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Enhancing Nutritional Characteristics of Maize Stover through Use of Targeted Additives for Sustainable Animal Production

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Abstract: The study focused on enhancing the feeding value of crop residues through the use of additives for sustainable smallholder feed production. Maize stover was selected due to its abundance and potential to support livestock production in resource-limited communities. The residues were subjected to various treatments including adding urea and molasses aimed at improving their nutritive composition, digestibility, and preservation quality. Results revealed that urea and urea–molasses treatments significantly increased crude protein levels while reducing fiber content, thereby improving the overall nutritional profile. The combined urea–molasses treatment yielded the best balance between nutrient enhancement, palatability, and long-term storage stability. The findings underscore the potential of additive treatments as cost-effective strategies for transforming low-value crop residues into nutritionally improved feed resources. This approach promotes sustainable livestock feed production and supports food security efforts under Zimbabwean smallholder farming systems. It also supports the country's Vision 2030, from where the country is poised to be a middle income economy by then.

Keywords: Crop Residues, Concentrates, Urea Based Ensiling, Molasses, Total Mixed Ration (TMR).

Research Paper

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CHAPTER 1.0: INTRODUCTION

1.1 Dry Season Feed Challenge

Feed shortage during the dry season has been cited as the major factor contributing to the failure of smallholder stock development programs by many researchers. The major and most readily available source of feed for cattle during the dry season in the small holder sector are mostly crop residues and especially maize Stover. Although crop residues are available in large quantities, only a small fraction is efficiently utilized. Much of the residues are grazed in-situ which results in large amounts being tramples on and wasted. Knowledge of the efficient use and improvement of the feeding value of crop residues already exists according to Manyuchi, Smith, (1992). Supplementation of poor quality roughages with good quality residues was also complimented by Smith, Manyuchi, Mikayiri, (1994). However, experiments done were using only sheep and goats.

1.2. Adoption of Crop Residue Centred Cattle Feeds

The main challenge in adoption lies in trying to find out if cattle conform to the pattern found in sheep and goats that there is a linear relationship between feed intake nutrient content and the output nutrient content, and if a well-defined relationship exists, how can this be related to meat or milk production. If a pattern exists, can it be used as a criterion for classifying feeds especially nutrient enriched crop residues to enhance experiments based on restricted diets for example a high fiber mixture, or a highly digestible mixture to be carried out using the known mixtures of known nutritional value. This study aims to recommend classification of crop residue based diets in relation to their digestibility in cattle. A combination of feed material should be sought that can be used as a substitute for natural forage or supplement natural forage so as to alleviate feed shortage in the dry season. There is every need to integrate knowledge obtained from goats and sheep based experiments to cattle.

1.3. Improving Quality of Crop Residues to Match Concentrates

Crop residues are abundant agricultural byproducts in Zimbabwe yet they are often underutilized due to their low nutrient content and poor digestibility. The scarcity and high cost of commercial livestock feeds have made it necessary to explore locally available feed resources that can be improved using affordable technologies. Enhancing crop residues quality through the use of urea and molasses additives offer a cost effective approach to improving feed quality while promoting circular resource use. This aligns with Zimbabwe's Vision 2030 and Sustainable Development Goals (SDGs) particularly SDG 2, "Zero Hunger" and SDG 12, Responsible Consumption and Production. These can address and help promote sustainable livestock production systems. This study provides practical insights for smallholder farmers in need of addressing optimized livestock production. It is also useful for agricultural extension officers and policy makers seeking to improve livestock nutrition using environmentally friendly and economically viable feed production technologies.

1.4 Assumptions of the Study

The study assumed that there must be a decrease in the level of essential nutrients concentration in the dung as compared to the original feed from which the animal was feeding. This play as an indicator of efficiency of digestion and absorption of available nutrients and in the form they exist. There was an assumption that the invitro method of analysis imitates the same environment as the invivo approach. Health of the study animals mattered a lot hence one major assumption was that the animals used were all in the same state of health throughout the research period. There are discrepancies on the outcome that may arise depending on the age of the animals. The study assumed that all animals used in the project were of the same age and make and their feeding habits were the same in any given season.

1.5 Limitations of the Study

Experimental animals available at the time of study were fistulated donor cows which needed a restricted diet to avoid them getting overweight. This would affect the fistula if left to gain too much weight. The animals used were all bulls. Since animals were bulls, milk production could not be used as an experimental parameter and since they required a restricted diet, an increase in body mass could not be taken into consideration as well so limiting the experiments to comparison of the digestibility of the experimental diets. Project needed to run at the peak of the dry season when the problem of feed shortage is really handy.

1.6 Scope of Study

The study focuses on improving the feeding value of locally available crop residues like maize Stover. It specifically investigates the effect of urea and molasses on the physical characteristics, chemical composition and storage stability of treated residues for sustainable feed production. The study is limited to the feed processing stage excluding animal feeding trials. The study also considers economic feasibility under Zimbabwean smallholder conditions.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction and Global Importance

Crop residues like straws, stovers, husks and stalks represent a vast underutilized feed resource in mixed and smallholder farming systems worldwide. Their seasonal abundance makes them a critical resource for ruminant production especially during the dry season when fresh forage is scarce. However, their nutritive value is intrinsically low because of high structural carbohydrate, which is cellulose, hemicellulose and lignin content, low crude protein (CP), poor mineral profile and low voluntary intake by animals. Improving the nutritive value of residues using low cost additives has therefore been a central strategy for increasing livestock productivity and improving resource use efficiency on small farms.

Figure 1: Maize stover stacked to reduce moisture content of maize prior to harvesting (Source: Ouda JO, Kari, Kenya)

Van Soest PJ, (1987), noted that adequate dietary analyses of any sort require that the methods employed are relevant to a nutritional classification of the dietary chemical components. Such classifications have often depended upon availability of energy and the dietary components associated with it. On the other hand, dietary fibre and forage also had a major role in determining the gastrointestinal environment, which does not necessarily relate to a classification based on availability. This brings a part of the equation that needs to be addressed prior to formulating feeds for such kind of study. Feed analyses as noted by Van Soest, (1987), is a procedure that attempt to classify substances into groups related to their nutritional character and availability. They provide analytical values of composition of dietary ingredients upon which balanced dietary formulations are based.

