THE ROLE OF CROP RESIDUES AS LIVESTOCK FEED RESOURCES IN SEMI-ARID AREAS OF ADAMI TULU DISTRICT, ETHIOPIA

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a degree in any other university.

---------------------------------- 4th June 1999

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This thesis has been submitted with our approval as university supervisors.

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DEDICATION

This work is dedicated to my wife Mrs. Bezawork Asrat who endured the burden of loneliness and wisely took care of our children and all our possessions while I was away for this study.

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ABSTRACT

The study was conducted in Adami-tulu district of Ethiopia, using structured questionnaire, to investigate the extent of crop residue production, utilization and socio-economic limitations facing their utilization for livestock feeding. Chemical composition, intake and digestibility studies were also undertaken for three crop residues, namely, maize stover, teff straw and haricot bean haulms that are abundantly produced in the area.

The results indicated that a significant amount of crop residue is annually generated from the production of maize, haricot bean, teff, wheat, sorghum and barley, all of which are used, though to a variable extent, for livestock feeding. Alternative uses of the crop residues and their leftovers include construction, firewood, fertilizer and sale. Although crop residues are badly required, both for livestock feeding and for other purposes, there is unavoidable wastage as a result of inability to collect them mainly because of lack of transportation, labour and associated financial constraints. Other contributing factors to crop residue wastage include storage problems, improper mode of utilization (e.g. *in situ* for maize and sorghum stovers) and lack of know-how as to the feeding value of some residues such as haricot bean haulms.

Chemical analyses of the three by-products studied indicated that the by-products have low nitrogen content ranging from 3.6 to 5.5% and are composed of cell wall components with little soluble cell contents. Despite such indications of the poor nutritional quality of the crop residues, none of the sampled households were found to use any improvement strategies such as physical or chemical treatment and concentrate or legume supplementation. The major bottlenecks for such practices were shortage of labour, finance, and lack of know-how about and accessibility to the methods.

The voluntary dry matter intakes by bulls fed on maize stover, teff straw and haricot bean haulms were 2.9, 4.3 and 3.9 kg DM/day, or 1.4, 2.0 and 1.8 kg/100 kg live weight, respectively. Generally, the intake values of maize stover were significantly lower ($P<0.05$) than that of the other two by-products. Crude protein intake was the highest for animals fed teff straw. There was no relationship between live weight of animals and the type of residues consumed. Digestibility study indicated that maize stover was more digestible than the other two residues. The apparent DM digestibility coefficients were 54.5, 50.5 and 53.0% and that of OM were 59.1, 54.4 and 55.0% for maize stover, teff straw and haricot bean haulms, respectively.

Generally, it is concluded that although large amounts of crop residues are produced and are mainly used for livestock feeding, their full and efficient utilization for livestock feeding has been hindered by economic problems and inadequate know-how of the farmers as to the handling and processing of the residues. Training farmers in the best methods of collection, storage and treatment of their crop residues, and in the principles of supplementation are suggested as vital measures that may lead to efficient utilization of these low quality but readily available feed resources. For this to be effective, the role of of government in terms improving the financial capabilities of farmers and their access to improved technologies related to crop residue feeding is of paramount importance.

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CHAPTER ONE

1. INTRODUCTION

1.1 Background information

Ethiopia is situated in the horn of Africa at 3^0 and 15^0 north latitude, and 33^0 and 48^0 east longitude. It is bounded by Eriteria in the north, Sudan in the west, Kenya and Somalia in the south and, Somalia and Djibuti in the east. The total area of the country is 111.1 million hectares. Sixty five percent of the land is classified as lowlands and the remaining 35% as highlands. Climatic zonation and land distribution in the lowlands include arid (64%), semi-arid (21%) and sub-humid (15%) zones. The low lands are home to 12% of the human population and 26% of livestock population (Coppock 1994). The human population of the country is estimated to be 53.3 million with an average annual growth rate of 3% (World Resources Institute 1993). About 85% of the population is engaged in agriculture.

Ethiopia stands first, second and third in Africa in cattle, sheep and goat population, respectively. There were 29 million heads of cattle, 16 million goats, 23 million sheep, 7 million equine and 1 million camels (World Resource Institute 1993). This huge population is likely to be related to the country's large area, high ecological diversity, large human population and, socio-cultural diversification. Livestock production is an important component of the national economy with an overall contribution of about 33% of the gross value of annual agricultural output and 15% of gross domestic product (Coppock 1994). However, this contribution is not proportional to the huge livestock population in the country. This is so because, the development of the livestock sector of the country is very much hampered by various human and natural factors. The major bottlenecks include high incidence of endemic diseases, indiscriminate animal breeding, the inherently low productivity of the indigenous breeds, lack of appropriate extension systems and inability of farmers, both in terms of finance and willingness, to accept improved livestock production systems (Alayu 1987). These problems are further aggravated by the scarcity of livestock feeds both in quantity and quality, especially during the dry seasons.

Under tropical conditions, natural pasture provides the main diet of the ruminant animals. However, it has been shown that animals depending on pasture alone fail to obtain sufficient nutrients to meet their production requirements simply because tropical pastures are capable of meeting only maintenance and moderate level of production at most times of the year (Christensen *et al.* 1973, Glover and Dougall 1961, Musangi 1969, Lawrence *et al.* 1974).

In Ethiopia, natural pastures are not only incapable of meeting the nutritional requirements of animals but also their total area is decreasing from year to year because of the allocation of more and more range and forest areas to crop production to feed the increasing human population. Simultaneously cattle population is also increasing to meet the additional draft power requirements. The net effect of such increased pressure on land would be a decreased area of grazing land per animal, leading to overgrazing, destruction of natural grasslands and forest, and starvation of animals, especially during dry seasons. During such periods, the use of conserved forages and concentrates could alleviate the problem. However, most of the Ethiopian farmers are restrained from such vital practices by financial constraints. Under such circumstances, arable farm by-products (crop residues) play an important role in reducing the dry season feed stress and hence mitigating the otherwise heavy weight losses of animals.

Crop residue may be defined as the sum total of all parts of a crop that remains after the desired portion of the crop has been removed. The processing of crops that leads to generation of crop residues can be carried out at field level, domestic level and at industrial level.

Crop residues are among the most widely available, low-cost feeds for ruminants in the majority of developing countries. These fibrous agricultural by-products constitute an important and often the major feed resources available and utilized by smallholder farmers in tropical livestock feeding systems (Smith 1993). They represent a large, but heterogeneous and diverse supply of supplemental energy for ruminants (Burns 1982). A number of inventories on crop residues, carried out by researchers on a national, regional and global basis (Aregheore and Chimarino 1992, Kossila 1985), have invariably concluded that large amounts of crop residues are available for livestock feeding, supplying over 20% of ruminant energy requirements.

In Ethiopia, information on the annual production of arable farm by-products is not well documented. However, from grain production figures, it is estimated that a total of 13 million tons of crop residues are annually produced in the country (Seyoum and Zinash 1998). Estimates by AACM (1984) indicated that, of the total feed resources available to livestock in the highland farming areas of Ethiopia, cereal crop residues provide 6.5, cereal aftermath grazing 1.8, pulse residues 0.4 and other by-products 0.2 million tons of dry matter.

1.2 Significance of the study

In line with the increasing livestock population in Adami Tulu district and the increasing encroachment of cropping on to the grazing lands, it is likely that crop residues could play a significant role in meeting the feed requirements of livestock in the area, especially during the dry seasons. However, apart from their inevitable production and their importance in providing animal feeds, there is no documentation on the quantity of crop residues that is annually produced in the district, the extent of their utilization and the constraints related to their utilization. Literature on their nutritional value is also scanty, and there is a general ignorance about the use of some of the agricultural by-products. For example, haricot bean haulms is hardly used as livestock feed by farmers in the area.

Investigation of the potential feed resources of an area, their nutritional quality and the socio-economic constraints associated with their improved utilization are major tasks in assessing the need for additional and alternative feeding and identifying means to improve feed resources. In Ethiopia such works, especially studies on the role of crop residues for livestock feeding, are limited to highlands (Daniel 1988, Lulseged and Jamal 1989) where rainfall condition is favourable and a variety of crops are produced. However, arid and semi-arid lowlands such as the Adami Tulu district also deserve equal attention as these areas play a crucial role in the national livestock economy, not to mention that feed problem is even more serious in such areas.

The determination of the quantitative and qualitative contribution of crop residues towards the livestock production in Adami Tulu district is imperative and will form a springboard for future research, and management programs like improvement of the nutritive value of the crop residues and development of appropriate feeding strategies which, in the long run, can lead to better livestock production and, hence, better living standards of the people in the district. It was on the basis of the foregoing that this study was formulated to investigate the role of crop residues as livestock feed in the semi-arid areas of Adami Tulu district of Ethiopia.

1.3 Objectives

The broad objective of this study was to investigate and document the extent of crop residue production, utilization, and the socio-economic and nutritional limitations of the same as livestock feeds in Adami Tulu district. Consequently, recommendations were to be made on the areas that need future research with respect to alleviating constraints and improving the feeding value of crop residues produced in the district. Specific objectives of the study were:

- To asses and document the extent of crop residue production, utilization and the possible limitations facing their use for livestock feeding.

- To determine the chemical composition of the major, i.e. the abundantly produced and extensively used crop residues, namely, maize stover, teff straw and haricot bean haulms in the area.

- To determine the voluntary intake and digestibility of the above-mentioned crop residues.

1.4 Hypothesis

In the study, it was hypothesized that there were no differences in chemical composition, voluntary intake and digestibility of maize stover, teff straw and haricot bean haulms produced in Adami Tulu district.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Production and utilization of crop residues

The quantities of different crop residues produced depend on the total area cultivated, the success of the season's rain fall, crop species as well as other inputs such as fertilizers. With regard to the effects of fertilizers, Lulseged and Jamal (1989) observed significant improvements in straw yield as well as quality due to nitrogen fertilization of wheat. Straw yields of 7900, 8600, 9100, 9200 and 10400 kg/ha were registered for nitrogen application of 0, 46, 69, 92 and 115 kg/ha, respectively. Similarly the authors observed higher straw yields from under-sowing of forage crops to wheat indicating the beneficial effect of such agronomic practices.

On a regional basis within tropical systems, Africa is second to Asia in crop residue production with a total production of 2.2 tons of dry matter per livestock unit of herbivores (Kossila 1985). As shown in Table 2.1, variations in amounts of available crop residues were observed among countries. Kossila attributed these variations to a number of factors including climate, agricultural production systems and land availability. According to the author, most countries in sub-Saharan Africa with a low ratio of crop residues to livestock units have large areas of arid to semi-arid rangelands, large livestock populations and subsequently low production of cereals.

Table 2.1 Crop residue availability to livestock for well-endowed and less well-endowed African countries.

COUNTRIES	tons DM/LSU
well-endowed	
Nigeria	5.2
Ivory coast	7.6
Zaire	7.7
Less well-endowed	
Ethiopia	0.6
Somalia	0.1
Botswana	0.2

Source: *Adapted from Kossila 1985.*

Numerous ways of crop by-product utilization may exist amongst the small-holder farmers. These may have a strong cultural and economic basis and may vary from society to society depending on the type of residue available. The value of crop by-products has long been recognized world-wide in many fields such as agronomy, soil engineering and animal nutrition.

In developing countries, the feeding regimes aim at the use of crop residues and agro-industrial by-products as the principal component of the diet for these are the locally available and relatively cheap resources. In industrialized countries, the contribution of straws rarely exceeds 20 to 40% of the diet, the rest of the ration being cereal grains, highly fertilized grasses and legumes, and oil seed cakes (Preston 1986). Research on the utilization of straw by ruminants in such countries has focused on the role of straws as a roughage supplement in concentrate diets. Preston and Leng (1986) stated that through out the world, the majority of draught animals probably depend on cereal straw or cane tops or a mixture of the two as the better quality feeds tend to be given to the more productive females or young animals or both. Daniel (1988) reported that, under Ethiopian condition, crop residues provide 40 to 50% of the annual livestock feed requirement. On the other hand, Olayiwole and Olorunju (1987) reported that Nigeria's transhumant ruminant livestock located in the Sudan and Sahel zones derive about 18% of their annual dry matter intake from crop residues.

McDowel (1988) stated that African pastoralists are dependent on crop residues from their own small plantings or from crop farms to supplement grazing during dry season. This fact is likely to be true as both the quantity and quality of grazing pastures decline during dry periods thus being unable to meet the energy requirements of animals. Taking northern Nigeria and central district in Botswana, McDowel (1988) showed the deficiencies of grazing to meet the animal's energy needs from December through May and from July through October for the two countries, respectively. This obviously indicates the need for dependence on other feed sources like crop residues to avoid serious weight losses during those periods.

Mixed crop-livestock farming systems exploit the complimentarity between crops and livestock. Livestock provide important inputs to cropping, especially manure and traction. They are often the only source of cash that farmers can use to buy agricultural inputs. In turn, crops provide livestock with feed in the form of residues and by-products which are then converted into valuable products like meat, milk, traction, etc. (ILCA 1992).

Supporting this complementarity, Kossila (1988) stated that the potential use of crop residues as livestock feed is greatest in integrated crop/livestock farming systems. Where crop and livestock production are segregated, most crop residues are wasted or used for non-feed purposes like bedding, mulching, firewood and building material.

In drier environments, there is a conflict between livestock and crop in the use of crop residues (ILCA 1992). Crop residues are required by animals to supply their dry season feeds while they are also vital to crop production (e.g. through increasing soil organic matter and nutrients). In this regard, it is very likely that changes in the way and time farmers harvest their crops and manage the residues offer a number of possibilities for increasing both crop and livestock production. For example, millet crop is harvested selectively (grain picked) so that the nutritious parts (upper sections of stover and the immature panicles and tillers) could be collected, leaving the remainder in the field for incorporation into the soil (ILCA 1992).

