.4±26.47	141.4±11.94	618.2±18.18	405.7±14.73	35.0±3.27	575.9±16.45
10 urea + 10 g molasses/kg (MZT3)	460.4±30.42	883.5±14.19	117.2±1.00	599.5±26.57	421.2±5.19	38.0±6.09	561.3±19.24
Millet stover (MT) treated with:							
10 g urea/kg (MTT1)	467.1±33.64	857.1±6.62	88.6±0.19	666.4±5.03	497.6±36.31	48.9±7.96	528.1±25.71
25 g urea/kg (MTT2)	412.5±44.37	847.3±16.45	81.7±4.75	696.0±5.00	431.3±2.26	49.5±3.33	546.8±41.06
10 urea + 10 g molasses/kg (MTT3)	392.0±32.70	855.2±4.91	108.6±2.81	540.7±24.14	441.1±13.16	12.7±2.23	652.7±13.11
Lucerne hay	946.9±4.64	907.4±4.24	123.8±10.25	532.4±36.82	441.1±27.25	55.5±3.28	573.1±26.45
Cotton seed meal (CSM)	937.2±8.20	924.5±5.03	301.3±4.31	308.0±21.74	204.5±8.06	30.2±2.56	715.3±23.46
Veld grass hay	940.0±3.13	906.3±2.19	52.9±4.75	667.7±8.26	458.8±8.68	45.7±2.02	503.9±15.04
Pen-feed	900.5±8.43	879.7±2.19	150.3±04.63	226.7±8.98	110.8±4.01	13.5±1.57	827.7±12.90

[1]s.e. = standard error of the mean. [2]DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin and IVDMD = *in vitro* dry matter digestibility

2.5 Feeding trials

The steers, goats and sheep were divided into two groups by species and assigned to the treatment diets in a crossover design as shown in Table 2.6. The feeding trails were conducted following the treatment of each batch of cereal crop stovers with urea or urea and molasses.

Table 2.6 Design of the feeding trials showing the treatment diets offered to the steers, goats and sheep

Trial	Group 1	Group 2
	Treatment diets	
1	Control diet (Control)	Lucerne hay (LH)
2	Maize stover treated with 10g urea/kg stover (MaizeT1)	Cotton seed meal (CSM)
3	Millet stover treated with 10g urea/kg stover (MilletT1)	Maize stover treated with 25g urea/kg stover (MaizeT2)
4	Sorghum stover treated with 25g urea/kg stover (SorghumT2)	Sorghum stover treated with 10g urea/kg stover (SorghumT1)
5	Maize stover treated with 10g urea + 10g molasses/kg stover (MaizeT3)	Millet stover treated with 25g urea/kg stover (MilletT2)
6	Millet stover treated with 10g urea + 10g molasses/kg stover (MilletT3)	Sorghum stover treated with 10g urea + 10g molasses/kg stover (SorghumT3)
7	Lucerne hay (LH)	Control diet (Control)
8	Cotton seed meal (CSM)	Maize stover treated with 10g urea/kg stover (MaizeT1)
9	Maize stover treated with 25g urea/kg stover (MaizeT2)	Millet stover treated with 10g urea/kg stover (MilletT1)
10	Sorghum stover treated with 10g urea/kg stover (SorghumT1)	Sorghum stover treated with 25g urea/kg stover (SorghumT2)
11	Millet stover treated with 25g urea/kg stover (MilletT2)	Maize stover treated with 10g urea + 10g molasses/kg stover (MaizeT3)
12	Sorghum stover treated with 10g urea + 10g molasses/kg stover (SorghumT3)	Millet stover treated with 10g urea + 10g molasses/kg stover (MilletT3)

According to Kushner (1999), an important advantage of a crossover design is that subjects become their own controls, thereby reducing the error variance. This means that, meaningful results are possible with this design even with a relatively small number of subjects (animals). In this crossover design, the steers, goats and sheep were sequentially provided with different treatment diets (Table 2.6). Each of the two groups of steers, goats and sheep was allocated half of the available treatment diets in a predetermined order. When both groups of steers, goats and sheep had received the different treatment diets allocated to them, the treatment diets were switched (crossed-over) and the steers, goats and sheep in the two groups received the feeds previously provided to the other group. The sequence in which the treatment diets were provided was maintained during the crossover (Table 2.6). This meant that the treatment diets were paired. For example, when CSM was provided to Group 1, Group 2 was provided with MaizeT1 and when MaizeT1 was provided to Group 1, Group 2 was provided CSM (Table 2.6). This pairing of treatment diets was randomly done.

2.6 Feed intake and digestibility

2.6.1 Provision of treatment diets

The digestion trials for each of the 12 treatment diets were run for 21 days; 14 days were allowed for adaptation to the treatment diets, followed by 7 days of sample collection. The sampling sequence always started with the same animal every day. At 08h00, the left over feed (veld grass hay) was removed, weighed, sampled and the remainder discarded. After this, the steers, goats and sheep were offered the treatment diets (Table 2.6). Treatment diets were provided once every morning (Table 2.4). When the entire allocation had been consumed (in about 30 minutes), the steers, goats and sheep were provided the first portion of their daily veld grass hay allowance (one-third for the steers and one-half for the goats and sheep) (Table 2.1).

2.6.2 Sampling of feeds and faeces

Samples of lucerne hay and CSM were obtained when these supplements were weighed out for the steers, goats and sheep. These samples were stored in labelled paper bags at room temperature. Samples of veld grass hay, Pen-feed and the ameliorated (ensiled) cereal crop stovers were obtained daily at feeding time (Jurgens, 1997) and stored in labelled airtight plastic bags. Samples were kept frozen at -20ºC pending analysis. Physical appraisal of the cereals crop stovers treated with urea or urea and molasses for colour was done with the aid of a Microsoft word colour chart while texture was assessed with bare hands during sample collection.

The total faecal material produced by each animal over a 24 hour period was collected and weighed. The faeces were thoroughly mixed. A sample of faeces from each animal was collected in a labelled plastic bag and stored at -20ºC pending analysis.

It is important to note that due to practical considerations, the collection of total urine for the determination of urinary N was not done. The collection of urine from animals kept in the type of facility used in this study was not feasible. For the collection of urine from the steers it would have required that they be tethered which would have placed unnecessary stress on the animals. Collecting urine from goats and sheep would have entailed the use of catheters for the does and ewes, again with unnecessary stress.

2.6.3 Determination of voluntary feed intake and metabolisable energy (ME)

Voluntary feed intake was calculated as the difference between what was offered and what remained after 24 hours (McDonald *et al.,* 2002). The intake of metabolisable energy (ME) was calculated by assuming that 1 kg of digestible organic matter (DOM) is equivalent to 19 MJ of digestible energy (DE) (ARC, 1980) and that ME = 0.82 DE (ARC, 1980).

2.6.4 Sampling of rumen fluid

During the first 4 days of the sampling period, rumen fluid was collected from each of the four rumen fistulated steers and by stomach tube from four of the goats and four of the sheep. Using a stomach tube that was perforated at one end and attached to a collapsible 1 litre plastic bottle, about 300 ml rumen fluid was aspirated from each steer via the fistula (De Waal & Biel, 1989). For the goats and sheep, the stomach tube was inserted into the rumen via the mouth and the oesophagus. As soon as enough rumen fluid had been collected, the rumen fluid was immediately poured in labelled, pre-heated (with water at 39ºC) vacuum flasks and taken to the laboratory to determine the pH. The rumen fluid was then strained through four layers of mutton cloth to remove excess coarse feed particles from the fluid. The strained rumen fluid was then acidified by mixing it with 0.2N hydrochloric acid (HCl) at a ratio of 4:1 (Broderick & Kang, 1980) and kept frozen (at –20ºC) in labelled, airtight plastic bottles pending analyses.

To obtain an indication of the diurnal variation in rumen pH and ammonia concentrations, an adaptation of the sampling schedule from De Waal and Biel (1989) was used when sampling rumen fluid from the four rumen fistulated steers.

Table 2.7 Sampling schedule for rumen fluid from steers

Day	Sampling time	Hours after intake of supplement
1	08h00	0
2	12h00	4
3	16h00	8
4	20h00	12

The rumen fluid sample obtained on Day 1 also represents samples obtained 24 hours after the intake of the supplement. This sampling regimen (Table 2.7) was attempted on goats and sheep but discontinued due to the obvious discomfort caused to the animals by inserting the stomach tube at too regular intervals. Rumen fluid samples from goats and sheep were therefore obtained only at 12h00 for each treatment diet.

2.7 Laboratory Analyses

2.7.1 Sample preparation

All veld grass hay, lucerne hay, CSM and cereal crop stover samples were prepared for analysis by grinding them in a Willey mill to pass through a 1 mm sieve. A sample of either Buffalo grass (*Cenchrus ciliaris*) or Napier grass (*Pennisetum purpureum*) of known chemical composition (check sample) was similarly processed and used to validate the results from the chemical analyses. After grinding, samples were stored in labelled plastic honey jars. Faecal samples were thawed at room temperature for 24 hours and then bulked by animal. The faecal samples were weighed and dried in a forced draught oven at 50ºC for 96 hours. The weight of the dried faecal samples was used in determining the DM output in the faeces. After drying, the samples were ground in the Willey mill to pass through a 1 mm sieve and stored in labelled honey jars pending analysis. The bottles containing rumen fluid were thawed at room temperature overnight before the fluid could be analysed for NH_3 or volatile fatty acids (VFA). The thawed bottles were shaken vigorously and then allowed to stand for about 30 minutes. Rumen fluid was then siphoned from the top of each bottle (De Waal, 1986). Samples for VFA analysis were mixed with 30% formic acid at a ratio of 4:1 and then centrifuged at 2 500 revolutions per minute before analysis in a gas chromatograph (GC).

2.7.2 Dry matter (DM)

The dry matter (DM) content of ground feed and faecal samples was determined by drying approximately 1.25 g sample in a forced draught oven at 105ºC for 24 hours (AOAC, 1995). The DM content of the feed and faecal samples was then calculated as:

$$\text{g DM} = \frac{\text{weight after drying (g)}}{\text{weight before drying (g)}} \qquad \text{Equation 2}$$

Where:

DM = dry matter

The DM content of the cereal crop stover treated with urea or urea and molasses was determined by drying duplicate samples of known weight in a freeze drier at –40ºC and 500 millitorr (pressure) for 24 hours. The samples were weighed into tarred labelled plastic plates before placing them in the freeze drier. The DM content was then calculated as shown in Equation 2 above.

2.7.3 Organic matter (OM)

Samples that had been dried as described in section 2.7.2 were used to determine the organic matter (OM) content. Crucibles containing the dried samples of known weight were incinerated in a muffle furnace at 550ºC for 4 hours (AOAC, 1995). The OM (g/kg DM) content of the feed and faecal samples was then calculated as:

$$\text{OM (g/kg DM)} = \frac{\text{weight loss (g)}}{\text{weight of dry sample (g)}} \text{ X } 1000 \qquad \text{Equation 3}$$

Where:

OM = organic matter

2.7.4 Nitrogen (N) and crude protein (CP)

The nitrogen (N) content of feed and faecal samples was determined by boiling about 1.25 g of each dried sample in concentrated sulphuric acid (H_2SO_4) followed by distillation over sodium hydroxide (NaOH) in accordance with AOAC (1995) procedures. The technique used was that proposed for the GERHARDT nitrogen analyser (Vapodest Gerhardt Type Vap 5 No 6550).

The N content of each sample was then determined by first distilling 25 ml solution with NaOH over 1% boric acid and then titrating against 0.01 N H_2SO_4 using a Kjeldahl titration unit. The amount of N in the solution was based on the amount of acid required to neutralise the N. From the N content, the CP content (DM basis) was then calculated (ILCA, 1990) as follows:

$$\text{Crude protein (g/kg DM)} = \text{Nitrogen X } 6.25 \text{ X } 1000 \qquad \text{Equation 4}$$

2.7.5 Neutral detergent fibre (NDF)

The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the technique developed by Ankom (1998a). The NDF content of feed and faecal samples was determined by digesting about 0.5 g ground sample in neutral detergent solution at 100ºC for 1 hour. The NDF was then calculated (Ankom, 1998a) as:

$$\text{NDF (g/kg DM)} = \frac{W_3 - (W_1 \text{ X } C_1)}{W_2} \text{ X } 1000 \qquad \text{Equation 5}$$

Where:

NDF = neutral detergent fibre

W_1 = bag tare weight

W_2 = sample weight expressed on a DM basis

W_3 = final bag and fibre weight

C_1 = blank bag correction (final oven dried weight/original blank bag weight)

2.7.6 Acid detergent fibre (ADF)

The technique used for the determination of ADF was essentially the same as the one used for NDF. The only difference was in the reagents used. The acid detergent fibre (ADF) content of feed and faecal samples was determined by digesting about 0.5 g ground sample in acid detergent solution at 100ºC for 1 hour. The ADF content was then calculated (Ankom, 1998a) as:

$$\text{ADF (g/kg DM)} = \frac{W_3 - (W_1 \text{ X } C_1)}{W_2} \text{ X } 1000 \qquad \text{Equation 6}$$

Where:

ADF = acid detergent fibre

W_1 = bag tare weight

W_2 = sample weight expressed on a DM basis

W_3 = final bag and fibre weight

C_1 = blank bag correction (final oven dried weight/original blank bag weight)

2.7.7 Acid detergent lignin (ADL)

The analysis for acid detergent lignin (ADL) content was done only on feed samples according to the Ankom (1998a) technique using samples that had been analysed for ADF. The bags containing samples of known weight were soaked in about 250 ml 72% H_2SO_4 for 3 hours. They were then rinsed and dried before being incinerated at 550ºC in a muffle furnace for 4 hours. The weight loss for each bag was calculated including the blank bag from which the blank bag correction factor (C_1) was determined. The ADL content was then calculated (Ankom, 1998a) as:

$$\text{ADL (g/kg DM)} = 1000\ \left(\frac{W_4 - (W_1 \text{ X } C_1)}{W_2}\right) \qquad \text{Equation 7}$$

Where:

ADL = acid detergent lignin

W_1 = bag tare weight

W_2 = sample weight expressed on a DM basis

W_3 = weight of filter bag and sample after digestion in acid and drying

W_4 = weight loss upon ignition (weight of empty crucible and filter bag /sample (W_3) less the weight of crucible and bag after ash)

C_1 = blank bag correction (weight loss upon ignition (W_4)/original blank bag weight)

2.7.8 *In vitro* dry matter digestibility (IVDMD)

The technique used for the analysis of *in vitro* dry matter digestibility (IVDMD) was a modification (Ankom, 1998b) of the method developed by Tilly and Terry (1963). The *in vitro* dry matter digestibility (IVDMD) of feed samples was determined by incubating about 0.25 g ground feed sample in a mixture of buffer solutions and rumen fluid in a Daisy incubator at 39ºC for 48 hours. The bags were then removed and thoroughly washed with tap water. The samples were then analysed for NDF (as described in section 2.7.5). The *in vitro* DM digestibility was then calculated (Ankom, 1998b) as:

$$\text{IVDMD (g/kg DM)} = 1000 - \left(\frac{\text{NDFy} - (W_1 \text{ X } C_1)}{W_2} \text{ X } 1000\right) \qquad \text{Equation 8}$$

Where:

IVDMD = *in vitro* DM digestibility

W_1 = Bag tare weight

W_2 = sample weight expressed on a DM basis

NDFy = Neutral detergent fibre content of sample

C_1 = blank bag correction (final oven dried weight/original blank bag weight)

The apparent nutrient digestibility was calculated as the difference between nutrients consumed and nutrients excreted in the faeces. It was calculated as follows (MacDonald *et al.*, 2002) on a DM basis:

$$\text{Apparent digestibility coefficient} = \frac{(\text{Nutrient consumed} - \text{Nutrient in faeces})}{\text{Nutrient consumed}} \qquad \text{Equation 9}$$

2.7.9 The pH of rumen fluid

The pH of rumen fluid was determined using a laboratory pH meter (HANNA 8520 instruments QA, supplies, LLC**.**1185 Pineridge Road Norfolk, Virginia 23502-2095 U.S.A). The probes of the pH meter were dipped twice into the rumen fluid. The mean of the readings obtained was taken as the pH of the rumen fluid. After each reading the probes were rinsed with distilled water before measuring the pH of the next sample.

2.7.10 Ammonia (NH3) concentration of rumen fluid

The technique and reagents used in this analysis were prepared as described by De Waal (1986). Previously collected rumen fluid (section 2.4) was analysed for ammonia nitrogen (NH_3-N) by first thawing the frozen rumen fluid overnight at room temperature. The thawed bottles were shaken vigorously and then allowed to stand for about 30 minutes. Then in duplicate, 20 ml rumen fluid was siphoned from the top of each bottle and placed in labelled distillation tubes using a 10 ml pipette. To each distillation tube was then added five glass beads, five heaped spatulas of magnesium oxide (MgO), 0.4 ml octyl alcohol ($C_7H_{18}OH$) and 50 ml distilled water. The distillation tube was attached to a Bucchi distillation unit and the process of distillation was allowed to run for 5 minutes. The distillate (about 200 ml) was collected in a 250 ml Erlenmeyer flask containing 50 ml 2% boric acid and indicator solution. The indicator in the flask changes colour from purple to green. The collected distillate was then back titrated to the original purple colour with 0.01 N H_2SO_4. The volume of H_2SO_4 used to titrate the distillate was used to calculate the NH_3 concentration of the rumen fluid (De Waal, 1986) samples as:

$$[NH_3] = \frac{(0.14 \text{ X N of } H_2SO_4) \text{ X (titration value X 1.2143)}}{\text{sample size (ml)}} * 100 \qquad \text{Equation 10}$$

Where:

[NH_3] = the concentration of ammonia (mg NH_3 per 100 ml rumen fluid)

N of H_2SO_4 = the normality of H_2SO_4

0.14 = constant

1.2143 = constant

2.7.11 Volatile fatty acids (VFA)

The preparation of external standards and the analysis of rumen fluid for VFA were done as described in the procedures of Goestsch and Galyean (1983). Four ml thawed rumen fluid was measured into a tube containing 1 ml 30% formic acid. The tubes were left for 60 minutes to allow a precipitation to form. The tubes were then put in a refrigerated (4ºC) centrifuge and centrifuged at 2 500 revolutions per minute for 40 minutes. One µ*l* of the supernatant was then extracted using a Hamilton syringe and injected into a Varian (3800) gas chromatograph (GC). Each sample injection was followed by the injection of 1 µ*l* 30% formic acid to rinse the column and to avoid the formation of ghost peaks. The GC was fitted with a 30 m X 0.25 mm Carbo-wax 20M 0.25 Micron column; Serial No: 114966 from OHIO VALLEY Speciality chemical. 115 Industry Road, Marieta, OH. Catalogue No: 2302502. The column oven conditions are provided in Table 2.8.

Table 2.8 Column oven conditions when determining volatile fatty acids in rumen fluid

Step	Temperature (ºC)	Rate (ºC/minute)	Hold	Total
Initial	80	-	-	0
1	100	8	3	5.5
2	120	5	1	10.5
3	200	80	4	15.0

The injector temperature was 180ºC and the detector temperature 270ºC. The gas pressure was 20 psi (pounds per square inch) (equivalent to 137.90 kPa) thus giving a column flow rate of about 3.4 ml/second. Helium (He) (99.999% purity) was used as the carrier whilst hydrogen (H) was used for the detector. The make up gas consisted of compressed air and the carrier gas (He). The GC was connected to a computer installed with Varian software for integrating and calculating the concentration of volatile fatty acids in samples based on a standard calibration curve.

2.8 Statistical Analysis

Data were subjected to an ANOVA with the aid of the GLM procedure of SAS (1999) and treatment means were separated and tested for significant differences using least squares (LS) means and Duncan's multiple range test.

Data for the treatment of cereal crop stovers with urea or urea and molasses was analysed to determine the effect of treatments on the chemical composition and IVDMD of cereal crop stovers while data from the feeding trials was tested for the effects of treatment diets on the intake and digestibility of DM, OM, CP, NDF and ADF. The influence of treatment diets on the metabolisable energy, body weight changes, pH of rumen fluid and NH_3 concentration of rumen fluid were also tested using the GLM procedures. Significance was declared at $P<0.05$.

In cases where data are presented in two-way tables (showing significant interactions), the standard errors of the means (s.e.) are presented below the tables. The first standard error of the mean is for the main treatment effect and is for data on the last column of the particular table. The second standard error of the mean is for the second main effect and applies to data on the last row of the table. The third (last) standard error of the mean is for the rest of the data within the table.

3. The effects of treatment with urea or urea and molasses on the physical and chemical properties of sorghum, maize and millet cereal crop stovers

3.1 Introduction

Applications of chemical and physical treatments to ameliorate highly lignified plant materials are well known (Sundstøl, 1988). Disintegration of poor quality roughage by grinding has been shown to improve the voluntary feed intake whereas chemical treatment improves the digestibility as well as the intake (Brand *et al.*, 1991; Fahmy & Klopfenstein, 1994). The choice of appropriate chemical treatment to ameliorate crop stovers depends on safety considerations, cost and potential detrimental effects to the environment (Chen *et al.*, 1995). The present study was aimed at evaluating and comparing the effects of treatment with urea or urea and molasses on the physical and chemical properties of cereal crop stovers of sorghum, maize and millet.

3.2 Physical changes (colour, texture and odour) of the cereal crop stovers

Treating cereal crop stovers with urea or urea and molasses resulted in physical changes of the stovers. Maize stover changed in colour from pale to orange or tan (untreated stover) to rown after treatment with T1 or T3 and dark to red when treated with T2. The higher concentration of urea in treatment T2 appeared to produce darker colours than for treatment T1. These colour changes are in agreement with those reported by Chenost and Kayouli (1997) who observed that well-treated forages have a dark brown or maroon colour. The colour changes in sorghum and millet stovers were not as distinct as observed for maize stover, probably because initially the untreated stovers of sorghum and millet were of darker hues than maize stover.

Another physical indicator that the cereal crop stovers were well-treated was the absence of mould (Chenost & Kayouli, 1997). Mould development was apparently suppressed by the presence of a NH_3 atmosphere within the stover mass and the fact that the plastic drums used for ensiling the cereal crop stovers were sealed airtight.

The treated stovers felt softer to touch compared to the untreated stovers. Ørskov (1993) explained that NH_3 acts on cereal crop stovers causing swelling of plant fibres. This result in changes in the texture of cereal crop stovers treated with urea. Chenost and Kayouli (1997) attributed these textural changes to the water added as a urea or a urea and molasses solution.

Cereal crop stovers treated with urea or urea and molasses had the strong, pungent urine like odour of NH_3. According to Chenost and Kayouli (1997), odour is one of the criteria that may be used to gauge the efficiency of treating stovers with urea. The absence of the characteristic NH_3 odour or a weak odour indicates failure or a low efficiency in treatment (Chenost & Kayouli, 1997).

3.2.1 Changes in the chemical composition and in vitro dry matter digestibility of the cereal crop stovers

In Tables 3.1 to 3.3 summaries are provided of the ANOVA tables showing the effects of treatments (Table 3.1), type of cereal crop stover (Table 3.2) and the interaction between treatments and type of cereal crop stovers (Table 3.3) on the chemical composition and *in vitro* DM digestibility of the cereal crop stovers.

Treating the three cereal crop stovers with urea or urea and molasses produced distinct and significant changes in chemical composition (Table 3.1). Untreated cereal crop stovers had more DM and OM, but less CP and ADF and a lower IVDMD than cereal crop stovers treated with urea or urea and molasses. Although treatments T1 and T2 did not affect NDF, they increased the ADL content of cereal crop stovers. Treatment T3 decreased NDF, but did not change the ADL content of cereal crop stovers.

It is evident from the results in Table 3.2 that cereal crop stovers of sorghum, maize and millet were similar in DM, OM, ADL content and IVDMD, but differed in CP, NDF and ADF content across treatments. Maize stover contained more CP and less NDF and ADF than sorghum and millet stovers. Sorghum and millet stovers were similar in CP, NDF and ADF content.

Table 3.1 The LS means for the effect of treatment with urea or urea and molasses on the chemical composition and *in vitro* DM digestibility of the cereal crop stovers

Chemical composition		[1]Treatments				
	Untreated	T1	T2	T3	SEM	P
Dry matter (g/kg)	942.07[a]	441.41[b]	435.84[b]	427.97[b]	10.58	<0.0001
Organic matter (g/kg DM)	893.99[a]	849.87[b]	847.01[b]	864.23[b]	8.94	0.0014
Crude protein (g/kg DM)	69.75[c]	99.94[b]	112.63[a]	110.50[a]	3.19	<0.0001
Neutral detergent fibre (g/kg DM)	633.26[a]	650.20[a]	657.40[a]	572.08[b]	9.38	<0.0001
Acid detergent fibre (g/kg DM)	374.48[b]	446.15[a]	428.23[a]	434.49[a]	9.27	<0.0001
Acid detergent lignin (g/kg DM)	28.62[b]	45.63[a]	40.45[a]	26.57[b]	3.35	<0.0001
In vitro DM digestibility (g/kg DM)	525.60[b]	531.73[b]	566.87[ba]	605.74[a]	17.21	0.0072

Means in a row with a common superscript do not differ significantly (P>0.05).

[1]T1 = cereal crop stover plus 10 g urea/kg stover

T2 = cereal crop stover plus 25 g urea/kg stover

T3 = cereal crop stover plus 10 g urea + 10 g molasses/kg stover.

SEM = standard error of the mean; P = probability

Table 3.2 The LS means for the effect of type of cereal crop stover on the chemical composition and *in vitro* DM digestibility

Chemical composition	Cereal crop stovers				
	Sorghum	Maize	Millet	SEM	P
Dry matter (g/kg)	576.36	557.68	551.43	9.16	NS
Organic matter (g/kg DM)	865.49	868.23	857.60	7.74	NS
Crude protein (g/kg DM)	94.00[b]	113.44[a]	87.19[b]	2.75	<0.0001
Neutral detergent fibre (g/kg DM)	644.86[a]	608.47[b]	631.37b[a]	8.11	0.0241
Acid detergent fibre (g/kg DM)	432.67[a]	394.22[b]	435.62[a]	8.03	0.0011
Acid detergent lignin (g/kg DM)	38.44	34.76	32.76	2.90	NS
In vitro DM digestibility (g/kg DM)	550.21	566.24	556.00	14.91	NS

Means in a row with a common superscript do not differ significantly (P>0.05).

SEM = standard error of the mean, P = probability and NS = not significant.

Significant interaction effects (treatment with urea or urea and molasses X type of cereal crop stover) were observed in DM, CP, NDF and ADL contents of the three cereal crop stovers (Table 3.3).

Table 3.3 The LS means for the interaction between treatments and type of cereal crop stover on the chemical composition and *in vitro* DM digestibility

Chemical composition	[1]Mean	SEM	P
Dry matter (g/kg)	561.82	18.34	0.0065
Organic matter (g/kg DM)	863.77	15.48	NS
Crude protein (g/kg DM)	98.19	5.50	<0.0001
Neutral detergent fibre (g/kg DM)	628.23	16.23	0.001
Acid detergent fibre (g/kg DM)	420.84	16.05	NS
Acid detergent lignin (g/kg DM)	35.32	4.86	0.0008
In vitro DM digestibility (g/kg DM)	557.48	29.82	NS

[1]Mean = interaction mean (treatment method X type of cereal stover).

SEM = standard error of the mean, P = probability and NS = not significant.

3.2.2 Dry matter (DM)

The dry matter (DM) of the cereal crop stovers appeared to decrease (Table 3.4) due to treatment with urea or urea and molasses.

The cereal crop stovers treated with urea or urea and molasses were on average 53.82% lower in DM content than untreated stovers. The treatments T1, T2 and T3 had a similar (P>0.05) effect on the DM content of the cereal crop stovers (Table 3.4). This was to be expected because the cereal crop stovers were treated by adding 1 litre of urea solution or urea and molasses solution per kg of stover, hence the large reduction in the DM content of the treated stovers. High moisture content improves the binding of NH_3 to straw, thus resulting in improved N fixation (Chenost & Kayouli, 1997).

The types of cereal crop stovers (sorghum, maize and millet) were similar in DM content across treatment methods (Table 3.4). This was probably because the cereal crop stovers were produced (grown), processed and stored under similar conditions.

