RELATIONSHIP BETWEEN DIET DIGESTIBILITY AND MORPHOLOGY OF DIGESTIVE SYSTEM OF LOCAL ZEBU CATTLE FINISHED ON AGRO – PROCESSING BY PRODUCTS

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ABSTRACT

The relationship between diets digestibility and morphology of digestive systems, were studied in local Tanzanian Short Horn Zebu (TSHZ) cattle finished on agro industrial by products. Forty five TSHZ were weighed and randomly allocated to five dietary treatments in a completely randomized design, and nine grazer animals were used as a control group which made a total of fifty four animals. The feedlot animals were fed on hay as a basal diet and supplemented with concentrate, the control group was fed on natural pasture. Animals under Treatments 1 – 5 were fed *adlibitum* with five concentrates formulated to contain Molasses + Maize meal (T1), Molasses + Maize bran (T2), Maize meal + Maize bran (T3), Molasses + Rice polishing (T4) and Maize meal + Rice polishing (T5). In addition, cotton seedcake, mineral mix, salt and urea were included in all Treatment diets, to meet the requirements for CP and minerals. Digestibility of the diets was measured using Acid Insoluble Ash as a marker. The Morphology of the rumen, duodenum, small intestine and liver from the animals were evaluated after slaughter using ruler and light microscope. Animals under Treatment 2 exhibited significantly higher apparent digestibility of DM (63.9%) and OM (58.8%) than those fed on T1 (62.2% and 55.3%) and lowest values were observed on control group (35.7% and 32.6%) respectively. Higher digestibility values for NDF and ADF ($P<0.01$) were observed in cattle under T2 (57.4% and 54.8%) and T1 (54.3% and 49.9%) than the other treatments. Rumen papillae length (16.1 mm) and width (3.4mm) for the cattle assigned to Treatment 2 were longest ($P<0.01$) and widest than those of other Treatments. The villi length (78.5 μm), and crypt depth (29.7 μm) of the small intestine from cattle under Treatment 2 were significantly ($P<0.01$) longer than those from cattle under the other

Treatments while the control had the shortest villi (54.2 μm) and narrowest crypt depth (17.5 μm). Cattle under Treatment 2 had heavier carcass (153kg), liver weight (3.86kg) and glycogen level (55.1%) than cattle assigned to the other Treatments. Treatment 5 had the lowest carcass weight (133kg), liver weight (3.03kg) and glycogen level (33.0%). At same time, there was a positive correlation between DM and OM digestibility with carcass, liver weight and glycogen level at ($P<0.05$), also NDF and ADF digestibility had significant ($P<0.05$) correlation with carcass and liver weight. Also there was a simple correlation coefficient between papillae (length and width), villi (crypt and depth) with a series of DM, OM, NDF and ADF apparent digestibility ($P<0.05$). From the above findings, it seems that, for better animal performance, cattle should be fed the well digested feed, which can lead to high morphological improvement. Treatment 2 was the best in categories of digestibility and morphology of digestive system and carcass weight; so it is recommended to be used for beef cattle fattening under feedlot system.

DECLARATION

I, **KULWA JUMA** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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DEDICATION

This work is dedicated to my mother Mrs. Habiba Mkwama, my father the late Juma Mkwama, my brothers, sisters and my lovely husband and daughter Lutfia Slim Muombwa for their moral and financial support throughout my education process.

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LIST OF ABBREVIATIONS AND SYMBOLS

±	Plus or Minus
ADF	Acid Detergent Fibre
ADFD	Acid Detergent Fibre Digestibility as
%DM	Percentage Dry Matter
AIA	Acid Insoluble Ash
CD	Crypt Depth
cm	Centimeter
CP	Crude Protein
DMD	Dry Matter Digestibility
g	Gram
GLP – 2	Glucagon–Like Peptide-2
Kcal	Kilo calories
Kg	Kilogram
LSMEANS	Least Square Means
mm	Millimeter
N	Nitrogen
NDF	Neutral Detergent Fibre
NDFD	Neutral Detergent Fibre Digestibility as
NFC	Non Fibre Content
O_2	Oxygen
OM	Organic Matter
OMD	Organic Matter Digestibility