Alternatively, animal responses are predicted from dietary composition. In particular, the fibrous fractions are associated with unavailability of energy and nutrients and are, therefore, indices of quality for such calculations. The macro Kjeldahl technique of the AOAC was used to assess the sample's crude protein content. To transform organic nitrogen into ammonium ions, the samples will be digested using concentrated sulphuric acid while employing copper and sodium sulphates as catalysts. Alkali will be added, and the released ammonia will be converted into extra boric acid by distillation. With sulphuric acid or hydrochloric acid, the distillate was titrated.

2.2. Composition of Forages

Nutrients in foods and feeds have been traditionally classified according to chemical composition and presumed structure, such as carbohydrates and protein as in the proximate system; or according to relative energy content, such as fats *versus* proteins and carbohydrates, or minerals of no energy content at all according to Van Soest PJ, (1987). Other basis involves that of presumed availability, such as fibrous *versus* non-fibrous carbohydrates. Solubility tests for protein as quality parameters for ruminants also follow this logic. The underlying principle of all of these classifications is the desire to categorise component substances into groups possessing similar nutritional effects and properties.

The most common classification is based on nutritive availability or expected digestibility. In this context fibre has a unique position nutritionally since it tends to measure less available components than those possessing relatively complete availability. This system categorizes forages as constituting of crude protein, crude fibre, ash then oils. Forage Dry matter is made up of true protein and non-protein that when multiplied by a factor of .25 give us crude protein. The cellulose, lignin and pentosans make up the crude fibre. The ash represents the mineral composition of the forage as a whole. Glycerides, waxes and fat soluble vitamins and pigments make up the oils. Above systems forms the basis of the Weende Method of classification and analysis. On this basis, it is possible to make comparisons albeit, arbitrary and somewhat approximate between one forage and another.

One useful measure of the nutritive value of a feedstuff is its apparent digestibility. This has been demonstrated by Nurdianti R.R, Dickhoefer U, Montoya J, Castro M. (2024), who noted that dietary fibre concentration is one of the main determinants for DMI in ruminants, because of its effects on rumen fill. This can be measured in-vivo by feeding the test feed to animal and monitoring intake and faecal output. Such trials are tedious because they require large quantities of feed, a large number of animals and accurate collection of dung and feed refusals. According to Von Soest, (1987), digestibility can be estimated from forage chemical composition. This is often insufficient to explain differences in in-vivo digestibility, especially in situation were comparisons are made between different species of forage plants.

Invitro digestion is a chemical laboratory method developed to attempt to predict the dry matter digestibility of forages. Feedstuffs are digested invitro by preparations of microorganisms and more recently, enzymes. The most widely used method is that originally developed by Tilley and Terry, (1963). This method uses rumen fluid as a source of microbes. A recognized attribute of the invitro system is its ability to provide digestibility values within a short period of time using very little resources. Invitro Dry Matter Digestibility (DMD) values differ from in vivo values mainly because animal factors especially changes in digesta retention time have a direct effect on digestibility. In vitro values have however been found to be highly correlated with in vivo values according to Tilley and Terry, (1963).

2.3. Chemical Treatments and Effects on Digestibility of Forages

Ammoniation which is typically using an ammoniated feed grade urea is one of the most widely implemented chemical method to upgrade crop residues of the straw nature and other residues. Urea ammoniation increases nitrogen content, partly hydrolyses lingo cellulose bonds and raises ruminal available nitrogen which stimulates microbial fermentation and increases digestibility and voluntary intake. A number of reviews report consistent increases in crude protein and invitro and in vivo digestibility with attendant improvements in intake and animal performance when proper protocol on dose, moisture, sealing duration are followed religiously according to Manyuchi B, Mikayiri S, Smith T, (1994). This method is especially valued because of its relative simplicity and scalability for smallholder farmers.

Typically, effective urea inclusion rates ranged from about 2-5% weight per weight dry matter basis with 2-3 weeks of airtight stacking, shorter ensiling with urea and molasses to balance on cost and labour. Report in gains on voluntary intake vary but can be large to increases between 20 – 50 % reported in some farm trials, while digestible organic matter and animal live weight responses are positive when basal proteins remains limiting. Trials by Ali I, Fontenoti J.P and Allen V.G. (2009), on sheep noted that dry matter intake was higher ($P<0.01$) for sheep fed the basal diet compared to other diets. They also noted that intake was higher ($P<0.05$) for sheep fed NH_3- and urea treated corn stover diets, compared to untreated stover. similarly, the intake was higher ($P<0.01$) for sheep fed 3% NH_3 treated corn. They came to the conclusion that ammonia treatment of corn stover was more effective in enhancing the dry matter intake by sheep than those fed urea or poultry litter-treated diets. Addition of cattle waste in urea treated stover tended to improve the palatability of corn stover over urea treatment alone, but the difference as non-significant.

2.4. Energy Fermentation Enhancers: Molasses and Ensiling Approaches

Molasses is widely used as energy and palatability enhancer in residue treatments. When combined with urea, molasses provides fermentable carbohydrate needed for efficient microbial protein synthesis and to reduce the risk of ammonia losses during ensiling. Molasses based ensiling (Urea –molasses treatment) improves fermentation quality, reduces pH and often increases feed intake and invitro digestibility compared to untreated residue. Molasses also acts as a practical binder and carrier for additives in smallholder contexts. This is an economic method to improve both the nutritive and storage qualities of ensiled residues, though the cost and local availability of molasses should be considered in cost effectiveness analyses.

2.5. Alkali Treatments Using Sodium Hydroxide or Calcium Hydroxide

The use of alkali treatments has been long applied to disrupt lignin – carbohydrate bonds and increase cellulose accessibility. Classic and modern studies demonstrate improvements in NDF and ADF digestibility, rumen fermentation parameters and voluntary intake following alkali treatments. Sodium hydroxide is often most effective but also presents higher handling hazards and cost. Lime offers a safer but often slower alternative. Alkali treated residues have produced significant increases in digestible energy and animal performance in many temperate and tropical experiments but the requirement for safe handling, neutralization of residual caustic soda and water use are practical constraints in some contexts.