Table 3.4 The LS means for the effect of treatment with urea or urea and molasses on the DM content (g/kg) of sorghum, maize and millet stovers

Treatments	Cereal crop stovers			Treatment mean
	Sorghum	Maize	Millet	
		g/kg		
Untreated stovers	938.97[a]	953.09[a]	934.14[a]	942.07[a]
10 g urea/kg stover (T1)	453.07[b]	407.06[b]	467.14[b]	441.41[b]
25 g urea/kg stover (T2)	484.92[b]	410.13[b]	412.48[b]	435.84[b]
10 g urea + 10 g molasses/kg stover (T3)	431.52[b]	460.44[b]	391.96[b]	427.97[b]
Type of cereal crop stover mean	576.36	557.68	551.43	561.82

Means in a column with a common superscript do not differ significantly (P>0.0001).

s.e. of the difference between two values in body of table = 18.34
s.e. of the difference between two treatment methods = 10.58
s.e. of the difference between two stover means = 9.16

Summary of table: Each treatment produced a significant reduction in the DM content of untreated stovers. In this respect, the treatments were similar.

The DM content of the untreated stovers used in the present study is in agreement with the findings of other researchers. Boitumelo (1999) found the DM content of bird resistant (BR) and non-bird resistant (NBR) sorghum stover to be 902 and 892 g/kg respectively. He attributed the differences between BR and NBR sorghum to the presence of large amounts of tannins in BR sorghum. Ocen and Dlamini (2002) reported the DM content of maize stover to be 916 g/kg.

Salem *et al.* (1994) found that the DM content of sorghum stover decreased from 890 to 804 g/kg when the stover was treated with urea at a rate of 53 g urea and 250 ml water/kg DM of stover. A study by Manyuchi *et al.* (1994) found that untreated maize stover had a DM content of 891 to 901 g/kg, which is slightly less than that reported in the present study. When urea solution was added to maize stover at a ratio of 1:5, the DM content of maize stover decreased from 901 to 881 g/kg.

The differences between the DM content of stovers found in other studies compared to the present study may be due to the varieties of cereal crop stovers used and the environmental conditions (ambient temperature and humidity) in which the cereal crops were grown, processed and stored. The intake of DM is important since it determines the amount of nutrients available to animals for maintenance and production. This means that cereal crop stovers treated with urea or urea and molasses would have to be consumed in large amounts if offered as the basal diet. However, it also means that the voluntary water intake of animals would be low since stovers treated with urea or urea and molasses had high moisture content.

3.2.3 Organic matter (OM)

Treating the cereal crop stovers with urea or urea and molasses appeared to reduce their organic matter (OM) content (Figure 3.1).

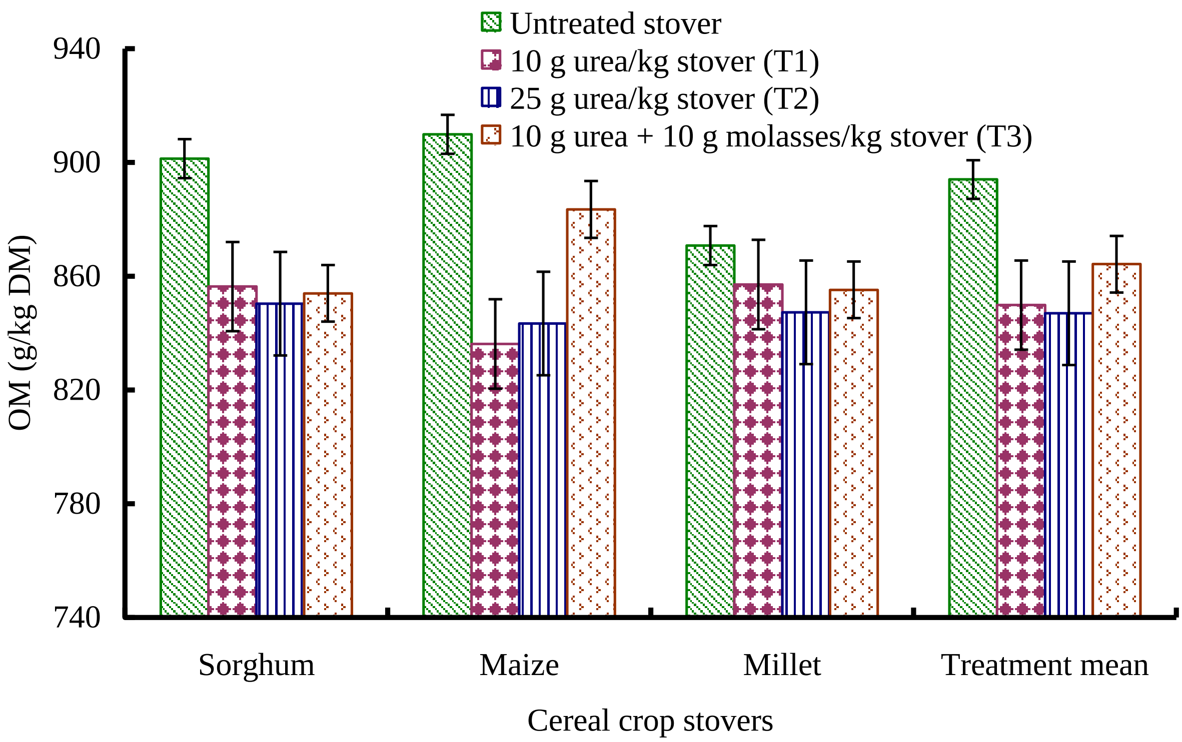


Figure 3.1 The LS means for the ameliorative effects of urea or urea and molasses on the organic matter (OM) content (g/kg DM) of sorghum, maize and millet stovers.

Treatment with urea or urea and molasses reduced the OM ($P<0.05$) content of sorghum stover. Untreated maize stover had more OM content than that treated with T1 ($P<0.001$) and T2 ($P<0.01$). However, treating maize stover with T3 appeared to have no effect ($P>0.05$) on its OM content (Figure 3.1). The apparent lack of effect on the OM content when maize stover was treated with T3 was probably due to the added molasses. Treatment with urea or urea and molasses apparently did not affect the OM content of millet stover (Figure 3.1).

Generally, the untreated cereal crop stovers were higher ($P<0.05$) in OM content than those treated with urea or urea and molasses (Figure 3.1). Cereal crop stovers treated with T1, T2 and T3 were respectively 4.94%, 5.25% and 3.33% lower in OM content than untreated stovers. Treatment T3 effected the least reduction in DM probably because of the molasses added during treatment. The treated stovers of sorghum, maize and millet were similar ($P>0.05$) in OM content regardless of treatment method.

Unlike the findings in the present study, Salem *et al.* (1994) found little difference in OM content between sorghum stover treated with urea (849 g OM/kg DM) or left untreated (850 g OM/kg DM). The Ministry of Agriculture (MoA, 1990) reported that untreated maize stover had an OM content of 971.5 g/kg DM compared to the 909.84 g/kg DM in the present study. After treatment with 10 g urea + 100 g molasses/kg stover, the OM content of maize stover increased marginally to 978.5 g/kg DM (MoA, 1990). This increase was probably due to the additional OM derived from the molasses. Broudiscou *et al.* (2003) found that treating rice straw with ammonia led to a decrease in OM content of straw. The authors hypothesised that the loss in OM was due to solubilisation of the hemicellulose fraction of NDF. This was consistent with the study by Rahal *et al.* (1997) who noticed that the ash content of rice straw increased after treatment with urea.

3.2.4 Crude protein (CP)

Treating the cereal crop stovers with urea or urea and molasses increased their crude protein (CP) content as shown in Table 3.5.

Cereal crop stovers treated with urea or urea and molasses were on average 40.77% higher in CP than the untreated stovers (Table 3.5). Treatments T2 and T3 had a similar ($P>0.05$) effect on stovers in increasing the CP content; both were better ($P<0.01$) than treatment T1 in improving the CP content of cereal crop stovers. This probably indicates that higher concentrations of urea or urea and molasses are more conducive for N uptake by stovers than lower concentrations of urea or urea alone.

Table 3.5 The LS means for the effect of treatment with urea or urea and molasses on the CP content (g/kg DM) of sorghum, maize and millet stovers

Treatments	Cereal crop stovers			Treatment mean
	Sorghum	Maize	Millet	
		g/kg DM		
Untreated stover	67.19^{c}	72.25^{b}	69.75^{b}	69.75^{c}
10 g urea/kg stover (T1)	88.19^{b}	122.94^{a}	88.75^{a}	99.94^{b}
25 g urea/kg stover (T2)	114.88^{a}	141.38^{a}	81.69^{b}	112.63^{a}
10 g urea + 10 g molasses/kg stover (T3)	105.69^{b}	117.19^{a}	108.63^{a}	110.50^{a}
Type of cereal crop stover mean	94.00^{b}	113.44^{a}	87.19^{b}	98.19

Means in a column with a common superscript do not differ significantly (P>0.05).

s.e. of the difference between two values in body of table = 5.50

s.e. of the difference between two treatment methods = 3.19

s.e. of the difference between two stover means = 2.75

Summary of table: For each cereal crop stover, treatment with urea or urea and molasses produced large and significant increases in the CP content. Differences between the observed CP content due to various treatment levels were greatest with treatment T2 and were significant even with T1.

Stovers of sorghum and millet did not differ in CP content and both had less CP than maize stover (P>0.05) (Table 3.5). Maize stover showed the greatest improvement in the CP content due to treatment with urea or urea and molasses.

Maphane and Mutshewa (1999) reported the CP content of sorghum, maize and millet stovers to be 63.69, 78.38 and 57.50 g/kg DM respectively. The CP content of stovers in the present study is in agreement with the findings of these authors but is slightly higher than those reported by Aganga and Nsinamwa (1997). According to Aganga and Nsinamwa (1997), the CP of untreated sorghum, maize and millet stovers in Botswana were 64, 54 and 57 g CP/kg DM respectively. The differences in the CP content may be due to different growing conditions for the cereal crops, stage of maturity at harvest, processing and storage conditions for the stovers.

A noticeable increase in the CP content of cereal crop stovers treated with urea is the main indicator of the success of treatment (Chenost & Kayouli, 1997). These authors explained that as urea hydrolyses into NH_3 and CO_2, the NH_3 is attached to the stover, thus increasing the amount of N in the stovers. The CP content of sorghum stover in a study by Salem *et al.* (1994) was 58 g CP/kg DM and upon treatment with 53 g urea in 250 ml H_2O/kg DM stover, the CP content of the stover increased more than twofold to 118 g CP/kg DM. Manyuchi *et al.* (1994) reported a 90% increase in CP content when maize stover was treated with urea at a rate of 25 g urea/kg stover. In a study by Methu *et al.* (1998), the CP content of maize stover increased from 88 to 132.8 g CP/kg DM when treated with 44.6 g urea/kg stover. In an evaluation of urea and/or sulphite as treatment of ground maize stalks, Fahmy and Klopfenstein (1994) reported an increase of 8.19% and 11.88% respectively in the CP content of maize stalks. These findings substantiate the results from the present study. Although the concentrations of urea used in the present study were lower (10 g urea/kg stover and 25 g urea/kg stover) than the recommended 50 g urea/kg stover (Chenost & Kayouli, 1997), the improvement in the CP content of the three cereal crop stovers was comparable to that obtained with the recommended urea concentration.

The cereal crop stovers, treated with urea or urea and molasses or left untreated, were higher in CP content than the 30 g CP/kg DM reported by Madibela *et al.* (2000) for grasses during the dry season in Botswana. The CP content of the cereal crop stovers was higher than the 52.94 g CP/kg DM found for veld grass hay in the present study (Table 2.5). This means that if used judiciously as animal feed the cereal crop stovers have the potential of supplying the CP deficit during the dry season. The study by Salem *et al.* (1994) indicated that most of the N fixed due to treatment with urea is soluble hence it is readily available for utilisation by rumen microbes.

3.2.5 Neutral detergent fibre (NDF)

The effect of the treatments on the neutral detergent fibre (NDF) of the cereal crop stovers is shown in Table 3.6. Treating the cereal crop stovers with urea or urea and molasses appeared to decrease the NDF content of the stovers.

Table 3.6 The LS means for the effect of treatment with urea or urea and molasses on the NDF content (g/kg DM) of sorghum, maize and millet stovers

Treatments	Cereal crop stovers			Treatment mean
	Sorghum	Maize	Millet	
	g/kg DM			
Untreated stover	675.02[a]	602.34	622.42[b]	633.26[a]
10 g urea/kg stover (T1)	670.30[a]	613.95	666.35[ba]	650.20[a]
25 g urea/kg stover (T2)	658.08[a]	618.15	695.99[a]	657.40[a]
10 g urea + 10 g molasses/kg stover (T3)	576.04[b]	599.46	540.74[c]	572.08[b]
Type of cereal crop stover mean	644.86	608.47	631.37	628.23

Means in a column with a common superscript do not differ significantly (P>0.05).

s.e. of the difference between two values in body of table = 16.23
s.e. of the difference between two treatment methods = 9.38
s.e. of the difference between two cereal crop stovers = 8.11

Summary of table: Treating cereal crop stovers with T3 significantly reduced their NDF content while the other treatments had no effect. The general trend is a moderate increase in stover NDF with T1 and T2 followed by a sharp decline when T3 was applied to stover.

Treating cereal crop stovers with T1 and T2 increased their NDF content by 2.68% and 3.81% respectively (Table 3.6). When the cereal crop stovers were treated with T3 the NDF content decreased by 9.66%. Cereal crop stovers treated with urea or urea and molasses had on average 1.07% more NDF than the corresponding untreated stovers.

The effects of treatments T1 and T2 were similar (P>0.05) in that they did not change the NDF content of cereal crop stovers. The untreated cereal crop stovers or those treated with T1 and T2 were higher (P<0.01) in NDF content than those treated with T3. This was probably because the fermentable sugars in treatment T3 enhanced the hydrolysis of the hemicellulose portion of NDF.

Stovers of sorghum and millet had a similar (P>0.05) NDF content and both had more (P<0.05) NDF than maize stover (Table 3.6). The NDF in maize stover was least affected by treatment with urea or urea and molasses. Since maize stover was higher in OM and CP content than sorghum and millet stover it is possible that it had lower amounts of hemicellulose.

The NDF content of untreated sorghum stover as found in the present study falls within the range 679 to 754 g/kg DM reported by Osafo *et al.* (1996). Salem *et al.* (1994) showed that untreated sorghum stover had NDF amounting to 687 g/kg DM which is slightly higher than that found in the present study. These authors also reported a slight decrease of 0.58% and 2.18% in NDF content respectively when sorghum stover was treated with ammonia and urea. Previously this has been attributed to the solubility of some portions of the NDF.

Methu *et al.* (1998) reported the NDF content of untreated maize stover to be 804 g/kg DM, which was higher than the 602.33 g/kg DM found in the present study. However, the NDF content of untreated maize stover in the present study is consistent with the NDF content (604 to 710 g/kg DM) of ten hybrid maize stovers (Galletti *et al.*, 1997).

According to Meissner *et al.* (1991), the threshold level of NDF in tropical grasses beyond which DM intake in cattle is affected is 600 g/kg. This suggests that if this threshold applies to cereal crop stovers, cattle would experience inadequate intake levels if fed solely on untreated stovers or those treated with T1 and T2. However, no such problems are likely to be encountered where animals are fed on stovers treated with T3.

3.2.6 Acid detergent fibre (ADF)

The acid detergent fibre (ADF) content of the three cereal crop stovers appeared to increase after treatment with urea or urea and molasses (Figure 3.2).

Untreated sorghum stover was similar in ADF content to that treated with T1 and T3 but was lower than that treated with T2. The ADF content of untreated maize stover was reduced by treatment with T1 and T2 ($P<0.05$) and T3 ($P<0.01$). The three treatments had a similar ($P>0.05$) effect on the ADF content of maize stover (Figure 3.2).

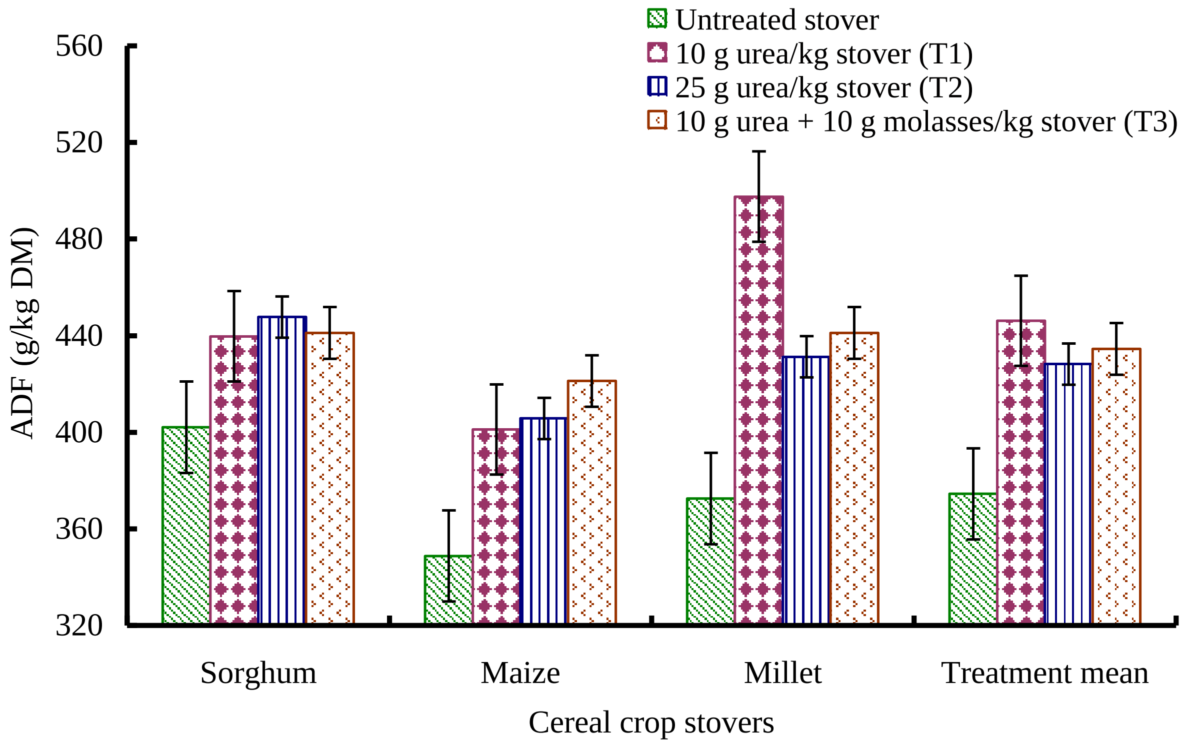


Figure 3.2 The LS means for the effect of treatment with urea or urea and molasses on the acid detergent fibre (ADF) content (g/kg DM) of sorghum, maize and millet stovers.

Untreated millet stover was lower in ADF content than that treated with T1 ($P<0.0001$), T2 ($P<0.05$) and T3 ($P<0.01$). Millet stover treated with T1 had a higher ADF content than that treated with T2 ($P<0.01$) and T3 ($P<0.05$) but treatments T2 and T3 were similar in their effect on the ADF content of millet stover (Figure 3.2).

As the CP and some of the NDF in cereal crop stovers dissolved, it is expected that the ADF content would increase since ADF is insoluble in water. The ADF content of cereal crop stovers treated with T2 and T3 was on average lower than that treated with T2, suggesting that higher concentrations of urea and a combination of urea and molasses possibly hydrolysed some ADF.

The ADF content of untreated sorghum and millet stovers obtained in the present study was lower than that found by Aganga *et al.* (1996) for a number of sorghum and millet varieties harvested at 120 days in Botswana. However, the ADF content of untreated sorghum stover as found in the present study (402.11 g/kg DM), is in agreement with the 408 g/kg DM reported by Salem *et al.* (1994). In the study by Salem *et al*. (1994), the ADF content of sorghum stover increased to 425 g/kg DM when treated with ammonia, but slightly decreased to 399 g/kg DM when treated with urea.

Ocen and Dlamini (2002) reported the ADF content of untreated maize stover to be 409.0 g/kg DM, which is higher than the 348.79 g/kg DM found in the present study. The disparities in ADF content may be due to differences in growing conditions of cereal crops coupled with differing crop varieties. The ADF content of maize stover from the present study falls within the range of 226 to 496 g/kg DM found by Tovar-Gomez *et al.* (1999). The nominal increase in the ADF content when cereal crop stovers were treated with urea or urea and molasses is in line with the results of Muller *et al.* (1999) and Broudiscou *et al.* (2003). Muller *et al.* (1999) reported a 1.5% increase in the ADF content of wheat straw due to ammoniation while the latter found a 13.79% increase in the ADF content when treating rice straw with ammonia.

3.2.7 Acid detergent lignin (ADL)

The acid detergent lignin (ADL) content of the three cereal crop stovers as influenced by treatments is shown in Table 3.7.

Table 3.7 The LS means for the effect of treatment with urea or urea and molasses on the ADL content (g/kg DM) of sorghum, maize and millet stovers

Treatments	Cereal crop stovers			Treatment mean
	Sorghum	Maize	Millet	
	g/kg DM			
Untreated stover	39.54^{b}	26.38^{c}	19.93^{b}	28.62^{b}
10 g urea/kg stover (T1)	48.39^{a}	39.61^{a}	48.88^{a}	45.63^{a}
25 g urea/kg stover (T2)	36.83^{b}	35.02^{ba}	49.51^{a}	40.45^{a}
10 g urea + 10 g molasses/kg stover (T3)	29.00^{c}	38.00^{a}	12.71^{b}	26.57^{b}
Type of cereal crop stover mean	38.44	34.76	32.76	35.32

Means in a column with a common superscript do not differ significantly (P>0.05).

s.e. of the difference between two values in body of table = 4.86
s.e. of the difference between two treatment means = 2.81
s.e. of the difference between two stover means = 2.43

Summary of table: Treating the cereal crop stovers with T1 and T2 significantly increased their ADL content. The ADL content of the cereal crop stovers was not affected by treatment with T3.

The cereal crop stovers treated with urea or urea and molasses were on average 31.20% higher in ADL content than untreated stovers (Table 3.7). Untreated cereal crop stovers or treated with T3 were similar and both were lower ($P<0.01$) in ADL content than those treated with T1 and T2. Treatments T1 and T2 were similar ($P>0.05$) in their effects on the ADL of cereal crop stovers. It is not clear why the ADL content of cereal crop stovers behaved in this manner. Stovers of sorghum, maize and millet had a similar ($P>0.05$) ADL content across treatments (Table 3.7).

The ADL content of untreated sorghum and millet stovers in the present study was less than that reported by Zerbini *et al*. (2002). In the study by Zerbini *et al*. (2002), the ADL content of untreated sorghum stover ranged from 194 to 219 g/kg DM while for millet stover the ADL content ranged from 171 to 207 g/kg DM. However, Salem *et al.* (1994) found the ADL content of sorghum stover to be 56 g/kg DM which is comparable to that observed in the present study. Upon treatment with ammonia and urea, the ADL content of the sorghum stover was reduced to 50 and 54 g/kg DM by ammonia and urea, respectively (Salem *et al.*, 1994). This was in contrast to the results of Chenost and Kayouli (1997) who reported a 1% increase in the ADL content of wheat straw due to treatment with 50 g urea/kg stover.

According to Wilman *et al.* (1999a), the ADL content of untreated maize stover ranged from 36 to 65 g/kg DM which is comparable to what was found in the present study and does not vary as much as the 2 to 350 g ADL/kg DM reported by Galletti *et al.* (1997).

The ADL content of the three cereal crop stovers responded differently to treatment with urea or urea and molasses. Possible explanations for this include differences in the initial botanical composition of the cereal crop stovers and random sampling errors. The cereal crop stovers were stored in an open-sided barn in which they were exposed to the elements from the sides. This may have led to the variable ADL values obtained in the present study. However, the ADL content of the lucerne hay used in the present study is in agreement with the findings of

Julier *et al*. (2000) and Aganga and Omphile (2005) and the ADL content of the check or validation sample (Section 2.7.1) was within the expected range.

3.3 *In vitro* dry matter digestibility (IVDMD)

The *in vitro* DM digestibility of the cereal crop stovers is shown in Figure 3.3. The untreated cereal crop stovers had a mean IVDMD of 525.6 g IVDMD/kg DM. The greatest improvement in the IVDMD of the cereal stovers was realised with treatment T3.

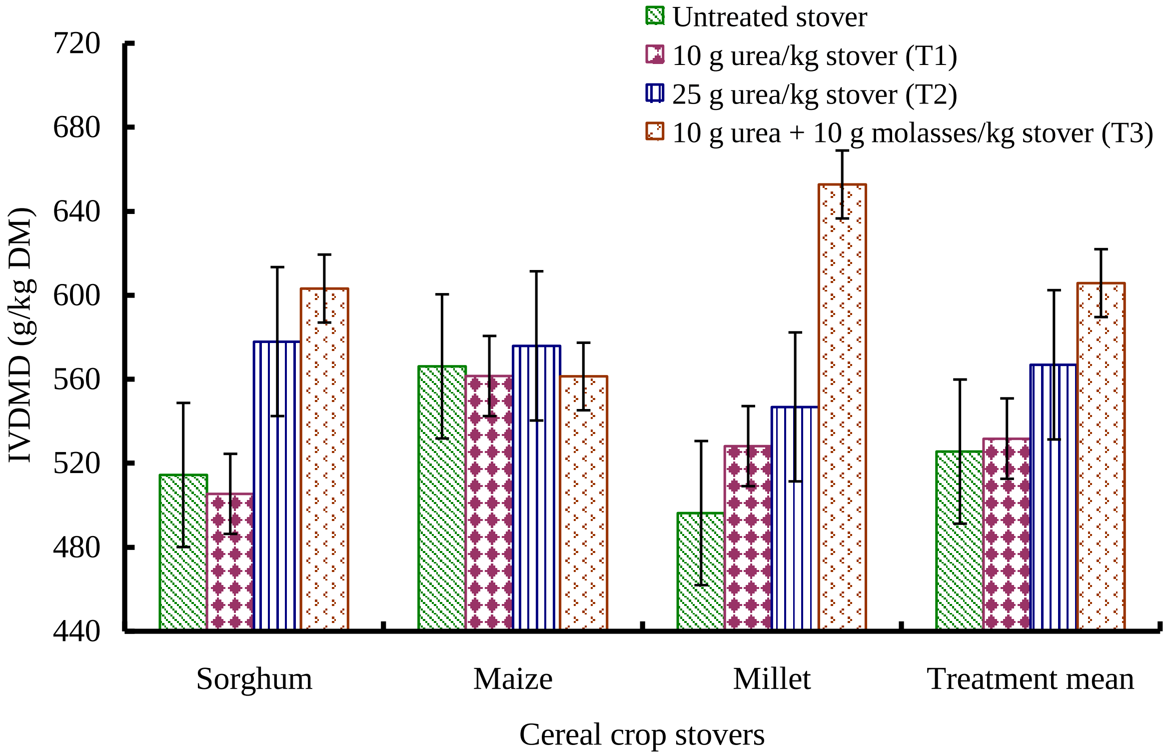


Figure 3.3 The LS means for the effect of treatment with urea or urea and molasses on the *in vitro* DM digestibility (IVDMD) (g/kg DM) of cereal crop stovers.

Sorghum stover, untreated or treated with T1, was lower (P<0.05) in IVDMD than that treated with T3 but similar to that treated with T2. Treatments T2 and T3 were similar (P>0.05) in their effect on IVDMD of sorghum stover (Figure 3.3).

The IVDMD of maize stover was not altered appreciably by any of the ameliorants. It is not clear why the treatments had no appreciable effect on the IVDMD in maize stover when they did in sorghum and millet stovers (Figure 3.3).

Treatments T1 and T2 were similar in that they did not improve the IVDMD of millet stover (Figure 3.3). Millet stover treated with T3 had an improved IVDMD compared to untreated ($P<0.001$) or treated with T1 ($P<0.01$) and T2 ($P<0.05$). The improvement in the IVDMD when millet stover was treated with T3 was probably due to the reduction in the NDF content. The IVDMD of millet stover from the present study appeared to be inversely related to NDF content. Madibela *et al*. (2005 unpublished) found a similar relationship between IVDMD and NDF content. The three cereal crop stovers maintained their similarity ($P>0.05$) in IVDMD regardless of treatment.

The LS means for the three cereal crop stovers treated with urea or urea and molasses show an increasing trend in IVDMD with treatments (Figure 3.3). The IVDMD of the cereal crop stovers increased on average by 1.17%, 7.85% and 15.25% respectively when treated with T1, T2 and T3. According to Manyuchi *et al.* (1994), treatment of stovers with urea causes a breakdown of the structural plant cell bonds by the NH_3 generated and renders the cell wall more degradable. No significant improvement in the IVDMD of stovers was achieved with treatments T1 and T2. However, stovers treated with T3 had improved ($P<0.05$) IVDMD compared to those treated with T1. Treating stovers with T3 had an effect similar to that of T2 on the IVDMD. It is possible that despite assertions to the contrary in literature (Sundstøl, 1988; Chenost & Kayouli, 1997; Rahal *et al.*, 1997) that the three weeks allowed for treatment with urea or urea and molasses in the present study were not sufficiently long enough to allow for the softening of the detergent fibres in the cereal crop stovers. In a study by Broudiscou *et al.* (2003), the degradability of OM was 27% higher in rice straw treated with ammonia than in untreated straw, while Makkar *et al.* (1997) reported significant improvements in the IVDMD of wheat straw due to amelioration with urea when the straws were ensiled for five weeks.