Crop residues left in the field provide cover that protect the soil from high temperature (high temperature reduces the activity and population of soil microbes, impairing mineralization and breakdown of any organic matter incorporated into the soil) and wind erosion, and plants from blasting by wind-driven soil particles (ILCA 1992). Their decomposition returns organic matter and nutrients to the soil, boosting yields of subsequent crops. Allison (1973) reported that plant residues added to the soil as mulch exert various physical, chemical and biological effects that are beneficial to plant growth. It increases water infiltration, reduces water evaporation, suppresses weed growth and improves soil fauna's aeration capability by furnishing the fauna with nutrients. He also noted that mulched soils do not suffer compaction due to heavy machinery.

2.2 Nutritive value of crop residues

The nutritional value of crop by-products varies according to a number of factors including cereal species, variety and tannin content, stage of harvest, length of storage, proportion of leaf to stem selected, fertilizer application and soil fertility, irrigation use, plant disease, weathering and maturity (Preston and Leng 1986). Munthali (1987) observed varietal differences in the nutritive value of maize stover. The composites tended to have more CP (8.6 to 8.9%) and yielded higher DM (5864 to 62160 kg/ha) than the hybrid which had only 6 to 6.5% CP and yielded 4748 to 4945 kg DM/ha. Van Soest (1988) stated that the environmental conditions under which the crops are grown and post-harvest storage conditions have a large effect on straw and stover quality. Higher temperatures, for example, increase lignification of the plant cell wall and promote more rapid metabolic activity, which decrease the pool of metabolites in the cell, the net effect being lowered digestibility. Van Soest further noted that exposure of tropical plants to long nights, during which soluble sugars and other highly digestible intermediates are respired, lowers their quality.

Straws and stovers comprise stems, leaf and leaf sheath, each of which has different nutritional quality. Preston and Leng (1986) reported a mean *in vitro* true organic matter digestibility of 70 and 65% for sorghum leaf and sorghum stem, respectively. The lignin as percent of organic matter was 6 and 6.6%, respectively. In this regard, Owen and Aboud (1988) suggested that harvesting, handling and storing systems should minimize the loss of more nutritious leaf and leaf sheath. They stated that delayed harvesting, or relay harvesting in an inter-cropped field would be expected to cause greater loss of leaf and leaf sheath, with a consequent reduction in nutritive value of the crop residues.

2.3 Problems related to crop residue utilization

2.3.1 Collection, transportation and storage problems

In spite of the large quantities of fibrous crop residues being used as animal feeds in many developing countries (Kossila 1988), there are still certain constraints to their efficient utilization. Cereal straws/stovers are commonly seen either left in the crop field or accumulated on the threshing ground which is often far from where animals are kept. This means that either the animals must be brought to the field or the crop residues have to be transported to the animals. The bulky nature of straws/stovers makes it difficult and costly to transport them thus inhibiting their greater and efficient utilization for livestock feeding. On a global basis, Kossila (1985) indicated that if all potentially available crop residues could be utilized for livestock feeding, each herbivore would receive over 9 kg DM and about 17 Mcal metabilizable energy (ME) per day, thus largely covering maintenance requirements. He further stated that, unfortunately, a much lower level of utilization is possible because of the problems of collection, transportation, storage, processing, alternative uses, seasonal availability and, perhaps most importantly, an apparently poor nutritional value.

Owen and Aboud (1988) listed risk of loss due to fire and reduction in nutritive value due to molding, especially under humid conditions, and damage by vermin and insects as the major problems associated with the storage of crop residues. Thairu and Tessema (1987) stated that because of the difficulties of collection, transportation and storage, only a small part of the thousands of tons of crop residues available in the croplands of Kenya are used as feed and when they are used, the efficiency of utilization is very low. Besides the above-mentioned practical problems of using crop residues for livestock feeding, there are also nutritional problems related to their feeding.

2.3.2 Nutritional problems

Preston and Leng (1986) cited the slow rate of and low total digestibility; the rate at which straw particles break down to a size that can leave the rumen; the low propionate fermentation pattern in the rumen, and the negligible content of both fermentable nitrogen and by-pass protein as the primary limitations to production when straws are fed to ruminants. They further stated that, on straw diets, rumen fermentation is limited primarily by the availability of fermentable nitrogen with the result that microbial growth and fiber break down are slow. The final consequence is that feed intake is less than 2% of live weight, the digestibility of the feed is usually less than 40% and the ratio of protein to energy in the products absorbed is low.

According to Meng (1992), the main shortcomings of crop residues, in relation to nutrition and physiology of ruminants, are their low digestibility, low feed intake, low nutrient content and low metabolizable energy efficiency. He stated that the dry matter digestibility of fibrous agricultural residues generally ranges from 35 to 50% so that the amount of available nutrients for ruminant feeding on them is small.

Ruminants, when fed fibrous agricultural residues, generally display a low feed intake due to the low bulk density of fibrous residue that can lead to a reduced rumen turn over rate.

This is primarily due to the high cell wall percentage which leads to a very slow degradation rate and subsequently low extent of degradation in the rumen

Stating that most crop residues are deficient in protein, essential minerals such as sodium, phosphorus and calcium, and are rather fibrous (40 to 45% crude fiber (CF)), Smith (1993) concluded that the consequences of such a profile for ruminants are a low intake (1 to 1.25 kg DM per 100 kg live weight), poor digestibility of the order of 30 to 45%, and a low level of performance. McDowell (1988) gave similar reason for low digestion, low rate of passage and limited intake of crop residues. As an example, he reported a case in which *ad libitum* intake of sorghum stover was 43% less than that of hay. Owen and Aboud (1988) also stated that crop residues are characteristically low not only in nitrogen content but also in metabolizable energy.

2.4 Improvement of the nutritional status of crop residues

Although crop residues are deficient in nutritionally important components mentioned in the preceding sections, there have been several mechanisms used to upgrade their nutritive value. According to Olayiwole and Olorunju (1987), this could be achieved through physical and/or chemical treatment and/or supplementation with concentrate agro-industrial by-products or legumes.

2.4.1 Physical treatment

Physical treatment of crop residues includes processes like grinding, chopping, soaking or wetting, pelleting, gamma irradiation and the use of high-pressure steam. These processes are known to improve intake and digestibility through their different effects on the crop residues. El Hag and Kurdi (1986) stated that grinding of fibrous materials increases the surface area exposed to microbial attack and accelerates the rate of flow of digesta through the gastro-intestinal tract. By feeding sheep either pelleted or ground (unpelleted) bagasse, they found improved palatability, DM intake and digestibility of all proximate components (except CF) at all levels (30, 40 and 50% of the ration DM) of bagasse. On the other hand, Thairu and Tessema (1987) stated that, though physical treatments such as chopping may not increase digestibility, they have advantage of increasing the amount consumed, and decreasing wastage by reducing selection by the animals. Soaking softens the harder crop residues like corn cob so that they are easily eaten by animals thus increasing their intake.

Smith (1993) reported that newer energy consuming methods such as steaming under pressure, gamma irradiation and explosion resulted in 10 to 31% increases in digestion of the treated residues by disrupting cell walls through physico-chemical mechanisms.

2.4.2 Chemical treatment

Chemical treatment involves the treatment of straws/stovers mainly with sodium hydroxide (NaOH) or ammonia (NH_3) or urea. Hofmeyr *et al.* (1981) summarized the action of NaOH on straw as follows:

- It breaks the bonds between lignin and the cellulose and hemicellulose fractions thus leading to improved digestibility through increased solubility of the hemicellulose fraction and through increased availability of cellulose and hemicellulose.

- It hydrolyses acetyl esters resulting in increased digestibility of the fiber fraction.

- It creates swelling of microfibriallae which results in disruption of the crystalline structure of cellulose thus giving rise to increased digestion as well as increased rate of digestion.

Smith (1993) stated that reported effectiveness of chemical treatments in terms of increased digestibility are variable because of several modifying factors like the level of the chemical, moisture content of the residue, temperature and duration of treatment, and plant and animal species. He further expressed that average improvement in digestibility after alkali treatment could generally be as high as 30 to 40%.

Musimba (1980) found that NaOH treatment of maize stover caused a steady increase in dry matter and organic matter digestibility (DMD and OMD) from 48.76% and 50.25% in untreated stover to 68.77% and 70.76% at 8% NaOH treatment, respectively. The D-value of the treated maize stover was also increased by both NaOH and magadi soda treatments compared to the untreated stover. El Hag and Kurdi (1986) also showed that treatment of sorghum straw with 7% NaOH (w/w) generally tended to improve the digestibility of all proximate components thus resulting in an increased total digestible nutrient (TDN) content of the treated straw. The authors concluded that both NaOH and kurkedi (7% NaOH + 1% (w/v) kurkedi solution) improved animal performance beyond that obtained from untreated sorghum straw, which provided only sheep maintenance requirements. On the other hand, Economides (1986) stated that the use of NH_3 has merits over NaOH possibly in that it is safer, although more unpleasant, to handle and also adds non-protein nitrogen to the straw. However, he emphasized that urea is more pleasant than NH_3, is less hazardous to handle and requires no pressure for storage and transportation. Smith *et al.* (1989) observed greater intake of urea treated maize stover by lambs (658, 698 and 583 g DM/day for 3, 5, and 7% urea treatment, respectively) compared to 437 g DM/day for untreated stover. There were also significant differences in digestibilities of DM, OM and acid detergent fiber (ADF) between 0 and 7% urea treatments.

Apart from chemical treatment, biological treatments through composting (bacterial decomposition), ensilage, fungal growth, fermentation and enzyme addition are also stated as the most promising methods of increasing the availability of the energy contained in straws. However, Smith (1993) reported that the improvement in digestibility due to these treatments is usually associated with some loss of DM or OM because, many organisms, particularly fungi, in addition to attacking lignin, also have well developed cellulase and hemicellulase activities.

It is worth mentioning that all the methods of crop residue treatment reviewed above often result only in increased intake and digestibility of materials that are usually inherently deficient and/or unbalanced in factors required for efficient fermentative digestion and for the efficient utilization of fermentative products by the rumen. In this regard, in addition to expansion of the feed base, Smith (1993) suggested improvement of the quality of feed resources and of feeding systems through better nutrient balance as strategies that could be adopted to increase both the quantity and quality of feeds available in order to improve livestock productivity. It is, therefore, necessary to complement this improvement in digestibility with the supply of nutrients that will correct imbalances in the crop residues. This could best be done by concentrate and/or legume supplementation.

2.4.3 Upgrading crop residues through supplementation

As it has been mentioned in the preceding sections, crop residues are deficient in nutritionally essential components, especially protein and energy, and hence, provide no more than maintenance ration unless they are supplemented with these essential components. When the diet is based on crop residues, the rate of degradation is of paramount importance as it is the rate of degradation of fiber that eventually limits feed intake and therefore animal productivity. The first supplement to be considered should be a source of soluble nitrogen (usually urea or ammonia) to raise the level of rumen ammonia above 150 mg per liter of rumen fluid as the generally recommended level (50 mg per liter) for maximizing microbial growth appears to be too low in terms of optimizing the rate of degradation of fibrous substrate (Preston and Leng 1986).

In investigating the effects of supplementation of tef straw with urea, molasses, molasses-urea, noug cake and legume hay on the intake and digestibility of the teff straw by sheep, Nuwanyakpa and Butterworth (1987) found the advantages of supplementation in that, the addition of urea at 0.7% to the air-dry weight of teff straw significantly increased nitrogen digestibility and rumen ammonia concentration, and it increased straw intake, apparent DM digestibility and neutral detergent fiber (NDF) digestibility by 3.7, 8.3 and 7.3% respectively, over the teff straw alone. Response of sheep to nitrogen (urea) supplementation was greater than to energy (molasses) supplementation, indicating that the nitrogen deficiency in cereal crop residues is a greater cause of poor animal performance than energy deficiency. Olayiwole and Olorunju (1987) found that supplementation of sorghum stover with either urea-molasses (1% molasses + 0.5% urea) or a limited amount of oil cake (0.45

kg groundnut cake) could support live weight maintenance and some productivity of steers during the dry season when range land is dry, bare and burnt.

As an alternative to concentrate supplements, the current emphasis is on the use of forage legumes. A legume, if used in a crop rotation system, plays two important roles: it fixes nitrogen which can be used by a subsequent crop and provides a fodder supplement that supplies soluble nitrogen, other nutrients for the rumen microbes, readily fermentable cellulose and bypass protein.

Kassu Yilala (1989) and Thairu and Tessema (1987) suggested the use of cheaper, preferably home-grown supplements such as *Leucaena leucocephala*, pigeon pea, *Sesbania*, cassava leaves and sweat potato leaves and vines to enhance the nutritional value of crop residues. Dzowela (1987) also suggested the incorporation of tropical forages in the maize cropping systems as the most logical way of alleviating the protein deficiency in animals fed on maize stover. After the maize ears have been removed, the forage legume component, especially the climbing types, could make an important contribution to maintaining adequate protein levels in the maize stover-based diets. The forage legume component increases the protein content above the 7% threshold thereby promoting increased intake of the stover.

In addition to the above mentioned mechanisms of enhancing the nutritional value of crop residues, some authors (e.g. Nordblom 1988) suggested the possibility of improving straw values through breeding and selection of plant cultivars which produce both good grain yields and more digestible crop residues. However, information regarding this approach is scanty.

2.5 Limitations to upgrading the nutritional value of crop residues

Apart from the potential benefits of the above-mentioned methods of upgrading the nutritive value of crop residues, many authors have reservations on the actual applicability of the methods to small scale-farmers. Owen and Aboud (1988) regarded upgrading of straws for feed as inappropriate for developing countries, especially for small-scale farmers, because it is expensive and needs technical expertise. Under Kenyan condition, Thairu and Tessema (1987) stated that the conventional energy and protein feeds such as grains and oil seed cakes (as a means of improving the utilization of low quality roughage) are not only unavailable but also too expensive for the small-scale farmer.