2.6. Biological Strategies: Exogenous Fibrolytic Enzymes and Microbial Inoculants

Biological additives including exogenous fibrolytic enzymes like cellulases and xylanases and inoculants like lactic acid bacterial and fungal pre-treatments are relatively recent and rapidly growing areas of research. Exogenous enzymes applied at ensiling or at feeding can increase degradability and in some cases improve animal performance. Silage inoculants can enhance fermentation of ensiled residues and when combined with fibrolytic enzymes may increase sugar release during ensiling to support favourable fermentation and subsequent ruminal digestion. Reviews indicate variable responses in animal performance to enzymes, there is noted positive effects on invitro digestibility and some invivo trials but response magnitude depends strongly on enzyme type, dose, substrate and application timing. The greatest promise appears in combined enzymes + inoculants or enzyme + ensiling strategies that condition the biomass before animal ingestion.

2.7. Combined Treatments and Integrative Approaches

Recent work highlights synergies between methods. A typical example is low rate urea plus molasses ensiling, or enzyme inoculation combined with ensiling or alkali pre-treatments which can reduce the required intensity of any single treatment while maintaining or improving outcomes. Integrated approaches are attractive because they can be tailored to constraint profiles like cost, labour, chemical availability and to the environmental considerations. These can be in the form of minimizing runoff or caustic residues. A current trend in research emphasises optimizing combinations that fit smallholder realities like low cost inputs, minimal specialized equipment and safety.

Musara P.J *et al*., (2021), argues that to transform Zimbabwe's low productive mixed farming into an economically and ecologically sustainable integrated farming system, farmers need relevant scientific information, skills, and crop-livestock integration practices, knowledge, and attitudes among farmers' competencies, on top of the physical resources. They noted that current options to improve these mixed smallholder farming systems lie in developing viable production technology options for targeted production systems and improving efficiency with existing resources.

2.8. Constraints, Risks and Socio Economic Considerations

Despite proven efficacy under controlled experiments, adoption at farm level is limited by several factors. The first constraint is the access and recurring cost of additives like urea, molasses, enzymes and many others. Labour and knowledge requirements for correct treatment and safe handling notably for sodium hydroxide can be a big challenge. The necessary infrastructure needs like plastic sheeting and airtight pits can be unreachable to many smallholder farmers. The heterogeneity or variable residue characteristics on parameters like moisture, maturity and contamination can have a big toll on performance of final products that influences effectiveness. There are possible dry matter losses during some biological treatments. Importantly, extension and training local demonstrations and cost benefit evidence oriented to farmers' realities are repeatedly recommended by reviews as essential to scale adoption. There is no direct way of measuring Dry Matter Digestibility of the diets. Dry matter digestibility (DMD) is the proportion of the feed's dry matter that is digested and absorbed by an animal indicating the energy available for use. It is a key measure of feed quality but can be difficult to measure directly. It is often estimated through invitro (in laboratory) or in vivo, insitu, within an animal, or by using chemicals. High DMD generally corresponds to higher nutritional value and energy content of feed.

According to Runomhodzi L *et al*., (2015), retention on the soil surface of 0, 25, 50, 75 and 100% of the maize stover yield produced per farm, and the use of the remainder as animal feed was quantified over a 12-year period for four farm types in Murehwa, Zimbabwe. Retaining 100% maize residues in the field led to an annual loss of on average 68 and 93 kg body weight per animal for cattle on farms of the relatively wealthiest farmers who had most land and cattle and is therefore unsustainable for livestock production. They noted that farmers without cattle may have a greater incentive for retaining their crop residues but they have to invest labour to keep the residues during the dry season. Their conclusion from an economic perspective was that it is logical that farmers prioritise the sustenance of cattle with crop residues over soil fertility management.

2.9. Environmental and Greenhouse Gas Implications

Several studies indicate that improving residue digestibility can reduce enteric methane per unit product by shifting fermentation toward propionate and increasing feed conversion efficiency. However environmental effects depend on the additive. Some chemicals treatment may have upstream environmental costs and runoff or misuse for example on sodium hydroxide spills which can cause hazards. Life cycle thinking and local environmental safeguards are necessary when recommending treatments at scale. According to Sha Mutjaba Ali *et al*., (2025), using these crop residues mitigates the methane production in ruminants and feed costs, particularly for harvesting the feed crops. They noted that traditionally, these materials have often been underutilized or even disposed of improperly leading to wastage of valuable nutrients and potential environmental pollution.

It has been noted that most developing countries burn crop residues, releasing significant amounts of carbon dioxide, methane, and particulate matter. According to Lohan S.K *et al*., (2025), this contributes to climate change and respiratory diseases. As a result of diverting these residues into animal feed, farmers were noted to reduce environmental pollution and simultaneously increase feed availability. Resilience and Decentralization in livestock production systems could be realized according to Van Zanten HH *et al*., (2018), by using local by-products. They noted that the carbon footprint associated with feed transportation and storage is reduced significantly by using these local by-products.

CHAPTER 3: METHODOLOGY

3.1. Study Area

Grasslands Research Station is one of the leading livestock and pasture research stations in Zimbabwe in the Department of Livestock Research under the Ministry of Agriculture, Mechanization and Water Resources.

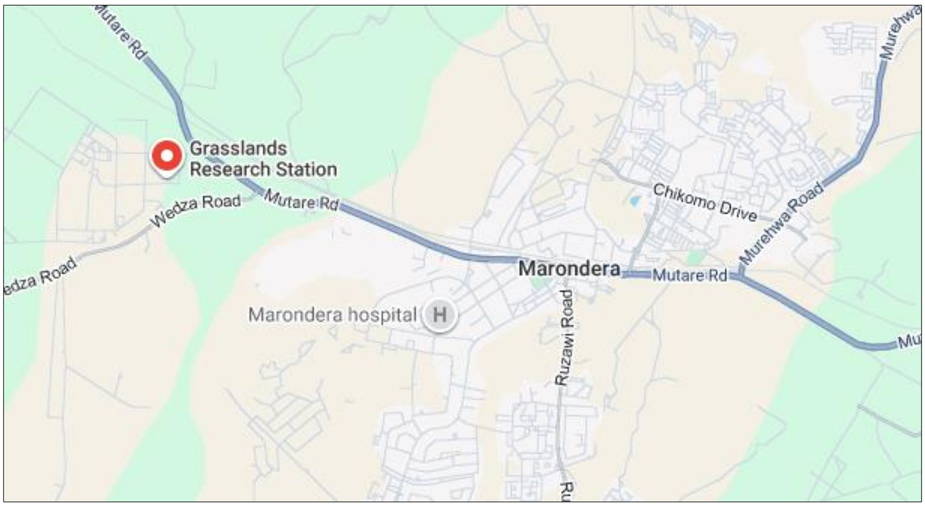

Figure 2: Map of Marondera town showing location of Grasslands Research Station. Source: Map Data (2026).