The IVDMD of untreated sorghum and millet stovers found in the present study is comparable to the results of Aganga *et al.* (1996). Wilman *et al.* (1999b) found comparable IVDMD values for sorghum (514 g/kg DM), maize (486 g/kg DM) and millet (501 g/kg DM) stovers. These authors also reported that millet stover was higher in IVDMD than wheat straw (383 g/kg DM) or rice (357 g/kg DM) straw regardless of the processing method.

Zerbini *et al.* (2002) reported that lignin accounted for most of the differences in the IVDMD of straws and it was found to be the main predictor of cell wall degradability because lignified cell walls are resistant to microbial. A poor but positive correlation (r = 0.300) was found between the ADL content and the IVDMD in the present study. Although Bruno-Soares *et al.* (2000) reported that the NDF and ADL content of legume straws were the best variables in explaining potential digestibility of the DM and NDF in feeds, Madsen *et al.* (1997) cautioned that chemical analyses do not predict digestibility well, except in instances where the relationship between the two has been established beforehand. This probably explains the low regression coefficients obtained when IVDMD was regressed against CP (r^2 = 0.250), ADF (r^2 = 0.050), NDF (r^2 = -0.012) and ADL (r^2 = 0.078).

Hinders (2001) recommended the replacement of ADF with NDF in the evaluation of forage energy values because in his study 99% of the variation in the feeding value of feedstuffs was explained by the NDF. Results from the present study do not support such a recommendation because the relationship between NDF and digestibility (r^2 = -0.012) was poor.

The stage at which cereal crop stover is harvested and the storage conditions have been shown to influence the quality of stover (Bwire & Wiktorsson, 2002). These authors found that early harvesting of stover yielded more tops with higher CP, digestibility and metabolisable energy (ME) and also lower in ADF and NDF content than stovers harvested later. They also noticed that storing stovers in a shed conserved nutritive value better than laying or stacking stovers in the open field. The cereal crop stovers used in the present study were harvested 12 months prior to treatment and stored in an open-sided barn. This probably influenced their chemical composition and IVDMD.

The untreated and treated cereal crop stovers from the present study were comparable to lucerne hay (Table 2.5) in terms of the OM (Figure 3.1) content. Although the cereal crop stovers treated with urea or urea and molasses in the present study were comparable to lucerne hay (Table 2.5) in CP content (Table 3.5), the lucerne hay was lower in CP content than reported by Macala *et al.* (1995) and Muller *et al.* (1999). Muller *et al.* (1999) described lucerne hay containing 169 g CP/kg DM as being of average quality, suggesting that the lucerne hay used in the present study (123.81±10.25 g CP/kg DM) was relatively low in quality. The cereal crop stovers untreated or treated with T1 and T2 had more NDF than lucerne hay (Table 2.5). Treating the cereal crop stovers with T3 made them comparable in NDF content (Table 3.6) to lucerne hay. Cereal crop stovers untreated or treated with T1 and

T2 were comparable in ADF (Figure 3.2) and ADL (Table 3.7) content to lucerne hay (Table 2.5). Treatment with T3 made the stovers generally lower in ADF and ADL content than lucerne hay. The three cereal crop stovers treated with urea or urea and molasses were comparable to lucerne hay and higher in IVDMD (Figure 3.3) than veld grass hay (Table 2.5).

3.4 Conclusions

3.4.1 The three cereal crop stovers treated with urea or urea and molasses were found to be softer to touch, with a darker colour and had the pungent urine-like odour of urea which was absent in the untreated stovers.

3.4.2 Treating cereal crop stovers with urea or urea and molasses lowered their DM content due to the added water.

3.4.3 The OM content of cereal crop stovers was unaffected by treatment with urea or urea and molasses.

3.4.4 Cereal crop stovers treated with urea or urea and molasses were higher in CP content than untreated stovers and in this respect comparable to lucerne hay. Maize stover had the best response to treatment with urea or urea and molasses in terms of N uptake while millet stover showed the least response.

3.4.5 Treatment with urea or urea and molasses reduced the NDF content in sorghum stover but increased it in maize and millet stover. Treating millet stover with 10 g urea + 10 g molasses/kg stover reduced its NDF content. Cereal crop stovers treated with 10 g urea + 10 g molasses/kg stover and untreated maize stover were comparable to lucerne hay in NDF content.

3.4.6 Treating cereal crop stovers with urea or urea and molasses increased the ADF content except in sorghum and millet stovers treated with 10 g urea + 10 g molasses/kg stover in which the ADF content decreased. Cereal crop stovers treated with 10 g urea + 10 g molasses/kg stover were found to be lower in ADF content compared to lucerne hay while those treated with 10 g urea/kg stover and 25 g urea/kg stover were similar to it.

3.4.7 Acid detergent lignin (ADL) in cereal crop stovers increased due to treatments except when treating sorghum and millet stovers with 10 g urea + 10 g molasses/kg stover.

3.4.8 The *In vitro* DM digestibility was improved to the greatest extent by treatment with 10 g urea + 10 g molasses/kg stover. Millet stover exhibited the best response to this treatment in terms of improved *in vitro* DM digestibility.

Treatment with urea or urea and molasses effected similar changes in the physical and chemical composition of the three cereal crop stovers except with regard to NDF. Ameliorated cereal crop stovers were comparable to lucerne hay in terms of CP and ADF content. The improvement in the CP content of cereal crop stovers that were treated with urea or urea and molasses makes them possible substitutes for lucerne hay as sources of supplementary CP in ruminant diets. Ameliorated cereal crop stovers cost less per unit than lucerne hay hence they are viable potential replacements for lucerne hay.

4. The utilization by steers of treatment diets containing cereal crop stovers treated with urea or urea and molasses

4.1 Introduction

Ruminant production in the dry tropics is limited by the imbalanced diet on which the animals subsist. These diets are low in energy, nitrogen, minerals and digestibility; consequently, the productivity of animals fed on such diets is also low. In order to optimize productivity, these ruminants require supplementation with critically deficient nutrients to correct the dietary imbalance. The primary objective when providing supplements is to utilize the available roughage. According to Leng *et al*. (1999), one of the reasons for the poor utilization (low digestibility) of tropical forage by ruminants is its failure to provide rumen microbes with all their nutrient requirements. Several studies (Akhtar *et al*., 1994; Beaty *et al*., 1994; Muller *et al*., 1999) demonstrated that digestibility and intake can be improved by proper supplementation. Madibela *et al*. (2002) showed that strategic supplementation of the goat diets in Botswana improved performance and productivity. Huston *et al*. (1999) found that providing supplements as infrequently as once per week reduced losses in live body weight and body condition score compared with no supplements. These authors also noted that providing supplements once per week was as effective as offering them once daily.

The objective in this study was to evaluate the utilization by steers of a basal diet consisting primarily of veld grass hay when supplemented with cereal crop stovers that had been treated with urea or urea and molasses. The term “basal diet” as used in this chapter (and subsequent chapters) refers to the “veld grass hay plus Pen-feed” as described in section 2.3.

4.2 The intake and digestibility of dry matter (DM)

The intake and digestibility of the dry matter (DM) as influenced by the treatment diets are shown in Tables 4.1 to 4.3.

Providing SorghumT1 to steers had a similar ($P>0.05$) effect to SorghumT2, lucerne hay, CSM and the Control diet in supplying total DM. When providing SorghumT3, the total DMI was higher (P<0.05) than with all treatment diets except MilletT3, probably because these treatment diets were paired in the experimental design.

Providing SorghumT1 and SorghumT2 to the steers improved the apparent DMD compared to offering CSM (P<0.01) and the Control diet (P<0.05) but had a similar effect to giving them lucerne hay (P>0.05). The apparent DMD when supplying SorghumT3 to steers was higher (P<0.05) than with all treatment diets except MilletT3.

The total DMI by steers when providing lucerne hay and CSM was comparable (P>0.05) to that realized when providing the Control diet (Table 4.1). However, the apparent DMD when providing lucerne hay was higher (P<0.05) than with CSM and the Control diet. The effect of providing CSM to steers on the apparent DMD was similar to that of the Control diet (Table 4.1).

Table 4.1 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of DM by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	kg DM/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	5.26	0.43	5.69^{ecd}	2.00	0.645^{cd}
25 g urea/kg (SorghumT2)	5.33	0.46	5.79^{ecd}	2.05	0.648^{cd}
10 urea + 10 g molasses/kg (SorghumT3)	7.10	0.39	7.49^{a}	1.90	0.750^{a}
Lucerne hay	4.95	0.95	5.90^{bcd}	1.98	0.635^{ecd}
Cottonseed meal (CSM)	4.44	0.94	5.38^{ecd}	2.40	0.545^{fg}
Control diet (Control)	4.73	0.00	4.73^{e}	1.73	0.557^{efg}
Standard error (s.e.)	0.36	0.03	0.34	0.18	0.026

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The total DMI when feeding steers on MaizeT1 was similar to that observed when providing the treatment diets MaizeT2, lucerne hay, CSM and the Control diet but was lower (P<0.01) than with MaizeT3 (Table 4.2). Treatment diet MaizeT3 produced higher total DMI by the steers than the Control diet (P<0.001), but had a similar effect (P>0.05) to the treatment diets MaizeT2, lucerne hay and CSM (Table 4.1).

Table 4.2 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of DM by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	kg DM/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	4.38	0.40	4.78^{e}	2.12	0.552^{efg}
25 g urea/kg (MaizeT2)	5.55	0.41	5.96^{cd}	2.33	0.568^{efg}
10 urea + 10 g molasses/kg (MaizeT3)	5.91	0.46	6.37^{bc}	2.16	0.671^{bc}
Standard error (s.e.)	0.36	0.03	0.34	0.18	0.026

[1]Refers to the treated maize stover addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The effect of the treatment diet MaizeT1, on the apparent DMD by steers was similar (P>0.05) to that of MaizeT2, CSM and the Control diet but lower than that of treatment diets MaizeT3 (P<0.01) and lucerne hay (P<0.05). The coefficients of DMD, when providing MaizeT2 to steers were comparable to providing lucerne hay and CSM (Table 4.1) but lower (P<0.05) than with treatment diet MaizeT3 (Table 4.2). Providing MaizeT3 improved the apparent DMD by steers compared to offering them CSM (Table 4.1), the Control diet (P<0.01) and lucerne hay (P<0.05).

The treatment diet MilletT1 was similar (P>0.05) in its effect on total DMI by steers to treatment diet MilletT2, lucerne hay, CSM and the Control diet, but was lower than (P<0.01) MilletT3. The total DMI when providing MilletT2 to steers was more (P<0.01) than when giving them the Control diet but similar to offering them lucerne hay and CSM (Table 4.3). Providing treatment diet MilletT3 to steers resulted in higher DMI than feeding them on CSM

(P<0.01) and the Control diet (P<0.0001) (Table 4.1), but was similar in effect to the treatment diet MilletT2.

Table 4.3 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of DM by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	kg DM/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	4.60	0.47	5.07[ed]	2.40	0.521[g]
25 g urea/kg (MilletT2)	5.82	0.43	6.25[bc]	2.11	0.615[cdef]
10 urea + 10 g molasses/kg (MilletT3)	6.52	0.38	6.90[ba]	1.88	0.729[ab]
Standard error (s.e.)	0.36	0.03	0.34	0.18	0.026

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The apparent DMD when providing the treatment diet MilletT1 to steers (Table 4.3) was similar (P>0.05) to that obtained when feeding them on MilletT2, CSM and the Control diet but lower than with MilletT3 (P<0.0001) and lucerne hay (P<0.01). The coefficient of DMD when feeding treatment diet MilletT2 to steers was similar to that obtained when giving them lucerne hay and CSM, but was lower than with MilletT3 (P<0.01). The apparent DMD when providing MilletT3 to steers was higher than with lucerne hay (P<0.05), CSM and the Control diet (P<0.0001) (Table 4.1).

It is evident from Tables 4.1 to 4.3 that the cereal crop stovers treated with urea or urea and molasses had low DM content. Therefore, the DM provided by 1 kg cereal crop stover treated with urea or urea and molasses was almost half of what was provided by 1 kg lucerne hay or CSM as fed. This in turn affected the amount of nutrients available to the steers from the cereal crop stovers treated with urea or urea and molasses. The low DM intakes observed when steers were offered maize stover treated with T1 and T2 may be due to the fact that steers were not used to consuming stovers treated with urea or urea and molasses. The odour of ammonia from the treated stovers may have limited its palatability to the steers. Muller *et* *al*. (1999) found a decline in DMI when ammoniated wheat straw replaced lucerne hay in dairy cow diets. Providing CSM is thought to improve intake by increasing the fermentable energy supply and/or increased availability of amino acids and peptides that are known to promote the growth of some rumen microbes (Manyuchi *et al*., 1994). Leng (1999) estimated that 40 to 60% of CSM protein is protected from degradation by rumen microbes hence its enhanced ability to supply amino acids and peptides beyond the reticulo-rumen.

Since the veld grass hay used in the trials was a random mixture of several grass species, it is possible that the steers may have received veld grass hay of relatively poor quality during one trial and then received veld grass hay of relatively good quality during another trial. The high coefficients of DMD obtained when providing treatment diets SorghumT3, MaizeT3 and MilletT3 may be due to the low amounts of faecal DM associated with these treatment diets (Table 4.1). The faeces obtained from trials involving these treatment diets were watery (about 84% in moisture content) thus making total faecal collection difficult because the faeces of the steers were splashed all over the pens during defaecation. The coefficients of apparent DMD as obtained in this study with all the treatment diets (except MaizeT1, MilletT1, CSM and the Control diet) are much higher than the 503.90±15.04 g/kg DM obtained for the IVDMD of the veld grass hay (Table 2.5). According to Weisbjerg and Hvelplund (2005), high coefficients of digestibility are usually due to overestimation of true digestibility. The possible overestimation of DMD in some of the trials is likely to have influenced the digestibility of individual nutrients in the treatment diets.

The mixed response in the effect of the treatment diets on the DMI is consistent with findings from other studies. Manyuchi *et al.* (1994) reported that though not significant, supplementing a basal diet with urea or urea and molasses increased DMI. Like in the present study, these authors also found that the total DMI was increased to the greatest extent on urea-molasses diets. Leng (2004) noted that when animal feed is supplemented to ensure an efficient digestion of forage in the rumen, the digestibility and intake are usually improved. Schiere and De Wit (1995) reported that DMI is increased by approximately 25% due to urea treatment. These authors also observed that there is high variability in the effect of urea treatment on DMI, sometimes even between experimental periods within the same trial. Therefore, the large differences in DMI found in the present study are not unusual.

Ferrell *et al*. (1999) found that providing supplementary feed to sheep did not result in substantial changes in the apparent DM digestibility of the forage. The authors attributed the differences in the digestibility of the total diet by supplemented versus control sheep to the high digestibilities of the supplements. The apparent DMD may also be high because estimating DMD by *in vivo* methods ignores the loss of energy through methane gas (Rymer, 2000).

4.3 The intake and digestibility of organic matter (OM)

The LS means for the effect of the treatment diets on the organic matter intake (OMI) and their digestibility by the steers are provided in Tables 4.4 to 4.6. The influence of treatment diets on the OMI followed a trend similar to that of the DMI.

Table 4.4 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of OM by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	kg OM/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	4.63	0.37	5.00[cdef]	1.70	0.653[cd]
25 g urea/kg (SorghumT2)	4.81	0.39	5.20[bcde]	1.76	0.660[cd]
10 urea + 10 g molasses/kg (SorghumT3)	6.43	0.33	6.76[a]	1.59	0.765[a]
Lucerne hay	4.54	0.86	5.40[bcd]	1.75	0.677[bcd]
Cottonseed meal (CSM)	4.00	0.87	4.87[cdef]	1.91	0.571[e]
Control diet (Control)	4.34	0.00	4.34[ef]	1.66	0.603[de]
Standard error (s.e.)	0.33	0.024	0.34	0.10	0.024

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Feeding SorghumT1 and SorghumT2 to steers had a similar effect (P>0.05) on their total OMI to giving them the Control diet. These treatment diets (SorghumT1 and SorghumT2) were also comparable (P>0.05) to lucerne hay and CSM (Table 4.4) in their effect on the OMI by the steers. When the steers received SorghumT3, the total OMI was higher (P<0.05) than with all treatment diets except MilletT3.

When the steers were fed on SorghumT1, the apparent OMD was similar (P>0.05) to when they received SorghumT2, lucerne hay and the Control diet. However, the apparent OMD when the steers were provided with SorghumT1 was higher (P>0.05) than when they were fed on CSM and lower than when offered MilletT3 (P<0.001). The coefficient of OM digestibility when the steers received SorghumT2 was similar to when they were given lucerne hay, but better than when they were provided with CSM (P<0.05) (Table 4.4). The apparent OMD when providing SorghumT3 to the steers was higher than when supplying SorghumT2 and lucerne hay (P<0.01), CSM and the Control diet (P<0.0001).

The total OMI when the steers received lucerne hay was comparable to when they were given CSM but was higher (P<0.05) than when they were fed on the Control diet (Table 4.4). Providing lucerne hay to the steers improved coefficients of OMD compared to offering them CSM (P<0.01) and the Control diet (P<0.05). The coefficient of OMD when steers received CSM was similar (P>0.05) to when they were provided with the Control diet.

Table 4.5 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of OM by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	kg OM/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	3.81	0.35	4.16^{f}	1.97	0.573^{e}
25 g urea/kg (MaizeT2)	4.88	0.34	5.22^{bcde}	1.98	0.606^{de}
10 urea + 10 g molasses/kg (MaizeT3)	5.41	0.39	5.80^{bc}	1.81	0.688^{bc}
Standard error (s.e.)	0.33	0.02	0.34	0.10	0.024

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The total intake of OM when the steers were fed on MaizeT1 (Table 4.5) was lower than when they received MaizeT2 ($P<0.05$), MaizeT3 ($P<0.001$) and lucerne hay ($P<0.01$). However, providing the steers with MaizeT1 had a similar ($P>0.05$) effect on the total OMI to offering them CSM and the Control diet. When fed on MaizeT2, the steers consumed more total OM than when offered the Control diet ($P<0.05$). Providing MaizeT2 to the steers had a similar ($P>0.05$) effect on their total OMI to offering them MaizeT3, lucerne hay and CSM. Feeding the steers on MaizeT3 resulted in higher total OMI compared to providing them with CSM ($P<0.05$) and the Control diet ($P<0.001$) though, similar to giving them lucerne hay (Table 4.4).

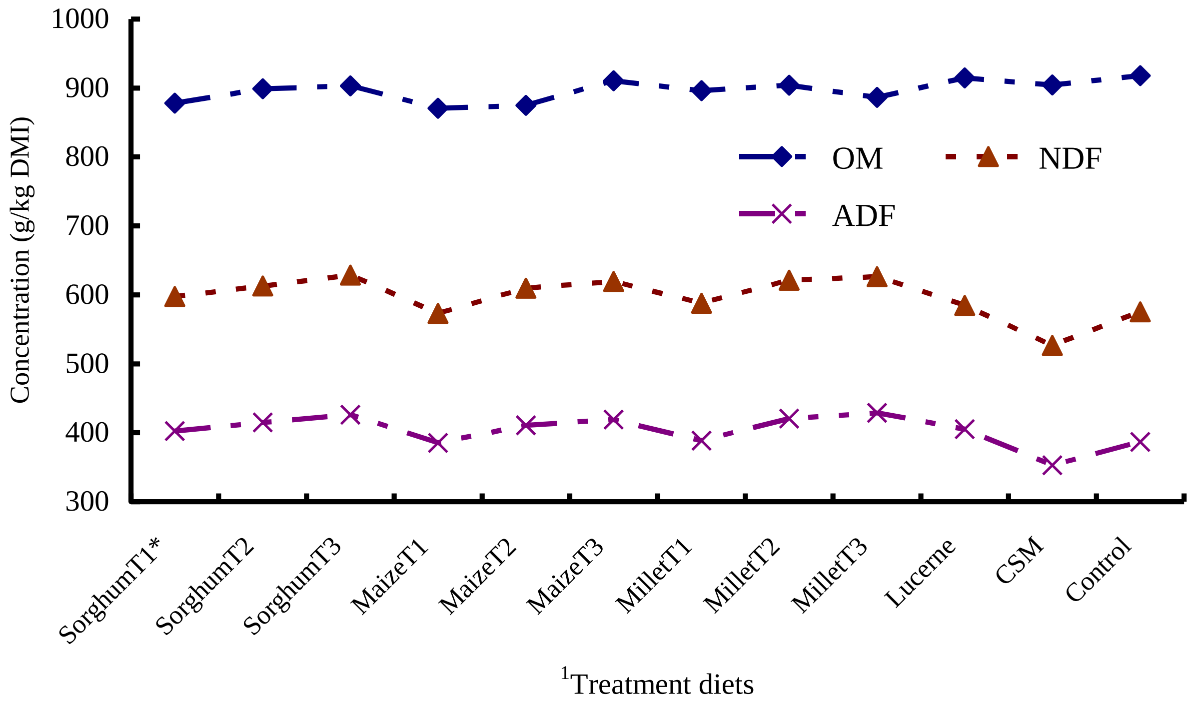
The apparent OMD when the steers were given MaizeT1 (Table 4.5) was similar ($P>0.05$) to that observed when they were fed on MaizeT2, CSM and the Control diet. When the steers were given MaizeT1, the apparent OMD was lower than when they received MaizeT3 ($P<0.01$) and lucerne hay ($P<0.05$). Providing the steers with MaizeT2 had a similar effect on the apparent OMD to giving them CSM, but resulted in lower coefficients of OMD than MaizeT3 and lucerne hay ($P<0.05$). Supplying MaizeT3 to the steers improved the coefficients of OMD compared to providing CSM ($P<0.001$) and the Control diet ($P<0.05$) (Table 4.4).

Table 4.6 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of OM by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	kg OM/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	4.14	0.40	4.54^{def}	2.00	0.556^{e}
25 g urea/kg (MilletT2)	5.28	0.37	5.65^{bc}	1.73	0.693^{bc}
10 urea + 10 g molasses/kg (MilletT3)	5.79	0.33	6.12^{ba}	1.58	0.741^{ab}
Standard error (s.e.)	0.33	0.02	0.34	0.10	0.024

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).



Where: DMI = dry matter intake, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre.

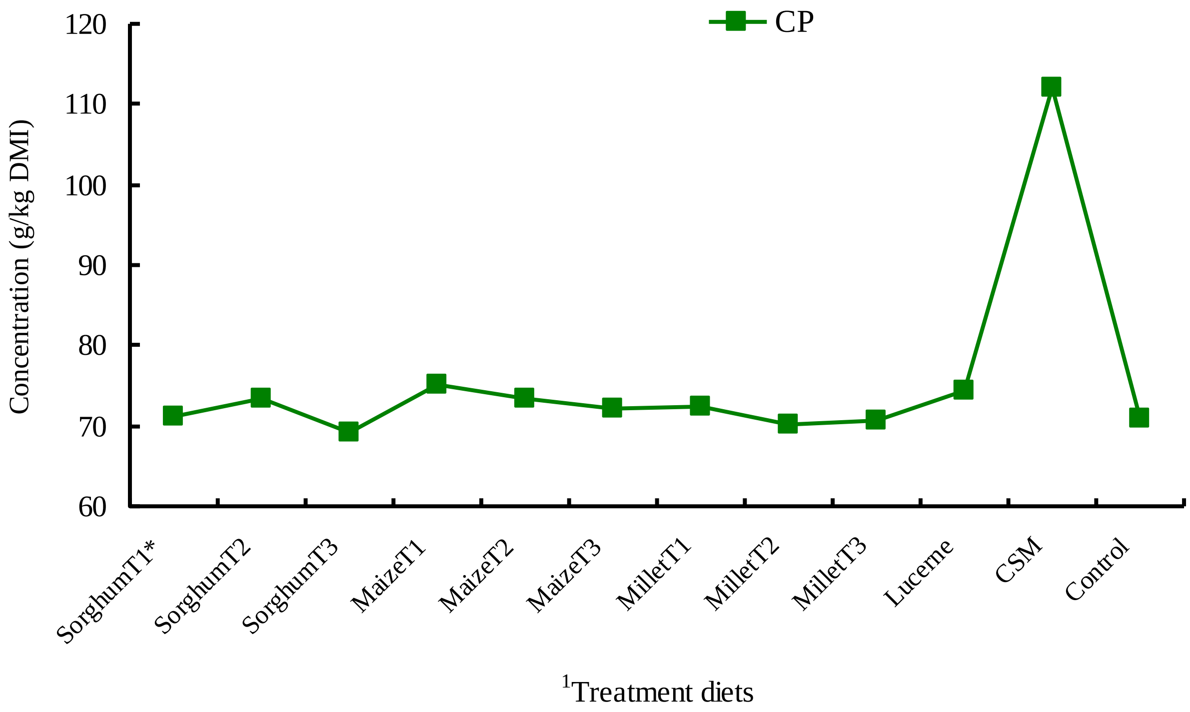
*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.1 The concentration of OM, NDF and ADF in the treatment diets given to the steers.

Feeding the steers on MiletT1 (Table 4.6) supplied them with less total OM than giving them MilletT2 (P<0.01), MilletT3 (P<0.001) and lucerne hay (P<0.05). When the steers were fed on MilletT2, their total OMI improved compared to when they consumed the Control diet (P<0.01). However, providing MilletT2 had a similar effect on the OMI by the steers to offering MilletT3, lucerne hay and CSM (Table 4.4). Feeding the steers on MilletT3 improved the total OMI compared to giving them CSM (P<0.01), although it was similar in its effect on total OMI (P>0.05) to providing lucerne hay.

Providing the steers with MilletT1 did not improve the coefficient of OMD (Table 4.6) compared to offering them MilletT2 (P<0.001), MilletT3 (P<0.0001) and lucerne hay (P<0.001). The apparent OMD by the steers was improved when they were fed on MilletT2 compared to when they received the Control diet (P<0.01) and CSM (P<0.001), but was similar (P>0.05) to when they were given MilletT3 and lucerne hay. Feeding MilletT3 to the steers improved the OMD coefficients compared to when they got CSM (P<0.0001) and the Control diet (P<0.001).



Where: DMI = dry matter intake and CP = crude protein

*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.2 The concentration of crude protein (CP) in the treatment diets given to the steers.

The variation in OMI was apparently a function of the DMI rather than the treatment diets. This appears to have been the case because the OMI was strongly correlated ($r^2 = 0.99$) with the DMI. It is clear from the data in Tables 4.4 to 4.7 that the OM supplied by the cereal crop stovers treated with urea or urea and molasses was low since OM was dependant on DM. The OMD could have been roughly estimated as 0.897±0.0046 x DMI. This means that, the coefficients of OMD were higher than those of DMD. This is consistent with the findings of Manyuchi *et al.* (1994).

4.4 The intake and digestibility of crude protein (CP)

The data presented in Tables 4.7 to 4.9 shows the effect of the treatment diets on the intake and utilisation by the steers of crude protein (CP).

Table 4.7 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of CP by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	365.22	39.47	404.69[de]	138.94	0.655[cde]
25 g urea/kg (SorghumT2)	373.12	51.26	424.38[d]	143.08	0.662[bcd]
10 urea + 10 g molasses/kg (SorghumT3)	478.07	40.81	518.88[b]	137.04	0.735[ab]
Lucerne hay	321.33	117.23	438.56[cd]	142.59	0.666[bcd]
Cottonseed meal (CSM)	320.93	282.38	603.31[a]	193.98	0.679[abcd]
Control diet (Control)	335.00	0.00	335.00[f]	93.28	0.651[cd]
Standard error (s.e.)	18.73	1.90	19.10	2.39	0.025

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein
Means in a column with a common superscript do not differ significantly (P>0.05).

The total intake of CP by the steers (Table 4.7) when they were fed on the Control diet was less than when they were given SorghumT1 and SorghumT2 ($P<0.05$). However, the intake of CP when the steers were fed on SorghumT1 and SorghumT2 was less than when they were given SorghumT3 and CSM ($P<0.001$). Providing the steers with SorghumT1 and SorghumT2 had a similar effect on the total CP intake to giving them lucerne hay ($P>0.05$). The total CP intake by the steers was improved when providing SorghumT3 compared to offering them the Control diet ($P<0.0001$) and lucerne hay ($P<0.01$). Although feeding the steers on lucerne hay (Table 4.7) improved the total CP intake compared to giving them the Control diet (P<0.001), the effect of lucerne hay on the total CP intake was less than that of CSM (P<0.001).