Smith (1993) stated that, though many of the treatment methods improve the consumption and digestibility of crop residues, only a few are suitable for target system under consideration. The most efficient methods, for example, NaOH treatment, are also unsuitable because of the non-availability of the chemical, health risks and costs of additional labour. He suggested that greater efforts should be made to exploit the demonstrated effectiveness of alkalis using resources available to the farmer. These include wood, oilpalm bunch, and cocoa pod ashes. From available evidences, the author concluded that these ashes are as effective as equimolar concentration of NaOH solution, with an added advantage of availability.

On the other hand, Preston and Leng (1987) showed that upgrading of the nutritional value of straws by ammoniation (urea ensiling) is more likely to be economically justifiable for lactating animals than for animals in other physiological states as, in most cases, the sale value of the extra milk produced would more than cover the cost of processing the straw.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location and climate

This study was carried out at two agricultural development sites, namely, Zeway-zurea (site I) and Abossa (site II) in Adami Tulu district, located in the middle rift valley of Ethiopia about 160 km south of Addis Ababa along the Addis Ababa-Moyale high way. The two sites were selected for the purpose of widening the area coverage of the study site; otherwise, they were treated as one site in all the analyses.

Adami Tulu district is a semi-arid area characterized by a long dry season and an erratic rainfall. Meteorological data for the last 15 years (1981 to 1996) indicate a mean annual rainfall of 763.7 mm with a range of 531.6 to 1023 mm. Most of the rains fall during the months of June through September. The mean annual maximum and minimum temperatures are 27.2^{0}C and 12.7^{0}C, with ranges of 26.5 to 28^{0}C and 9.5 to 13.7^{0}C, respectively (Adami Tulu Research Center Meteorology Station, Personal communication).

3.1.2 Topography and soils

According to the 1993 report of the Adami Tulu District Agricultural Development Office (ATDADO), the district covers an area of 55,783 ha of which flat plains comprise 35%, sloppy areas 62% and mountains the remaining 3%. The altitude of the area ranges from

1600 to 1650 meters above sea level. The soils are black, grey and brown comprising 13, 65 and 22%, respectively.

3.1.3 Human and livestock population

The human population of the district is estimated at 73,227 with an average family size of 7.9 (ATDADO, personal communication). The livelihood of the people is, almost exclusively, dependent on both livestock and crop production. The livestock population, according to the ATDADO, is 77,186 cattle, 20,476 goats, 3,380 sheep and 7,078 equine. This would mean an average herd size of about 10 cattle, 3 goats and less than one sheep and equine per household unit. Traditionally cattle are kept primarily to meet domestic milk needs, draught power and customary requirements such as payment of bride price. Small ruminants are important sources of cash income besides providing the family with meat, especially during festivals.

3.1.4 Agriculture and land use

Of the total area of the district, farm land (cultivated and cultivable land) comprises about 54.6%, grazing land 20.1%, and forest and bushes 9.9%, the balance being unusable and waste (mountainous, rocky and marshy) land. The major crops grown in the area are maize, haricot bean, and teff. According to 1996/97 cropping season, the annual area coverage of these crops was about 56, 23 and 10% of the total area under cultivation, respectively. The remaining percentage is covered by wheat, sorghum, pepper, and to a lesser extent, barley and pulses (ATDADO, personal communication).

Although the grazing land covers only 20% of the total area of the district, natural pastures constitute the major livestock feed resource in the area, particularly during the wet seasons. In dry seasons, however, the quantity and quality of the natural pastures deteriorate so that the energy requirements of animals are hardly met. Consequently, crop residues and crop aftermath play a significant role in minimizing heavy weight losses of animals during such periods. In addition to their attempt to survive on feed resources produced in their own locality, the people also migrate, with some classes of their animals, to distant places in search of feed and water.

3.2 Assessment of crop residue production, utilization and constraints

Information regarding crop residue production, utilization and constraints were retrieved by interviewing sampled households in the study sites using structured questionnaire.

3.2.1 Sampling and data collection

Stratified systematic sampling procedure was employed whereby total households in the selected study sites were stratified into four strata according to their farm size, and a proportional number of households were systematically selected from each stratum. The four strata were:

- Those households owning one or less ha of farm land
- Those households owning 1.1 to 2.0 ha of farm land
- Those households owning 2.1 to 3 ha of farm land
- Those households owning greater than 3 ha of farm land.

Due to resource and time constraints, only a total of 100 households were included in this study. The questionnaire (Appendix 1) was constructed to enable the collection of the following basic data:

- Livestock type and number
- Current size of farm and grazing land
- Crops grown and their yield
- Livestock feed resources and feeding practices
- Different uses of crop residue and constraints to their use, etc.

3.2.2 Estimation of the potential annual crop residue production

Figures of grain yields during the 1995/96 and 1996/97 cropping season were obtained, for each crop type and from all sampled households, through interview. The grain yield figures were then converted to crop residue yields using 3, 2 and 1.5 as multipliers for maize, wheat and barley, respectively, as recommended by Kossila (1988). For teff straw and haricot bean, there was no information on the ratio of their grain to their residue yields. As a result, their grain to residue ratios were determined and found to be 1:3 and 1:1 for teff and haricot bean, respectively. This was then used in estimating their respective residue yields.

3.3 Chemical analysis

As per the second objective, chemical analyses were carried out for maize stover, teff straw and haricot bean haulms. For each of these residues ten samples were randomly collected from ten different households at times of feeding. Samples of the residues used in the determination of intake and digestibility were also included as the eleventh sample. The samples were ground in Willey mill to pass through a 1 mm screen and packed air tightly in a plastic bag until they were analyzed in the laboratory within the Range Management Department, University of Nairobi, Kenya. The analyses undertaken were: DM, Ash, CP, NDF, ADF, Acid Detergent Lignin (ADL), *In vitro* DM and OM Digestibility (IVDMD and IVOMD).

DM and total ash were analyzed according to the conventional methods given by AOAC (1970). Percent nitrogen in the samples was determined by the micro-Kjeldhal technique and the result was converted to CP percent by multiplying by a factor 6.25. The cell wall constituents of the samples were determined by procedures described by Georing and Van Soest (1979).

In vitro DM and OM digestibilities were determined by the two-stage technique as described by Tilley and Terry (1963). Due to lack of laboratory facilities, it was not possible to determine the calorific value of the by-products. As a result, the digestible and metabolizable energies (DE and ME) of the feeds were estimated using the following equation (Butterworth 1964):

$$\mathbf{y = 0.219 + 0.0418x}$$

$$\mathbf{ME = 0.83DE}$$

Where, y = DE in kcal/gm DM and

x = Digestibility coefficient of the DM

3.4 Determination of voluntary intake and *in vivo* digestibility

This part of the study was conducted at Adami Tulu research center, which is found in the district. As was stated in the objectives, both intake and digestibility were determined only for the three major residues, namely, maize stover, tef straw and haricot bean haulms.

3.4.1 Experimental animals

Nine Boran bulls, 2 to 2.5 years old and ranging from 140 to 300 kg live weight were used to determine the voluntary intake and digestibility of the 3 major crop residues mentioned above. The animals were drenched and sprayed against parasites before the start of the experiment.

3.4.2 Description of the experimental feeds

Maize stover comprises the stalks, leaves and husks of maize crop after the ears are removed upon maturation. In this experiment, the stover was manually chopped into about 10.0 cm particles to ease consumption and reduce selection by the animals.

Teff (*Eragrostis tef*) is a C_4, self-pollinated annual crop accounting for about two-thirds of the daily protein intake in the diet of the Ethiopian population (Seyfu 1993). Teff straw is the whole of what is left behind after the harvested crop is threshed and the grain is cleaned and separated. Cattle prefer teff straw to any other cereal straw.

Haricot bean (*Phasealus vulgaris*), also known in different countries as field beans, kidney beans, runner bean, etc., is the best known and most widely cultivated species of *phaseolus*.

There are many varieties, sizes, and colors of haricot bean. After harvesting, seeds of haricot bean are threshed out of pods. The pods with leaves and tender stems are left behind as a by-product, which is commonly known as haricot bean haulms.

3.4.3 Experimental design and feeding of the animals

The animals were divided into three weight groups, namely, light (140 to 198 kg), medium (199 to 250 kg) and heavy (251 to 300 kg). Then each group was individually fed on the three crop residues in a 3x3 factorial experiment for 7-days adaptation and 7-days collection periods. The residues were given as a sole diet to the animals twice daily- half of the daily feed allowance at 08:00 and the remaining half at 18:00 hours. The animals were fed *ad libitum* with 20 to 25% refusals. Water was given *ad libitum* and mineral licks were also provided.

3.4.4 Sample collection

Sample of each feed, i. e. maize stover, teff straw and haricot bean haulms offered to the animals was taken daily and bulked in separate sacks throughout the experimental period. On the last day of the experiment, the composite sample was sub-sampled such that from each bulk sample about 300 gm of a representative sample was obtained. Feed refusals were daily collected, weighed, sampled and bulked, for each animal and feed type separately, over the feeding periods. The bulked sample from each animal was sub-sampled as described earlier for feeds offered.

Total collection of faeces was carried out. The daily faeces of each animal were collected in a plastic bucket with a tight lid. The faeces collected over the 24 hours were weighed at

08:00 hours, mixed thoroughly and a 10% sample was bulked daily for each animal separately over the collection period. All faecal samples were kept in a deep freezer at -5°c until the end of the experiment after which the bulked samples were thoroughly mixed and sub-samples taken and dried at 65°C for 48 hours. in a forced draught oven. At the end of the experiment, all the feed and faecal samples were ground in a Willey mill to pass through a 1 mm sieve and placed individually in well labeled plastic bags until they were analyzed as described in section 3.3 above.

3.5 Statistical analysis

Data collected through questionnaire were analyzed using the SPSS (Statistical Package for Social Sciences) software programme. Descriptive statistics (frequency distribution and tabulations) were employed to describe the different parameters. All other data were subjected to the analysis of variance (ANOVA) according to the standard procedures outlined by Steel and Torrie (1980). Means were compared using the Least Significant Difference (LSD).

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Crop residue production, utilization and constraints

4.1.1 Crop residue production

The types of crops and the estimated amount of their residues produced in the study area during the 1995/96 and 1996/97 cropping seasons are given in Table 4.1. As can be seen from the table, the allocation of cultivated land to the different crops is not constant every year. However, in both years, maize, followed by haricot bean and teff, occupied the largest area. As a result, maize stover, teff straw and haricot bean haulms were abundantly produced, their respective estimated total annual production being 197.8, 25.8 and 21.7 tons dry matter (DM) for the year 1995/96, and 336.7, 48.8 and 36.9 tons DM for the year 1996/97. The higher total crop residue production in the year 1996/97 compared to the year 1995/96 was attributed to the higher annual rainfall during that year which favoured both the crop and their residue production. All in all, a total of about 477.2 tons DM of residues were produced by the sampled households in the year 1996/97 compared to the 271.5 tons in 1995/96.

Taking the average of the two years, and assuming an average effective use of 60%, the annual crop residue production by the sampled households was estimated at 0.8 tons DM per Tropical Livestock Unit (TLU). For the whole country, Kossila (1985) reported an annual production of 0.6 ton DM per TLU. The figure in the current study, however, seems to have been exaggerated, since: (1) the grain yield data were purely based on farmers' estimation which might have been over-estimated, (2) there could be problem of recall as farmers might have forgotten the figures from the 1995 to 1997, (3) there was unavoidable wastage during collection and feeding and, (4) the residues were also used for purposes other than animal feed (e.g. construction and firewood). Moreover, it was possible that most of the sampled households could be those who had fewer animals as sampling was based only on farm size. It can not be concluded, therefore, that all the potential production was used for livestock feeding. These production figures are, nevertheless, useful because they indicate the types and amounts of crop residues that can be produced in the district.

Table 4.1 Area cropped (ha) and estimated crop residue production (tons DM) in the study area.

Crop type	1995/96		1996/97	
	Area[1]	Residue[2] Production	Area	Residue Production
Maize	111.9 (100)	197.8	115.3 (100)	336.7
Tef	31.7 (67)	25.8	34.2 (74)	48.8
H. bean	39.4 (79)	21.7	38.4 (78)	36.9
Wheat	12.9 (36)	12.8	17.1 (42)	27.5
Sorghum	3.8 (14)	5.0	3.9 (17)	13.2
Barley	8.8 (30)	8.5	10.0 (33)	14.0
TOTAL	208.4	271.5	218.9	477.2

[1] *Figures in parenthesis are percentage of households who grew the particular crop*
[2] *Calculated on the basis of 94% DM*

4.1.2 Crop residues and their leftover utilization

The different types of crop residues produced in the study area are put to different uses such as animal feeding, construction and firewood (Table 4.2). From the table, it is evident that all the available types of residues are used for livestock (mostly for cattle) feeding. Only maize and sorghum stovers were used as fuel mainly because of their woody nature. Their woody stems also made them utilizable for construction of house walls and roofs, and grain storage barrels. The role of teff straw, and in rare cases, wheat straw in construction consists in their use, together with mud, as binding materials for walls of local houses and barrels. Second to cattle feeding, wheat and barley straws are used as a filling material in making local mattresses. As indicated by the interviewed households, wheat straw is, relatively, less used for livestock feeding because of the health problem that it causes. Ninety five percent of the households growing wheat expressed that wheat straw is poor in feeding value and causes health problem to cattle, especially when fed in wet seasons. However, scientific reasoning for this is not available, except that Mcdonald *et al.*(1995) reported it to be so poor in nutritional value (unless alkali treated) that its usage as a feed for farm animals is not recommended.