Grasslands Research Station is located 67Km Southeast of Harare along the Harare – Mutare road, Zimbabwe. It focuses on livestock breeding, pasture development and crop research. Grasslands Research Station (GRS) is one of the four Livestock and Pasture Research Stations in Zimbabwe in the division of Livestock Research, Department of Research and Specialist Services (DR&SS) under the Ministry of Agriculture, Mechanization and Water Resources. Grasslands Research Institute conducts its research in collaboration with other organizations through consultations, partnerships and joint planning and execution of programmes and information exchange. The station's research partners include farmers, farmer organizations, extension and livestock development service, other local research institutes, non-governmental organizations and international research centres (Source: https://www.drss.gov.zw).

3.2. Animal Management

Eight bulls, Boran and crossbred were blocked in individual pens were water was freely available and a pair of the eight was allocated to a restricted quantity of the four proposed diets as indicated in Table 1. The diets were offered as a total mixed ration (TMR) in two equal portions at 0700 and 1600hours every day. Diet 2 and 4 were mixed once a week whereas diet 1 and 3 were mixed daily to safeguard against feed spoilage.

Dung samples were collected during week four of the experiment and digestibility and nutrient composition determined. Dung was collected anytime of the day from the caecum of each set of animals on a particular diet and for comparisons sake, was treated in the same manner as the experimental feeds. All analysis required dry samples ground to very fine particles so all fresh dung and wet feed like silage first underwent drying in oven for overnight at 78°C and later milled to small particles for laboratory analysis. Nutritional values of the non-nutrient enriched feeds were included in this presentation to show improvement in the nutritive value of the crop residues due to the presence of the concentrates.

3.3. The Experimental Diets

Table 1: The formulation of the four diets for the study

Diet	Composition
1	Maize Silage + Concentrates in the ratio 7:3
2	Urea treated maize Stover + concentrates in the ratio 7:3
3	Maize silage + Concentrates in the ratio 3:7
4	Urea treated maize Stover + Concentrate in the ratio 3:7

3.4. Preparation of Urea Treated Maize Stover

100 kg of chopped maize Stover (3–5 cm pieces) was weighed and a solution of 4 kg urea and 10 kg molasses in 100 L of clean water sprinkled over the chopped Stover while mixing thoroughly. The treated material was tightly packed into airtight plastic silos. The containers were sealed and incubate for 21 days under shade. After incubation, they were opened and material aerated for 24 hours before feeding.

3.3. Laboratory Analytical Determination

All laboratory analysis was carried out at the Grasslands Research Station Analytical Chemistry Laboratory. All animals used to extract the rumen leak were penned at the Grasslands Research Institute Farm and staff at the farm helped with the preparation of diets, insertion of the thimbles for invitro digestion tests and collection of dung.

3.3.1. Determination of Moisture Content

Petri dish was dried in an oven for about 10 minutes, after cooling in a desiccator with calcium chloride for approximately 20 minutes was weighed empty (W1). The Petri dish (W2) was filled with around 2g of the material and heated to 105°C for 8 hours. After being removed, it was chilled in a desiccator and weighed (W3). The process was performed several times until the weight remained consistent.

$$\% \text{ MOISTURE} = \frac{W2-W3}{W2-W1} \text{ x } 100$$

3.3.2. Ash Determination

After being fire-polished in a muffle furnace, an empty crucible was placed in a desiccator filled with calcium chloride for 20 minutes, and it was then weighed (W1). The sample was weighed into a crucible (W2) and heated at 550°C until it was fully reduced to ash. The crucible was then withdrawn, and a drop of water was added to reveal the non ashed component. Back in the muffle furnace, the crucible was heated for a further 30 minutes. After being taken out, this was placed in a desiccator to cool, and then the crucible containing the ash was weighed (W3).

$$\% \text{ ASH} = \frac{W3-W1}{W2-W1} \text{ x } 100$$

3.3.3. Crude Protein Determination

About 1g sample was weighed and put into the Kjeldahl digestion flask. 3g of a catalyst, a combination of copper sulphate pentahydrate and sodium sulphate pentahydrate in a ratio of 10:1 was added. To prevent the mixture from adhering to the flask during digestion and to improve boiling, four anti-bumping chips were added. With 25ml of concentrated sulphuric acid, the Kjeldahl flask's contents were digested. The flask was tilted and gently heated at first until the foaming stopped, then it was heated vigorously and shaken intermittently to wash down burnt particles from the flask's edges. The mixture was heated continuously until it became transparent and was devoid of any brown or black tint. This was allowed to cool, and then distilled water was used to dilute the contents of the flask to 100ml. The distillation flask was filled with 20ml of this diluted digest. A conical flask was filled with 50ml of 2% sulphuric acid solution, along with a few drops of screened methyl red indicator. The conical flask and its contents were set on the receiver with the delivery tube's end resting slightly below the acid's level. To make the liquid in the distillation flask alkaline, 40ml of a 40% sodium hydroxide (NaOH) solution was poured into the flask, along with a few bits of granulated zinc and anti-bumping granules. The mixture was forcefully heated until the flask's contents developed bumps. The distillate was titrated with 0.1N HCl until the end point (V/ml) had a purple colour.