Providing the steers with SorghumT1, SorghumT2 and SorghumT3 had a similar effect on the apparent CP digestibility (Table 4.7) to feeding them on lucerne hay and CSM. When the steers were fed on SorghumT3, the coefficient of CP digestibility was improved compared to when they were given SorghumT1, SorghumT2 and the Control diet. Lucerne hay and CSM had a similar (P>0.05) effect on the apparent CP digestibility by the steers and both were not different from the Control diet.

Table 4.8 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of CP by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	307.20	52.11	359.31^{ef}	150.25	0.588^{ef}
25 g urea/kg (MaizeT2)	380.40	56.48	436.88^{cd}	169.64	0.602^{de}
10 urea + 10 g molasses/kg (MaizeT3)	407.67	53.33	461.00^{cd}	152.80	0.665^{bcd}
Standard error (s.e.)	18.73	1.90	19.10	2.39	0.025

[1]Refers to the treated maize stover addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

Means in a column with a common superscript do not differ significantly (P>0.05).

Feeding the steers on MaizeT1 (Table 4.8) provided them with less total CP compared to giving them MaizeT2 (P<0.01) and lucerne hay (Table 4.7), MaizeT3 (P<0.001) and CSM (P<0.0001). Providing the steers with MaizeT2 and MaizeT3 did not improve their total CP intake compared to feeding them on CSM (P<0.0001). However, giving the steers MaizeT2 and MaizeT3 improved the total CP intake compared to offering them the Control diet (P<0.001) and both were comparable in total CP provision (P>0.05) to lucerne hay (Table 4.7). Providing the steers with MaizeT3 (Table 4.8) improved the apparent CP digestibility compared to giving them MaizeT1 and MaizeT2 (P<0.05). However, feeding the steers on

MaizeT3 had a similar effect on the apparent CP digestibility than feeding them on lucerne hay, CSM and the Control diet (Table 4.7).

Table 4.9 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of CP by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	325.31	41.38	366.69[ef]	172.29	0.525[f]
25 g urea/kg (MilletT2)	403.66	35.53	439.19[cd]	142.35	0.668[abcd]
10 urea + 10 g molasses/kg (MilletT3)	446.10	42.28	488.38[bc]	125.55	0.745[a]
Standard error (s.e.)	18.73	1.90	19.10	2.39	0.025

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

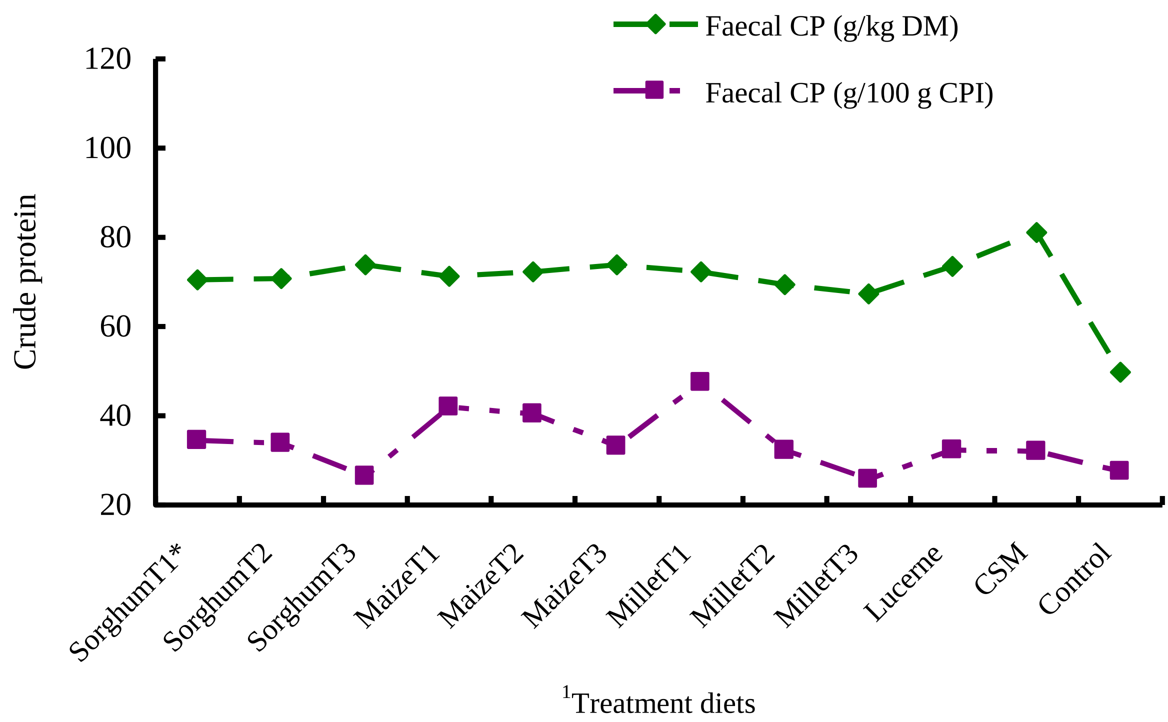
Means in a column with a common superscript do not differ significantly (P>0.05).

The steers consumed less total CP from MilletT1 (Table 4.9) than from MilletT2, lucerne hay (P<0.01), MilletT3 and CSM (P<0.0001). Giving the steers MilletT1 had a comparable effect on the total CP intake to offering them the Control diet (P>0.05). Providing the steers with MilletT2 had a similar effect on the total CP intake to giving them MilletT3. These treatment diets (MilletT2 and MilletT3) improved the total CP intake by the steers compared to the Control diet (P<0.001). When fed on MilletT2 and MilletT3, the total CP intake by the steers was less than when they were given CSM (P<0.0001) though, it was comparable to when they received lucerne hay (Table 4.7).

When providing the steers with MilletT1 (Table 4.9), the apparent CPD was less than that obtained when feeding them on MilletT2 and MilletT3 (P<0.0001), lucerne hay (Table 4.7) and the Control diet (P<0.001) and CSM (P<0.0001). Feeding the steers on MilletT2 had a similar (P>0.05) effect on the apparent CP digestibility to giving them the Control diet, lucerne hay and CSM (Table 4.7). The apparent CP digestibility when the steers were provided with MilletT3 was higher than that observed when feeding them on lucerne hay and the Control diet (P<0.05), but was not different (P>0.05) from that obtained with CSM.

The intake of CP by steers appears to have been influenced more by the CP content (Table 2.5) of the treatment diets than by the DMI because when the CP intake is expressed as a proportion of the DMI (Figure 4.2), most of the significant differences in CP intake due to treatment diets varnish. Providing CSM to steers had the most notable effect (P<0.0001) in increasing the intake of CP compared to offering them the Control diet. Among the cereal crop stovers treated with urea or urea and molasses, only feeding MaizeT1 to steers resulted in a DMI that was higher than the Control diet in CP concentration. Although their DM content was low, cereal crop stovers treated with urea or urea and molasses contributed 8 to 15% of the total CP in the treatment diets. Although Rymer (2000) recommended 12% as the minimum CP/kg DM for animals in digestibility studies, the reality is that ruminants often survive on feeds with less than 7% CP when grazing tropical pastures on communal lands (Madsen *et al.,* 2003). Veld grass hay as used in the present study had 52.9 g CP/kg DM (Table 2.5) which is the amount of CP available for most ruminants that are not provided with supplementary feeds during the dry season in Botswana. The treatment diets in the present study were on average more than 20 g CP/kg DM higher in CP than what is normally available to livestock on pastures during the dry season.

The loss of CP in the faeces appears to have had the major influence on the coefficients of CP digestibility (Figure 4.3). When steers received treatment diets such as MilletT1, which were associated with low coefficients of CP digestibility (Table 4.7), the loss of CP via the faeces was higher than when they received treatment diets such as MilletT3, which were associated with high coefficients of CP digestibility. The loss of CP as a proportion of the CP intake was low when the steers received the Control diet. This probably explains the higher coefficients of CP digestibility obtained with the Control diet than with some of the treatment diets. This was probably due to the steers' ability to recycle nitrogen (MacDonald *et al*., 2002). The high coefficients of CP digestibility observed with treatment diets such as MilletT3 and SorghumT3 may also be due to the possible overestimation of DM digestibility during trials involving these treatment diets. Ferrell *et al.* (1999) stated that the high fibre and low CP concentrations of low quality forages are expected to result in a low apparent digestibility of nitrogen (N) because metabolic faecal N constitutes a high proportion of the N in the faeces. According to De Waal and Biel (1989), a considerable proportion of N from the reticulo-rumen is excreted in the urine if there is no suitable fermentable substrate for rumen microbes. Since the present study did not include the analysis of urine for N, it is possible that the high apparent digestibilities of CP are also a result of an underestimation of N loss. The CP content of steers' faeces is in agreement with Powell *et al*. (1998) who found the N content of cattle manure ranging from 1.2 to 1.7%, which suggests that contamination with urinary N was minimal in the present study.



Where: CP = crude protein, CPI = intake of crude protein

*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.3 The influence of treatment diets on the crude protein (CP) content of faeces from the steers.

4.5 The intake and digestibility of neutral detergent fibre (NDF)

The influence of the treatment diets on the utilization by steers of neutral detergent fibre (NDF) is shown in Tables 4.10 to 4.12. The intake and digestibility of NDF followed a trend similar to that of the DMI.

Table 4.10 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of NDF by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	kg NDF/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	3.12	0.28	3.40[cdef]	1.30	0.605[dc]
25 g urea/kg (SorghumT2)	3.25	0.30	3.55[cde]	1.32	0.626[bc]
10 urea + 10 g molasses/kg (SorghumT3)	4.49	0.22	4.71[a]	1.23	0.739[a]
Lucerne hay	2.95	0.50	3.45[cdef]	1.26	0.605[cd]
Cottonseed meal (CSM)	2.55	0.29	2.84[ef]	1.55	0.441[f]
Control diet (Control)	2.72	0.00	2.72[f]	1.26	0.504[def]
Standard error (s.e.)	0.24	0.001	0.23	0.07	0.034

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre
Means in a column with a common superscript do not differ significantly (P>0.05).

The treatment diets that contained ameliorated sorghum stover (SorghumT1, SorghumT2 and SorghumT3) improved the intake of NDF by the steers compared to the Control diet (P<0.05). Providing the steers with SorghumT1 had a comparable effect on the total intake of NDF to that obtained when they were fed on SorghumT2, lucerne hay and CSM (Table 4.10). The total NDF supplied when feeding the steers on SorghumT3 was more than that obtained with SorghumT1, SorghumT2 and lucerne hay (P<0.001), CSM and the Control diet (P<0.0001).

Feeding the steers on SorghumT1 (Table 4.10) improved NDF digestibility compared to providing them with CSM and the Control diet (P<0.01). Treatment diet SorghumT2 had a similar effect on the apparent NDF digestibility by steers to lucerne hay (P>0.05) but improved it compared to CSM and the Control diet (P<0.001). Feeding the steers on SorghumT3 improved the apparent NDF digestibility compared to giving them SorghumT1

(P<0.001), SorghumT2 (P<0.05), CSM and the Control diet (P<0.0001) and lucerne hay (P<0.01).

Offering lucerne hay to the steers increased their total intake of NDF compared to giving them the Control diet (P<0.05). Providing CSM to the steers had a similar effect on the total intake of NDF to that of the Control diet. However, when the steers were fed on lucerne hay, their total intake of NDF was similar (P>0.05) to that observed when they were given CSM (Table 4.10). The apparent NDF digestibility when the steers were given lucerne hay was improved compared to when they were fed on CSM (P<0.01) and the Control diet (P<0.05), while the effect of providing CSM on the NDF digestibility by the steers was similar (P>0.05) to that of the Control diet (Table 4.10).

Table 4.11 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of NDF by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	kg NDF/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	2.49	0.25	2.74^{f}	1.38	0.490^{ef}
25 g urea/kg (MaizeT2)	3.39	0.25	3.64^{bcd}	1.49	0.559^{cde}
10 urea + 10 g molasses/kg (MaizeT3)	3.67	0.28	3.95^{bc}	1.38	0.659^{abc}
Standard error (s.e.)	0.24	0.001	0.23	0.07	0.034

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Offering MaizeT1 (Table 4.11) to the steers resulted in a lower total intake of NDF than MaizeT2 (P<0.01), MaizeT3 (P<0.001) and lucerne hay (P<0.05) but had a similar effect to feeding them on CSM and the Control diet. Providing the steers with MaizeT2 had a similar effect on the total intake of NDF to MaizeT3 and lucerne hay (P>0.05). However, offering MaizeT2 supplied more total NDF to the steers than giving them CSM (P<0.05) and the Control diet (P<0.01). Feeding the steers on MaizeT3 supplied them with more total NDF than CSM (P<0.01) and the Control diet (P<0.001) but did not differ from lucerne hay (Table 4.10) in supplying total NDF.

Feeding the steers on MaizeT1 (Table 4.11) had a similar effect on the apparent NDF digestibility to giving them MaizeT2, CSM and the Control diet but this effect was lower than that obtained when offering them MaizeT3 (P<0.01) and lucerne hay (P<0.05). Providing MaizeT3 improved the apparent NDF digestibility by steers compared to feeding them on CSM (P<0.001) and the Control diet (P<0.01). This treatment diet, MaizeT3, was comparable in its effect on the apparent NDF digestibility by steers to feeding them on lucerne hay. The apparent NDF digestibility by steers when providing them with MaizeT2 was higher than that obtained with CSM (P<0.05) but akin to that observed when they were given lucerne hay and the Control diet (Table 4.10).

Table 4.12 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of NDF by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	kg NDF/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	2.66	0.32	2.98^{def}	1.55	0.472^{ef}
25 g urea/kg (MilletT2)	3.58	0.30	3.88^{bc}	1.29	0.662^{abc}
10 urea + 10 g molasses/kg (MilletT3)	4.12	0.20	4.32^{ba}	1.18	0.724^{ab}
Standard error (s.e.)	0.24	0.001	0.23	0.07	0.034

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Feeding MilletT1 to the steers (Table 4.12) supplied less total NDF than MilletT2 (P<0.01) and MilletT3 (P<0.001). Providing the steers with MilletT1 and MilletT2 had a similar effect to that of lucerne hay on the total intake of NDF. Offering the steers MilletT2 increased their total NDF intake compared to giving them CSM (P<0.01) and the Control diet (P<0.001) but its effect on the total NDF intake was like that of providing MilletT3 (Table 4.10). When the steers were provided with MilletT2 and MilletT3, the total intake of NDF was more than when they were given lucerne hay (P<0.01) and CSM (P<0.0001).

The apparent NDF digestibility when the steers were offered MilletT1 (Table 4.12) was much lower than when they were given MilletT2 (P<0.001), MilletT3 (P<0.0001) and lucerne hay (P<0.01). Feeding the steers on MilletT2 and MilletT3 improved the apparent NDF digestibility compared to giving them CSM (P<0.001) and the Control diet (P<0.01). Although offering the steers MilletT2 had a similar effect on the NDF digestibility to giving them MilletT3 and lucerne hay (Table 4.10), when providing MilletT3, the apparent NDF digestibility by the steers was higher than when they were fed on lucerne hay (P<0.05).

The variation in NDF intake was apparently a function of the DMI rather than the treatment diets since the intake of NDF was strongly correlated (r^2 = 0.969) to the DMI, such that the NDF intake could be approximated as 0.755 DMI – 0.907 with a probability of 0.0048. Due to the low amount of DM from the cereal crop stovers treated with urea or urea and molasses, the contribution of these stovers to the total NDF intake was only about 5 to 11% of the total NDF intake (Tables 4.10 to 4.12).

The NDF content of the basal diet (Table 2.5) was higher than the threshold limit (600 g/kg DM) for NDF in tropical grasses beyond which intake is limited (Meissner *et al*., 1991). However, the average concentration of NDF (Figure 4.1) in the steers' total diet ranged from 526.76 to 628.61 g/kg DMI. This was probably due to the dilution of NDF content by treatment diets such as CSM and MilletT3 that had low NDF content. The Pen-feed that formed part of the basal diet was also particularly low in NDF content (Table 2.5). The dilution of NDF probably explains why supplementary feeding often improves DMI. Allen (2000) showed a general decline in DMI as NDF concentrations in diets exceeded 25%. Meissner *et al*. (1991) noted that at high NDF concentrations in diets, rumen-fill limits DMI but when the NDF concentration is low, energy intake feedback inhibitors limit DMI. Muller *et al*. (1999) found a decline in DMI when ammoniated wheat straw replaced lucerne in dairy cow diets and attributed it to the bulkiness of the diet due to increasing NDF levels.

The high coefficients of NDF digestibility observed when steers were provided with treatment diets such as MilletT3 and SorghumT3 may be due to a possible overestimation of DMD due to incomplete collection of faeces. This notwithstanding, results from the present study are consistent with work by other researchers who found that NDF digestibility increased when providing urea supplements. In a study by Fahmy and Klopfenstein (1994), NDF digestibility increased from 52.98% with untreated stover to 62.90% with treated stover. Haddad *et al.* (1995) reported NDF digestibilities of 63.1%, 75.1% and 79.4% when heifers were fed on untreated wheat straw (control) and wheat straw treated with 2.5% and 5% sodium hydroxide (NaOH) respectively.

4.6 The intake and digestibility of acid detergent fibre (ADF)

The effect of the treatment diets on the utilization by steers of acid detergent fibre (ADF) is shown in Tables 4.13 to 4.15. The intake and digestibility of ADF followed a trend similar to that of the DM and NDF.

Table 4.13 The effect of providing sorghum stover treated with urea or urea and molasses on intake and apparent digestibility of ADF by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	kg ADF/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	2.10	0.19	2.29[cde]	0.95	0.565[cd]
25 g urea/kg (SorghumT2)	2.19	0.21	2.40[cd]	0.98	0.583[bcd]
10 urea + 10 g molasses/kg (SorghumT3)	3.04	0.15	3.19[a]	0.89	0.720[a]
Lucerne hay	1.97	0.42	2.39[cd]	1.03	0.544[cde]
Cottonseed meal (CSM)	1.71	0.19	1.90[e]	1.26	0.323[g]
Control diet (Control)	1.83	0.00	1.83[e]	1.01	0.422[efg]
Standard error (s.e.)	0.16	0.001	0.23	0.06	0.041

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre
Means in a column with a common superscript do not differ significantly (P>0.05).

Providing SorghumT1 and SorghumT2 to the steers increased (P<0.05) the total intake of ADF compared to feeding them the Control diet. These treatment diets (SorghumT1 and

SorghumT2) were comparable (P>0.05) to lucerne hay in providing ADF (Table 4.13) to the steers. The total intake of ADF when the steers were fed on CSM was comparable to that obtained with SorghumT1, but was less than that obtained with SorghumT2 (P<0.05). Offering the steers SorghumT3 supplied them with more ADF (P<0.05) than all the other treatment diets except MilletT3.

Feeding SorghumT1 to the steers had a similar effect on the apparent ADF digestibility to offering them SorghumT2 and lucerne hay, but improved the coefficient of ADF digestibility compared to giving them CSM (P<0.001) and the Control diet (P<0.05) (Table 4.13). The apparent ADF digestibility when the steers were fed on SorghumT2 was similar to that obtained when they were given lucerne hay but more than that realized with CSM (P<0.0001) and the Control diet (P<0.01). Giving the steers SorghumT3 improved the apparent ADF digestibility compared to all other treatment diets except MilletT3.

Feeding the steers on lucerne hay improved (P<0.05) the total ADF intake by the steers compared to offering them CSM and the Control diet. When the steers received CSM, the total intake of ADF was akin (P<0.05) to when they were offered the Control diet (Table 4.13). Providing lucerne hay to the steers improved the apparent ADF digestibility compared to giving them CSM (P<0.001) and the Control diet (P<0.05). Giving the steers CSM had a similar (P>0.05) effect on the apparent ADF digestibility to that obtained with the Control diet (Table 4.13).

The total intake of ADF when the steers were given MaizeT1 (Table 4.14) was lower than when they were fed on MaizeT2 (P<0.01), MaizeT3 (P<0.001) and lucerne hay (P<0.05) but comparable to when they received CSM and the Control diet. Feeding the steers on MaizeT2 had a similar (P>0.05) effect on their total intake of ADF to providing them with MaizeT3 and lucerne hay. Providing MaizeT2 and MaizeT3 to the steers supplied them with more total ADF (P<0.01) than CSM (Table 4.13) and the Control diet (P<0.05).

The apparent ADF digestibility when the steers were fed on MaizeT1 (Table 4.14) was comparable (P>0.05) to that obtained when providing them with MaizeT2, CSM and the Control diet. However, this ADF digestibility was lower than that realized when the steers were given lucerne hay (P<0.05) and MaizeT3 (P<0.01). Providing the steers with MaizeT2 improved their ADF digestibility compared to giving them CSM (P<0.05) but not to MaizeT3

(P>0.05). The coefficient of ADF digestibility when offering MaizeT3 to the steers was higher than that obtained from feeding them on CSM (P<0.001) and the Control diet (P<0.01). Feeding the steers on MaizeT2 and MaizeT3 had a similar (P>0.05) effect on the apparent ADF digestibility to that of lucerne hay (Table 4.13).

Table 4.14 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of ADF by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	kg ADF/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	1.68	0.16	1.84^{e}	1.10	0.397^{fg}
25 g urea/kg (MaizeT2)	2.28	0.17	2.45^{cd}	1.18	0.474^{def}
10 urea + 10 g molasses/kg (MaizeT3)	2.48	0.19	2.67^{bc}	1.07	0.599^{abcd}
Standard error (s.e.)	0.16	0.001	0.23	0.06	0.041

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 4.15 The effect of providing millet stover treated with urea or urea and molasses on intake and apparent digestibility of ADF by steers

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	kg ADF/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	1.75	0.22	1.97^{de}	1.24	0.371^{fg}
25 g urea/kg (MilletT2)	2.44	0.19	2.63^{bc}	1.00	0.617^{abc}
10 urea + 10 g molasses/kg (MilletT3)	2.84	0.12	2.96^{ab}	0.88	0.700^{ab}
Standard error (s.e.)	0.16	0.001	0.23	0.06	0.041

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

The effect of providing MilletT1 (Table 4.15) on the total intake of ADF by steers was lower than that of MilletT2 ($P<0.01$) and MilletT3 ($P<0.001$), but similar ($P>0.05$) to that of lucerne hay, CSM and the Control diet. A higher total intake of ADF was realised when the steers were fed on MilletT2 ($P<0.001$) and MilletT3 ($P<0.0001$) than when they were given the Control diet. Providing MilletT3 to the steers increased their total intake of ADF compared to giving them lucerne hay ($P<0.05$) and CSM ($P<0.0001$). The total intake of ADF when the steers were given MilletT2 was higher than when they received CSM ($P<0.01$), but similar ($P>0.05$) to when they were fed on MilletT3 and lucerne hay (Table 4.13).

The apparent ADF digestibility when the steers were offered MilletT1 (Table 4.15) was less than when they received MilletT2 ($P<0.001$), MilletT3 ($P<0.0001$) and lucerne hay ($P<0.01$) but similar to when they were given CSM and the Control diet ($P>0.05$). Providing MilletT2 to the steers improved their ADF digestibility compared to offering them CSM ($P<0.0001$) and the Control diet ($P<0.01$) but had a similar ($P>0.05$) effect to giving them MilletT3. The apparent ADF digestibility was improved by providing the steers with MilletT3 compared to giving them lucerne hay ($P<0.01$), CSM ($P<0.0001$) and the Control diet ($P<0.0001$) (Table 4.13).

The variation in the intake of ADF was apparently a function of the DMI rather than the treatment diets since the intake of ADF was strongly correlated ($r^2 = 0.970$) with the DMI. The intake of ADF was about 0.527 x DMI – 0.710 with a probability value of 0.0022. The intake of ADF was also strongly correlated to the intake of NDF ($r^2 = 0.997$). Cereal crop stovers treated with urea or urea and molasses made up about 4 to 12% of the total ADF in their respective treatment diets. The apparent digestibility of ADF was strongly correlated to that of NDF ($r^2 = 0.996$) and weakly correlated to that of DM ($r^2 = 0.401$).

The response observed in ADF digestibility by the steers from the present study is less than that from studies by Saijpaul and Makkar (1996). These authors reported that the digestibility of the ADF of maize stover fed to male buffalo calves increased from 66.0% (untreated maize stover) to 78.6% and 79.1% for alkaline hydrogen peroxide and urea-fermented alkaline hydrogen peroxide respectively. Haddad *et al.* (1995) also found that the ADF digestibility of wheat straw fed to heifers increased from 59.1% to 73.1% and 77.7% when the straw was treated with 2.5% and 5% NaOH respectively.

4.7 Metabolisable energy (ME)

The influence of the treatment diets on the utilization by steers of metabolisable energy (ME) is shown in Tables 4.16 to 4.18. The ME followed a trend similar to that of the OMI and digestibility.

Table 4.16 The effect of providing sorghum stover treated with urea or urea and molasses on the ME available to steers

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Sorghum stover treated with:			
10 g urea/kg (SorghumT1)	51.36^{cdef}	8.96^{cde}	0.82^{d}
25 g urea/kg (SorghumT2)	53.71^{cde}	9.25^{bcd}	0.86^{cd}
10 urea + 10 g molasses/kg (SorghumT3)	80.84^{a}	10.77^{a}	1.26^{a}
Lucerne hay	$57.60b^{cd}$	9.65^{bc}	1.04^{b}
Cottonseed meal (CSM)	$43.75d^{ef}$	8.05^{ef}	0.77^{de}
Control diet (Control)	41.05^{ef}	8.61^{efd}	0.76^{de}
Standard error (s.e.)	4.68	0.33	0.04

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake
Means in a column with a common superscript do not differ significantly (P>0.05).

Feeding SorghumT1 and SorghumT2 to the steers had a similar (P>0.05) effect on the total ME provided daily (Table 4.16) to providing them with lucerne hay, CSM and the Control diet. The total ME when the steers were fed on SorghumT3 was higher (P<0.0001) than with all other treatment diets. The treatment diet SorghumT1 (Table 4.16) had a similar (P>0.05) effect on the ME concentration to providing the steers with SorghumT2, lucerne hay, CSM and the Control diet. However, offering the steers SorghumT1 resulted in a lower ME concentration than giving them SorghumT3 (P<0.05). When the steers were fed on SorghumT2, their ration was similar (P>0.05) in ME concentration to when they were given lucerne hay, but higher (P<0.05) than when they got CSM. When offering SorghumT3 to the steers the ME/kg DMI was higher (P<0.05) than with all treatment diets except MaizeT3. The

ME/kg $W^{0.75}$ of the steers was improved when providing SorghumT3 compared to SorghumT2 ($P<0.001$), SorghumT1, CSM and the Control diet ($P<0.0001$).

Offering lucerne hay to the steers provided them with more ($P<0.05$) ME daily than when they were fed on CSM and the Control diet. Providing the steers with CSM had a similar ($P>0.05$) effect on the daily provision of ME and on the ME concentration to offering them the Control diet (Table 4.16). When the steers were fed on lucerne hay, the ME/kg DMI provided was more ($P<0.05$) than when they were given the Control diet.

Table 4.17 The effect of providing maize stover treated with urea or urea and molasses on the ME available to steers

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
		Megajoule (MJ)	
Maize stover treated with:			
10 g urea/kg (MaizeT1)	37.74^{f}	7.79^{f}	0.67^{ef}
25 g urea/kg (MaizeT2)	50.47^{cdef}	8.28^{def}	0.81^{d}
10 urea + 10 g molasses/kg (MaizeT3)	62.66^{bc}	9.76^{abc}	1.03^{b}
Standard error (s.e.)	4.68	0.33	0.04

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Offering MaizeT1 (Table 4.17) to the steers had a similar ($P>0.05$) effect in ME provision to feeding them on MaizeT2, CSM and the Control diet (Table 4.16). However, when the steers were fed on MaizeT1, the ME provided was lower than that observed when they were given lucerne hay ($P<0.01$) and MaizeT3 ($P<0.001$). Providing MaizeT3 to the steers improved the ME supply compared to giving them CSM ($P<0.01$) and the Control diet ($P<0.001$) but not MaizeT2 and lucerne hay. When steers were offered MaizeT3, the ME/kg $W^{0.75}$ improved compared to when they were fed on MaizeT1 ($P<0.0001$) and MaizeT2, CSM and the Control diet ($P<0.01$).