Table 4.2 Crop by-product utilization by the households

Residue type[1]	Crop by-product usage[2]					Total No. of uses out of 5	Relative importance value (%)[3]
	Animal feed	Const-ruction	Fuel	Sale	Mattress making		
MS	69	96	95	3	--	4	80
TS	86	34	--	6	--	3	60
HBH	88	--	--	--	--	1	20
WS	44	52	--	10	9	4	80
SS	63	61	50	--	--	3	60
BS	58	--	--	10	7	3	60
No. of residues used	**6**	**4**	**2**	**4**	**2**		

[1] *MS = Maize stover, TS = Teff straw, HBH = Haricot bean haulms, WS = Wheat straw, SS = Sorghum stover, BS = Barley straw*
[2] *Numbers under each usage indicate percentage of households using the crop residue for that t use*
[3] *Total No. of uses of the residue as percent of overall number of uses*

Although crop residues are important feed resources, livestock compete with many other uses such as construction and fuel. This survey revealed that, except haricot bean haulms, all other residues have more than two uses with a relative importance value of more than 60%. It appeared that, because of the acute feed shortage in the area, farmers were forced to use the highest proportion of all types of their crop by-products for livestock feeding rather than for any other uses. The importance of haricot bean in the farming system can be derived from the fact that it is grown on a large area of land next to maize. However, the relative importance of its residue happened to be the lowest as it is solely used for livestock feeding.

Crop residue leftover means that portion of the crop residue which is left behind after animals have selectively fed on it. Depending on the residue type, such leftovers may or may not exist, and if it exists, it may or may not be put to some uses (Table 4.3). As indicated in the table, no crop residue is completely consumed by animals without leaving some amount of leftover behind. The existence of leftovers of maize and sorghum stovers was reported by almost all the interviewed households. This is likely to be due to the hard and stemy nature of these residues as a result of which animals could not eat them comfortably. In this regard, physical treatment of such residues, either to reduce their size (e.g. by chopping) or to soften them (e.g. by soaking or wetting) is of paramount importance as it reduces the problem thus leading to efficient utilization of the residues. The fact that about two third (63%) of the respondents stated the absence of teff straw leftover agrees with a report by Seyfu (1993) who observed teff straw to be the most preferred crop by-product by animals.

Table 4.3 Percentage of households who reported the presence or absence of leftover (L/o) of crop residues

Residue type	Percent of households who reported:		
	L/o present and used	L/o present but not used	L/o not present
MS	98	--	2
TS	37	--	63
HBH	52	32	16
WS	48	42	10
SS	97	3	--
BS	48	10	42

Percentage distribution of households according to utilization of leftovers from their crop residues is given in Table 4.4. The highest proportion of households (95 and 81% for maize and sorghum stovers, respectively) stated that the leftover from these residues are used primarily for firewood. Practically leftovers of all the crop residues are used as fertilizers by spreading them on crop fields and/or pasture land. Sixty eight percent of the respondents indicated that leftover from teff straw is used in construction of local houses to make the mud stick to the walls. Leftovers from wheat and barley straws are used for making mattresses after proper drying and removal of any manure or soil.

Table 4.4 Distribution of households according to utilization of crop residue leftovers

Residue type	Percent of households using L/o for:				
	Firewood	Fertilizer	Re-feeding	Construction	Others[1]
MS	95	2	3	--	--
TS	--	17	15	68	--
HBH	--	100	--	--	--
WS	--	70	--	--	30
BS	--	33	--	--	67
SS	81	7	--	12	--

[1] *Making mattresses*

4.1.3 constraints to crop residue utilization

The major problems associated with crop residue utilization for livestock feeding are collection, transportation, storage and feeding problems. Table 4.5 shows the percentage of households who reported to have these problems.

Table 4.5 Distribution of households (h/hs) according to problems associated with each crop residue

Residue type	Percent of households having:		
	Coll. & trans. problem	Storage problem	Feeding problem
MS	98	75	81
HBH	88	71	2
TS	73	33	5
WS	77	73	81
BS	73	59	0
SS	100	60	87

4.1.3.1 Collection, transportation and their problems

For a crop residue to be used efficiently it has to be transported from the crop fields or from the threshing ground to homesteads. In the study area, more than 70% of the sampled households stated that they had problems in collecting and transporting all their crops and crop residues from the field to homesteads (Table 4.5). The major problems, as summarized in Table 4.6, were labour, capital, lack of donkey and donkey cart, and distance. Forty percent of the sampled households were identified as having no donkey and donkey cart and 35% as having labour and financial constraints to transport their crop residues. As a result, only 33% of the respondents were able to collect their maize and sorghum stovers. However, almost all the respondents collect the by-products of the other crops mainly because the nature of the crops demands them to harvest, transport and thresh them near their houses. Nevertheless, in some cases, it was observed that the residues of such crops were left on the threshing ground whereby they were trampled and spoiled by animals. This was especially true for haricot bean haulms for which some farmers revealed that transportation and storage were not their routine practices. Distance from the field to homesteads was a problem of a few (12%) farmers. According to estimates by the respondents, the maximum distance reported was about 5 km.

Table 4.6 Distribution of households according to the major types of constraints to crop residue collection and transportation.

Type of constraint	% of h/hs having the problem
Labour shortage	23
Financial problem	12
Lack of donkey & its cart	40
Distance	12
Trans. not accustomed or needed	13

Regarding the means of transporting crops and crop residues from the field to homesteads, it was found that about 52% of the sampled households hire donkey and donkey carts, 4% borrow the same whereas the remaining 44% have their own donkey and donkey cart. The consequence of lack of this means of transportation by the majority of households is that most of the crop residues are wasted as some of the farmers are also unable to hire donkeys and donkey carts. Out of about 90% of the households who reported to have had wastage of maize and sorghum stovers, 91 and 84% respectively, attributed the wastage to their inability to collect the residues (Table 4.7). For all other types of residues, improper storage was reported to have been the major cause of wastage. Besides, certain proportions of crop residues such as wheat straw, haricot bean haulms and sorghum stover are also wasted as these residues are not needed by some farmers for livestock feeding.

With regard to crop residue wastage, Sibanda (1986) reported that farmers who do not collect their stover, but leave it in the field, could possibly lose half of its value through trampling by animals. In the present study, though it was not possible to estimate the actual loss of crop by-products due to various factors, the loss, particularly of maize and sorghum stovers, could be very high as most of the farmers were not able to collect these residues but used them *in situ.*

Table 4.7 Distribution of households according to causes of crop residue wastage

Residue type	% of h/hs whose wastage cause was:		
	Inability to collect	Improper storage	Residue not needed
MS	91	8	1
HBH	39	53	8
TS	15	85	--
WS	13	48	39
BS	11	86	3
SS	84	6	10

The average cost of transporting crop residues from a hectare of land, as estimated by the respondents, is about 34 Ethiopian Birr (ETB) with a range of 10 to 80 ETB, depending on the distance of transportation and whether the season is peak or slack with respect to cropping activities.

4.1.3.2 Storage and its problems

Storage of crop residues is undertaken either by stacking it in the open air near homesteads or in shelters. In the former case a fence may be constructed around the stack to protect it from damage by roaming animals. The majority of the sampled households, 64 and 81% for maize and sorghum stovers respectively, do not store these residues (Table 4.8). They rather prefer to feed them *in situ* (Table 4.9) as storage demands transportation of the residue from the field to the storage site which is usually near homesteads. In all other crop by-products, stacking in the open air near homesteads was found to be the dominant method of storage as evidenced by the proportion of households employing the method.

Table 4.8 Distribution of households according to the method they use to store their crop residues

Residue type	Percent of households who:		
	Stack outside	Stack in shelter	Do not Store at all
MS	28	8	64
HBH	47	6	47
TS	88	12	--
WS	58	5	37
BS	87	11	2
SS	12	7	81

As shown in Table 4.5, storage comes as the second most important problem, next to transportation, facing efficient utilization of crop residues. This problem was observed in as few as 33 and as many as 75% of the households for teff straw and maize stover, respectively. The major storage problems reported were decay due to moisture conditions and attack by termites. Generally the former plays an important role accounting for most of the storage problems of almost all types of crop residues. This is likely because most of the residues stacked in the open air are exposed to moist conditions.

4.1.3.3 Feeding and its problems

Practically all farmers use all the types of crop residues for feeding cattle rather than small ruminants. Crop residues are grazed either *in situ* or they may be harvested and piled near homesteads whereby the animals are allowed to feed from the stacks or given in small quantities in the morning and evening. About 66% of the respondents (Table 4.9) pointed out that they graze their animals on maize and sorghum stovers *in situ* after the ears are removed. This is in agreement with the work of Kabatange and Kitalyi (1989) in which, for 61% of the respondents, they found grazing in the crop fields after grain harvest to be the most common method of availing crop residues to livestock. All other crop residues were mostly stacked near homesteads after threshing and fed in stall. As can be seen from the table, some respondents stated that they also allow their animals to feed on the crop residues like haricot bean haulms, wheat straw, sorghum stover and barley straw directly from threshing grounds.

Problems associated with feeding of crop residues result mainly from improper feeding practices, or are caused by the physical nature of the residues. Both *in situ* grazing and feeding from threshing grounds are regarded as improper feeding practices in the sense that they result in inefficient utilization of the residues as a result of the trampling effect of animals, and the spoilage by their dung and urine. In investigating the role of crop residues in intensive smallholder system in the tropics, Smith (1993) reported that when left on the field, crop residues rapidly deteriorate, and a large amount is usually trampled upon and wasted. In addition, the nutrient imbalance that characterizes these fibrous residues is not corrected by appropriate supplementation.

Table 4.9 Percentage of households employing different strategies of feeding crop residues

Residue type	Percent of households:			
	Employing *in situ*	Employing stall feeding	Feeding from threshing ground	Not using at all
MS	67	33	--	--
HBH	--	54	43	3
TS	--	100	--	--
WS	--	57	16	27
BS	--	97	3	--
SS	66	17	17	--

The physical nature of residues as a feeding problem is evident mostly in maize and sorghum stovers. These residues are hard and stemy so that, animals prefer the finer parts thus causing significant losses of the residues. About 98% of the respondents reported the prevalence of this feeding problem for maize and sorghum stovers. Another crop residue reported to have a feeding problem is wheat straw. According to the farmers' belief, it causes animal health disorders when fed, especially during the wet seasons. This is the reason why 27% of the respondents stated that they do not use this residue for livestock feeding (Table 4.9).

In addition to the above-mentioned constraints, crop residues have also nutritional problems limiting their efficient utilization for livestock feeding. All farmers knew that crop residues are poor in their nutritve value; however, almost none of them treated their residues, either physically or chemically, (except the inevitable threshing of cereals like teff, barley, wheat and haricot bean), or used supplementary feeds to amend the feeding values of their crop residues. Only 19 and 8% of the households revealed that they chop and thresh their maize stover, respectively, compared with 5 and 3% in the case of sorghum stover.

4.1.4 Constraints to improving the nutritional quality of crop residue

Regarding the constraints farmers face in treating their crop residues and in using supplements to improve the nutritional status of crop residues, the first major ones were labour for physical treatment, and lack of know-how for all other improvement strategies (Table 4.10). The other major constraints were lack of finance for physical treatment and inaccessibility for chemical treatment and concentrate supplementation. Planting leguminous plants such as *leucaena* and *sesbania* species to be used as supplements in crop residue feeding systems was the only improvement strategy constrained by the scarcity of land. The farm size distribution in the study sites indicated that about 60% of the sampled households own 2 and less hectares of cropping land. This is hardly enough to grow subsistence crops let alone forage plants for supplementing crop residues.

Table 4.10 Percentage of households facing constraints in using methods of improving the nutritional status of crop residues.

Constraint	Percent of h/hs facing constraints to use:			
	Physical treatment	Chemical treatment	Concentrate supplement	Legume supplement
Finance	26	1	1	--
Labour	73	--	--	--
Access	--	14	46	4
Know-how	1	85	53	69
Land	--	--	--	27

With regard to crop residue treatment, Smith (1993) listed chopping, grinding, ensiling with urea or animal manure, and ammoniation using urea as the most appropriate methods of improving the feed value of crop residues at the small-holder level. This study, however, revealed that under current condition where farmers are constrained by lack of finance and know-how, none of these methods were applied. This aspect of crop residue utilization needs strengthening of the farmers both financially and educationally through strong extension services and credit systems.

4.1.5 Livestock feed situation in the study area

4.1.5.1 Livestock feed resources

Animals in the study area derive their feed from grazing, crop residues, weeds, crop thinning, and browse trees at different times of the year. Crop residues and crop aftermath, pods and leaves of browse trees like *Acacia, Balanites* and *Zizyphus* species are mostly used during the dry season starting from October to March. Grazing becomes an important feed source shortly after rains of April and June. Together with weeds and crop thinning, grazing lasts up to the end of September. However, due to the long dry season and the scarcity of grazing land, livestock feed shortage is prevalent in the study area and in the district as a whole. Forty two percent of the sampled households had an average of 0.1 to 0.8 ha private grazing land. Communal grazing land varied from 20 ha for the second site to 40 ha for the first site. From this, one can easily conclude that there is an acute shortage of grazing land and hence, feed problem in the areas.