Calculation

$$\text{Nitrogen}(\%) = \frac{1.4 \text{ x Titre Volume x total volume of digest}}{1000\, x weight of Sample x Aliquot distilled} \text{ x } 100$$

$$\text{Crude Protein } (\%) = \%\text{Nitrogen x } 6.25$$

3.3.4. Crude Fat Determination: Soxhlet Extraction

Utilizing the AOAC's, 2019, Soxhlet extraction procedure, the crude fat was identified (1999). Before being weighed, a 500ml fit round bottom flask was cleaned, dried in the oven for about 25 minutes, and then allowed to cool (W1). The sample, which weighed around 5g (W), was wrapped in a thimble. The condenser was used to introduce this thimble and its contents into the extraction column. The round bottom flask was filled with around 350ml of the extracting solvent (n-hexane), and the extraction device was then attached to it. An electro thermal heater was used to heat the flask to 60°C for six hours. The condenser was used to check for solvent losses caused by heating since it cooled and refluxed the evaporated solvent. The thimble was taken out after extraction, and the solvent was recovered using distillation. To remove the solvent, the flask and its contents were put in a water bath. To completely dry the flask and residue, the oven was heated for a few minutes while the solvent and moisture were still present. It weighed and was desiccator-cooled (W2).

$$\% \text{ Crude fat} = \frac{W2-W1}{W} \text{ x } 100$$

3.3.5. Acid Detergent Fibre Determination

The ADF (0.5–1.0 g) is placed in a tared Gooch crucible. A saturated potassium permanganate solution (50 g l^{-1} $KMnO_4$, 0.05 g l^{-1} $AgSO_4$) and buffer solution (6 gl^{-1} $Fe(NO_3)_3{\cdot}9H_2O$, 0.15 gl^{-1} $AgNO_3$, 500 ml l^{-1} glacial acetic acid, 5 g l^{-1} potassium acetate, 400 mll^{-1} *t*-butyl alcohol) are mixed in a 2:1 ratio (by volume). This mixture (25 ml) is added to the crucible for 90 min at room temperature to oxidize the lignin in the ADF. The spent reagent is then removed by vacuum filtration. The crucible contents are soaked for 5 min in demineralizing solution (50 g l^{-1} oxalic acid dihydrate, 700 ml l^{-1} 95% ethanol, 50 ml l^{-1} 12 M HCl), which is then removed by filtration. The filter contents are washed with ethanol and acetone. The crucible is dried at 100 °C for 8 h. The crucible contains cellulose and insoluble ash. The crucible could also be placed in a 500 °C oven for 3 h; the weight loss corresponds to the cellulose content.

3.3.6. Neutral Detergent Fibre

1g air dried sample was put in an Erlenmeyer flask and 100ml Neutral Detergent Fiber solution added with a few drops of decaline as antifoam. This was heated to boil with reduction of heat to avoid foaming. Heating continued under reflux using a cold finger condenser then filtered using a sintered glass crucible and vacuum. Vacuum was later removed and crucible contents were washed with acetone and sucked dry. Crucible was then dried in an oven overnight, cooled in a desiccator and weighed.

$$\%NDF = \frac{(\text{weight of crucible} + \text{residue}) - (\text{weight of crucible}) \text{ X } 100}{\text{Mass of sample taken}}$$

3.3.7. Dry Matter Digestibility

The fistulated donor cows were fitted with a ruminal cannula (inner diameter 10 cm) as described by Mabjeesh SJ, Cohen M., Arieli A., 2000 in their sheep studies. The TMR contained a 35:65 ratio of forage: concentrate with 17% CP, 31% NDF, and 1.72 Mcal NEL (on a DM basis). The donor cows were maintained on diets sufficient for their maintenance allowance. The TMR was offered once daily at 0900 h. Rumen digesta was collected before the morning meal from the reticulum near the reticulo omasal orifice by vacuum pump. The digesta from each animal was filtered through eight layers of gauze cloth, mixed on a volume basis for each species, purged with CO_2, and kept in a prewarmed thermos until use (within approximately 20 min). The incubation inoculum was prepared by diluting the digesta inoculum with the buffer (Tilly and Terry, 1963) in a 1:4 (vol/vol) ratio and stirring in a water bath at 39°C with purging CO_2 until its use (10 to 15 min later). In the test samples trial, 250 mg of each sample was placed into 50-ml sterile plastic tubes, and 20 ml of the incubation inoculum was added. The tube was stoppered with a Bunsen valve and incubated for 48 h at 39°C. Tubes were gently swirled by hand four times every 12 h. Each sample was incubated in six replicates for each source of inoculum at two different occasions (runs; at least 2 weeks apart). At the end of the 48-h incubation period, tube and vessel contents were acidified by adding 6*M* HCl to reach a final pH of 1.3 to 1.5. After a few seconds, when the foam subsided, pepsin powder (EC 3.4.23.1) was added to a final concentration of 0.2% (wt/vol). The tubes and the vessels were reincubated for an additional 48 h. At the end of this stage, the bags were rinsed thoroughly with tap water until the rinse was min, and the supernatant was discarded. To the pellet, 50 ml of H2O was added and the tubes were recentrifuged to wash out the residual acid. The tubes containing the pellets and the bags were dried in a forced air oven at 60°C for 48 h to determine the residual DM weights. IVDMD was calculated as the DM which disappeared from the initial weight inserted into the bag or tube.

$$\%DMD = \frac{(\text{weight of sample taken}) - (\text{weight of residual Dry Matter after oven drying}) \text{ X } 100}{\text{Mass of sample taken}}$$

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Digestibility of Diets Basing on Moisture Content as Percentage

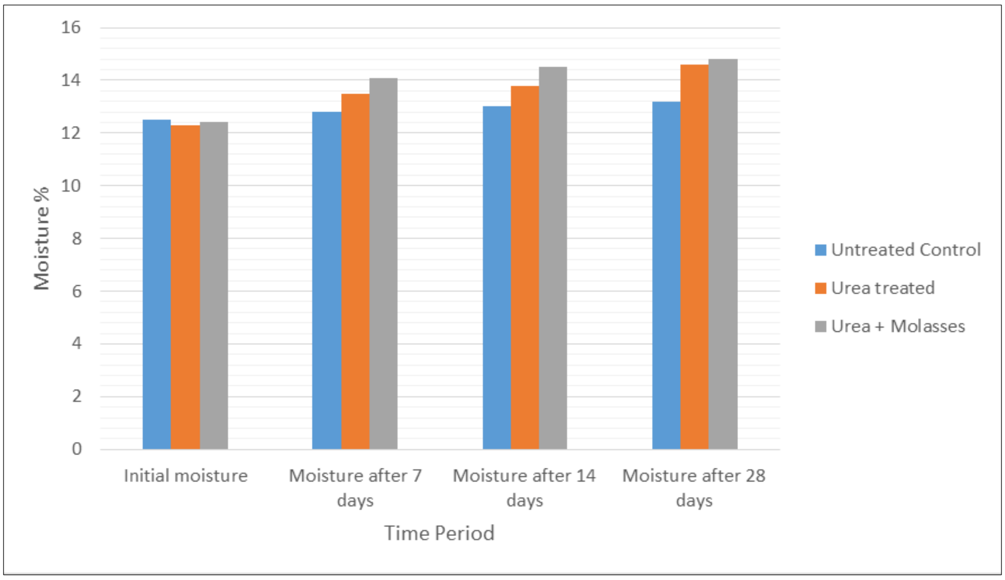

Figure 3: Comparison of moisture retention in treated maize stover over certain time periods