The ME/kg DMI when providing MaizeT1 and MaizeT2 (Table 4.17) to the steers was comparable to that obtained when they were given CSM and the Control diet, but less than that obtained when they were offered lucerne hay (P<0.01). The treatment diets MaizeT1 and MaizeT2 were comparable (P>0.05) in ME/kg DMI. Although providing MaizeT3 to the steers was better in ME/kg DMI than offering them MaizeT1 (P<0.0001), MaizeT2 (P<0.01), CSM (P<0.001) and the Control diet (P<0.05), it had a similar effect on the ME concentration to providing the steers with lucerne hay (Table 4.16).

Table 4.18 The effect of providing millet stover treated with urea or urea and molasses on the ME available to steers

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Millet stover treated with:			
10 g urea/kg (MilletT1)	39.80^{ef}	7.77^{f}	0.64^{f}
25 g urea/kg (MilletT2)	61.22^{bc}	9.77^{abc}	0.95^{bc}
10 urea + 10 g molasses/kg (MilletT3)	71.03^{ab}	10.23^{ab}	1.07^{b}
Standard error (s.e.)	4.68	0.33	0.04

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing MilletT1 to the steers (Table 4.18) had a similar (P>0.05) effect on the total ME to offering them CSM and the Control diet. However, feeding the steers on MilletT1 supplied them with less ME daily than when they were given MilletT2 (P<0.01), MilletT3 (P<0.0001) and lucerne hay (P<0.01). Offering the steers MilletT2 improved the daily supply of ME than CSM (P<0.05) and the Control diet (P<0.01) though, it had a similar (P>0.05) effect to MilletT3 and lucerne hay (Table 4.16). When the steers were fed on MilletT3 they received more ME daily than when they were given CSM (P<0.001) or lucerne hay (P<0.05).

The ME concentration when providing MilletT1 to the steers (Table 4.18) was less than when they were offered MilletT2, MilletT3 (P<0.0001) and lucerne hay (P<0.001) but was comparable (P>0.05) to that observed when they got CSM and the Control diet (Table 4.16). Feeding the steers on MilletT2 improved the ME/kg DMI compared to offering them CSM (P<0.001) and the Control diet (P<0.05) but was similar (P>0.05) in ME/kg DMI to providing MilletT3 and lucerne hay. Giving the steers MilletT3 improved the ME/kg DMI compared to offering them CSM ($P<0.001$) but was similar ($P>0.05$) to offering them lucerne hay. Offering the steers MilletT3 improved the ME/kg $W^{0.75}$ compared to providing them with MilletT1 ($P<0.0001$), MilletT2 ($P<0.001$), CSM and the Control diet ($P<0.05$).

Since ME was calculated based on the digestible OM, it was highly correlated to the OMI ($r^2 = 0.974$) and the coefficient of OM digestibility ($r^2 = 0.904$). Since the ME/kg DMI was calculated based on the total intake of ME which in turn was a function of the digestible OM, it was highly correlated to the OMI ($r^2 = 0.831$) and the coefficient of OM digestibility ($r^2 = 0.953$).

The ME requirements for maintenance and growth in cattle of about 200 kg body weight is 30 to 40 MJ (MacDonald *et al*., 2002), suggesting that the ME requirements for the steers in the present study were met. The concentration of ME in the diets used in this study falls within the range of ME concentration values found by Abate and Meyer (1997) for tropical forages. The ME content of forages as reported by these authors ranged from 5.4 to 11.1 MJ/kg DM and from 6.8 to 13.3 MJ/kg DM when determined by *in vitro* analysis and by calculations respectively. The value for ME/kg $W^{0.75}$ from the present study is comparable to that found by Pearson and Lawrence (1992) for working cattle of comparable body weight.

4.8 The changes in animal body weight

The data in Tables 4.19 to 4.21 shows the effect of the treatment diets on the body weights of the steers. The steers lost weight when they received the Control diet (Table 4.19), MaizeT2 (Table 4.20) and MilletT2 (Table 4.21).

Generally, neither the daily weight gain nor the metabolic live weight (kg $W^{0.75}$) of the steers differed significantly with treatment diets. The DMI/kg $W^{0.75}$ when providing SorghumT1 and SorghumT2 to the steers (Table 4.19) was similar to when they were offered CSM and the Control diet. However, when providing SorghumT1 and SorghumT2 to steers, the DMI/kg $W^{0.75}$ was lower than when they were fed on SorghumT3 ($P<0.01$) and lucerne hay ($P<0.05$). Feeding the steers on SorghumT3 improved the DMI/kg $W^{0.75}$ compared to giving them CSM ($P<0.05$) and the Control diet ($P<0.01$) but had a similar effect on the DMI/kg $W^{0.75}$ to offering them lucerne hay.

Table 4.19 The LS means for average daily gains, metabolic live weights (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of steers provided with sorghum stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Sorghum stover treated with:			
10 g urea/kg (SorghumT1)	369.05[a]	62.82[a]	0.092[de]
25 g urea/kg (SorghumT2)	273.81[a]	63.68[a]	0.093[cde]
10 urea + 10 g molasses/kg (SorghumT3)	23.81[a]	65.52[a]	0.117[a]
Lucerne hay	297.62[a]	54.52[a]	0.107[ab]
Cottonseed meal (CSM)	436.67[a]	56.32[a]	0.095[bcde]
Control diet (Control)	-178.57[a]	53.77[a]	0.088[de]
Standard error (s.e.)	59.95	1.43	0.004

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 4.20 The LS means for average daily gains, metabolic live weights (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of steers provided with maize stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Maize stover treated with:			
10 g urea/kg (MaizeT1)	396.67[a]	55.38[a]	0.086[de]
25 g urea/kg (MaizeT2)	-146.67[a]	61.37[a]	0.097[bcd]
10 urea + 10 g molasses/kg (MaizeT3)	119.05[a]	62.28[a]	0.106[abc]
Standard error (s.e.)	59.95	1.43	0.004

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing lucerne hay to the steers increased the DMI/kg $W^{0.75}$ (Table 4.19) compared to giving them the Control diet (P<0.05) but was similar in effect on DMI/kg $W^{0.75}$ to offering them CSM. However, providing CSM to the steers had a similar effect on their DMI/kg $W^{0.75}$ to offering them the Control diet.

Providing MilletT1 to the steers (Table 4.21) was comparable in effect on the DMI/kg $W^{0.75}$ to offering them MilletT2, CSM and the Control diet though its effect was lower than that observed when the steers were given MilletT3 ($P<0.05$) and lucerne hay ($P<0.01$). Giving the steers MilletT2 and MilletT3 made the DMI/kg $W^{0.75}$ comparable to providing them with lucerne hay, CSM and the Control diet. These treatment diets (MilletT2 and MilletT3) had a similar effect on the DMI/kg $W^{0.75}$ of the steers.

Table 4.21 The LS means for average daily gains, metabolic live weights (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of steers provided with millet stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Millet stover treated with:			
10 g urea/kg (MilletT1)	-8.10[a]	62.67[a]	0.082[e]
25 g urea/kg (MilletT2)	452.38[a]	65.38[a]	0.097[bcd]
10 urea + 10 g molasses/kg (MilletT3)	412.86[a]	66.61[a]	0.106[abc]
Standard error (s.e.)	59.95	1.43	0.004

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Due to the sequential manner in which the treatment diets were offered (Table 2.6), the steers were on average heavier when given treatment diets such as SorghumT3 and MilletT3 (Table 4.21) that were offered in the final trials than when they were provided treatment diets such as lucerne hay and the Control diet (Table 4.19), which were offered in the initial trials. Steers were on average growing at a rate of just over 200 g/day, which probably explains the differences in body weight between the initial and final trials. However, the differences in the metabolic body weights of the steers (kg $W^{0.75}$) were not significantly altered by the treatment diets (Tables 4.19, 4.20 and 4.21).

Table 4.22 Design of the feeding trials flipped and crossed over

Trial	Group 1	Group 2
	[1]Treatment diets	
1	Control diet (Control)	Lucerne hay (LH)
2	Maize stover [2]plus 10 g urea/kg stover (MaizeT1)	Cottonseed meal (CSM)
3	Millet stover plus 10 g urea/kg stover (MilletT1)	Maize stover plus 25 g urea/kg stover (MaizeT2)
4	Sorghum stover plus 25 g urea/kg stover (SorghumT2)	Sorghum stover plus 10 g urea/kg stover (SorghumT1)
5	Maize stover plus 10 g urea + 10 g molasses/kg stover (MaizeT3)	Millet stover plus 25 g urea/kg stover (MilletT2)
6	Millet stover plus 10 g urea + 10 g molasses/kg stover (MilletT3)	Sorghum stover plus 10 g urea + 10 g molasses/kg stover (SorghumT3)
7	Sorghum stover plus 10 g urea + 10 g molasses/kg stover (SorghumT3)	Millet stover plus 10 g urea + 10 g molasses/kg stover (MilletT3)
8	Millet stover plus 25 g urea/kg stover (MilletT2)	Maize stover plus 10 g urea + 10 g molasses/kg stover (MaizeT3)
9	Sorghum stover plus 10 g urea/kg stover (SorghumT1)	Sorghum stover plus 25 g urea/kg stover (SorghumT2)
10	Maize stover plus 25 g urea/kg stover (MaizeT2)	Millet stover plus 10 g urea/kg stover (MilletT1)
11	Cottonseed meal (CSM)	Maize stover plus 10 g urea/kg stover (MaizeT1)
12	Lucerne hay (LH)	Control diet (Control)

[1]Refers to the particular treated cereal crop stover, lucerne hay, CSM or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

[2]Plus means 'treated with' as explained in section 2.4

To avoid these differences in body weight due to growth between the initial and final trials, the sequence in which the treatment diets were provided could also have been flipped over during the switching (cross over). The design (Table 2.6) would then have looked such as presented in Table 4.22. This might have been a possible solution to the problem, but could not be substantiated from the literature consulted.

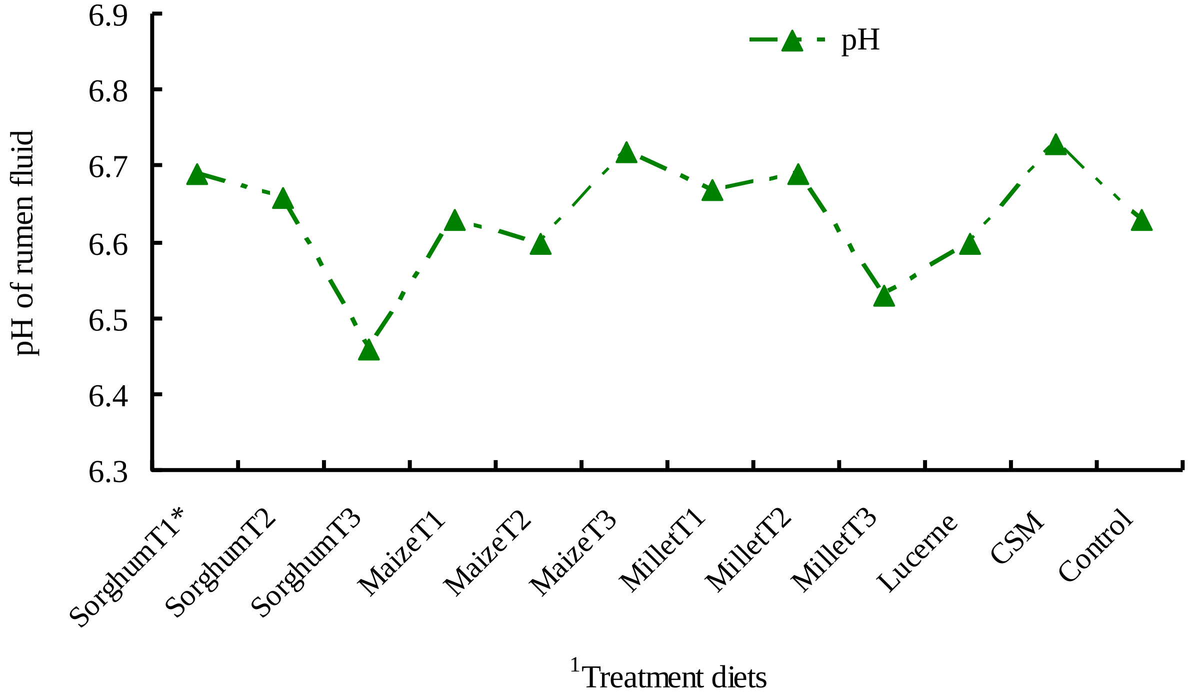
Steers gained weight except when providing the Control diet, MaizeT2 and MilletT1, in which they lost weight (Tables 4.19, 4.20 and 4.21). This was probably due to the low DMI and DMD (Tables 4.1, 4.2 and 4.3) observed when providing these treatment diets. The loss of weight observed when steers were fed on MilletT1 may also be attributed to the fact that 37% of the total CP intake from this treatment diet was lost in the faeces (Figure 4.3).

The absence of significant differences in ADG due to treatment diets may be explained by the low concentration of CP in the diets (Table 4.7). Madsen *et al*. (2003) concluded that although ruminants can survive on diets with less than 7% CP, the potential for weight gain is low unless their diet is supplemented with a feed high in CP. Due to the low performance of animals on roughage diets such as in the present study, Brand *et al*. (1991) suggested that such diets should be used for maintenance feeding and not for production. The low ADG observed when steers were provided with SorghumT3 may be confirmation that the DMD (Table 4.1) when steers were fed on the treatment diet SorghumT3 was overestimated.

4.9 The effect of treatment diets on the chemical properties of rumen fluid from the steers

The mean daily pH and ammonia (NH_3) concentration of the steers' rumen fluid when provided with different treatment diets are shown in Figure 4.4 and Figure 4.5 respectively.

The average daily pH of the steers' rumen fluid when provided with different treatment diets showed little variation (Figure 4.4). Since the basal diet was high in fibre (Table 2.5), it must have required a lot of regurgitation and re-chewing. The process of rumination buffers rumen pH due to the carbonate salts contained in the copious amounts of saliva produced when ruminants chew the cud during rumination (Fimbres *et al*., 2002).

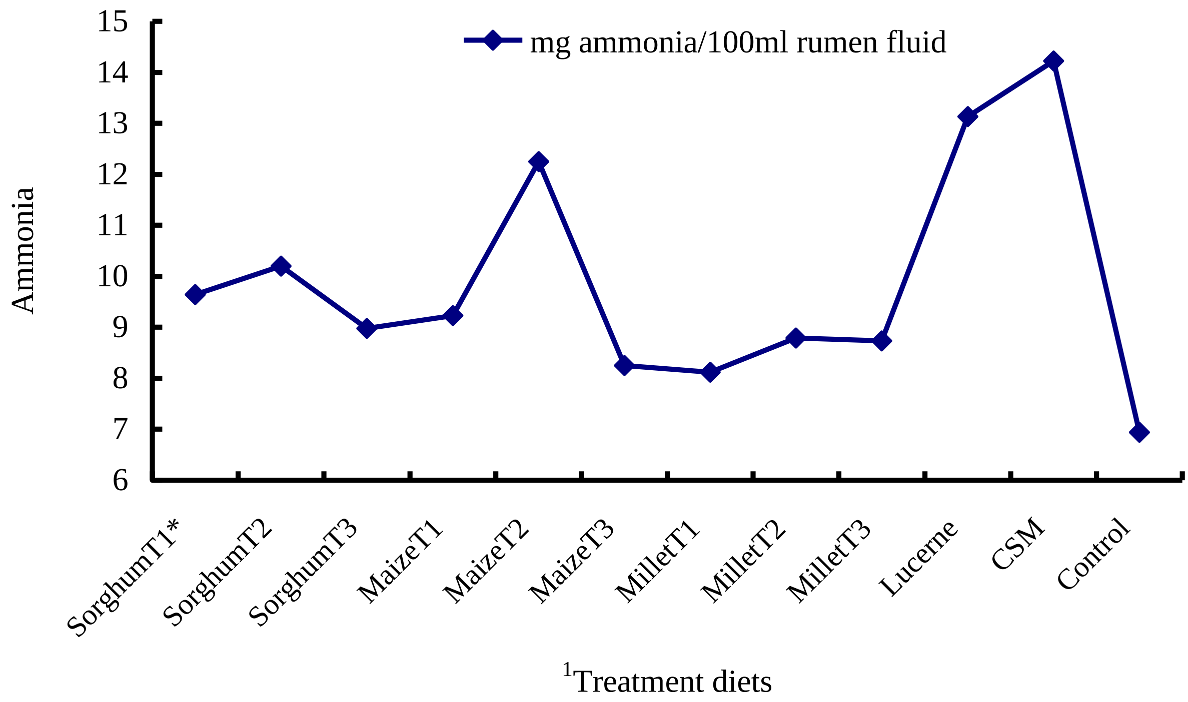


*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.4 The LS means for the daily variation in the pH of the steers' rumen fluid as influenced by the treatment diets.

There was variation in the NH_3 concentration of the steers' rumen fluid with different treatment diets (Figure 4.5). This variation appears to have been influenced by the CP intake (Tables 4.7, 4.8 and 4.9). Treatment diets such as CSM that provided a large quantity of CP were associated with higher concentrations of NH_3 in rumen fluid than treatment diets such as MaizeT1 that provided low amounts of CP. De Waal and Biel (1989) also attributed differences in prevailing ruminal NH_3 to differences in CP content and to a lesser extent the OMD of the forage ingested by animals.



*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

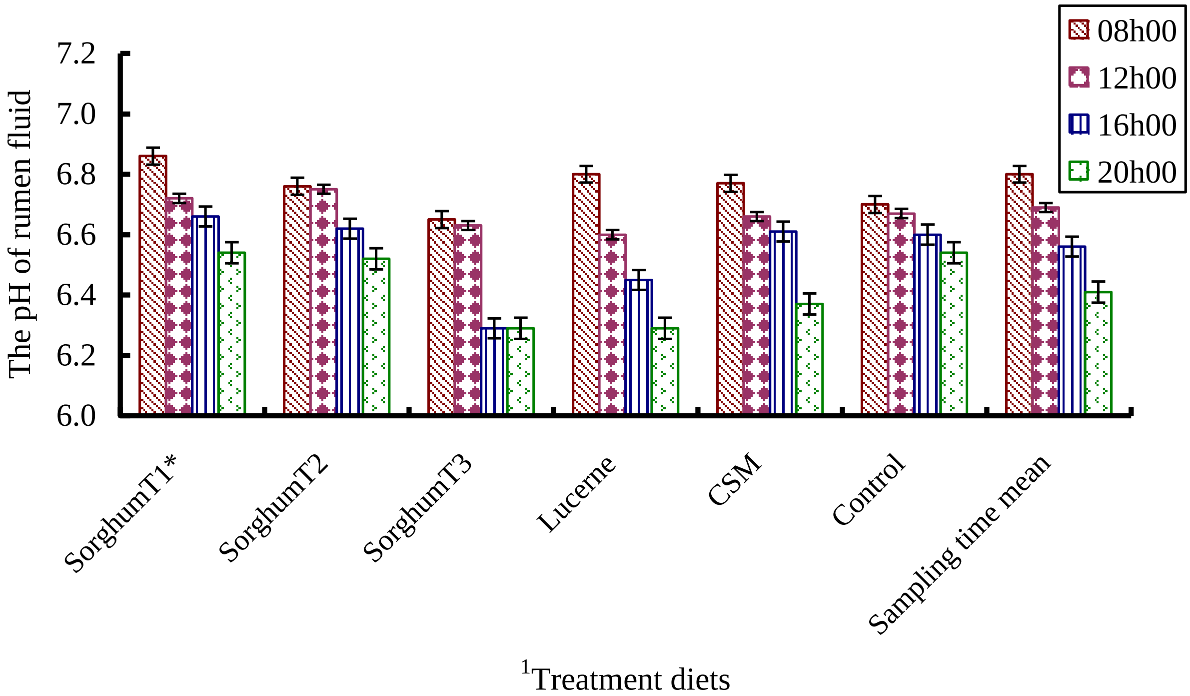
[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.5 The LS means for the daily concentration of ammonia in the steers' rumen fluid as influenced by the treatment diets.

4.9.1 The pH of rumen fluid

The diurnal effects of the treatments on the pH of the steers' rumen fluid are shown in Figures 4.6 to 4.8. The pH of the rumen fluid was highest at 08h00 and lowest at 20h00.

Offering SorghumT1 and SorghumT2 to the steers (Figure 4.6) had a similar effect on the pH of their rumen fluid to providing them with lucerne hay, CSM and the Control diet but increased their rumen fluid pH compared to SorghumT3 ($P<0.01$). These treatment diets (SorghumT1 and SorghumT2) had a similar effect on the rumen pH of steers.



*The suffixes T1, T2 and T3 appended to sorghum are the treatments used on the stover i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

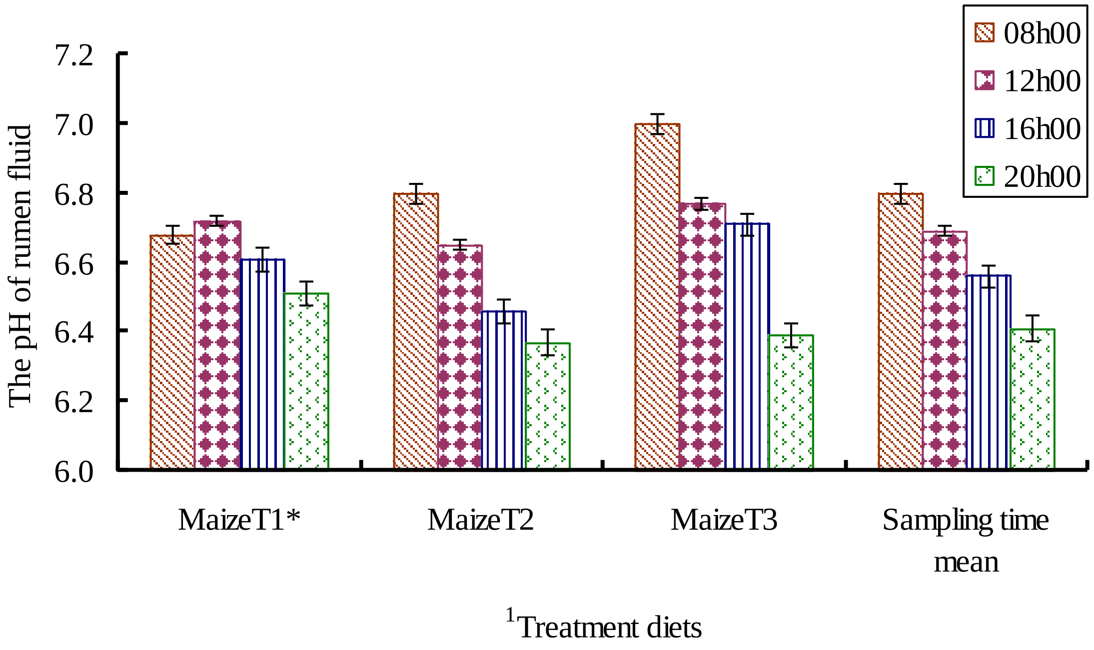
[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.6 The effect of providing the steers with sorghum stover treated with urea or urea and molasses and the time after intake on the pH of their rumen fluid.

Providing MaizeT1, MaizeT2 and MaizeT3 to the steers (Figure 4.7) had a similar effect on their rumen fluid pH. The effects of the three treatment diets on the steers' rumen fluid pH were similar to that of CSM and the Control diet. Offering MaizeT3 to the steers increased their rumen fluid pH ($P<0.05$) compared to giving them lucerne hay (Figure 4.6).

The treatment diets MilletT1, MilletT2 and MilletT3 (Figure 4.8) had a similar effect on the pH of rumen fluid from the steers. The effects of these three treatment diets on the steers' rumen fluid pH was similar to that of lucerne hay, CSM and the Control diet (Figure 4.6)

The time of sampling rumen fluid from the steers had a similar effect on its (rumen fluid) pH irrespective of the treatment diet. Rumen fluid sampled from the steers at 08h00 had a higher pH than that collected at 12h00 ($P<0.05$), 16h00 ($P<0.001$) and 20h00 ($P<0.0001$). The steers' rumen fluid sampled at 12h00 had a higher pH than that obtained at 16h00 ($P<0.01$) and at 20h00 ($P<0.0001$), whilst the pH of rumen fluid sampled at 16h00 was higher ($P<0.001$) than that collected at 20h00.

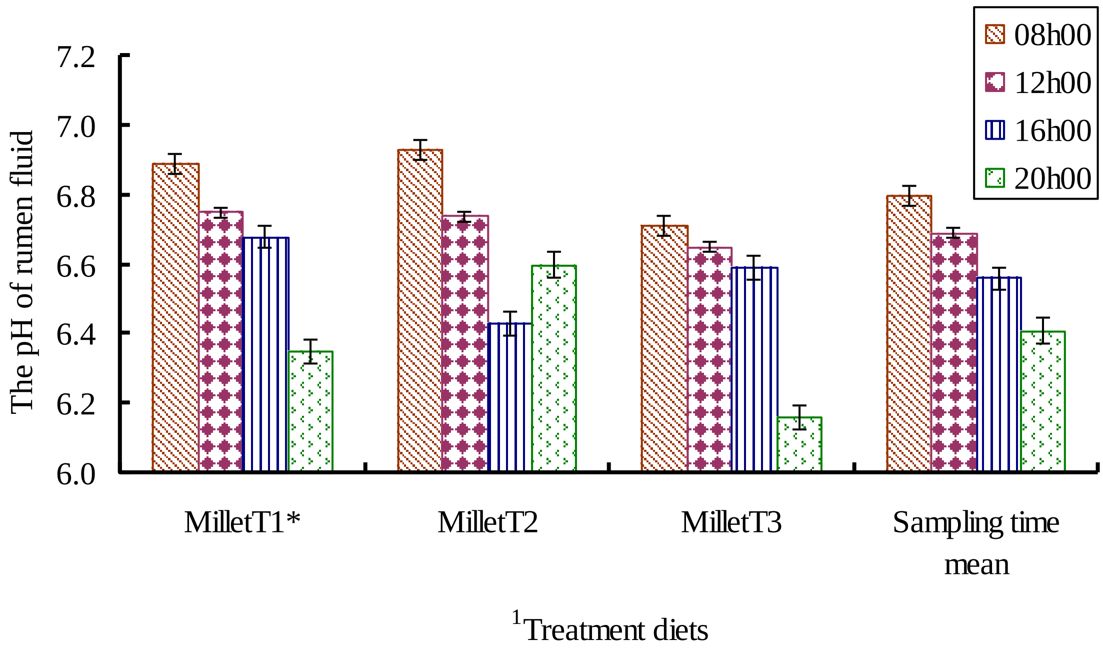


*The suffixes T1, T2 and T3 appended to maize are the treatments used on the stover i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively.

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.7 The effect of providing the steers with maize stover treated with urea or urea and molasses and time after intake on the pH of their rumen fluid.

According to De Waal and Biel (1989), rumen pH is primarily determined by the feeding schedule and not the time of day at which it is measured. Since the steers were provided with protein sources once a day, this may explain the declining trend observed in the pH of rumen fluid with different treatment diets. On average, the pH of rumen fluid as found in the present study agrees with the study by Manyuchi *et al*. (1994) although it is higher than that reported by Meissner and Du Preez (1996). The difference between the latter and results from the present study may be due to differences in the composition of the diets. Maximum fibre degradation occurs between pH 6.7 and 7.0 (Saijpaul & Makkar, 1997). Therefore, rumen pH in the present study would not have limited microbial activity. This probably explains the high digestibility of NDF when feeding treatment diets such as MaizeT3.



*The suffixes T1, T2 and T3 appended to millet are the treatments used on the stover i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively.

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 4.8 The effect of providing the steers with millet stover treated with urea or urea and molasses and time after intake on the pH of their rumen fluid.

4.9.2 The concentration of ammonia (NH_3) in the rumen fluid of steers

The diurnal effects of the treatments on the concentration of ammonia (NH_3) in the steers' rumen fluid are shown in Tables 4.23 to 4.25. The concentration of ammonia (NH_3) in rumen fluid was highest at 12h00 and lowest at 20h00.

Providing SorghumT1 to the steers (Table 4.23) increased the NH_3 concentration of their rumen fluid compared to feeding them on the Control diet ($P<0.05$) but had an effect similar to that of offering them SorghumT2 and SorghumT3. Feeding the steers on SorghumT2 improved the NH_3 concentration of their rumen fluid compared to giving them the Control diet ($P<0.01$) but had a similar effect to providing them with SorghumT3. The effect of offering SorghumT3 to the steers on the NH_3 concentration of their rumen fluid was similar to that of giving them the Control diet. The treatment diets SorghumT1, SorghumT2 and

SorghumT3 provided less NH_3 in the rumen compared to lucerne hay ($P<0.01$) and CSM ($P<0.0001$) when offered to the steers.