4.1.5.2 Measures taken to overcome feed shortages

The major measures taken by households to overcome the livestock feed problems in the area include moving animals during certain times of the year to better places within or out of the district, getting additional feeds through different means, using reserve feeds and selling surplus animals. Sixty percent of the sampled households considered livestock movement as their prime measure whereas, 15% resorted to getting of additional feeds of some sort from elsewhere through either purchase or gift or borrowing. According to estimation by the respondents, one household expends 20 to 400 Ethiopian Birr (ETB), an average of 107 ETB, per annum to get an additional feed for his animals. With regard to livestock movement, all other classes of cattle except lactating cows and draught oxen are moved in most cases. The respondents stated that, on average, they travel up to 33 km away from their permanent homes and stay for about 3 to 4 months. As most respondents replied, livestock movement starts around July after the land has been planted with subsistence crops and the crop residue reserves are exhausted, and when the weeds and crop thinning can hardly provide enough forage for the sedentary animals.

Although about 90% of the sampled households revealed that they conserve feeds, either in the form of crop residues or hay, only 22% of them were found to have relayed on conserved feeds during the feed scarcity periods. Crop residues were the most widely conserved feed types. Selling of animals in excess of the available feed was practiced only by 3% of the sampled households.

4.2 Chemical composition of the crop residues and faeces

4.2.1 Chemical composition of the crop residues

Chemical composition of the three major crop residues, namely, maize stover, haricot bean haulms and teff straw produced in the study area is shown in Table 4.11. The three by-products did not differ in their dry matter (DM) and organic matter (OM) contents. The average values were 94 and 91% for DM and OM, respectively. Maize stover had a relatively lower crude protein (CP) content than both haricot bean haulms and teff straw. Generally, the by-products had high cell wall and low cell contents- characteristic of all agricultural by-products.

Fiber analysis by detergent method indicated that haricot bean haulms had a relatively lower (69.2%) neutral detergent fiber (NDF) and higher (30.8%) neutral detergent soluble (NDS) contents than the other two residues. However, the lower proportion (18.4%) of its NDF was hemicellulose and the higher proportion (81.6%) was acid detergent fiber (ADF). Therefore, the NDF of haricot bean haulms had lower proportion of the soluble fraction and higher proportion of the insoluble fraction compared to that of the maize stover and teff straw. The ADF of haricot bean haulms contained a higher percentage of acid detergent lignin (ADL) and a lower percentage of acid insoluble ash (AIA) than that of maize stover and teff straw.

The cellulose component constituted 42.9, 39.3 and 48% of the ADF of maize stover, teff straw and haricot bean haulms, respectively.

Table 4.11 Average[1] chemical composition and energy values of the major crop residues

Component	Residue type		
	MS	TS	HBH
DM, %	94.3	94.4	94.4
Composition of DM,%			
OM	91.1	91.3	91.5
CP	3.6	5.5	5.4
NDF	76.0	75.6	69.2
NDS	24.0	24.4	30.8
ADF	48.4	46.2	56.5
Hemicellulose	27.6	29.4	12.7
Cellulose	42.9	39.3	48.0
ADL	3.0	3.9	8.3
AIA	2.8	3.0	0.3
DE (Kcal/g DM)	2.5	2.3	2.4
ME (Kcal/g DM)	2.1	1.9	2.0

[1] *Average values represent data from 11 replicate samples.*

The results of this study agreed with the general statement made by Preston and Leng (1986) that all cereal straws have low nitrogen content and are composed of cell wall components with little soluble cell contents, and therefore have to be digested by microbial fermentation. The CP contents (3.6 to 5.5%) obtained for the crop residues were lower than the threshold value of 7% known to limit intake (Milford and Minson 1966). Consequently, it can be expected that intake and digestibility of the crop residues would be low unless supplemented with nitrogen-rich sources. Lulseged and Jamal (1989) identified teff straw to be relatively the best among the cereal straws, being comparable to good natural pasture hay. The percent CP obtained for teff straw in the current study was almost similar to the 5.2% reported by these authors, but higher by 1.72 percentage units than what was reported by Nuwanyakapa and Butterworth (1987). Its NDF content was lower by 4.02 percentage units than what the latter authors reported. These differences can be attributed to differences in variety, location and agronomic practices used while growing the crop.

The energy contents (DE and ME) of the three crop residues, calculated from their dry matter digestibility (Butterworth 1964), are presented in Table 4.11. The three crop residues did not vary widely in their energy contents. Hemicellulose and cellulose are important fractions of plant cell wall that are potentially rich in energy. Accordingly, the high values of hemicellulose and cellulose in these crop by-products must have contributed to their high energy contents. Their estimated values ranged from 2.3 to 2.5 kcal DE per g DM or 1.9 to 2.1 kcal ME per g DM. These values were almost similar to the maintenance digestible gross energy requirements of 11 MJ/kg DM reported by Karue (1971) for a 250 kg steer. Stating that maize stover has a high nutrient content and is more digestible than most other straws, Mcdonald *et al.* (1995) reported a ME value of about 9 MJ/kg DM for maize stover.

4.2.2 Chemical composition of the faecal samples

The chemical composition of faeces from bulls fed on the three by-products is given in Table 4.12. Similar trend was observed in OM, ADF, cellulose and ADL contents of the faeces and the feeds. The faecal samples contained higher amounts of NDS, CP, ADF, ADL and AIA than the feed samples. However, NDF, hemicellulose and cellulose percentages were higher in feeds than in the faeces with the exception of the NDF of haricot bean haulms.

Faecal material excreted by animals is composed of undigested residues of feed material; residues of gastric juices, bile, pancreatic juice, and enteric juices; cellular debris from mucosa of the gut; and cellular debris and metabolites of microorganisms (Church and Pond 1974). The higher faecal NDF in the case of haricot bean haulms compared to the other two by-products must have been resulted from high proportion of undigested feed residue as the haricot bean haulms have higher ADL percentage (100 and 167% higher) than both teff straw and maize stover. The markedly high faecal NDS and CP implies that the bulls had much of their faecal wastes composed of endogenous excretions (all faecal components except the undigested residues of feed material).

Table 4.12 Average[1] chemical composition of the faeces from bulls fed the crop residues

Items	Residue type		
	MS	TS	HBH
DM, %	91.0	90.9	92.1
Composition of DM,%			
OM	79.8	82.12	86.6
CP	8.0	9.0	7.8
NDF	64.7	61.1	72.4
NDS	35.3	38.9	27.7
ADF	52.8	52.1	60.2
Hemicellulose	11.9	9.0	12.1
Cellulose	29.6	27.1	38.8
ADL	10.3	14.0	18.5
AIA	12.9	11.0	3.0

[1] *Average values represent data from 9 bulls*

4.3 Voluntary intake and digestibility of the crop residues

4.3.1 Voluntary intake

Digestibility and chemical composition are inadequate attributes to describe the nutritive value of fibrous feeds as they give little indication of the quantity of such feed an animal eats and the quality of nutrients derived through digestion. Therefore, feed intake i.e., how much an animal eats, is one of the most important factors that determines the quality of feed and hence the productivity of ruminant animals.

As shown in Table 4.13, the average voluntary dry matter intakes (DMI) were 2.9, 4.3 and 3.9 kg/day by bulls fed on maize stover, teff straw and haricot bean haulms, respectively. The DMI for maize stover was significantly lower ($P<0.05$) than that of teff straw and haricot bean haulms. Expressed as percent of body weight, the daily dry matter intakes were 1.4, 2.0 and 1.8 kg for maize stover, teff straw and haricot bean haulms, respectively. These values were equivalent to 52.0, 74.7 and 69.3 g/kg $W^{0.75}$, respectively. In both cases, the values for maize stover were significantly lower ($P<0.01$) than the values for the other two by-products.

Higher DMI of both teff straw and haricot bean haulms led to improved organic matter (OMI) intake by the animals. The daily OM intakes by the bulls fed with maize stover, teff straw and haricot bean haulms were 2.6, 3.9 and 3.5 kg, respectively. The values for teff straw and haricot bean haulms were higher ($P<0.05$) than the value for maize stover. These daily intake values were equivalent to 48.4, 73.3 and 64.8 g/kg $W^{0.75}$, respectively. OMI, both as percent of body weight and on metabolic body weight basis, also differed ($P<0.05$) among the bulls, with those fed on teff straw having the highest and those fed on maize stover having the lowest intakes.

Crude protein intake (CPI) was significantly higher ($P<0.01$) for bulls fed on teff straw followed by those fed on haricot bean haulms. The values for daily intake per animal were 99.8, 242.6 and 192.9 g for maize stover, teff straw and haricot bean haulms, respectively.

These were equivalent to 42.5, 119.0 and 93.9 g/100 kg body weight, and 1.6, 4.6 and 3.6 g/kg $W^{0.75}$, respectively.

Table 4.13 Average[1] daily nutrient intake by bulls fed on maize stover, teff straw and haricot bean haulms

Parameters	Residue type			Level of signif.
	MS	TS	HBH	
Dry matter intake				
kg/day	2.9^a	4.3^b	3.9^b	*
kg/100 kg body wt.	1.4^a	2.0^b	1.8^b	**
g/ kg $W^{0.75}$	52.0^a	74.7^b	69.3^b	**
Organic matter intake				
kg/day	2.6^a	3.9^b	3.5^b	*
kg/100 kg body wt.	1.3^a	1.9^b	1.7^b	*
g/ kg $W^{0.75}$	48.4^a	73.3^b	64.8^b	*
Crude protein intake				
g/day	99.8^a	242.6^b	192.9^c	*
g/100 kg body wt.	42.5^a	119.0^b	93.9^c	**
g/ kg $W^{0.75}$	1.6^a	4.6^b	3.6^c	*

[1] ***Average values represent data from 9 bulls.***

[a, b, c] ***In a row, numbers followed by a different letter are significantly different (* = P < 0.05, ** = P < 0.01)***

The voluntary DMI of these by-products by bulls did not exceed 2% of body weight or 75 g/kg $W^{0.75}$. These values were similar to those reported by Preston and Leng (1986), but higher than the 1 to 1.25% of body weight reported by Smith (1993). The daily DMI obtained for maize stover in this trial was similar to the 3.11 kg/head reported by Biwi (1989). The relatively higher nutrient intakes by bulls fed on teff straw and haricot bean haulms than those fed on maize stover could be due to the higher CP content and the lower NDF content of these feeds than the maize stover. In this regard, citing protein as the most common example, McDonald *et al.* (1995) indicated that nutrient deficiencies that reduce the activities of rumen microorganisms are liable to reduce feed intake. The higher daily CP intake achieved for teff straw and haricot bean haulms could partly be attributed to the higher DM intakes and partly to the higher CP content of these feeds than the maize stover.

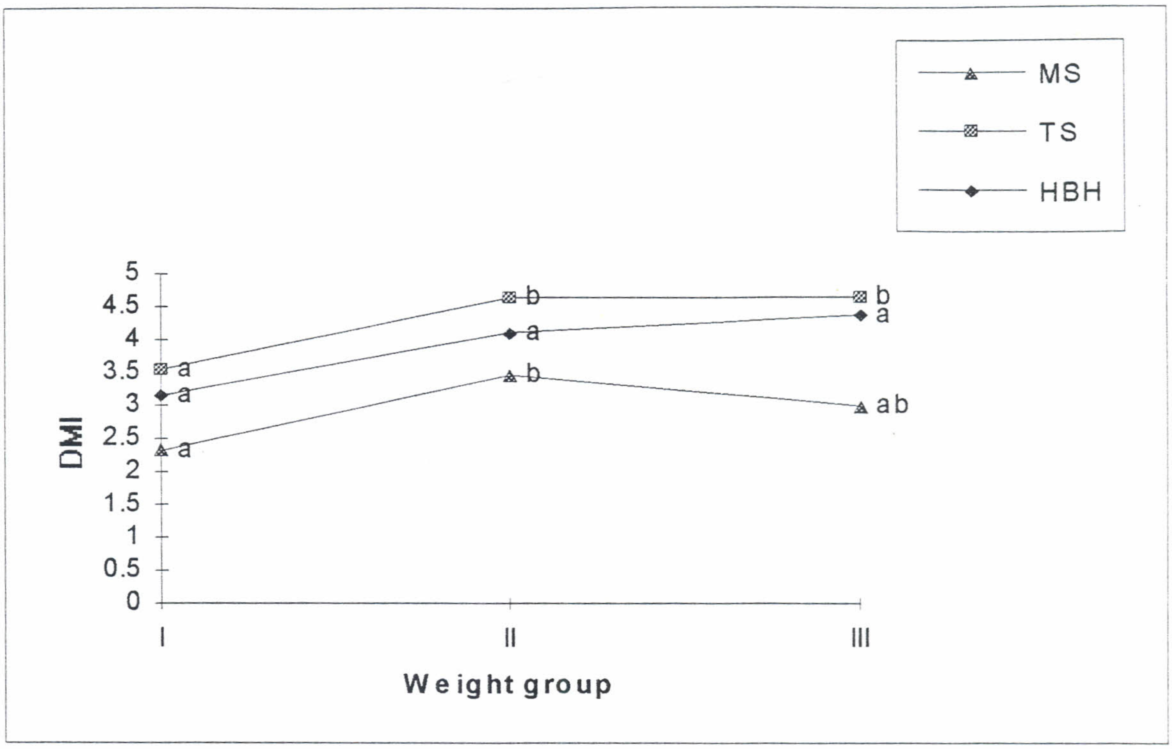
Intake is more closely related to the rate of digestion of diets than to digestibility. The faster the rate of digestion the more rapidly is the digestive tract emptied, and the more space is made available for the next meal. However, these by-products have high NDF, the chemical component of feed that determines their rate of digestion and which has negative relationship with the rate of digestion (McDonald *et al.* 1995), so that they have low intake values. Moreover, their bulky nature might have a filling effect in the reticulorumen, thus inducing a depressing effect on intake. There is usually a slower breakdown of high fiber roughages by the microorganisms in the rumen before optimum particle size is obtained for passage from the rumen. This leads to a slower digestion and concurrently a longer retention time of the residues in the rumen and hence to a reduced intake (Meng 1992). The author reported that ruminants fed on agricultural residues display a low feed intake due to the low bulk density of fibrous residues (this reduces rumen turnover rate) and their high cell wall percentages (this leads to a very slow degradation rate and very low degradation extent in the rumen).