Treated residues generally retained more moisture than untreated control as indicted in Figure 3. This retention indicates improved fermentation and preservation potential. Urea + Molasses treatment resulted in the highest moisture retention due to better binding and fermentable sugar content.

4.2. Digestibility of Diets Based on Ash Content

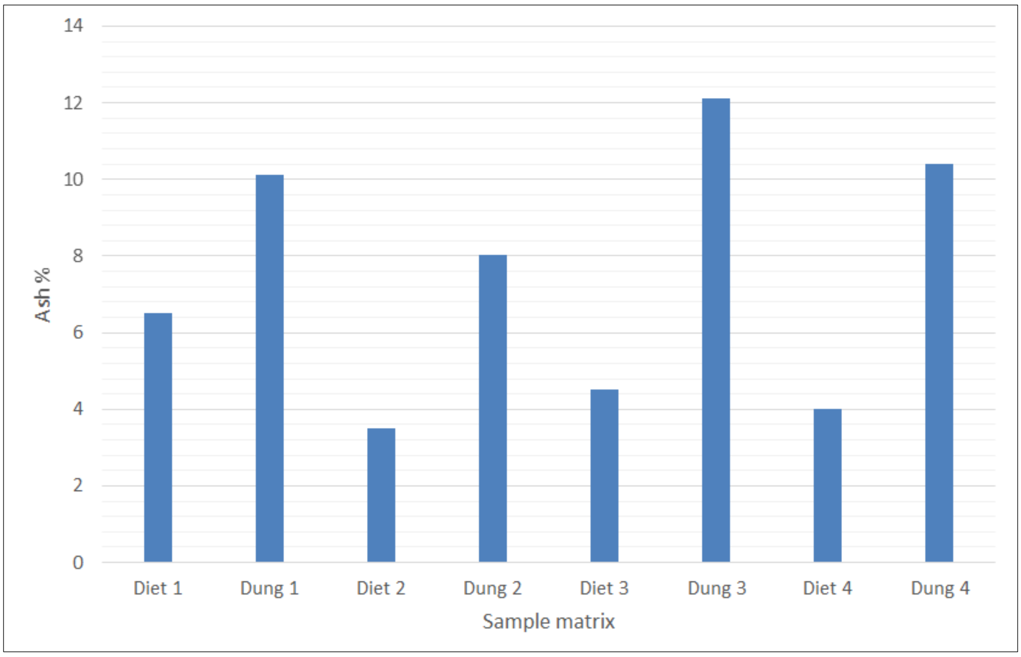

Figure 4: Graph showing distribution of ash in diet feed and its corresponding dung

Ash is the inorganic residue left when the organic matter is burnt out typically by heating to high temperature; as depicted in Figure 4, the high concentrates diets scored more on increase in ash content in dung as compared to the corresponding feed. Diet 3 scored the highest discrepancy between the two and the higher the concentrates the higher is the digestibility of the feed under study. This ash digestibility refers to the indigestibility of ash and is used as a marker most commonly as acid insoluble ash (AIA) to estimate the indigestible portion of a feed sample. By measuring the ratio of the AIA in the feed versus the dung, digestibility can be calculated using a formula that accounts for the indigestible marker rather than requiring a complete and time consuming collection of dung.

4.3. Digestibility of Study Samples Basing on Fat Content

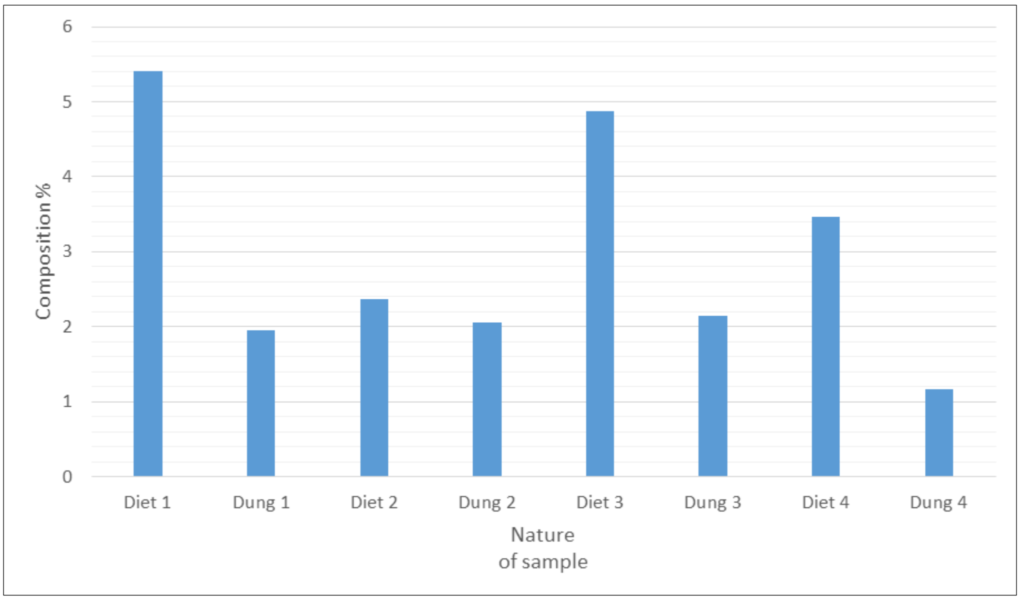

Figure 5: Graph showing the relationship between Fat content and its corresponding dung

Figure 5 showed that silage based diets had the highest fat content per unit mass and showed the highest drop in fat content of the corresponding dung hence depicting better digestibility and assimilation of the digested material. Analyzing fat content is crucial for assessing a feed's nutritional value and can help predict its digestibility as high fat can negatively impact rumen function and the digestibility of other nutrients particularly where there is also high fibre.