Table 4.23 The effect of providing the steers with sorghum stover treated with urea or urea and molasses and time after intake on the concentration (mg NH_3/100 ml rumen fluid) of ammonia in rumen fluid

[1]Treatment diets	Sampling time			
	08h00	12h00	16h00	20h00
	mg NH_3/100 ml rumen fluid			
Sorghum stover treated with:				
10 g urea/kg (SorghumT1)	11.50[ab]	13.98[bc]	9.58[bcde]	3.52[c]
25 g urea/kg (SorghumT2)	8.64[bc]	17.30[abc]	11.30[bc]	3.56[c]
10 urea + 10 g molasses/kg (SorghumT3)	7.27[bc]	18.79[abc]	6.36[de]	3.50[c]
Lucerne hay	14.39[a]	16.61[bc]	17.42[a]	4.12[bc]
Cottonseed meal (CSM)	10.43[abc]	24.37[a]	14.02[ab]	8.07[a]
Control diet (Control)	7.20[bc]	12.44[c]	5.20[e]	2.91[c]
Sampling time mean	9.91	17.25	10.65	4.28

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Means in a column with a common superscript do not differ significantly ($P>0.05$).

s.e. of the difference between two values in body of table = 1.58

s.e. of the difference between two sampling time means = 0.46

Summary of table: For each treatment diet in Table 4.23, the concentration of NH_3 in rumen fluid from the steers peaked at 12h00 and was lowest at 20h00 except when providing lucerne hay in which it peaked at 16h00.

Providing the steers with MaizeT1 had a similar effect on the NH_3 concentration of rumen fluid to giving them MaizeT2 and MaizeT3 (Table 4.24). Offering MaizeT1 to the steers improved the NH_3 concentration of rumen fluid compared to giving them the Control diet ($P<0.05$). However, this improvement was lower than that obtained when the steers were offered lucerne hay ($P<0.001$) and CSM ($P<0.0001$). Providing MaizeT2 to the steers increased the NH_3 concentration of rumen fluid compared to offering them MaizeT3 ($P<0.01$) and the Control diet ($P<0.001$) but had a similar effect to providing them with lucerne hay (Table 4.23). However, the NH_3 concentration of rumen fluid when the steers were fed on MaizeT2 was lower than that observed when they were given CSM ($P<0.05$). The NH_3 concentration of rumen fluid when providing MaizeT3 to the steers was lower than that realized when they were given lucerne hay and CSM ($P<0.0001$).

Table 4.24 The effect of providing the steers with maize stover treated with urea or urea and molasses and time after intake on the concentration (mg NH_3/100 ml rumen fluid) of ammonia in rumen fluid

[1]Treatment diets	Sampling time			
	08h00	12h00	16h00	20h00
	mg NH_3/100 ml rumen fluid			
Maize stover treated with:				
10 g urea/kg (MaizeT1)	5.81^{c}	18.18^{abc}	9.07^{cde}	3.83^{bc}
25 g urea/kg (MaizeT2)	8.42^{bc}	20.97^{ab}	10.39^{bcd}	6.20^{ab}
10 urea + 10 g molasses/kg (MaizeT3)	9.03^{bc}	15.24^{bc}	4.94^{e}	3.77^{bc}
Sampling time mean	7.75	18.13	8.13	4.60

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed)

Means in a column with a common superscript do not differ significantly ($P>0.05$).

s.e. of difference between two values in body of table = 1.58

s.e. of difference between two sampling time means = 0.46

Summary of table: For each treatment diet in Table 4.24, the concentration of NH_3 in rumen fluid from the steers peaked at 12h00 and was lowest at 20h00.

Providing MilletT1, MilletT2 and MilletT3 to the steers (Table 4.25) had a similar effect on the concentration of NH_3 in rumen fluid to each other and to offering them the Control diet. The concentration of NH_3 in rumen fluid when the steers were given MilletT1, MilletT2 and MilletT3 was lower ($P<0.0001$) than when they were offered lucerne hay and CSM (Table 4.23).

The time of sampling had a similar effect on the concentration of NH_3 in rumen fluid from the steers regardless of treatment diets. Rumen fluid sampled from steers at 12h00 had a higher ($P<0.0001$) concentration of NH_3 than that collected at 08h00, 16h00 and 20h00. Rumen fluid from the steers sampled at 08h00 and 16h00 did not differ in NH_3 concentration and both had more NH_3 than that obtained at 20h00 ($P<0.0001$). This was in agreement with De Waal and Biel (1989) who found the highest levels of NH_3 in rumen fluid at 12h00 though, in some cases peak concentrations were found at 16h00 as observed with lucerne hay (Table 4.23) in the present study. These authors explained that the elevated NH_3 levels in response to supplementary CP, was a result of the rapid hydrolysis of urea to NH_3 in the rumen. In the present study, a significant ($P = 0.0014$) variation in the concentration of NH_3 in the rumen fluid from steers could not be explained by differences in treatment diets or the sampling times.

Table 4.25 The effect of providing the steers with millet stover treated with urea or urea and molasses and time after intake on the concentration (mg NH_3/100 ml rumen fluid) of ammonia in rumen fluid

[1]Treatment diets	Sampling time			
	08h00	12h00	16h00	20h00
	mg NH_3/100 ml rumen fluid			
Millet stover treated with:				
10 g urea/kg (MilletT1)	7.63^{bc}	15.19^{bc}	6.68^{de}	2.99^{c}
25 g urea/kg (MilletT2)	6.78^{bc}	15.98^{bc}	6.16^{de}	3.72^{bc}
10 urea + 10 g molasses/kg (MilletT3)	7.95^{bc}	20.39^{ba}	5.04^{e}	1.54^{c}
Sampling time mean	7.39	16.43	6.99	3.77

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed)

Means in a column with a common superscript do not differ significantly ($P>0.05$).

s.e. of difference between two values in body of table = 1.58

s.e. of difference between two sampling time means = 0.46

Summary of table: For each treatment diet in Table 4.25, the concentration of NH_3 in rumen fluid from the steers peaked at 12h00 and was lowest at 20h00.

Although the sampling frequency used in the present study may not have been adequate to characterise ruminal NH_3 profiles, the results suggest that microbial growth was unlikely to have been inhibited by NH_3 availability in the rumen. De Waal and Biel (1989) suggested that 2-5 mg NH_3-N/100 ml rumen fluid is the optimum concentration for microbial protein synthesis. Saijpaul and Makkar (1997) found NH_3-N ranging from 8.7 to 11.9 mg/100ml rumen fluid sufficient to sustain microbial CP synthesis in buffalo calves fed on ameliorated wheat straw. According to Beever (1996), NH_3 absorption from the rumen depends on rumen pH since the un-ionised ammonia (NH_3) is absorbed more rapidly than the ammonium ion (NH_4^+). Since the pH of rumen fluid in the present study was optimum, the absorption of NH_3 must have been enhanced.

4.10 Conclusions

4.10.1 Providing the treatment diets SorghumT1, SorghumT2, SorghumT3, MaizeT3 and MilletT3 to steers improved their total intake of DM and OM compared to offering them the Control diet. The treatment diets SorghumT1, SorghumT2, MaizeT2 and MilletT2 had similar effects on the apparent DMD and OMD by steers to offering lucerne hay while SorghumT3, MaizeT3 and MilletT3 improved DMD and OMD compared to lucerne hay.

4.10.2 Including cereal crop stovers treated with T2 and T3 in the steers' diet improved their total CP intake compared to providing them with the Control diet and made it comparable to that observed when providing lucerne hay. The apparent digestibility of CP by steers fed on these treatment diets was also comparable to that found when they were given lucerne hay suggesting that these treatment diets may be suitable substitutes for lucerne hay in the diets of steers.

4.10.3 The influence of the treatment diets on the intake and digestibility by steers of NDF was similar to that on the DMI and DMD with the exception that providing MaizeT3 to the steers was not comparable to offering lucerne hay in its effect on DMD. The influence of the treatment diets on the intake and digestibility by steers of ADF followed a trend similar to that on the DM and NDF.

4.10.4 Since the calculation of ME was based on the digestible OM, it was highly correlated to the OMI and the coefficient of OM digestibility by the steers. The ME was adequate for the steers' maintenance requirements.

4.10.5 Generally, the daily weight gain and the metabolic live weight of the steers did not significantly differ with the treatment diets.

4.10.6 The pH of the steers' rumen fluid decreased with time from 08h00 to 20h00 while the concentration of ammonia in the rumen fluid peaked at 12h00 and then decreased in all treatment diets except lucerne hay in which it peaked at 16h00. The concentration of ammonia in the steers' rumen fluid appeared to be directly related to the CP content of the treatment diets. The pH and the concentration of ammonia in the rumen fluid when providing cereal crop stovers treated with urea or urea and molasses to the steers were found to be within the range required for enhanced fibre degradation in the rumen without inhibiting microbial activity. This was evident from the increase in the digestibility coefficients of DM and NDF. This means that, incorporating cereal crop stovers treated with urea or urea and molasses can be beneficial to ruminant animals in terms of supplying microbial protein and improved feed utilization.

5. The utilisation by goats and sheep of treatment diets containing cereal crop stovers treated with urea or urea and molasses

5.1 The intake and digestibility of dry matter (DM)

The intake and digestibility of dry matter (DM) by the goats and sheep as influenced by the treatment diets is shown in Table 5.1 to 5.6.

Table 5.1 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of dry matter (DM) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	g DM/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	665.11	64.65	729.76[bc]	332.21	0.556[e]
25 g urea/kg (SorghumT2)	701.21	69.60	770.81[abc]	279.96	0.648[dc]
10 urea + 10 g molasses/kg (SorghumT3)	884.46	57.90	942.36[a]	263.01	0.723[abc]
Lucerne hay	820.04	142.05	962.09[a]	211.03	0.780[a]
Cottonseed meal (CSM)	644.45	140.55	785.00[abc]	215.61	0.728[abc]
Control diet (Control)	865.39	0.00	865.39[ab]	241.80	0.725[abc]
Standard error (s.e.)	60.31	3.74	60.31	34.26	0.030

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

On average, goats consumed 153 g less DM compared to sheep. The treatment diets SorghumT1 and SorghumT2 had a similar (P>0.05) effect on the total DMI by goats (Table 5.1). Providing SorghumT3 to the goats resulted in a higher total DMI compared to SorghumT1 (P<0.01) and SorghumT2 (P<0.05). The three treatment diets did not improve (P>0.05) the DMI by goats compared to the Control diet. Feeding lucerne hay to the goats supplied them with more total DM than SorghumT1 (P<0.01), SorghumT2 and CSM

(P<0.05). However, providing the goats with lucerne hay had an effect similar to that of SorghumT3 on their DMI.

Feeding SorghumT2 to the goats improved their apparent DM digestibility (P<0.05) compared to SorghumT1. The coefficient of DMD was less by providing SorghumT1 to goats than when they were fed on lucerne hay (P<0.0001), SorghumT3, CSM and the Control diet (P<0.001).

Table 5.2 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of dry matter (DM) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	g DM/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	921.98	64.65	986.63[bcd]	344.88	0.647[a]
25 g urea/kg (SorghumT2)	763.25	69.60	832.85[d]	303.91	0.633[a]
10 urea + 10 g molasses/kg (SorghumT3)	954.95	57.90	1012.85[bc]	261.68	0.742[a]
Lucerne hay	1088.26	142.05	1230.31[a]	340.44	0.707[a]
Cottonseed meal (CSM)	831.78	140.55	972.33[bcd]	319.93	0.668[a]
Control diet (NS)	1007.92	0.00	1007.92[bc]	278.18	0.720[a]
Standard error (s.e.)	47.99	3.74	47.99	26.14	0.036

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The treatment diets SorghumT1 and SorghumT2 had a similar (P>0.05) effect on the total DMI by sheep (Table 5.2). Providing SorghumT3 to sheep resulted in a higher total DMI compared to SorghumT1 and SorghumT2 (P<0.05). The three treatment diets, did not improve (P>0.05) the DMI of sheep compared to the Control diet. Feeding sheep lucerne hay supplied more total DM than SorghumT1, SorghumT3, CSM and the Control diet (P<0.001) and SorghumT2 (P<0.0001). The coefficients of DM digestibility by sheep appeared to be unaffected by the treatment diets.

Table 5.3 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of dry matter (DM) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	g DM/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	660.35	60.45	720.80[bc]	221.40	0.700[abcd]
25 g urea/kg (MaizeT2)	656.94	61.20	718.14[bc]	209.11	0.682[bcd]
10 urea + 10 g molasses/kg (MaizeT3)	731.07	68.40	799.47[abc]	275.54	0.668[bcd]
Standard error (s.e.)	60.31	3.74	60.31	34.26	0.030

[1]Refers to the treated maize stover addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Maize stover treated with T1, T2 and T3 fed to goats had a similar (P>0.05) effect on their total DMI and coefficient of DM digestibility (Table 5.3). Providing lucerne hay to goats (Table 5.1) supplied them with more DM than MaizeT1, MaizeT2 (P<0.01) and MaizeT3 (P<0.05). The apparent DM digestibility by goats was improved by offering them lucerne hay (Table 5.1) compared to giving them MaizeT1 and MaizeT2 (P<0.05).

The treatment diets MaizeT1, MaizeT2 and MaizeT3 were similar (P>0.05) in their effect on the total DMI and coefficient of DM digestibility (Table 5.4) by sheep. Providing sheep with lucerne hay (Table 5.2) supplied them with more DM than giving them MaizeT1 (P<0.0001), MaizeT2 (P<0.001) and MaizeT3 (P<0.01).

Providing MilletT1 to goats had a similar effect on their total DMI and apparent DM digestibility to MilletT2. Feeding goats on MilletT3 (Table 5.5) and lucerne hay (Table 5.1) supplied them with more DM than MilletT1. However, the coefficient of DM digestibility by goats fed on MilletT3 was less than that obtained when they were given MilletT1 ($P<0.01$), MilletT2 ($P<0.001$) (Table 5.5) and lucerne hay (Table 5.1).

Table 5.4 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of dry matter (DM) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	g DM/day				
Maize stover treated with:					
FS10 g urea/kg (MaizeT1)	876.18	60.45	936.63[bcd]	297.16	0.677[a]
25 g urea/kg (MaizeT2)	919.68	61.20	980.88[bcd]	348.76	0.635[a]
10 urea + 10 g molasses/kg (MaizeT3)	976.21	68.40	1044.61[b]	333.41	0.670[a]
Standard error (s.e.)	47.99	3.74	47.99	26.14	0.036

[1]Refers to the treated maize stover addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Table 5.5 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of dry matter (DM) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	g DM/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	593.91	70.05	663.96[c]	188.89	0.728[abc]
25 g urea/kg (MilletT2)	745.16	65.25	810.41[abc]	207.87	0.748[ab]
10 urea + 10 g molasses/kg (MilletT3)	785.24	57.00	842.24[abc]	322.81	0.615[de]
Standard error (s.e.)	60.31	3.74	60.31	34.26	0.030

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

The treatment diets MilletT1, MilletT2 and MilletT3 had a similar effect on the total DMI and apparent DM digestibility by sheep (Table 5.6). These three treatment diets supplied less total DM to sheep compared to providing lucerne hay (Table 5.2). However, their effect on the coefficient of DM digestibility by sheep was similar to that of lucerne hay.

Table 5.6 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of dry matter (DM) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]DMI	Faeces	DM digestibility coefficient
	g DM/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	904.63	70.05	974.68[bcd]	321.69	0.663[a]
25 g urea/kg (MilletT2)	936.67	65.25	1001.92[bc]	266.36	0.727[a]
10 urea + 10 g molasses/kg (MilletT3)	812.81	57.00	869.81[cd]	224.21	0.743[a]
Standard error (s.e.)	47.99	3.74	47.99	26.14	0.036

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake.

Means in a column with a common superscript do not differ significantly (P>0.05).

The DMI of goats in the present study is comparable to the findings of Adogla-Bessa and Aganga (2000) for goats with *ad lib.* access to water and fed on 60% *Cenchrus ciliaris* and 40% *Medicago sativa* (762 g/day). Franz *et al*. (2004) found higher values of DMI (967 to 1022 g/day) for Alpine goats fed on maize bran. These authors also found that the particle size of the maize bran did not affect DMI. In a study by Manyuchi *et al*. (1994), the DMI of lambs fed on maize stover treated with urea was 394 g. The DMI increased to 485 g when cottonseed meal was added to the lambs' diet. Ferrell *et al*. (1999) found DM intakes ranging from 1 010 to 1 400 g/day for sheep consuming poor quality brome grass hay (*Bromus inermis*). The differences in DMI by ruminants may be due to factors such as forage quality, particle size, digestion and passage rates (Ferrell *et al.*, 1999; Fimbres *et al*., 2002).

The provision of cereal crop stovers treated with urea or urea plus molasses did not result in significant improvements in the apparent DM digestibility of the treatment diets compared to offering the Control diet to both goats and sheep. The study by Fimbres *et al*. (2002) reported a DM digestibility of 66.6% for a ration containing 30% forage. This is comparable to the DM digestibilities for diets in the present study, though the treatment diets from the present study had a much higher content of veld grass hay. On average, the coefficient of DM digestibility of treatment diets by goats and sheep was 0.692. This was higher than the mean DM digestibility coefficient (0.627) of the treatment diets by cattle. The mean apparent DM digestibility when steers, goats and sheep were offered the treatment diets was much higher than the IVDMD of veld grass hay (503.9±15.04 g/kg DM, Table 2.5). This probably suggests that the apparent DM digestibility of the veld grass hay was improved by providing cereal crop stovers treated with urea or urea and molasses, lucerne hay, CSM and Pen-feed.

5.2 The intake and digestibility of organic matter (OM)

As was the case with the steers (Chapter 4), the intake of organic matter (OM) by goats and sheep followed the same pattern as total DMI.

Table 5.7 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of organic matter (OM) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	g OM/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	599.08	55.28	654.36[bc]	283.19	0.575e
25 g urea/kg (SorghumT2)	631.78	58.26	690.04[abc]	245.63	0.655[cde]
10 urea + 10 g molasses/kg (SorghumT3)	797.81	49.45	847.26[a]	223.04	0.738[abc]
Lucerne hay	739.45	128.84	868.29[a]	184.96	0.787[a]
Cottonseed meal (CSM)	580.36	130.01	710.37[abc]	182.11	0.745[abc]
Control diet (Control)	780.53	0.00	780.53[ab]	210.20	0.735[abc]
Standard error (s.e.)	54.64	3.61	54.64	28.95	0.028

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The treatment diets SorghumT1 and SorghumT2 had a similar (P>0.05) effect on the total OM intake by goats (Table 5.7). Providing SorghumT3 to goats resulted in a higher total OM intake compared to SorghumT1 and SorghumT2 (P<0.05). The three treatment diets did not improve (P>0.05) the OM intake by goats compared to the Control diet. Feeding lucerne hay to the goats (Table 5.7) supplied them with more total OM than SorghumT1 (P<0.01), SorghumT2 and CSM (P<0.05). However, providing lucerne hay to the goats had an effect similar to that of SorghumT3 on their OM intake. The coefficient of OM digestibility when goats were offered SorghumT1 was less than when they received SorghumT3, lucerne hay, CSM (P<0.0001) and the Control diet (P<0.001). Feeding SorghumT2 to goats improved their apparent OM digestibility (P<0.05) compared to SorghumT1. Providing goats with SorghumT1 and SorghumT2 did not improve their OM digestibility compared to offering them the Control diet.

Table 5.8 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of organic matter (OM) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	g OM/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	844.06	55.28	899.34[d]	295.72	0.670[bc]
25 g urea/kg (SorghumT2)	702.12	58.26	760.38[bcd]	261.83	0.653[c]
10 urea + 10 g molasses/kg (SorghumT3)	929.70	49.45	979.15[b]	219.51	0.777[a]
Lucerne hay	1007.75	128.84	1136.59[a]	284.69	0.737[abc]
Cottonseed meal (CSM)	745.22	130.01	875.23[bcd]	263.54	0.698[abc]
Control diet (Control)	928.66	0.00	928.66[bc]	240.19	0.738[abc]
Standard error (s.e.)	44.36	3.61	44.36	19.31	0.030

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing sheep with SorghumT2 (Table 5.8) resulted in a lower total OM intake compared to SorghumT1 (P<0.05) and SorghumT3 (P<0.001). The three treatment diets did not improve (P>0.05) the OM intake by sheep compared to the Control diet. Feeding lucerne hay to sheep (Table 5.8) supplied them with more total OM than SorghumT1, SorghumT2, CSM and the Control diet (P<0.001) and SorghumT3 (P<0.05). When the sheep were fed on SorghumT3 their apparent OM digestibility was improved compared to when they were given SorghumT1 (P<0.05) and SorghumT2 (P<0.001). The coefficient of OM digestibility by sheep was not improved by providing SorghumT1 SorghumT2 or SorghumT3 compared to feeding them on the Control diet.

Feeding maize stover treated with T1, T2 and T3 to goats did not differ (P>0.05) in its effect on their total OM intake and coefficient of OM digestibility (Table 5.9). Providing goats with lucerne hay (Table 5.7) supplied them with more OM than with MaizeT1 and MaizeT2 (P<0.05). The apparent OM digestibility by goats was improved by providing them with lucerne hay compared to MaizeT1 and MaizeT2 (P<0.05).

Table 5.9 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of organic matter (OM) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	g OM/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	594.76	53.26	648.02^{bc}	187.18	0.717^{abcd}
25 g urea/kg (MaizeT2)	591.68	51.59	643.27^{bc}	177.98	0.697^{abcd}
10 urea + 10 g molasses/kg (MaizeT3)	658.84	58.41	717.25^{abc}	233.77	0.685^{bcd}
Standard error (s.e.)	54.64	3.61	54.64	28.95	0.028

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Offering MilletT1 to goats had a similar effect on their total OM intake and apparent OM digestibility to providing them with MilletT2. When goats were offered MilletT3 (Table 5.11) and lucerne hay (Table 5.7) they consumed more OM than when they were given MilletT1. However, the coefficient of OM digestibility when providing MilletT3 to goats was less than that obtained when feeding MilletT2 ($P<0.05$), (Table 5.11), lucerne hay ($P<0.001$) and CSM ($P<0.01$) (Table 5.7).

Table 5.10 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of organic matter (OM) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	g OM/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	788.28	53.26	841.54^{bcd}	246.82	0.707^{abc}
25 g urea/kg (MaizeT2)	846.20	51.59	897.79^{bcd}	279.28	0.678^{abc}
10 urea + 10 g molasses/kg (MaizeT3)	910.82	58.41	969.23^{b}	272.94	0.710^{abc}
Standard error (s.e.)	44.36	3.61	44.36	19.31	0.031

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Table 5.11 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of organic matter (OM) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	g OM/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	534.57	59.75	594.32^{c}	162.18	0.740^{abc}
25 g urea/kg (MilletT2)	671.60	55.27	726.87^{abc}	171.30	0.767^{ab}
10 urea + 10 g molasses/kg (MilletT3)	707.92	48.85	756.77^{abc}	272.89	0.638^{de}
Standard error (s.e.)	54.64	3.61	54.64	28.95	0.028

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Table 5.12 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of organic matter (OM) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]OMI	Faeces	OM digestibility coefficient
	g OM/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	820.00	59.75	879.75^{bcd}	265.81	0.690^{abc}
25 g urea/kg (MilletT2)	826.18	55.27	881.45^{bcd}	216.51	0.750^{abc}
10 urea + 10 g molasses/kg (MilletT3)	740.51	48.85	789.36^{cd}	188.99	0.757^{ab}
Standard error (s.e.)	44.36	3.61	44.36	19.31	0.031

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]OMI = organic matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing sheep with MilletT1 had a similar effect on their total OM intake and apparent OM digestibility (Table 5.12) than when fed on MilletT2 and MilletT3. Offering lucerne hay to sheep (Table 5.8) improved their OM intake compared to MilletT1, MilletT2 and MilletT3 (P<0.001). However, the apparent OM digestibility when providing MilletT1, MilletT2 and MilletT3 to sheep was comparable to that obtained when offering them lucerne hay, CSM and the Control diet (Table 5.8).

Since the OM intake depended on the DMI, goats consumed on average less OM (719.78 g/day) compared to sheep (903.20 g/day). However, on average goats and sheep did not differ in their ability to utilize OM. The mean coefficient of OM digestibility was 0.706 and 0.713 for goats and sheep respectively. The OM intake by the goats and sheep from the present study is in agreement with the findings of other workers. A study by Adogla-Bessa and Aganga (2000) found the OM intake of goats fed on *Cenchrus ciliaris* and lucerne hay to be 672 g/day, while de Bruyn *et al*. (1998) found an OM intake of 836 g/day for sheep fed on Bana grass[1]. In general, the treatment diets did not improve the apparent OM digestibility compared to the Control diet in both goats and sheep. This was unlike Meeske *et al*. (1993)

[1] Bana grass is a hybrid between *Pennisetum glaucum* (an annual babala) and *P. purpureum* (perennial Napier grass) (de Bruyn *et al*., 1998)

who found an improvement in the apparent OM digestibility when sheep were fed on wheat straw treated with sodium hydroxide (NaOH) and alkaline hydrogen peroxide (H_2O_2). However, the apparent OM digestibility of the diets in the present study is akin to the 66.8% recorded by Adogla-Bessa and Aganga (2000) for goats and 70.3% for sheep fed on a high fibre diet (Linington *et al*., 1997).

5.3 The intake and digestibility of crude protein (CP)

On average, goats consumed less CP (61.85 g/day) compared to sheep (78.68 g/day). However, the average coefficient of CP digestibility for goat was 0.71 while that for sheep was 0.72.

Table 5.13 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of crude protein (CP) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	48.31	5.92	54.23[d]	23.09	0.575[g]
25 g urea/kg (SorghumT2)	50.22	7.66	57.88[cd]	19.02	0.673[ef]
10 urea + 10 g molasses/kg (SorghumT3)	59.93	6.14	66.07[bc]	19.71	0.703[efd]
Lucerne hay	56.52	17.47	73.99[b]	16.49	0.778[bc]
Cottonseed meal (CSM)	47.22	42.31	89.53[a]	13.20	0.853[a]
Control diet (Control)	58.91	0.00	58.9[cd]	18.37	0.688[def]
Standard error (s.e.)	3.19	1.29	3.19	1.83	0.021

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein
Means in a column with a common superscript do not differ significantly (P>0.05).

Providing SorghumT1 to goats had similar effect on the total CP intake to feeding SorghumT2 (Table 5.13). However, feeding SorghumT1 to goats supplied them with less total CP compared to SorghumT3 ($P<0.05$). The apparent digestibility of CP by goats was improved when offering them SorghumT2 ($P<0.01$) and SorghumT3 ($P<0.0001$) compared to SorghumT1. Feeding goats on CSM improved their total CP intake ($P<0.01$) and apparent CP digestibility ($P<0.05$) compared to the other treatment diets.

Providing SorghumT1 to sheep had a similar effect on the total CP intake to feeding SorghumT2 (Table 5.14). However, feeding sheep on SorghumT2 supplied them with less total CP compared to SorghumT3 ($P<0.001$). These treatment diets had a similar effect on the apparent digestibility of CP by sheep and all three were comparable in their effect on the coefficient of CP digestibility to providing lucerne hay and the Control diet to sheep. Feeding sheep on CSM improved the total intake ($P<0.001$) and apparent digestibility ($P<0.05$) of CP compared to SorghumT1 and SorghumT2.

Table 5.14 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of crude protein (CP) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	69.60	5.92	75.52[bcd]	24.47	0.675[a]
25 g urea/kg (SorghumT2)	60.66	7.66	68.32[d]	21.51	0.683[a]
10 urea + 10 g molasses/kg (SorghumT3)	74.87	6.14	81.01[bc]	19.01	0.767[a]
Lucerne hay	73.56	17.47	91.03[a]	27.99	0.693[a]
Cottonseed meal (CSM)	53.85	42.31	96.16[a]	20.46	0.790[a]
Control diet (Control)	75.63	0.00	75.63[bcd]	20.14	0.733[a]
Standard error (s.e.)	2.57	1.29	2.57	2.71	0.037

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Providing maize stover treated with T1, T2 and T3 to goats had a similar effect on their total CP intake (Table 5.15). However, the apparent CP digestibility by goats fed on MaizeT3 was lower than when they received MaizeT1 ($P<0.001$), MaizeT2 ($P<0.05$) and CSM ($P<0.0001$) (Table 5.13).