The *in vivo* DM digestibility of these crop residues ranged from 51 to 55% and these could have also contributed to their low intake values. Mugerwa *et al.* (1973) showed that a digestibility coefficient below 66% limits intake of tropical forages by grazing animals. In the current study, the low intake of maize stover, despite being more digestible than the other residues, could have been due to the physical difference of the residues. The woody stems of maize stover are likely to have caused more feeding problems than the relatively tender stems of both teff straw and haricot bean haulms.

The effect of live weight on voluntary intakes of the by-products is shown in Fig. 4.1 to 4.6. There was no relationship between live weight of the animals and the type of residue. This indicates that the preference of the animals to one or the other type of residue did not vary according to their body weight. However, on a given type of residue, there was a significant difference in intake among the three weight groups. On daily basis, lighter animals consumed significantly lower ($P<0.05$) DM, OM and CP of teff straw and maize stover than both the medium and the heavy weight groups. The same trend was observed for animals fed on haricot bean haulms. However, the difference among the weight groups was not statistically significant ($P>0.05$).

On metabolic body weight basis, animals in the three weight groups did not differ ($P>0.05$) in intakes of all the nutrients, although the light and medium animals consumed more ($P<0.05$) DM and OM of maize stover than the heavy ones. However, the difference between light and heavy animals was not statistically significant ($P>0.05$).

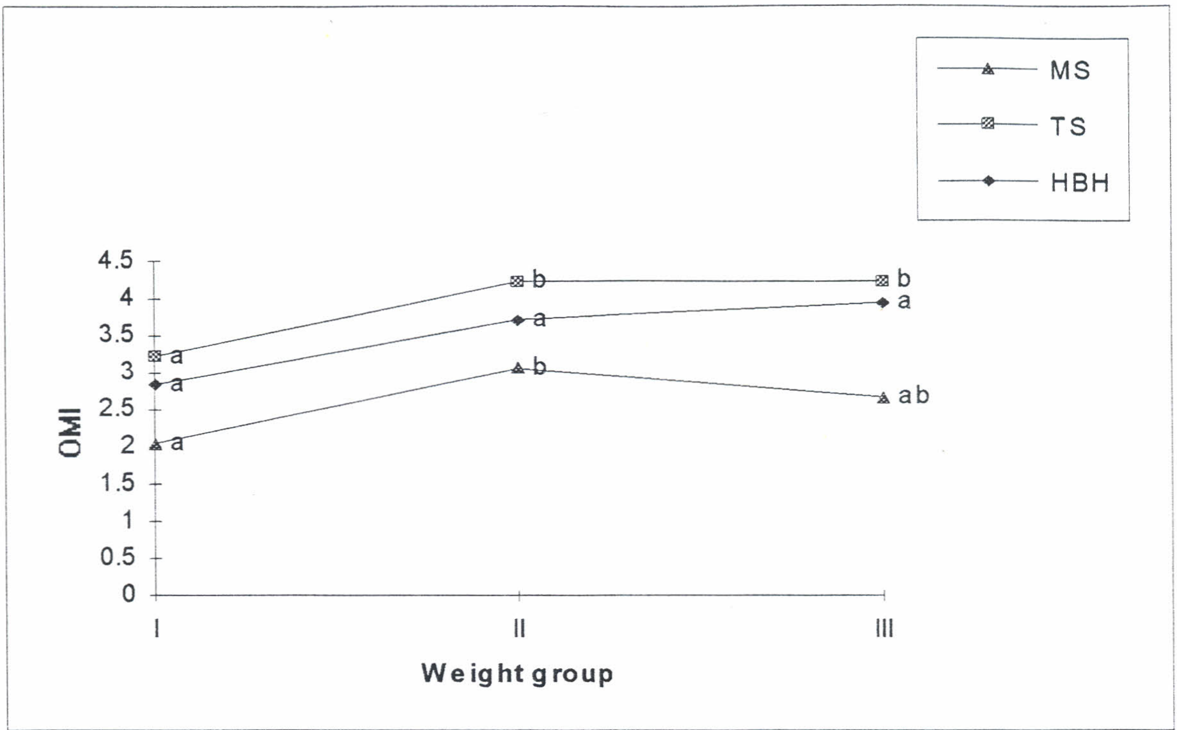
Figure 4.1 Average daily DMI (kg/animal) of maize stover (MS), teff straw (TS) and haricot bean haulms (HBH) by bulls of different weight groups[1]



[1] *I, II and III denote Light, Medium and Heavy weight groups, respectively.*

[a, b] *Different letters along each line graph indicate significant difference (P<0.05) in DMI among the weight groups.*

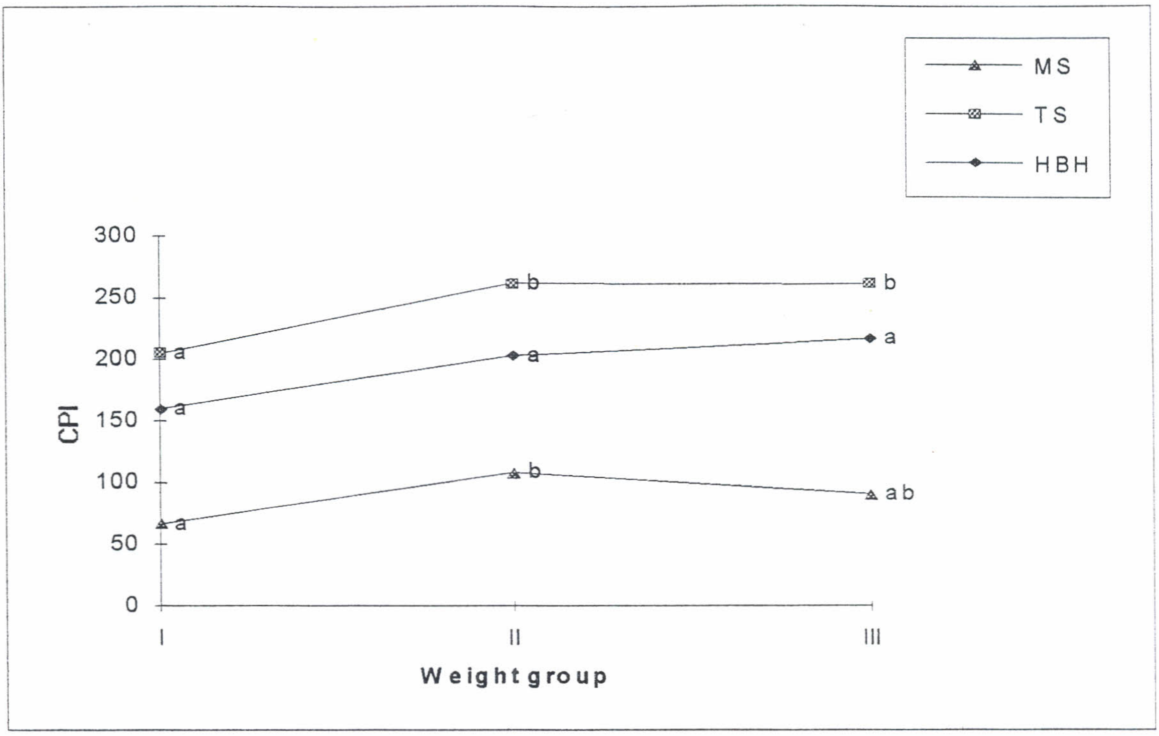
Figure 4.2 Average daily OMI (kg/animal) of maize stover (MS), teff straw (TS) and haricot bean haulms (HBH) by bulls of different weight groups[1]



[1] *I, II and III denote Light, Medium and Heavy weight groups, respectively.*

[a, b] *Different letters along each line graph indicate significant difference ($P<0.05$) in OMI among the weight groups.*

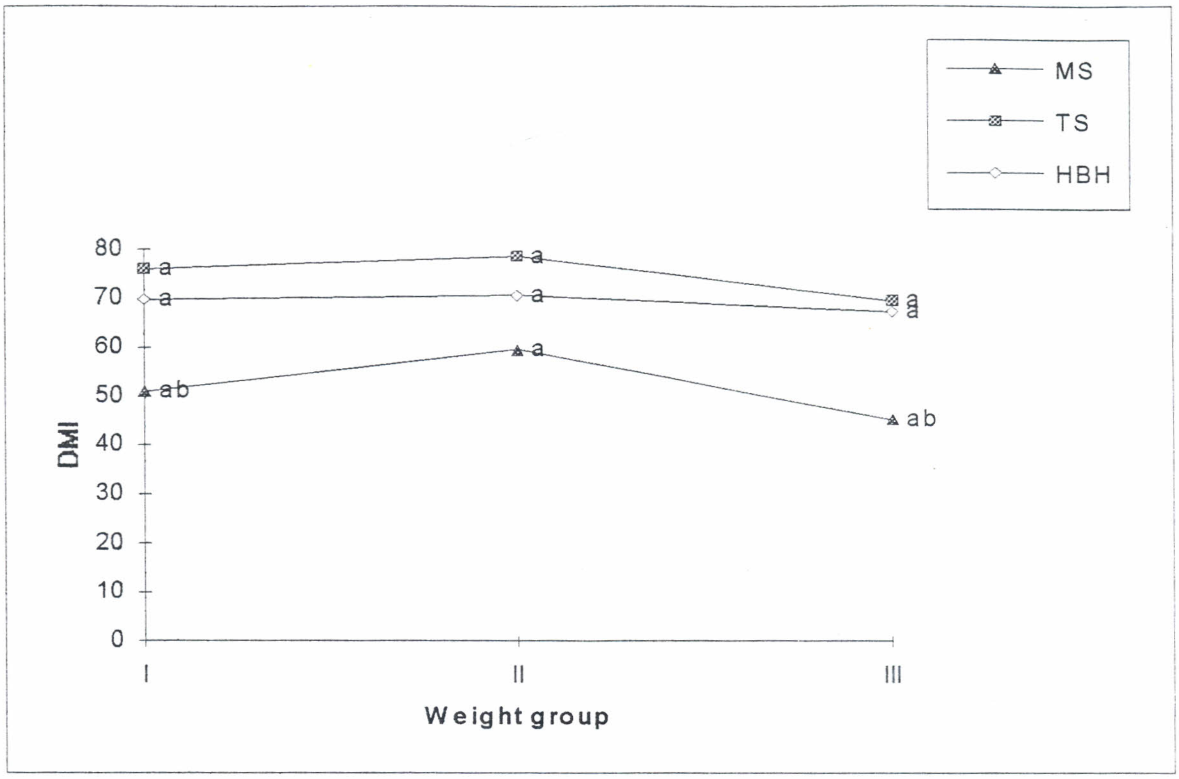
Figure 4.3 Average daily CPI (g/animal) of maize stover (MS), teff straw (TS) and haricot bean haulms (HBH) by bulls of different weight groups[1]



[1] *I, II and III denote Light, Medium and Heavy weight groups, respectively.*

[a, b] *Different letters along each line graph indicate significant difference (P<0.05) in CPI among the weight groups.*

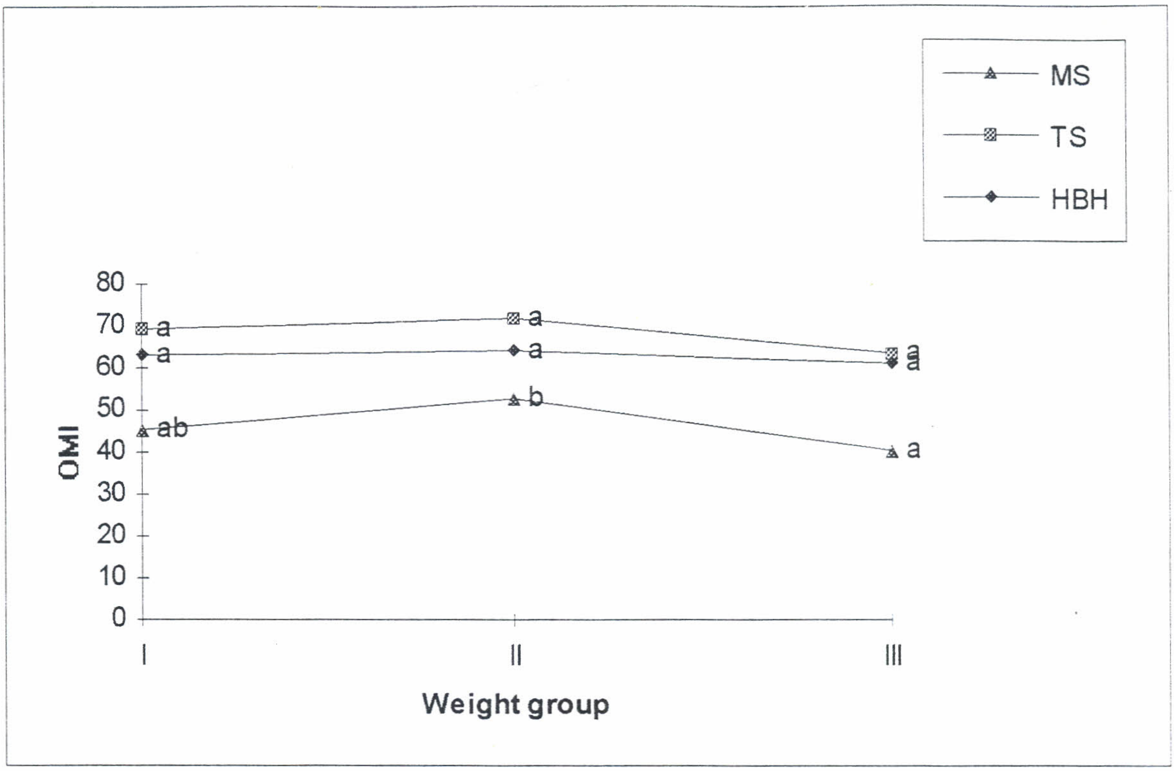
Figure 4.4 Average daily DMI (g/kg $W^{0.75}$) of maize stover (MS), teff straw (TS) and haricot bean haulms (HBH) by bulls of different weight groups[1]



[1] *I, II and III denote Light, Medium and Heavy weight groups, respectively.*

[a, b] *Different letters along each line graph indicate significant difference ($P<0.05$) in DMI among the weight groups.*

Figure 4.5 Average daily OMI (g/kg $W^{0.75}$) of maize stover (MS), teff straw (TS) and haricot bean haulms (HBH) by bulls of different weight groups[1]



[1] *I, II and III denote Light, Medium and Heavy weight groups, respectively.*

[a, b] *Different letters along each line graph indicate significant difference (P<0.05) in OMI among the weight groups.*

4.3.2 *In vivo* digestibility

The *in vivo* digestibility coefficients of the experimental by-products are presented in Table 4.14. The apparent dry matter digestibility (DMD) coefficients of maize stover, and haricot bean haulms were higher ($P<0.05$) than that of teff straw. However, the value obtained for maize stover was lower than the 59% reported by Ndlovu and Manyame (1989) for unhydrated maize stover. The DMD coefficients of maize stover and haricot bean haulms were not statistically different ($P>0.05$).