4.4. Digestibility of Experimental Diets Based on Acid Detergent Fibre (ADF)

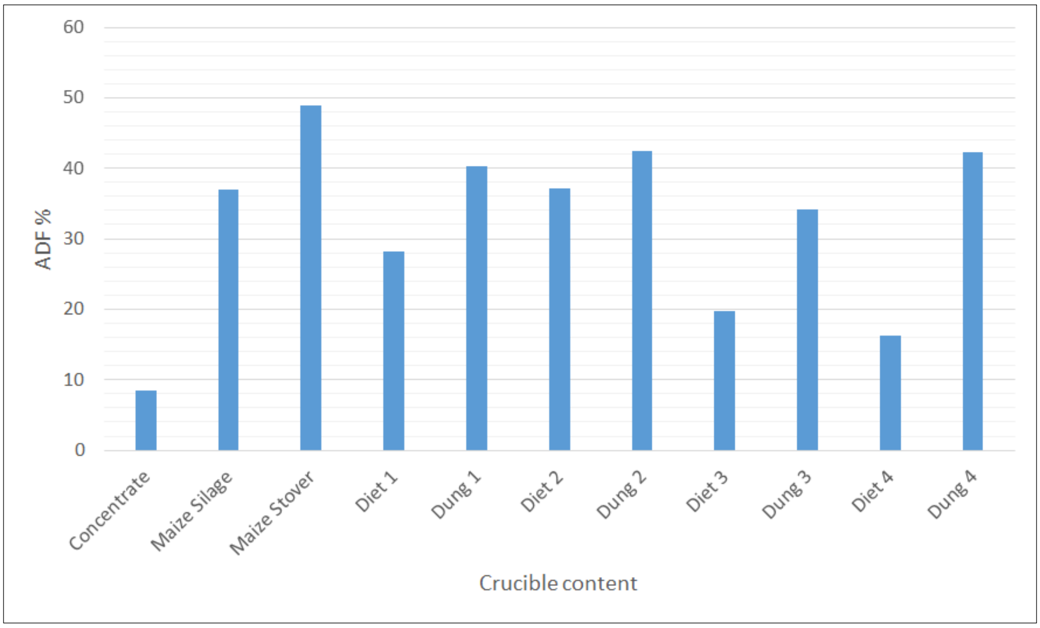

Figure 6: Comparisons of digestibility of experimental diets on ADF basis

As Figure 6 depicts, concentrates improved the digestibility of crop residues by diluting the ADF content of feeds. ADF is a measure of the indigestible portion of fiber which includes cellulose and lignin and is used to estimate the energy content and digestibility of a feed. As ADF levels increase, the overall digestibility and energy yield of the feed decrease. Forages low in ADF are typically higher in energy and ADF is a key component used to calculate measures like total digestible nutrients (TDN) and net energy for forage based diets.

4.5. Determination of Digestibility of study Samples Basing on Crude Protein (CP)

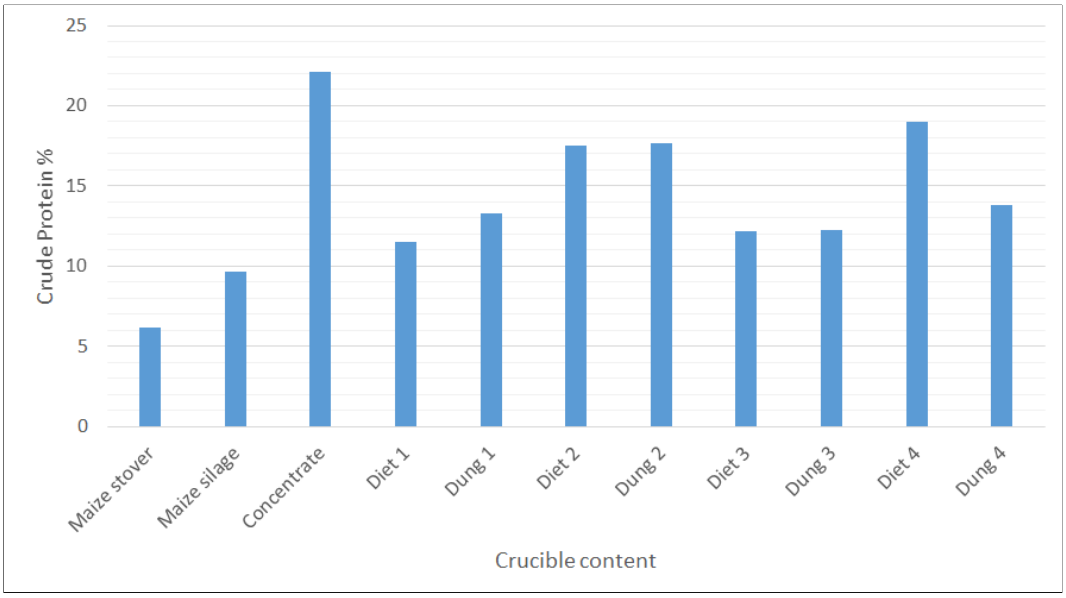

Figure 7: Graph showing comparisons of crude protein content of diets under study in relation to dung

The silage based diets show an increase in dung CP content as compared to the corresponding feed as depicted in Figure 7. The Stover based diet show a decrease in CP content of dung in relation to original feed. This proves that it is very unreliable to compare digestibility of feeds basing on crude protein. Crude protein in feed is a measure of total nitrogen content which includes both true protein and non-protein nitrogen. While CP is a standard measure, it does not directly reveal the protein's nutritive value or digestibility as its calculation does not account for amino acid composition or how it is readily it is digested by an animal.