Feeding MaizeT3 to sheep provided them with more CP than MaizeT1 ($P<0.05$) but had a similar effect on the total intake of CP to providing MaizeT2 (Table 5.16). However, the apparent CP digestibility when feeding sheep MaizeT2 and MaizeT3 was lower than when they received CSM ($P<0.05$) (Table 5.14).

Table 5.15 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of crude protein (CP) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	51.80	7.80	59.60^{cd}	14.88	0.753^{bcd}
25 g urea/kg (MaizeT2)	47.88	8.45	56.33^{cd}	14.32	0.738^{cde}
10 urea + 10 g molasses/kg (MaizeT3)	48.06	8.00	56.06^{cd}	20.21	0.647^{f}
Standard error (s.e.)	3.19	1.29	3.19	1.83	0.021

[1]Refers to the treated maize stover addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Providing MilletT1 and MilletT2 to goats improved their total CP intake ($P<0.05$) and coefficients of CP digestibility ($P<0.0001$) compared to MilletT3 (Table 5.17). Although offering MilletT1 and MilletT2 to goats supplied them with less total CP ($P<0.001$) compared to lucerne hay (Table 5.15) and CSM ($P<0.0001$), their effect on the apparent digestibility of CP by goats was comparable to that of lucerne hay and CSM.

Table 5.16 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of crude protein (CP) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	65.29	7.80	73.09[cd]	19.35	0.735[a]
25 g urea/kg (MaizeT2)	68.22	8.45	76.67[bcd]	24.10	0.678[a]
10 urea + 10 g molasses/kg (MaizeT3)	74.28	8.00	82.28[b]	24.33	0.677[a]
Standard error (s.e.)	2.57	1.29	2.57	2.71	0.037

[1]Refers to the treated maize stover addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.17 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of crude protein (CP) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	52.55	6.21	58.76[cd]	11.16	0.813[ab]
25 g urea/kg (MilletT2)	54.67	5.33	60.00[cd]	12.16	0.800[abc]
10 urea + 10 g molasses/kg (MilletT3)	44.54	6.33	50.87[d]	24.87	0.517[g]
Standard error (s.e.)	3.19	1.29	3.19	1.83	0.021

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing MilletT1, MilletT2 and MilletT3 to sheep had a similar effect on their total CP intake and apparent CP digestibility (Table 5.18). Although feeding MilletT1, MilletT2 and MilletT3 to sheep reduced their total CP intake compared to lucerne hay (P<0.001) and CSM

(P<0.0001), their effect on the apparent digestibility of CP was comparable to that of lucerne hay and CSM (Table 5.16).

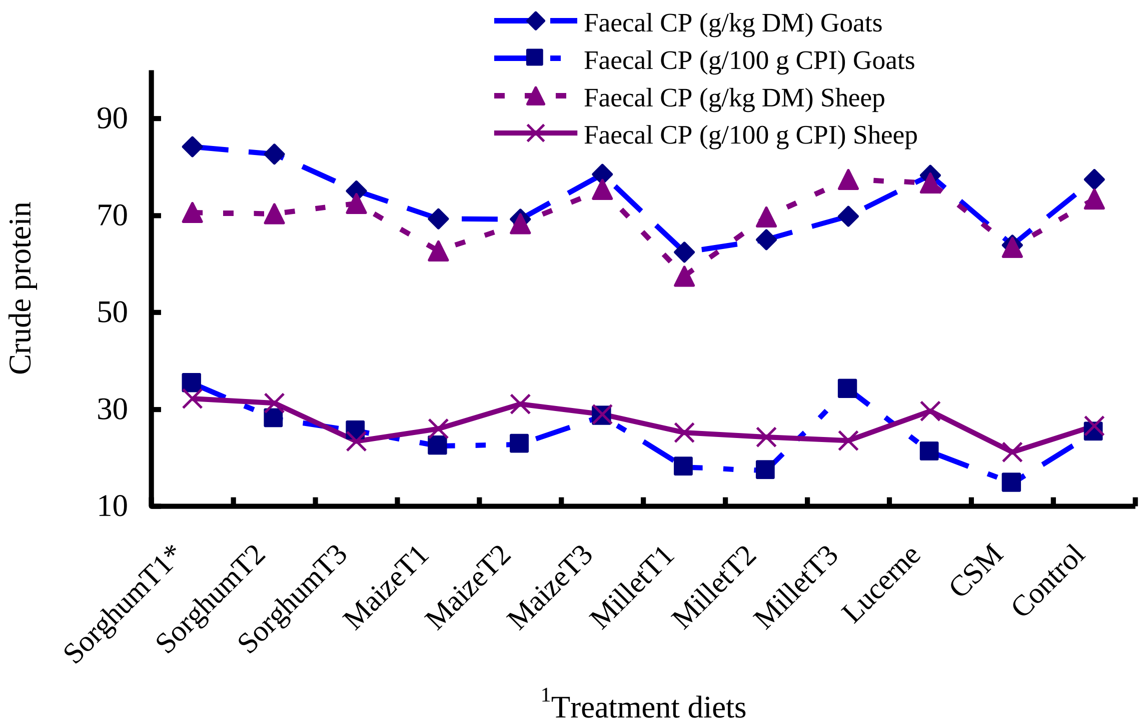
Table 5.18 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of crude protein (CP) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]CPI	Faeces	CP digestibility coefficient
	g CP/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	68.18	6.21	74.39[bcd]	19.04	0.745[a]
25 g urea/kg (MilletT2)	70.35	5.33	75.68[bcd]	18.54	0.755[a]
10 urea + 10 g molasses/kg (MilletT3)	68.15	6.33	74.48[bcd]	17.65	0.765[a]
Standard error (s.e.)	2.57	1.29	2.57	2.71	0.037

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]CPI = intake of crude protein

Means in a column with a common superscript do not differ significantly (P>0.05).

As observed in the data for steers, treatment diets such as MilletT3 that were associated with low coefficients of CP digestibility tended to have higher losses of CP in the faeces than treatment diets such as CSM which resulted in high coefficients of CP digestibility (Figure 5.1). The values of CP intake from the present study are in agreement with the findings of Merkel *et al*. (2001) on goats and Ferrell *et al*. (1999) on sheep. The intake of CP appears to have been influenced mainly by the CP content of the treatment diets. However, unlike Qinisa and Boomker (1998) who found that goats consumed more of the ration with the highest CP content, this was not the case in the present study. The DMI in the present study was not related to the CP intake. The results on the CP intake from this study appear to substantiate Ogwang and Karua (1996) and De Waal and Biel (1989) who reported that supplementary CP did not significantly affect herbage intake by goats and sheep respectively.



Where: DM = dry matter, CP = crude protein, CPI = crude protein intake

*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 5.1 The variation in faecal crude protein (CP) from goats and sheep as influenced by treatment diets.

Adogla-Bessa and Aganga (2000) reported a CP digestibility of 67.6% by goats whilst Ferrell *et al.* (1999) found a CP digestibility of 64.5% when sheep were fed on *Bromus inermis* hay supplemented with urea. This compares favourably with the coefficients of CP digestibility observed in the present study when providing lucerne hay to goats (0.778) and sheep (0.693). However, the apparent digestibility when providing the other treatment diets was higher while others were lower than these values.

Providing SorghumT3 to goats (Table 5.19) supplied them with more NDF than SorghumT1 and SorghumT2 (P<0.05). However, the digestibility of NDF when providing SorghumT3 to goats was similar to that when they were given SorghumT2, though it was higher than that observed when they were offered SorghumT1 (P<0.001). Feeding goats on SorghumT3 was comparable in its effect on total NDF intake and digestibility to lucerne hay, CSM and the Control diet.

5.4 The intake and digestibility of neutral detergent fibre (NDF)

On average, for all the treatment diets, goats consumed 469.12 g of NDF while sheep consumed 564.93 g. However, the average coefficient of NDF digestibility for all treatment diets by goats (0.678) was slightly higher than that by sheep (0.650).

Providing SorghumT2 to sheep (Table 5.20) supplied them with less NDF than SorghumT1 ($P<0.05$) and SorghumT3 ($P<0.001$). However, the digestibility of NDF when the sheep were given SorghumT3 was higher than when they were offered SorghumT1 ($P<0.01$) and SorghumT2 ($P<0.001$). Feeding SorghumT3 to sheep had a comparable effect on NDF digestibility to lucerne hay, CSM and the Control diet.

Table 5.19 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of neutral detergent fibre (NDF) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	g NDF/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	384.62	42.41	427.03[b]	180.71	0.567[c]
25 g urea/kg (SorghumT2)	408.73	44.89	453.62[ab]	153.26	0.657[b]
10 urea + 10 g molasses/kg (SorghumT3)	531.09	33.52	564.61[a]	168.31	0.703[ab]
Lucerne hay	488.08	75.57	563.65[a]	135.71	0.758[a]
Cottonseed meal (CSM)	370.82	43.29	414.11[b]	126.32	0.695[ab]
Control diet (Control)	518.36	0.00	518.36[ab]	151.60	0.708[ab]
Standard error (s.e.)	38.84	1.41	38.84	16.41	0.027

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre
Means in a column with a common superscript do not differ significantly ($P>0.05$).

The treatment diets MaizeT1, MaizeT2 and MaizeT3 (Table 5.21) did not differ in their effect on the total intake and apparent digestibility of NDF by goats. These treatment diets did not improve the digestibility of NDF by goats compared to the Control diet (Table 5.19). Although providing MaizeT3 to goats had a similar effect on total NDF intake to giving them lucerne hay, the influence of this treatment diet on the digestibility of NDF was lower ($P<0.01$).

Offering MaizeT3 to sheep (Table 5.22) increased their intake of NDF compared to MaizeT1 ($P<0.05$). The treatment diets MaizeT1, MaizeT2 and MaizeT3 had a similar effect on the apparent digestibility of NDF by sheep. These treatment diets did not improve the intake and digestibility of NDF by sheep compared to the Control diet and they supplied less NDF compared to lucerne hay (Table 5.20).

Table 5.20 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of neutral detergent fibre (NDF) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [1]NDFI	Faeces	NDF digestibility coefficient
	g NDF/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	516.65	42.41	559.06[bcd]	229.67	0.586[bc]
25 g urea/kg (SorghumT2)	410.91	44.89	455.80[d]	200.87	0.560[c]
10 urea + 10 g molasses/kg (SorghumT3)	579.11	33.52	612.63[bc]	165.52	0.730[a]
Lucerne hay	648.61	75.57	724.18[a]	229.38	0.675[abc]
Cottonseed meal (CSM)	466.76	43.29	510.05[cd]	195.68	0.617[abc]
Control diet (Control)	578.32	0.00	578.32[bc]	178.01	0.690[ab]
Standard error (s.e.)	32.21	1.41	32.21	25.06	0.039

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Table 5.21 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of neutral detergent fibre (NDF) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	g NDF/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	381.44	37.06	418.50[b]	130.78	0.687[ab]
25 g urea/kg (MaizeT2)	379.16	38.01	417.17[a]	126.61	0.652[b]
10 urea + 10 g molasses/kg (MaizeT3)	428.66	41.66	470.32[ab]	165.72	0.660[b]
Standard error (s.e.)	38.84	1.41	38.84	16.41	0.027

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.22 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of neutral detergent fibre (NDF) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	g NDF/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	479.82	37.06	516.88[cd]	188.80	0.638[abc]
25 g urea/kg (MaizeT2)	516.36	38.01	554.37[bcd]	225.65	0.583[bc]
10 urea + 10 g molasses/kg (MaizeT3)	583.93	41.66	625.59[b]	225.08	0.645[abc]
Standard error (s.e.)	32.21	1.41	32.21	25.06	0.039

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.23 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of neutral detergent fibre (NDF) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	g NDF/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	356.18	47.98	404.16^{b}	115.28	0.727^{ab}
25 g urea/kg (MilletT2)	438.07	45.18	483.25^{ab}	116.98	0.762^{a}
10 urea + 10 g molasses/kg (MilletT3)	464.84	29.79	494.63^{ab}	221.45	0.555^{c}
Standard error (s.e.)	38.84	1.41	38.84	16.41	0.027

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing MilletT3 to goats (Table 5.23) resulted in a lower apparent digestibility of NDF compared to MilletT1 and MilletT2 (P<0.0001). However, these treatment diets did not differ in their effect on the total intake of NDF by goats. Although feeding goats on MilletT1 supplied them with less total NDF compared to offering them the Control diet (P<0.05) and lucerne hay (P<0.01) (Table 5.19), it was comparable to these two treatment diets in its effect on the apparent digestibility of NDF.

Providing MilletT3 to sheep (Table 5.24) improved the apparent digestibility of NDF compared to MilletT1 (P<0.05). However, the treatment diets containing Millet stover had a similar effect on the total intake of NDF by sheep. Although feeding these treatment diets to sheep resulted in a lower intake of total NDF compared to lucerne hay (P<0.001), they were comparable in their effect on the apparent digestibility of NDF to lucerne hay (Table 5.20).

The intake and digestibility of NDF by goats and sheep, like that of the steers, appear to have been influenced by the intake and digestibility of DM. Goats of comparable body weight to those used in the present study were reported consuming 192 to 330 g NDF/day (Merkel *et* *al*. (2001). However, the digestibility of NDF by goats observed by these authors was much lower (23.5 to 37.0%) compared to that observed in the present study probably due to differences in diet. In a study by Meeske *et al*. (1992), the NDF digestibility by sheep fed on wheat straw increased from 58.7% with untreated straw to 76.1% and 81.0% when the straw was treated with NaOH and alkaline hydrogen peroxide respectively. Brand *et al*. (1991) also working with sheep found NDF digestibility of 55.6%, 55.2% and 66.1% for untreated, urea supplemented and urea treated stovers respectively.

Table 5.24 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of neutral detergent fibre (NDF) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]NDFI	Faeces	NDF digestibility coefficient
	g NDF/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	500.37	47.98	548.35[bcd]	207.32	0.622[abc]
25 g urea/kg (MilletT2)	518.46	45.18	563.64[bc]	162.83	0.710[ab]
10 urea + 10 g molasses/kg (MilletT3)	500.56	29.79	530.35[bcd]	139.40	0.742[a]
Standard error (s.e.)	32.21	1.41	32.21	25.06	0.039

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]NDFI = intake of neutral detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

5.5 The intake and digestibility of acid detergent fibre (ADF)

On average, for all the treatment diets, goats consumed 315.28 g ADF, while sheep consumed 378.54 g ADF. The average coefficient of ADF digestibility for all treatment diets by goats (0.629) was lower than that by sheep (0.618).

Offering SorghumT3 to goats (Table 5.25) provided them with more ADF than SorghumT1 (P<0.05). However, providing SorghumT3 to goats had a similar effect on the apparent digestibility of ADF to SorghumT1 and SorghumT2 (P>0.05). Feeding sorghum stovers treated with urea or urea plus molasses to goats was comparable in its effect on total ADF intake and digestibility to providing lucerne hay, CSM and the Control diet (Table 5.25).

Table 5.25 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility of acid detergent fibre (ADF) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	g ADF/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	258.18	28.25	286.43[bc]	129.15	0.532[b]
25 g urea/kg (SorghumT2)	274.74	31.04	305.78[abc]	107.82	0.630[ab]
10 urea + 10 g molasses/kg (SorghumT3)	358.81	22.99	381.80[a]	119.19	0.687[ab]
Lucerne hay	329.26	62.64	391.90[a]	95.93	0.748[a]
Cottonseed meal (CSM)	248.70	28.81	277.51[bc]	98.79	0.643[ab]
Control diet (Control)	350.06	0.00	350.06[ab]	108.03	0.692[ab]
Standard error (s.e.)	27.67	1.36	27.67	11.44	0.058

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre
Means in a column with a common superscript do not differ significantly (P>0.05).

Giving SorghumT2 (Table 5.26) to sheep supplied them with less total ADF compared to SorghumT1 (P<0.05) and SorghumT3 (P<0.001). The digestibility of ADF by sheep was improved when providing SorghumT3 compared to SorghumT1 (P<0.05) and SorghumT2 (P>0.01). Offering lucerne hay to sheep increased their total intake of ADF compared to SorghumT1 (P<0.001), SorghumT2 (P<0.0001) and SorghumT3 (P<0.05). However, the effect of SorghumT1 and SorghumT2 on the apparent digestibility of ADF by sheep was similar to that of lucerne hay and the Control diet (Table 5.26).

The treatment diets MaizeT1, MaizeT2 and MaizeT3 did not differ in their effect on the total intake and the apparent digestibility of ADF by goats (Table 5.27). These treatment diets did not improve the digestibility of ADF by goats compared to CSM and the Control diet (Table 5.25). Providing MaizeT3 to goats had a similar effect on the total intake of ADF to feeding lucerne hay (Table 5.25) though its effect on the digestibility of ADF was lower (P<0.01).

Table 5.26 The effect of providing sorghum stover treated with urea or urea and molasses on the intake and apparent digestibility acid detergent fibre (ADF) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	g ADF/day				
Sorghum stover treated with:					
10 g urea/kg (SorghumT1)	345.66	28.25	373.91[bcd]	160.24	0.565[ab]
25 g urea/kg (SorghumT2)	272.40	31.04	303.44[d]	143.69	0.523[b]
10 urea + 10 g molasses/kg (SorghumT3)	387.08	22.99	410.07[bc]	123.84	0.697[a]
Lucerne hay	430.45	62.64	493.09[a]	162.45	0.653[ab]
Cottonseed meal (CSM)	310.65	28.81	339.46[cd]	145.20	0.568[ab]
Control diet (Control)	387.20	0.00	387.20[bc]	133.67	0.652[ab]
Standard error (s.e.)	22.35	1.36	22.35	10.80	0.043

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.27 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of acid detergent fibre (ADF) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	g ADF/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	255.99	24.54	280.53[bc]	105.67	0.618[ab]
25 g urea/kg (MaizeT2)	254.43	25.28	279.71[bc]	94.46	0.582[ab]
10 urea + 10 g molasses/kg (MaizeT3)	288.44	28.8	317.24[abc]	122.88	0.595[ab]
Standard error (s.e.)	27.67	1.36	27.67	11.44	0.058

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

The treatment diets MaizeT1, MaizeT2 and MaizeT3 had a similar effect on the apparent digestibility of ADF by sheep (Table 5.28). Feeding MaizeT3 to sheep increased their total intake of ADF compared to MaizeT1. These treatment diets did not improve the intake and digestibility of ADF in sheep compared to the Control diet (Table 5.26). The intake of ADF when providing lucerne hay to sheep was lower than that observed when offering them MaizeT1 ($P<0.0001$), MaizeT2 ($P<0.001$) and MaizeT3 ($P<0.05$). However, MaizeT1, MaizeT2 and MaizeT3 had a similar effect on the apparent digestibility of ADF by sheep to that of lucerne hay.

Table 5.28 The effect of providing maize stover treated with urea or urea and molasses on the intake and apparent digestibility of acid detergent fibre (ADF) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	g ADF/day				
Maize stover treated with:					
10 g urea/kg (MaizeT1)	320.76	24.54	345.30^{cd}	135.71	0.597^{ab}
25 g urea/kg (MaizeT2)	344.11	25.28	369.39^{bcd}	140.91	0.600^{ab}
10 urea + 10 g molasses/kg (MaizeT3)	390.73	28.80	419.53^{b}	157.61	0.607^{ab}
Standard error (s.e.)	22.35	1.36	22.35	10.80	0.043

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Providing MilletT3 to goats (Table 5.29) resulted in a lower apparent digestibility of ADF compared to MilletT2 ($P<0.01$) but not to MilletT1. However, Millet stover treated with urea or urea and molasses did not differ in its effect on the total intake of ADF by goats. Although feeding goats on MilletT1 depressed their total intake of ADF compared to offering them the Control diet ($P<0.05$) and lucerne hay ($P<0.01$) (Table 5.25), it had a comparable effect on the apparent digestibility of ADF to these two treatment diets.

Table 5.29 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of acid detergent fibre (ADF) by goats

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	g ADF/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	225.51	32.29	257.80[c]	86.42	0.585[ab]
25 g urea/kg (MilletT2)	294.90	28.19	323.09[abc]	80.76	0.740[a]
10 urea + 10 g molasses/kg (MilletT3)	313.29	18.24	331.53[abc]	164.77	0.502[b]
Standard error (s.e.)	27.67	1.36	27.67	11.44	0.058

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.30 The effect of providing millet stover treated with urea or urea and molasses on the intake and apparent digestibility of acid detergent fibre (ADF) by sheep

[1]Treatment diets	Basal diet	Supplement	Total [2]ADFI	Faeces	ADF digestibility coefficient
	g ADF/day				
Millet stover treated with:					
10 g urea/kg (MilletT1)	334.02	32.29	366.31[bcd]	153.54	0.570[ab]
25 g urea/kg (MilletT2)	349.48	28.19	377.67[bc]	115.86	0.685[a]
10 urea + 10 g molasses/kg (MilletT3)	338.93	18.24	357.17[bcd]	106.81	0.698[a]
Standard error (s.e.)	22.35	1.36	22.35	10.80	0.043

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ADFI = intake of acid detergent fibre

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing MilletT1, MilletT2 and MilletT3 to sheep had a similar effect on their total intake and apparent digestibility of ADF (Table 5.30). These treatment diets did not improve the intake and the digestibility of ADF by sheep compared to CSM and the Control diet (Table

5.26). Offering lucerne hay to sheep (Table 5.26) improved their intake of ADF compared to MilletT1 and MilletT2 (P<0.001) and MilletT3 (P<0.0001).

Bhatta *et al*. (2002) reported a mean ADF digestibility coefficient of 0.233 for range goats in a Shrubland of Western India. This is much lower than what was found in the present study possibly due to differences in diet and goat breed. A lower intake of ADF (328.2 g/day) than in the present study was found by Lenington *et al.* (1997) on Merino wethers fed on a high fibre diet. However, the total tract ADF digestibility coefficient reported by these authors is less than what was found when sheep were provided with most of the treatment diets in the present study.

5.6 Metabolisable energy (ME)

For all the treatment diets, goats utilized on average 8.58 MJ ME/day in rations containing 10.60 MJ ME/kg DM, while on average sheep received 10.13 MJ ME/day from the treatment diets. On average, the ME concentration in sheep diets was 10.16 MJ/kg DM.

Providing SorghumT3 to goats supplied them with more ME (P<0.01) and at a higher concentration (P<0.05) than SorghumT1. The other treatment diets did not differ in ME content (Table 5.31). When goats were offered SorghumT3, the ME/kg metabolic weight ($W^{0.75}$) was improved compared to when they were fed on SorghumT1 (P<0.001), SorghumT2 (P<0.01), CSM and the Control diet (P<0.05).

Providing SorghumT3 to sheep supplied them with more ME (Table 5.32) compared to SorghumT1 and SorghumT2 (P<0.001). Offering SorghumT3 to sheep had a similar effect on ME supply to that provided by lucerne hay, CSM and the Control diet. The concentration of ME (ME/kg DMI) was higher when feeding sheep on SorghumT3 than when giving them SorghumT1, SorghumT2 and CSM (P<0.001). Feeding SorghumT2 to sheep supplied them with less ME/kg $W^{0.75}$ (Table 5.32) compared to SorghumT1 (P<0.05), SorghumT3 and lucerne hay (P<0.001). On average, feeding SorghumT1, SorghumT2 and SorghumT3 to sheep did not improve the ME available to them compared to giving them the Control diet.

Table 5.31 The effect of providing sorghum stover treated with urea or urea and molasses on the metabolisable energy (ME) available to goats

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Sorghum stover treated with:			
10 g urea/kg (SorghumT1)	7.19[b]	9.77[b]	0.65[c]
25 g urea/kg (SorghumT2)	8.28[ab]	10.60[ab]	0.74[bc]
10 urea + 10 g molasses/kg (SorghumT3)	10.57[a]	11.14[ab]	0.96[a]
Lucerne hay	9.60[ab]	9.91[b]	0.90[ab]
Cottonseed meal (CSM)	8.60[ab]	10.95[ab]	0.82[abc]
Control diet (Control)	8.74[ab]	9.98[b]	0.83[abc]
Standard error (s.e.)	0.90	0.45	0.05

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.32 The effect of providing sorghum stover treated with urea or urea and molasses on the metabolisable energy (ME) available to sheep

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Sorghum stover treated with:			
10 g urea/kg (SorghumT1)	9.40[bc]	9.49[b]	0.81[bcde]
25 g urea/kg (SorghumT2)	7.77[c]	9.31[b]	0.65[f]
10 urea + 10 g molasses/kg (SorghumT3)	11.84[ab]	11.67[a]	0.93[ab]
Lucerne hay	13.27[a]	10.60[ab]	0.99[a]
Cottonseed meal (CSM)	9.53[bc]	9.77[b]	0.71[def]
Control diet (Control)	10.73[ba]	10.61[ab]	0.80[bcde]
Standard error (s.e.)	0.90	0.45	0.05

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Treatment diets containing maize stover treated with T1, T2 or T3 (Table 5.33) had similar effects on the provision of ME and the concentration of ME in goat diets. Offering MaizeT3 to goats had a similar affect on the ME, the ME/kg DMI and the ME/kg $W^{0.75}$ compared to when they were fed on MaizeT1, MaizeT2 (Table 5.33), CSM and the Control diet (Table 5.31).

Table 5.33 The effect of providing maize stover treated with urea or urea and molasses on the metabolisable energy (ME) available to goats

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Maize stover treated with:			
10 g urea/kg (MaizeT1)	7.99[ab]	11.07[ab]	0.77[abc]
25 g urea/kg (MaizeT2)	7.99[ab]	10.71[ab]	0.72b[c]
10 urea + 10 g molasses/kg (MaizeT3)	8.47[ab]	10.42[b]	0.72b[c]
Standard error (s.e.)	0.90	0.45	0.05

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.34 The effect of providing maize stover treated with urea or urea and molasses on the metabolisable energy (ME) available to sheep

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Maize stover treated with:			
10 g urea/kg (MaizeT1)	9.26[bc]	9.80[b]	0.68[ef]
25 g urea/kg (MaizeT2)	9.64[bc]	9.67[b]	0.85[bcd]
10 urea + 10 g molasses/kg (MaizeT3)	10.85[ba]	10.26[ab]	0.89[ab]
Standard error (s.e.)	4.68	0.45	0.05

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The treatment diets MaizeT1, MaizeT2 and MaizeT3 had a similar effect in the provision of ME and the concentration of ME (Table 5.34) in sheep diets. However, when feeding MaizeT1 to sheep, the ME/kg $W^{0.75}$ (Table 5.34) was lower than when providing MaizeT2 ($P<0.05$), MaizeT3 ($P<0.01$) and lucerne hay ($P<0.0001$) (Table 5.32).

Table 5.35 The effect of providing millet stover treated with urea or urea and molasses on the metabolisable energy (ME) available to goats

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Millet stover treated with:			
10 g urea/kg (MilletT1)	7.64^{ab}	11.08^{ab}	0.68^{c}
25 g urea/kg (MilletT2)	9.73^{ab}	11.97^{a}	0.84^{abc}
10 urea + 10 g molasses/kg (MilletT3)	8.12^{ab}	9.62^{b}	0.75^{bc}
Standard error (s.e.)	0.90	0.45	0.05

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly ($P>0.05$).

Although providing MilletT1, MilletT2 and MilletT3 to goats did not differ in total ME supply (Table 5.35), the concentration of ME in the treatment diet MilletT3 was lower than that realized when feeding goats on MilletT1 ($P<0.05$) and MilletT2 ($P<0.001$). Offering the goats MilletT2 improved the ME/kg $W^{0.75}$ compared to when they were fed on MilletT1 ($P<0.05$) but had a similar effect to MilletT3, CSM and the Control diet.

Providing MilletT1, MilletT2 and MilletT3 to sheep had a similar effect on the total ME supply, the concentration of ME in the treatment diet and the ME/kg $W^{0.75}$ (Table 5.36). Providing lucerne hay to sheep (Table 5.32) improved the ME available to them compared to MilletT1 and MilletT3 ($P<0.01$) and MilletT2 ($P<0.05$). However, offering lucerne hay to sheep had a similar effect on the concentration of to MilletT1, MilletT2 and MilletT3 ME. When sheep were offered MilletT2, the ME/kg $W^{0.75}$ was improved ($P<0.05$) compared to when they were fed on CSM (Table 5.32). Offering lucerne hay to sheep improved the ME/kg $W^{0.75}$ compared to MilletT1 ($P<0.05$) and MilletT3 ($P<0.001$).