Table 4.14 Average[1] apparent digestion coefficients of certain nutrients in maize stover, teff straw and haricot bean haulms

Item	Digestibility coefficient (%) of:		
	MS	TS	HBH
DM	54.5^{a}	50.5^{b}	53.0^{ab}
OM	59.1^{a}	54.4^{b}	55.0^{b}
D-values	52.6^{a}	49.7^{a}	49.8^{a}
CP	-25.2^{a}	21.5^{b}	26.6^{c}
NDF	59.9^{a}	57.8^{a}	49.2^{b}
ADF	49.6^{a}	42.2^{b}	47.1^{a}
Cellulose	69.7^{a}	65.5^{ab}	61.3^{b}
Hemicellulose	78.7^{a}	83.5^{a}	57.4^{b}

[1] *Average values represent data from 9 bulls*
[a, b, c] ***Means in a row followed by different superscript letter(s) are significantly different (P<0.05).***

The average *in vivo* organic matter digestibility (OMD) coefficients of the three by-products followed their respective DMD values. The values were 59.1, 54.4 and 55.0% for maize stover, teff straw and haricot bean haulms, respectively. The value for maize stover was significantly higher ($P<0.05$) than the values for the other two by-products. The D-values (OMD expressed on dry matter basis) were, however, not statistically different ($P>0.05$) among the three crop residues. These were 52.6, 49.7 and 49.8% for maize stover, teff straw and haricot bean haulms, respectively.

The digestibility of protein was significantly different ($P<0.01$) among the three crop residues and was negative for maize stover. The higher CP digestibility coefficients observed for teff straw and haricot bean haulms (21.5 and 26.6%) reflect the relatively high CP content of these by-products, and may also be associated with the difference in protein quality of the by-products. However, such measures are obviously influenced by endogenous nitrogen excretion in the faeces (Boonlom and Boonserm 1984) and are consequently of limited value.

The digestibilities of NDF, cellulose and hemicellulose of maize stover and teff straw were significantly higher ($P<0.05$) than those of the haricot bean haulms (Table 4.14). This is attributed to the low lignin contents of the two by-products compared with the lignin content of the haricot bean haulms. This agrees with what Karue (1975) stated regarding the importance the degree of lignification in the digestion of fiber by ruminants: the higher the lignin content, the lower the digestibility of cellulose.

4.3.3 *In vitro* digestibility

The DM and OM digestibility coefficients of the by-products, as determined by the two-stage *in vitro* technique, are shown in Table 4.15. These values paralleled their respective *in* *vivo* digestibility values. However, they were lower than the *in vivo* digestibility values. The *in vitro* dry matter digestibility (IVDMD) coefficients for maize stover, teff straw and haricot bean haulms were 50.3, 40.5 and 48.0%, respectively, while their respective *in vitro* organic matter digestibility (IVOMD) coefficients were 51.9, 42.1 and 49.1%. In all cases, the values for teff straw were significantly lower ($P<0.001$) than the values for both maize stover and haricot bean haulms.

Table 4.15 Average[1] *In vitro* digestibility coefficients of maize stover, teff straw and haricot bean haulms

Residue type	*In vitro* digestibility coefficient (%)		
	DMD	**OMD**	**D-value**
MS	50.3^{a}	51.9^{a}	47.3^{a}
TS	40.5^{b}	42.1^{b}	38.5^{b}
HBH	48.0^{a}	49.1^{a}	44.9^{a}

[1] *Average values represent data from 11 replicate samples*

[a, b] ***Means in a column followed by a different superscript letter are significantly different ($P<0.001$).***

The digestibility of a feed depends on a number of factors some of which are associated with the feed, the animal and the environment under which the animal lives. However, it is primarily determined by the nature of the feed. Pearce *et al.* (1988) stated that straw intake and digestibility in ruminants are influenced by straw characteristics such as chemical composition, morphological and anatomical features, physical nature and palatability, and by feeding conditions including the amount offered and the frequency of feeding. Other authors (McDonald *et al.* 1995, Crampton and Harris 1969) reported that the digestibility of feeds by farm animals is generally related to the proportion and character of the fiber they contain. A high content of NDF and lignin results in lower fiber degradation compared to a low content of both. Another feed component affecting digestibility is crude protein. When CP level falls below 7%, which is the minimum nitrogen requirement of rumen bacteria, both intake and digestibility are depressed.

From both *in vivo* and *in vitro* results of this study, it can be concluded that maize stover was more digestible than both teff straw and haricot bean haulms. This is likely to be associated with its lower lignin content compared to the other two residues. However, the haricot bean haulm, despite having a higher percentage of lignin than maize stover, was found to be almost as digestible as the maize stover. It seems that the digestion depressing effect of lignin in haricot bean haulms is compensated for by the lower NDF and higher NDS proportions found in the haricot bean haulms than those in the maize stover. On the other hand, in spite of having almost similar proportions of NDF and lignin to that of maize stover, teff straw was found to be less digestible. In this case, factors other than chemical composition seem to have contributed to the observed variations. The actual reason, however, calls for further detailed investigations.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

This study has revealed that, although crop residues are produced in large amounts in the study area, their full and efficient utilization for livestock feeding has been hindered partly by economic problems and partly by inadequate know-how of the farmers as to the handling and processing of the residues to make the best use out of them. Crop residues like maize and sorghum stovers, for example, are grazed *in situ*, haricot bean haulms are hardly collected and stored for future uses and wheat straw was reported to be health hazard. As a result, a significant wastage of these valuable feed sources was evident in the area. Most of the residues are also put to uses other than livestock feeding. However, livestock feeding was the top priority usage among all farmers. This is likely to be due to lack of adequate alternative feed sources, especially during the dry season.

Like any other by-products, the three crop residues included in this trial had high proportions of cell wall constituents and low proportions of cell contents. The high cell wall lignin content and the chemical bonding between this fraction and the potentially nutritious cell wall constituents such as cellulose and hemicellulose generally result in low digestibility and intake of crop residues. Accordingly, the intakes of the studied crop residues were less than 2% of body weight of the animals and their digestibility coefficients were around 50%.

It is known that treatment of crop residues, either physically, chemically, or biologically increases, in one way or the other, both intake and digestibility. However, the results of this study revealed that none of the interviewed farmers used any of the above mentioned treatments to improve the nutritional value of their by-products. The major bottlenecks for the failure to apply these strategies were inadequate knowledge about the methods, lack of finance and accessibility to the methods.

Crop residues are generally characterized by the unbalanced nature of the nutrients they supply. Most of them do not contain adequate soluble nitrogen and fermentable carbohydrates, or essential minerals, and these need to be supplied to ensure a balance of nutrients. Though exhaustive nutrient analysis was not undertaken in the current study, the by-products studied would not be exceptions to this general statement. Therefore, a complementary strategy of nutrient balancing through supplementation is required to optimize the efficiency of transforming absorbed nutrients into products. In this regard, it is highly recommended that the farmers are made aware of such principles and be assisted in getting the above-mentioned invaluable nutrients in the form of molasses, protein-rich fodder trees, molasses-urea blocks, etc. For this to be effective, the role of government in terms of facilitating the ways (e.g. providing transportation services) and means of acquiring (e.g. availing credit services) these items is essential, at least until the farmers fully understand the advantages of such supplementation and get used to the practice.

With regard to crop residue treatment, emphasis should be placed on the methods that are within the reach of farmers (e.g. physical treatment methods like chopping, wetting, ensiling with urea or animal manure). To point out the advantages of such simple practices, it would be sufficient to cite the works of Munthali *et al.* (1992) in which they found comparable DM intakes for maize stovers treated with water followed by ensiling and that treated with 4% urea and ensiled. Nowadays, the use of ashes for crop residue treatment is being advocated to be as effective as NaOH solutions. In line with its availability, this method seems to be applicable to farmers. However, as information on this aspect is scanty, it is recommended that future research in the area of crop residue sorts out such alkali-active ashes and their effects in treating fibrous crop residues. The use of magadi soda, a locally available stuff at local salt and mineral mining, is also another alternative that deserves research consideration.

Although planting of leguminous fodder trees such as *leucaena* and *sesbania* is being promoted by the Ministry of Agriculture, the uptake of this technology by farmers is very minimal. It seems that it takes more time and effort by the ministry before farmers could fully understand the merits of such improved technologies so as to adopt them. Therefore, strong extension services in terms of making valuable technologies available to farmers and training them in the basic principles of using these technologies is highly recommended. The training component, among other things, should include the proper mechanisms of collection, storage and treatment of crop residues, followed by the principles of supplementation of these low quality but readily available feeds with nitrogen sources to balance their inherent deficiencies.

Even though the information obtained through this study does indicate the status of crop residue production, utilization and constraints to their utilization for animal feeding in the study area, more work on a wider scale should be undertaken to furnish more vital information that can be useful in the development of appropriate interventions and technologies for more efficient utilization of crop residues.

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APPENDICES

Appendix 1 . Questionnaire

House hold No... Date................
Respondent's: Name... Village.............
Family size Male............. Female.............. Total................

1.0 Major occupation: 1= agriculture 2= livestock keeping
3= both agriculture & livestock keeping 4= Trade (specify)........
5= others (specify)........

2.0 Land use (ha)
2.1 For cultivation........... 2.2 For grazing (if private) 2.3 For fallow.............
2.4 Trend (1 = increasing, 2 = decreasing, 3 = constant) of current land use for cultivation and grazing as compared to past years (1967-1989) and reasons for the trend (fill in he table):

Land use	Trend	Reason
cultivation		
Grazing		
Fallow		

*= If communally owned indicate the amount and when, how and for which livestock spp. you use it

3.0 What is the range condition? 1= poor 2= fair 3= good 4= very good
5= excellent
If it is poor what are the possible constraints:
1= overstocking/overgrazing 2= low rainfall 3= poor soil fertility
4= bush encroachment 5= others (specify) 6= none

4.0 Which range condition improvement practice do you apply?: 1= burning
2= irrigation 3= over-sowing 4= fertilizer use 5= manure use
6= others (specify) 7= none

5.0 Crop production, and seed (1= local, 2= improved) and fertilizer used (fill in the table)

5.1 current year's production (1996/97):

Crop type	Area (ha)	Production (kg)	Seed used (1 or 2)	Fertilizer (name & kg/ha)
Maize				
Teff				
H. bean				
Wheat				
Sorghum				
Barley				
Others(name)				

5.2 previous year's production (1995/96):

Crop	Area (ha)	Production (kg)	Seed used (1 or 2)	Fertilizer (name & kg/ha)
Maize				
Teff				
H. bean				
Wheat				
Sorghum				
Barley				
Others(name)				

6.0 Means to grow crops: 1= rainfed 2= irrigation 3= both

7.0 Major production constraints of cultivated crops (fill in the table):
1= rainfall failure2= soil fertility 3= shortage of land
4= predator animals (specify) 5= disease (name) 6= Others(specify)

CROP TYPE	CONSTRAINTS
Maize	
Teff	
Haricot bean	
wheat	
Sorghum	
Barley	
Others (name)	

8.0 Agronomic practices used in the area for both crop & pasture :
1= inter-cropping (name the plants).............
2= under-sowing (name the plants).............
3= over-sowing (name the plants).................
4= irrigation (name the plants irrigated)........
5= other practices (name)............................
6= none

9.0 How many months do each of the following livestock feed source cover for you in a year? (name the months):
9.1 Grazing.. 9.2 Crop residues...............................
9.3 Browse trees....................................... 9.4 Weeds/crop thinning....................
9.5 Purchased feeds................................. 9.6 From migration...........................
9.7 Others (name)...................................

10.0 indicate all possible usages to which you put your crop residues (Rank):

Type of usage	**Maize stover**	**Teff straw**	**H/bean haulms**	**wheat straw**	**Barely straw**	**Sorghum stover**	**Maize cobs**
L/S[1] feed							
Construction							
Firewood							
Plowed back							
Bedding							
Sale							
Ridge making							
Other(name)							

[1] ***Livestock***

11.0 Indicate crop residues most preferred for feeding the different animals (in order of importance:

Animals	**Crop residues preferred**
Cattle	
Goats	
Sheep	
Equine	

12.0 For which classes of cattle do you mostly use crop residues:
1= draft oxen 2= dry cows & heifers 3= lactating cows 4= young calves

13.0 Crop residue utilization and wastage (fill in the table)

13.1 Major mode of utilization: 1= *In situ* 2= stall feeding 3= Not used

13.2 peak season of use: (write the months)

13.3 Presence of crop residue wastage: 1= No wastge 2 = Yes

13.4 If yes name the major cause of wastage: 1= inability to collect
2= improper storage 3= not needed 4= others (name)...............