4.6. Determination of Digestibility of Study Samples Basing on Dry Matter Digestibility (DMD)

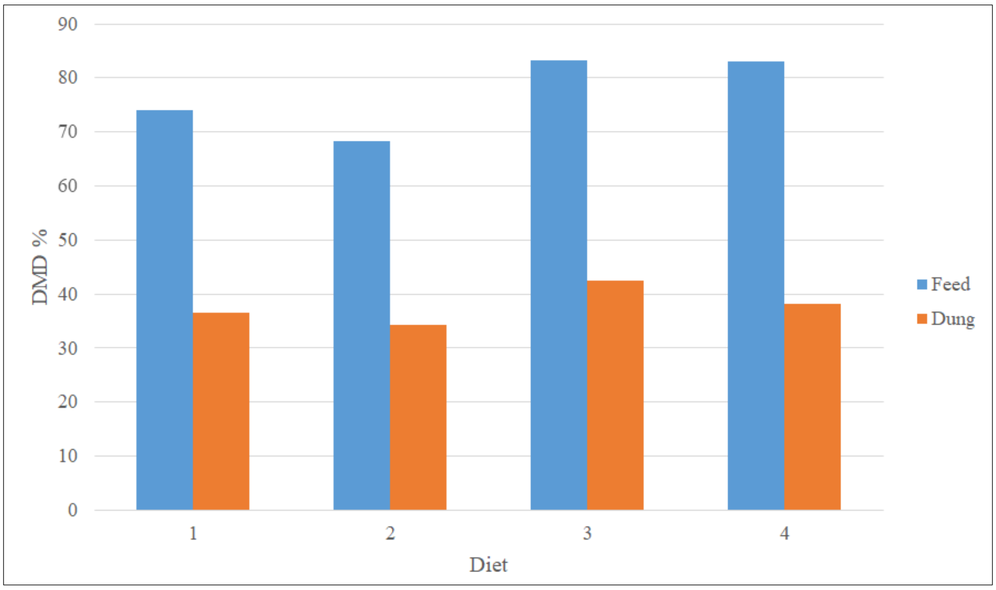

Figure 8: Comparisons of the Invitro DMD of experimental samples and their corresponding dung

The invitro DMD of experimental feeds was significantly ($p < 0.05$) higher than that of the corresponding dung samples as depicted in Figure 8. Feed digestibility ranged from 68.5 to 80.3% while dung digestibility ranged from 32.4 to 42.6%. The reduction in digestibility indicates substantial utilization of digestible nutrients by the animals prior to excretion. Higher feed digestibility is associated with improved nutrient availability, animal performance and feed conversion efficiency. The lower digestibility in dung confirms that the digestive process effectively removed a large proportion of the available nutrients.

CHAPTER 5: CONCLUSION

Multiple additives strategies can substantially improve voluntary intake and digestibility of crop residues hence have a significant impact on animal performance. Overall digestibility of a feed cannot be determined using only one parameter on the feed composition. Digestibility is determined by measuring the amounts of nutrients an animal can absorb versus what is consumed. Various factors like the feed's chemical composition, the animal's characteristics like species, age, gut health physiological status and processing methods can all influence digestibility. Comparing feed and dung digestibility, the difference reflects the extent of nutrient utilization within the animal and serves as an important indicator of feed quality and digestive efficiency. It also provides a useful insight into the effectiveness of feed treatments and nutrient recovery in ruminant production systems.

CHAPTER 6: RECOMMENDATIONS

Smallholder farmers should be encouraged to adopt urea–molasses treatment methods since they are cost-effective, locally adaptable, and significantly improve the nutritive value and palatability of crop residues such as maize stover and peanut shells. Extension services and agricultural colleges should establish hands-on training for farmers on safe handling and application of chemical and biological additives. Demonstrations should focus on proper moisture control, additive ratios, and storage techniques to ensure safety and efficiency. Further research and dissemination should focus on enzyme and microbial inoculant technologies, which have shown potential to sustainably improve digestibility and reduce environmental risks associated with chemical treatments. Integrated additive system such as combining urea with molasses or enzymes with ensiling should be promoted to achieve synergistic effects on fiber degradation and animal performance while minimizing costs. Government and research institutions should support the establishment of residue treatment centers and facilitate the availability of key inputs like urea and molasses at subsidized rates to rural communities.

Treatment practices should comply with environmental safety standards, ensuring proper disposal of chemical residues and promoting eco-friendly biological alternatives to minimize soil and water contamination. Localized studies should be conducted to evaluate the performance of treated residues on different ruminant species under Zimbabwean climatic and socio-economic conditions. These studies should integrate cost-benefit and environmental impact assessments to make the studies conclusive. Although global and regional reviews demonstrate clear potential of additive strategies, location specific evidence is needed for Zimbabwean residues like maize stover from local varieties. There is need to take cognizance of composition, local availability and pricing, for practical protocols that fit labour cycles and farmer preferences. Research should therefore combine controlled digestibility and animal performance trials with on farm demonstrations, participatory cost analyses and safety training modules. Trials that directly compare combinations like urea versus urea + molasses versus enzyme + ensile. If this could be done under Zimbabwean field conditions, then this would be particularly useful to inform extension recommendations.

Index

Index 1: Definition of Terms

Digestibility: Refers to the capacity of a food substance to be effectively broken down by the digestive system and absorbed into the body as nutrients.

Feed Concentrates: Are nutrientdense animal feed opti ons that are low in fiber and high in energy and protein.

Total Mixed Ration:
Is a feeding method used primarily for dairy and beef cattle and involves mixing various ingredients such as forages, grains and proteins into a single balanced diet.

Molasses Based Ensiling: Urea –molasses treatment meant to improve fermentation quality, reduces pH and often increases feed intake and invitro digestibility of crop residues or straws.

Dry Matter Digestibility (DMD): is the proportion of the feed's dry matter that is digested and absorbed by an animal indicating the energy available for use.

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Ethical Considerations

All animal handling and experimental procedures complied with institutional and national ethical standards for the care and use of animals in research. Appropriate welfare measures, including proper feeding, housing, and humane handling, was observed throughout the study.

Abbreviations

ADF – Acid Detergent Fibre
NDF – Neutral Detergent Fibre
CP –Crude Fibre
TMR – Total Mixed Ration
HCl – Hydrochloric acid
H_2SO_4 – Sulphuric acid
HNO_3- Nitric acid
DMD – Dry Matter Digestibility
CO_2 – Carbon Dioxide
Wt/Vol – Weight per volume
Vol/Vol – Volume per volume
DM – Dry Matter
$KMnO_4$ – Potassium permanganate
$AgSO_4$ – Silver Sulphate
$AgNO_3$ – Silver Nitrate

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