Table 5.36 The effect of providing millet stover treated with urea or urea and molasses on the metabolisable energy (ME) available to sheep

[1]Treatment diets	[2]ME/day	ME/kg DMI	ME/kg $W^{0.75}$
	Megajoule (MJ)		
Millet stover treated with:			
10 g urea/kg (MilletT1)	9.57[bc]	9.72[b]	0.83[bcd]
25 g urea/kg (MilletT2)	10.36[bc]	10.26[ab]	0.87[abc]
10 urea + 10 g molasses/kg (MilletT3)	9.35[bc]	10.73[ab]	0.73[cdef]
Standard error (s.e.)	0.90	0.45	0.05

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]ME = metabolisable energy, DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Muhikambele *et al.* (1996) reported daily energy intakes of 10.99 and 12.59 MJ ME for male and castrate Saanen goats respectively. Hatendi *et al*. (1996) found ME intakes of 0.482 to 0.519 MJ ME/kg$^{0.75}$ per day for castrate Zimbabwean (Matabele) goats offered diets differing in roughage content. Weaned lambs in Tanzania consumed 4.6 to 7.9 MJ ME/day (Mtenga & Madsen, 1996). This compares well with some of the daily energy intake from the present study. However some of the values for ME intake from the present study are lower than those reported by these authors probably because the animals used in the present study were females. The ME required for maintenance in goats with comparable body weight to the ones used in the present study is 4.01 to 5.44 MJ/day (Church, 1991). McDonald *et al*. (2002) stated that the ME required for maintenance by 20 to 35 kg ewes is 3.2 to 5.2 MJ ME/day, suggesting that the goats and sheep used in the present study had more than sufficient ME for maintenance. However, the DMI (0.46 to 0.92 kg/day) of the ewes reported by McDonald *et al*. (2002) was lower than that found in the present study (Tables 5.2, 5.4 and 5.6).

5.7 The changes in animal body weight

On average, for all the treatment diets, goats gained only 10.48 g/day while sheep gained 38.10 g/day. Goats on average had lower metabolic weights (10.92 kg $W^{0.75}$) compared to sheep (12.44 kg $W^{0.75}$). However, the consumption of DMI/kg $W^{0.75}$ (73.5 g) by goats was almost similar to that of sheep (79.5 g).

Table 5.37 The LS means for average daily gain, metabolic weight (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of goats provided with sorghum stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Sorghum stover treated with			
10 g urea/kg (SorghumT1)	12.70[a]	10.97[a]	0.067[cd]
25 g urea/kg (SorghumT2)	3.17[a]	11.03[a]	0.070[cd]
10 urea + 10 g molasses/kg (SorghumT3)	19.84[a]	11.05[a]	0.085[ab]
Lucerne hay	15.87[a]	10.49[a]	0.092[a]
Cottonseed meal (CSM)	17.46[a]	10.62[a]	0.074[bc]
Control diet (Control)	15.08[a]	10.41[a]	0.083[ab]
Standard error (s.e.)	11.21	0.58	0.004

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

The treatment diets containing sorghum stovers treated with T1, T2 and T3 appeared to have a similar effect on the average daily gain of goats (Table 5.37). This was probably because the metabolic weights of the goats did not differ. However, providing SorghumT3 to goats resulted in a higher DMI/kg $W^{0.75}$ (Table 5.37) compared to SorghumT1 (P<0.001) and SorghumT2 (P<0.01).

Providing SorghumT3 to sheep improved their average daily gain (ADG) (Table 5.38) compared to SorghumT1 and SorghumT2 (P<0.05), lucerne hay (P<0.001), CSM and the Control diet (P<0.0001). However, SorghumT1, SorghumT2 and SorghumT3 had a similar effect on the metabolic weights of the sheep. The DMI/kg $W^{0.75}$ (Table 5.38) was higher when offering SorghumT1 to sheep than when providing them with SorghumT2 (P<0.01).

Table 5.38 The LS means for average daily gain, metabolic weight (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of sheep provided with sorghum stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Sorghum stover treated with:			
10 g urea/kg (SorghumT1)	63.73^{abc}	11.68^{ab}	0.084^{ab}
25 g urea/kg (SorghumT2)	67.54^{abc}	11.96^{ab}	0.070^{d}
10 urea + 10 g molasses/kg (SorghumT3)	127.94^{a}	12.84^{ab}	0.079^{bc}
Lucerne hay	37.30^{bc}	13.19^{ab}	0.093^{a}
Cottonseed meal (CSM)	15.08^{cd}	13.29^{ab}	0.073^{cd}
Control diet (Control)	-3.17^{cd}	13.31^{ab}	0.076^{cd}
Standard error (s.e.)	24.37	0.62	0.003

[1]Refers to the treated sorghum stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Providing MaizeT1 and MaizeT2 to goats resulted in weight loss, whilst feeding MaizeT3 produced a weight gain (Table 5.39). However, the differences in average daily gain, kg $W^{0.75}$ and DMI/kg $W^{0.75}$ when providing MaizeT1 MaizeT2 and MaizeT3 to goats were not statistically significant.

Offering MaizeT1, MaizeT2 and MaizeT3 to sheep had a similar effect on their ADG (Table 5.40). However, the sheep consumed more DM/kg $W^{0.75}$ when provided with MaizeT2 ($P<0.001$) and MaizeT3 ($P<0.01$) than when offered MaizeT1. The ADG observed when feeding sheep MaizeT1, MaizeT2 and MaizeT3 was comparable to that realized when providing lucerne hay, CSM and the Control diet (Table 5.38).

Table 5.39 The LS means for average daily gain, metabolic weight (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of goats provided with maize stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Maize stover treated with:			
10 g urea/kg (MaizeT1)	-4.76[a]	10.37[a]	0.070[cd]
25 g urea/kg (MaizeT2)	-5.56[a]	10.88[a]	0.066[cd]
10 urea + 10 g molasses/kg (MaizeT3)	7.14[a]	11.56[a]	0.069[cd]
Standard error (s.e.)	11.21	0.58	0.004

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.40 The LS means for average daily gain, metabolic weight (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of sheep provided with maize stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Maize stover treated with:			
10 g urea/kg (MaizeT1)	24.60[bcd]	13.47[a]	0.070[d]
25 g urea/kg (MaizeT2)	9.13[cd]	11.23[b]	0.087[ab]
10 urea + 10 g molasses/kg (MaizeT3)	17.86[cd]	12.08[ab]	0.086[ab]
Standard error (s.e.)	24.37	0.62	0.003

[1]Refers to the treated maize stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Treatment diets containing millet stovers treated with T1, T2 and T3 appeared similar in their effect on the average daily gain of the goats (Table 5.41). These treatment diets also had a similar effect on the metabolic weight of the goats. However, providing MilletT3 to goats resulted in a higher DMI/kg $W^{0.75}$ (Table 5.37) compared to MilletT1 ($P<0.01$).

Table 5.41 The LS means for average daily gain, metabolic weight (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of goats provided with millet stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Millet stover treated with:			
10 g urea/kg (MilletT1)	19.05[a]	11.01[a]	0.060[d]
25 g urea/kg (MilletT2)	3.17[a]	11.63[a]	0.070[dc]
10 urea + 10 g molasses/kg (MilletT3)	23.02[a]	10.98[a]	0.077[bc]
Standard error (s.e.)	11.21	0.58	0.004

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

Table 5.42 The LS means for average daily gain, metabolic weight (kg $W^{0.75}$) and DMI/kg $W^{0.75}$ of sheep provided with millet stover treated with urea or urea and molasses

[1]Treatment diets	Average daily gain (ADG) (g/day)	kg $W^{0.75}$	[2]DMI/kg $W^{0.75}$
Millet stover treated with:			
10 g urea/kg (MilletT1)	-42.46[d]	11.49[ab]	0.085[ab]
25 g urea/kg (MilletT2)	38.10[bc]	11.93[ab]	0.084[ab]
10 urea + 10 g molasses/kg (MilletT3)	99.92[ab]	12.77[ab]	0.068[d]
Standard error (s.e.)	24.37	0.62	0.003

[1]Refers to the treated millet stover in addition to the basal diet (veld grass hay plus Pen-feed), [2]DMI = dry matter intake

Means in a column with a common superscript do not differ significantly (P>0.05).

When the sheep received MilletT1, they lost weight. This probably explains the significant difference in ADG (Table 5.42) between providing sheep with MilletT1 and MilletT2

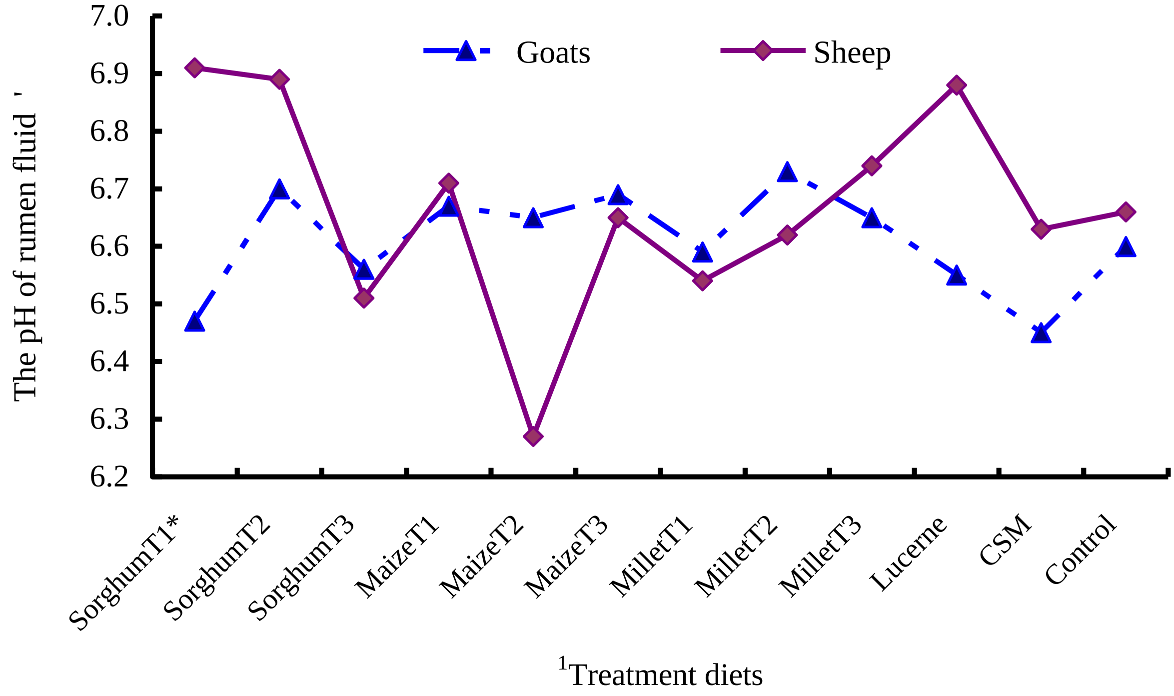
($P<0.01$) and MilletT3 ($P<0.0001$). However, the sheep appeared to consume more DM/100 kg live weight when offered MilletT1 and MilletT2 ($P<0.01$) than when fed on MilletT3.

Steele (1996) observed that kids can vary in growth rates from 20 to 180 g/day. As in the present study, this author also stated that goats generally have slower growth rates compared to lambs. Ogwang and Karua (1996) reported slightly higher growth rates for grazing Swazi goats supplemented with maize stover. A study by Njwe and Kona (1996) found average daily weight gains of 9, 60 and 78 g/day respectively for West African Dwarf sheep fed on elephant grass hay ((*Pennisetum purpureum*) without supplement or supplemented with *Stylosanthes* hay or concentrate. This observation compares favourably with some of the average daily gains for sheep in the present study. Treatment diet MaizeT2 had a similar effect on goats (Table 5.39) as for steers (Table 4.20). Feeding MilletT1 (Table 5.42) and the Control diet (Table 5.38) to sheep had a similar effect (loss of weight) to providing these treatment diets to steers (Table 4.19 and 4.21).

5.8 The effect of treatment diets on the pH and ammonia concentration (NH_3) of rumen fluid from goats and sheep

As explained in section 2.7, rumen fluid samples from goats and sheep were obtained only at 12h00 for each treatment diet. The pH of goat rumen fluid varied between 6.45 and 6.73 while that of sheep ranged from 6.27 to 6.91 (Figure 5.2). The differences between the pH of goat and sheep rumen fluid were least when provided with MilletT1 and greatest when given SorghumT1. On average, rumen fluid from goats (pH 6.61) was lower in pH than that from sheep (pH 6.67).

The treatment diets had a similar effect on the pH of rumen fluid sampled at 12h00 from goats (Figure 5.2). Providing SorghumT1 and SorghumT2 to sheep resulted in a higher pH ($P<0.05$) of rumen fluid compared to SorghumT3 (Figure 5.2). The pH of sheep rumen fluid provided with MaizeT2 was lower than when they were fed on MaizeT1 ($P<0.01$), MaizeT2, CSM and the Control diet ($P<0.05$) and lucerne ($P<0.001$). Such variation in the pH of rumen fluid was found to have no adverse effect on the performance of sheep grazing natural pasture (De Waal & Biel, 1989). Fimbres *et al*. (2002) found a rumen fluid pH of 6.7 when lambs were fed on diets containing 30% roughage, while Manychi *et al*. (1994) reported the pH of rumen fluid ranging from 6.9 to 7.0. These findings are consistent with results from the present study.



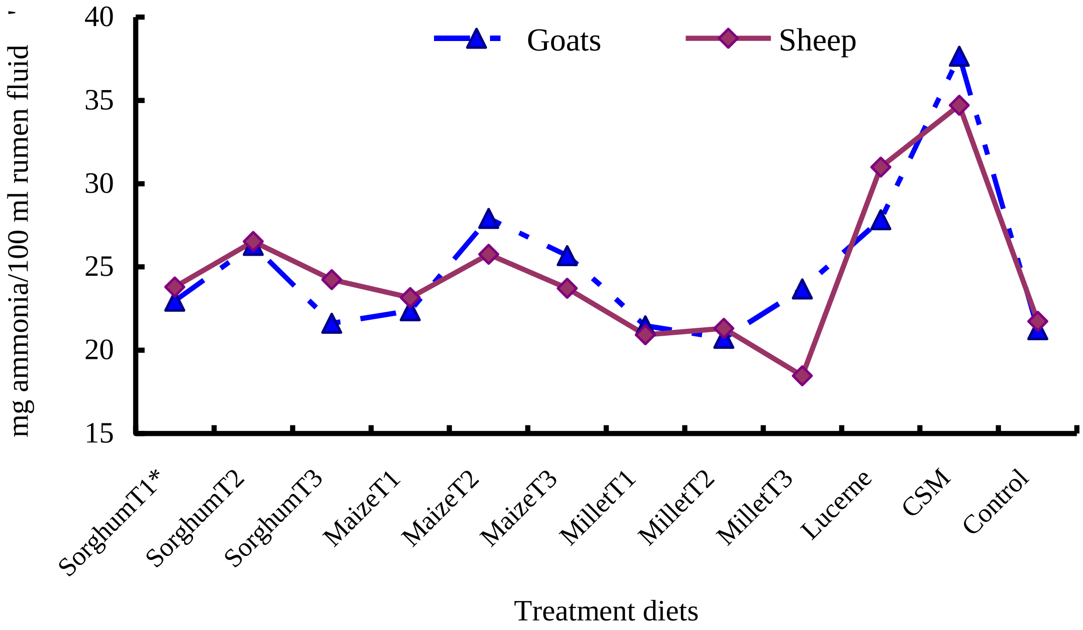
*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 5.2 The influence of treatment diets on the pH of rumen fluid from goats and sheep sampled at 12h00.

The ammonia (NH_3) concentration of goat and sheep rumen fluid sampled at 12h00 followed a similar pattern (Figure 5.3).

Providing SorghumT1, SorghumT2 and SorghumT3 to goats had a similar effect on the NH_3 concentration of rumen fluid sampled at 12h00 (Figure 5.3). A similar observation was made when offering MaizeT1, MaizeT2 and MaizeT3 to goats as well as when providing MilletT1, MilletT2 and MilletT3 (Figure 5.3). The NH_3 concentration of goat rumen fluid when they were fed on lucerne hay was comparable to that observed when giving other treatment diets ($P>0.05$). Providing CSM to goats increased the NH_3 concentration of rumen fluid compared to SorghumT3, MaizeT1, MilletT1, MilletT2, the Control diet ($P<0.01$) and SorghumT1, MaizeT3 and MilletT3 ($P<0.05$).



*The suffixes T1, T2 and T3 appended to sorghum, maize and millet are the treatments used on the stovers i.e. 10 g urea/kg stover, 25 g urea/kg stover and 10 g urea plus 10 g molasses/kg stover respectively

[1]Refers to the particular treated cereal crop stover, lucerne hay, cottonseed meal (CSM) or nothing (Control) in addition to the basal diet (veld grass hay plus Pen-feed)

Figure 5.3 The influence of treatment diets on the ammonia (NH_3) concentration of rumen fluid from goats and sheep sampled at 12h00.

Providing SorghumT1, SorghumT2 and SorghumT3 to sheep had a similar effect on the NH_3 concentration of their rumen fluid sampled at 12h00 (Figure 5.3). A similar observation was made when offering MaizeT1, MaizeT2 and MaizeT3 to sheep as well as when providing them with MilletT1, MilletT2 and MilletT3 (Figure 5.3). The NH_3 concentration of sheep rumen fluid was increased when providing them with lucerne hay compared to giving them MilletT3 ($P<0.05$). Providing CSM increased the NH_3 concentration of sheep rumen fluid compared to SorghumT1, MaizeT1, MaizeT3, MilletT1, MilletT2, Control diet ($P<0.05$) and MilletT3 ($P<0.01$). This as observed on cattle (section 4.9) and goats (section 5.3) indicates that the CP content of the treatment diets had the greatest influence on the NH_3 concentration of rumen fluid. This is in agreement with the results of a study by Ndlovu and Hove (1995) on goats and Manyuchi *et al*. (1994) on sheep. The average NH_3 concentration of rumen fluid from goats and sheep sampled at 12h00 was 24.78 and 24.61 mg/100 ml rumen fluid respectively. This seems to substantiate the findings of Dayal *et al*. (1995) and Marais and Roux (2004) who reported higher concentrations of NH_3-N in goats than in sheep fed on low quality diets. However, when feeding complete diets, Rao *et al*. (1998) found that the NH_3-N peaked two hours after feeding and was higher in sheep than in goats.

5.9 Conclusions

5.9.1 Providing cereal crop stovers treated with urea or urea plus molasses to goats and sheep in addition to veld grass hay and Pen-feed did not result in significant improvements in their DMI, OMI, apparent DM and OM digestibility compared to offering them the Control diet.

5.9.2 The additional CP from the stovers treated with urea or urea and molasses did not significantly affect herbage intake by goats and sheep. However, offering the treatment diet SorghumT3 to goats was comparable in supplying total CP to providing lucerne hay. Offering MilletT1 and MilletT2 to goats appeared to improve the digestibility of the total diet compared to giving them the Control diet. The treatment diets appeared to have a similar effect on the CP digestibility in sheep.

5.9.3 The influence of the treatment diets on the intake and digestibility by goats of NDF was similar to that on the DMI and DMD with the exception that MilletT1 had a similar effect to the Control diet in supply NDF. The intake and digestibility of the treatment diets by goats and sheep of ADF followed a trend similar to that on the DM and NDF.

5.9.4 The ME intake by the goats and sheep appeared to have been more than adequate for their maintenance requirements.

5.9.5 The daily weight gain and the metabolic weight of the goats did not significantly differ with the treatment diets. Providing SorghumT3 and MilletT3 to sheep appeared to improve ($P<0.05$) their average daily gain compared to giving them the Control diet. A loss of weight was observed when offering the treatment diet MaizeT2 to goats and MilletT1 and the Control diet to sheep.

5.9.6 The cereal crop stovers treated with T1, T2 and T3 did not significantly impact on the pH and the NH_3-N concentration of rumen fluid from goats. The treatment diet MaizeT2 appeared to significantly reduce the pH of sheep rumen fluid ($P<0.05$) compared to the Control diet. The NH_3-N concentration of sheep rumen fluid was not improved by providing cereal crop stovers treated with T1, T2 or T3 compared to offering them the Control diet.

6. Overall conclusions

6.1 Treatment of sorghum, maize and millet stovers with urea or urea and molasses

Treating stovers of sorghum, maize and millet with 10 g urea/kg stover (T1), 25 g urea/kg stover (T2) or 10 g urea + 10 g molasses/kg stover (T3) made them softer in texture, darker in colour and pungent in smell compared to untreated stovers. The dry matter (DM) content of the cereal crop stovers was reduced while their organic matter (OM) content appeared unaffected by treatment with T1, T2 or T3. Treatment with T1, T2 or T3 significantly improved the crude protein (CP) content of the stovers of sorghum, maize and millet and in this respect, made them comparable to lucerne hay. The greatest improvement in CP content was on maize stover while millet stover showed the least response. The concentrations of urea used in the present study were lower than those used in other studies. Nonetheless, the improvement in the CP content of the three cereal crop stovers was comparable to that obtained in studies by other workers using the customary 50 g urea/kg stover recommended in literature.

Treatment with T1, T2 or T3 reduced the neutral detergent fibre (NDF) content in sorghum stover but increased it in maize and millet stover. Treating the cereal crop stovers with T1, T2 or T3 increased their acid detergent fibre (ADF) and acid detergent lignin (ADL) contents. However, treating sorghum and millet stovers with T3 reduced their ADF content. Cereal crop stovers treated with T3 showed the greatest improvement in their *in vitro* DM digestibility. The treated cereal crop stovers were comparable to lucerne hay but had higher *in vitro* DM digestibility than veld grass hay. Due to improvements in CP content and *in vitro* DM digestibility, stovers of sorghum, maize and millet treated with T1, T2 or T3 have the potential of being viable alternatives to lucerne hay especially in times when the quality of ruminant feeds is low.

6.2 Steers

The amount of DM supplied by 1 kg cereal crop stover treated with T1, T2 or T3 (as fed) was low, yet some treatment diets containing these treated stovers improved the total DMI by steers. Providing sorghum stover treated with T1, T2 or T3 to steers in addition to their basal diet of veld grass hay and Pen-feed improved their total intake of DM and OM compared to giving them the Control diet (basal diet only). A similar observation was made when maize and millet stover treated with T3 was fed to steers in addition to the basal diet. Some of the treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 and T3 thus appear to have stimulated DMI in steers unlike those that contained lucerne hay and CSM, which apparently improved the total DM intake (DMI) by substitution.

Feeding the steers on sorghum stover treated with T1 and T2 in addition to their basal diet had a comparable effect on the digestibility coefficients of DM and OM to offering them lucerne hay. A similar response was noticed when the steers received maize and millet stovers treated with T2 in addition to their basal diet. Treatment diets containing stovers of sorghum, maize and millet treated with T3 improved the DM and OM digestibility coefficients by steers compared to the Control diet and the lucerne hay used in the present study.

Offering stovers of sorghum, maize and millet treated with T2 and T3 in addition to the basal diet of steers improved their total CP intake compared to supplying them with the Control diet and made it comparable to that observed when feeding them on lucerne hay. The digestibility coefficient of CP by steers fed on treatment diets containing stovers of sorghum, maize and millet treated with T2 and T3 was also comparable to that found when they were given lucerne hay. This suggests that these treatment diets may be suitable substitutes for lucerne hay in the diets of steers.

The effect of the treatment diets on the intake and digestibility by steers of NDF was similar to that on the DMI and the digestibility coefficients of DM. However, providing maize stover treated with T3 to steers in addition to the basal diet was not comparable in its effect on the digestibility coefficient of DM to giving them lucerne hay. The treatment diets influenced the intake and digestibility by steers of ADF in a way similar to that on the DM and NDF.

The intake of metabolisable energy (ME) by the steers was adequate for their maintenance requirements. The ME was highly correlated to the intake and the digestibility coefficient of OM by the steers because it was calculated from the digestible OM.

Treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 and T3 did not significantly improve the average daily gain and the live weights of the steers compared to lucerne hay and the Control diet. This suggests that these treatment diets may be best suited for use as maintenance rations rather than for production. Steers lost weight when they were offered the Control diet, maize stover treated with T2 and millet stover treated with T1 in addition to their basal diet.

The rumen fluid from steers fed on treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 or T3 decreased in pH with time of sampling from 08h00 to 20h00. Rumen fluid sampled from steers at 12h00 was significantly higher in ammonia (NH_3) concentration than that collected at 08h00, 16h00 and 20h00, except when offering them lucerne hay in which the NH_3 concentration peaked at 16h00. The CP content of the treatment diets had a direct influence on the concentration of ammonia in the rumen fluid of steers. The improvements in the digestibility coefficients of DM and NDF suggest that the pH and NH_3 concentration in the rumen fluid when steers were fed on these treatment diets were adequate for optimal fibre breakdown in the rumen without suppressing microbial activity. Therefore, incorporating stovers of sorghum, maize and millet treated with T1, T2 or T3 in the diet of cattle in Botswana has the potential benefit of providing microbial protein and enhancing feed utilization.

6.3 Goats and sheep

Offering stovers of sorghum, maize and millet treated with T1, T2 or T3 to goats and sheep in addition to their basal diet did not significantly improve their intakes and digestibility coefficients of DM and OM compared to giving them the Control diet.

The additional CP supplied by stovers of sorghum, maize and millet treated with T1, T2 or T3 to the basal diet of goats and sheep was inadequate to significantly stimulate their herbage intake compared to providing them with the Control diet. Providing sorghum stover treated with T3 to goats in addition to the basal diet was comparable in supplying total CP to offering them lucerne hay.

Providing millet stover treated with T1 and T2 to goats in addition to the basal diet improved their digestibility coefficients of CP compared to offering them the Control diet. Feeding treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 or T3 to sheep did not significantly improve their digestibility coefficients of CP compared to giving them the Control diet.

The effect of treatment diets on the intake and digestibility by goats of NDF was similar to that on the DMI and the digestibility coefficient of DM. However, unlike the DMI, the intake of NDF when providing millet stover treated with T1 to goats in addition to the basal diet was similar to that of the Control diet. The intake and digestibility coefficients of ADF by goats and sheep followed a trend similar to that of the DM and NDF.

Goats and sheep in the present study consumed more ME than what is recommended for their maintenance requirements. However, treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 and T3 did not significantly improve the intake of ME compared to the Control diet. The treatment diets did not result in significant improvements in the average daily gains and the live weights of the goats. The average daily gain by sheep was improved when feeding them on sorghum and millet stovers treated with T3 in addition to the basal diet compared to offering them the Control diet. Offering maize stover treated with T2 to goats in addition to their basal diet resulted in loss of weight. Sheep lost weight when offered the Control diet and millet stover treated with T1 in addition to the basal diet.

The pH and the concentration of NH_3 in rumen fluid sampled at 12h00 from goats were not significantly altered by the treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 and T3. Providing maize stover treated with T2 to sheep in addition to the basal diet significantly reduced their rumen fluid pH compared to giving them the Control diet. Offering treatment diets containing stovers of sorghum, maize and millet treated with T1, T2 and T3 to sheep did not significantly improve the NH_3 concentration in their rumen fluid compared to providing them with the Control diet.

7. Recommendations

Lower concentrations of urea (10 g urea/kg stover and 25 g urea/kg stover) than the customary 50 g urea/kg stover recommended in literature may be successfully used to improve the CP content in stovers of sorghum, maize and millet.

The incubation period when treating stovers of sorghum, maize and millet with urea or urea and molasses in Botswana may be kept at three weeks if the aim is to improve the CP content of the stovers. However, the three week period was inadequate to significantly improve the digestibility of these cereal crop stovers.

For enhanced digestibility of sorghum, maize and millet stovers, it is recommended that urea be used in combination with molasses. However, further studies are needed to establish the interaction between the ensiling period and the concentration of urea or urea and molasses for optimum improvement in the digestibility of cereal crop stovers. This is because it is not clear whether the ensiling period or the concentration of urea has the greatest effect in improving the digestibility of stovers treated with urea or urea and molasses.

Since they were comparable to lucerne hay and better than the Control diet in their effect on the intake and apparent digestibility of DM, OM, CP and NDF by steers, cereal crop stovers treated with T2 and T3 may be used to replace lucerne hay in the diets of cattle in Botswana. However, their inclusion rates at the levels used in the present study are recommended for the maintenance of Tswana cattle during the drought season and not for production purposes. Therefore, further research is required to determine the inclusion levels of cereal crop stovers treated with urea or urea and molasses in ruminant diets which would suit not only maintenance but production requirements also.

The same recommendation cannot be made for goats and sheep, because in general the treatment diets did not significantly improve the intake or utilization of nutrients by goats and sheep. More work is required to find out why this was the case and how to rectify the lack of positive effect.

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