Crop residue	**Mode of utilization**	**Peak time of utilization**	**Presence of wastage**	**Causes of wastage**
Maize stover				
H. bean hauls				
Teff straw				
Wheat straw				
Maize cobs				
Barley straw				
Sorghum				

14.0 crop residue feeding system:

1= alone (name the residues)...

2= mixed with each other or with other plants (name which ones are mixed)........

3= sprayed with molasses, urea, etc.(specify)...

4= other systems (specify)..

15.0 Crop residue feeding level: 1= *Ad libium* 2= restricted

16.0 Crop residue feeding time: 1= Morning 2= evening 3= day time
4= both morning & evening

17.0 Do you supplement your crop residues with protein (e.g. legumes) or energy (e.g. molasses) feeds? 1= yes (name them)..................... 2= no

18.0 Major problem related to crop residue feeding and uses to which their left over are put (fill in the table):

18.1 Presence of feeding problem: 1= No problem 2 = There is

18.2 If there is problem indicate the major one: 1= being stemy/hard 2 = cause health problem 3= has bad smell 4= poor in feeding value 5= other reasons (specify)................

18.3 Presence of crop residue left over: 1 = Present 2 = not present

18.4 If present indicate their uses: 1= firewood 2= re-feeding 3= as fertilize 4= not used 5= others(specify).........................

Crop residues	**Presence of feeding problem**	**The problems**	**Presence of left over**	**Uses of left over**
Maize stover				
Teff straw				
H/bean haulms				
Wheat straw				
sorghum straw				
Barley straw				
Maize cobs				
Others (name)				

19.0 Crop residue collection

19.1 Do collect your maize and/or sorghum stover? 1 = yes 2 = No

19.2 If yes indicate the period of collection (days after grain harvest).............................

19.3 Do collect other residues? 1 = yes 2 = No

19.4 If yes indicate the period (days after harvest and threshing)..................................

20.0 Crop residue transportation:

20.1 Do you transport your crop residues? 1 = yes 2 = No

20.2 If yes indicate the major mode of transportation:
1= Own equine 2= head carry 3= hire equine 4= borrow equine
5= hire vehicle 6= others (specify)......................................

20.2 Average distance transported (km)..

20.3 Estimated cost of transportation (ETB/ha)...............................

21.0 Do you get balling service? 1= yes 2= no
If yes, Name the residues balled, and indicate cost of balling (ETB per bale or per ha).....

22.0 Crop residue storage and treatment (fill in the table):

22.1 Do you store your crop residues? 1 = yes 2 = No

22.2 If yes, state the major method of doing so:
1= stack outside 2= keep in shade 3= others (name)......................

22.3 For how long do you store your crop residues? (give in months)

22.4 Do you treat crop residues before feeding to animals? 1 = No 2 = yes

22.5 If yes, name which treatment method you apply: 1= chopping (hand/machine)
2= soaking 3= threshing 4= traditional (name)...........................

Crop residues	Residue storage	Method of storage	Length of storage	Residue Treatment	Method of treatment
Maize stover					
Haricot bean haulm					
Teff Straw					
Wheat straw					
Sorghum stover					
Barley straw					
Others					

23.0 Do you have constraint to the use of methods of improving the feeding value of crop residue? (fill in the table): 1 = No 2 = yes

23.1 If yes, indicate the major constraint: 1= finance 2= access 3= labor
4= land 5= lack of know-how 6= others (name)

Methods of improvement	Presence of Constraints	Major constraint
Physical (chop, grind, etc.)		
Chemical (NaOH, Urea, Local)		
Concentrate supplement		
Legume supplement		
Others (name)		

24.0 Transportation and storage problems related to crop residues (fill in the table):
24.1 Do you have transportation problem?: 1 = No 2 = yes

24.2 If yes, state the major problem: 1= labor shortage 2= capital
3= Distance4= lack of equine 5= others (specify).......................
6 = Transportation not known or needed
24.3 Do you have storage problem? 1 = No 2 = yes
24.4 If yes, indicate the major problem: 1= fire 2= mould 3= termites
4= others (name)........... 6= not stored

Crop residue	**Presence of Transportation problem**	**Transportation problem**	**Presence of storage problem**	**Storage problem**
Maize stover				
H. bean haulms				
Teff straw				
Wheat straw				
Maize cobs				
Barley straw				
Sorghum stover				

25.0 Is there period of critical feed shortage? 1= yes 2= no
If yes state the period and the major measure you take to overcome the problem:
25.1 Periods (months)..
25.2 Measures taken: 1= sale animals 2= buy feed 3= move animals
4= use reserve feed (specify) 5= social alliance
6= Lopping browse trees (name) 7= use non-conventional feeds (name).....

26.0 Do you conserve feed for dry period? 1= yes 2= no
If yes, state the type of feed you mostly conserve: 1= standing hay 2= cut hay
3= crop residues 4= browse (pods, leaves, etc.)
5= silage (name the plants) 6= others (name) 7= none

27.0 Do you get additional livestock feed other than your own production? 1= yes 2= none
If yes, indicate the type of feed, the major source of acquisition and the estimated annual cost in the following table:
Source : 1= gift 2= purchase 3= borrow 4= others (specify).

Type of feed	Source	Estimated total cost (ETB)

28.0 Do you use fodder/browse for livestock feeding? 1 = yes 2 = No
If yes, indicate, in the table:
28.1 Status of the fodder/browse: 1= natural 2= introduced
28.2 Parts used (in order of importance): 1= leaves & twigs 2= stem 3= pod
4= Bark 5= whole plant 6= others (specify)..................
28.3 Major animal species for which the fodder/browse is most used:
1= Cattle 2= goats 4= sheep 5= equine
28.4 Season of use: In months

Plant name	Status	Parts used	Animals Spp.	Season of use

28.5 Name which of the above are traditionally protected for animal feeding.........................

29.0 Current livestock number. & their TLU equivalent:

Livestock type	**Number**	**TLU equiv.**	**Livestock type**	**Number**	**TLU equiv.**
Oxen			Goats		
Cows			Sheep		
Heifers & bulls			Donkeys		
Calves			Mule/horse		
TOTAL			**TOTAL**		

30.0 Is the trend increasing (1), decreasing (2) or constant (3) as compared to the past 10 years? give reasons:

30.1 For cattle........... 30.2 For small ruminants........... 30.3 For equine...........

31.0 Future plan concerning the livestock number: 1= increase 2= decrease 3= keep the same number

32.0 Livestock production constraints (rank):

Constraints	**Cattle**	**Goat**	**Sheep**	**Equine**
1= Feed				
2= Disease				
3= Genetic				
4= Predators				
5= Social taboos*				
6= Insecurity				
7= unreliable market				
8= Environment				
9= Others (specify)				

* = name social taboos that constrained livestock production...

33.0 Do you some times move your animals away from your place? 1 = yes 2 = No
If yes indicate:
33.1 Purpose of movement: 1= feed shortage 2= water shortage
3 = livestock disease 4= others (specify)...
33.2 Animals moved..............................
33.3 Place moved to...............................
33.4 Distance from residence (km)..........
33.5 Duration of stay (months): From.............................. to ....
33.6 Ownership of the place moved to: 1= ones own 2= relative's
3= communal 4= others (name)...............
33.7 State problems related to movement...
33.8 State measures taken to alleviate the problems..................................

Appendix 2 Analysis of variance (ANOVA) tables.

Note: *In all the following ANOVA tables, ns = non significant; * = P < 0.05; ** = P < 0.01 and *** = P < 0.001*

Appendix 2.1. ANOVA table for daily DM, OM and CP intakes of bulls fed on maize stover, teff straw and haricot bean haulms

DM Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	14.979	3.745	9.601***
A = Feed	2	8.652	4.326	11.091**
B = Weight group	2	6.327	3.164	8.111***
AB	4	0.467	0.117	0.300ns
Error	18	7.021	0.390	
TOTAL	26	22.467		

OM Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	13.116	3.279	9.983***
A = Feed	2	7.936	3.968	12.081***
B = Weight group	2	5.180	2.590	7.886**
AB	4	0.342	0.085	0.260ns
Error	18	5.912	0.328	
TOTAL	26	19.370		

CP Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	101837.037	25459.259	15.094***
A = Feed	2	94565.852	47282.926	28.033***
B = Weight group	2	7271.185	3635.593	2.155ns
AB	4	4701.481	1175.370	0.697ns
Error	18	30360.000	1686.667	
TOTAL	26	136898.519		

Appendix 2.2. **ANOVA table for daily DM, OM and CP intakes (as percent of body weight) of bulls fed on maize stover, teff straw and haricot bean haulms**

DM Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	2.055	0.514	7.094***
A = Feed	2	1.548	0.774	10.683***
B = Weight group	2	0.508	0.254	3.504*
AB	4	0.066	0.016	0.226ns
Error	18	1.304	0.072	
TOTAL	26	3.425		

OM Intake

Main effect	4	2.390	0.598	9.564***
A = Feed	2	1.892	0.946	15.141***
B = Weight group	2	0.498	0.249	3.986*
AB	4	0.062	0.015	0.247ns
Error	18	1.125	0.062	
TOTAL	26	3.577		

CP Intake

Main effect	4	28874.095	7218.524	41.199***
A = Feed	2	27391.472	13695.736	78.167***
B = Weight group	2	1482.623	741.311	4.231*
AB	4	538.997	134.749	0.769ns
Error	18	3153.793	175.211	
TOTAL	26	32566.885		

Appendix 2.3. ANOVA table for daily DM, OM and CP intakes (on metabolic body weight basis) of bulls fed on maize stover, teff straw and haricot bean haulms.

DM Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	2904.515	726.129	7.599***
A = Feed	2	2539.816	1269.908	13.289***
B = Weight group	2	364.699	182.349	1.908ns
AB	4	102.939	25.735	0.269ns
Error	18	1720.080	95.560	
TOTAL	26	4727.534		

OM of Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	3164.790	791.198	8.814***
A = Feed	2	2869.390	1434.695	15.982***
B = Weight group	2	295.401	147.700	1.645ns
AB	4	77.259	19.315	0.215ns
Error	18	1615.827	89.768	
TOTAL	26	4857.876		

CP Intake

Source of variation	DF	Sum of Squares	Mean Square	F
Main effect	4	40.975	10.244	38.791***
A = Feed	2	40.154	20.077	76.028***
B = Weight group	2	0.821	0.410	1.554ns
AB	4	0.459	0.115	0.435ns
Error	18	4.753	0.264	
TOTAL	26	46.187		

Appendix 2.4. **ANOVA table for apparent digestibility coefficients of Different components of maize stover, teff straw and haricot bean haulms**

DM digestibility coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Main Effects	4	85.248	21.312	1.495ns
A = Feed	2	10.859	5.430	0.381ns
B = Weight group	2	74.388	37.194	2.605ns
AB	4	17.814	4.454	0.312ns
Error	18	256.668	14.259	
TOTAL	26	359.730		

OM digestibility (on DM basis) coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Main Effects	4	64.918	16.230	1.330ns
A = Feed	2	15.087	7.543	0.618ns
B = Weight group	2	49.832	24.916	2.042ns
AB	4	9.976	2.494	2.04ns
Error	18	219.650	12.203	
TOTAL	26	294.544		

OM digestibility (on OM basis) coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Main Effects	4	131.695	32.924	2.336ns
A = Feed	2	14.939	7.469	0.530ns
B = Weight group	2	116.757	58.378	4.142*
AB	4	12.729	3.182	0.226ns
Error	18	253.700	14.094	
TOTAL	26	398.124		

NDF digestibility coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Main Effects	4	632.423	158.106	7.585***
A = Feed	2	63.155	31.577	1.515*
B = Weight group	2	569.269	284.634	13.655***
AB	4	35.051	8.763	0.420ns
Error	18	375.214	20.843	
TOTAL	26	1042.688		

Appendix 2.4 (cont.)

ADF digestibility coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Main Effects	4	301.674	75.418	2.855***
A = Feed	2	257.788	128.894	4.879***
B = Weight group	2	43.886	21.943	0.831ns
AB	4	18.468	4.617	0.175ns
Error	18	475.540	26.419	
TOTAL	26	795.681		

Hemicellulose digestibility coefficient

Main Effects	4	3558.611	889.653	15.819***
A = Feed	2	97.249	48.625	0.865*
B = Weight group	2	3461.362	1730.681	30.773***
AB	4	224.124	56.031	0.996ns
Error	18	1012.324	56.240	
TOTAL	26	4795.059		

Cellulose digestibility coefficient

Main Effects	4	336.256	84.064	2.802ns
A = Feed	2	22.751	11.375	0.379ns
B = Weight group	2	313.505	156.753	5.225*
AB	4	27.377	6.844	0.228ns
Error	18	539.964	29.998	
TOTAL	26	903.597		

Appendix 2.5. ANOVA table for in vitro dry matter and OM digestibility (IVDMD and IVOMD) coefficients, and for D-values of maize stover, teff straw and haricot bean haulms

IVDMD coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Feed type	2	575.5501	287.7751	14.6349***
Error	30	589.9096	19.6637	
TOTAL	32	1165.4597		

IVOMD coefficient

Source of Variation	DF	Sum of squares	Mean square	F
Feed type	2	559.0856	279.5428	15.3197***
Error	30	547.4182	18.2473	
TOTAL	32	1106.5038		

D-values

Source of Variation	DF	Sum of squares	Mean square	F
Feed type	2	460.6883	230.3441	15.5703***
Error	30	443.8147	14.7938	
TOTAL	32	904.5030		