PAS	Periodic Acid Schiff
PDV	Portal Drain Viscera
SEM	Standard Error Mean
VD	Villi Depth
VH	Villi Height
μm	Micrometer
TSHZ	Tanganyika Short Horn Zebu

CHAPTER ONE

1.0 INTRODUCTION

Local Zebu Cattle are one of the tropical cattle breeds (Bos indicus) widely distributed in Tanzania. The breed has envolved in arid and semi arid setup, but later on it was distributed and adapted to the wide agro ecological zones. Feed availability and quality is one of the major problems limiting productivity of these animals. The problem become more serious during the dry season, when available feeds contain low soluble carbohydrate, fermentable nitrogen, mineral and other nutrients (Schiere and Ibrahim, 1989). This lead to low supply of nutrients to the rumen microbes, resulting in low intake, poor digestibility and animal performance (Leng, 1993). Thus poor performance results is due to undeveloped nutrient absorption sites, which are ruminal and intestinal morphology (papillae and villi) (Lesmeister and Heinrichs, 2004).

The development of cattle ruminal and intestinal morphology depends on diet nutrients, digestibility due to the availability of rumen microbes. Poor diet which is attributed to low digestibility of nutrient content, has been ascribed to be the major factor that compromises these development which leads to poor animal production (Leng, 1993). Many feed resources such as industrial by products that could have major impact on cattle production, continue to be unused, undeveloped and poorly utilized. A critical factor in this regard has been lack of proper understanding of the nutritional principles underlying their utilization, which is attributed to digestion process.

Feedlot fattening has been advocated as an alternative way of reducing these problems, which involve keeping animals in confined areas and subject them to energy rich diet. Energy-rich feeding causes an increase in the size of rumen papillae, intestinal villi and leads to considerable mucosa proliferation (Dirksen *et al.,* 1985). In animals fed low or high energy diets rumen mucosa revealed progressive reduction or intensive proliferation, respectively (Dirksen *et al.,* 1985). Intensity of rumen fermentation increases with increasing intake of concentrate and simultaneously the occurring volatile fatty acids promote the structural development of the rumen epithelium (Zitnan *et al.,* 2003).

Mir *et al*. (1997) considered the length of papillae, villi and depth of crypts as important factors in nutrient absorption. Growth and development of the ruminal and intestinal absorptive surface area is necessary to enable absorption and utilization of end products of microbial digestion specifically rumen Volatile Fatty Acid (VFA) (Warner, 1991). Rumen absorptive surface area increases as papillae length and width increase (Lesmeister and Heinrichs, 2004). The papillary growth (Duff *et al.,* 2000) and taller villi may indicate an increased absorptive surface area for improved nutrient uptake.

The rumen and reticulum are usually treated as a single compartment, the ruminoreticulum forming the largest part of the stomach occupying 73% - 84% of the total volume in adult ruminants (Van Soest, 1994). The ruminal - reticulum is considered to be the most important fermentation and absorption chamber for coarse or fibrous feed and the contents can move freely between the two chambers (Van

Soest, 1994). About 50% of all digestion takes place in the rumen. Fingerlike projections, called papillae, in the rumen increase the surface area for the absorption of nutrients after digestion. Reticular ridges in the reticulum help in the sorting and handling of particles before they pass to the omasum. The omasum connects the reticulum to the abomasum and is the main absorptive organ. In cattle 30-60% of the total water and 40-69% of total volatile fatty acids (VFA) entering the omasum are absorbed there (Van Soest, 1994). Well digested and absorbed diet, lead to increase in animal production such as carcass weight and visceral organs. So far, insufficient investigations have been carried out on the effects of feedlot diets' digestibility upon the morphology of the rumen and the small intestine of fattened cattle. This investigation would therefore contribute to development of proper fattening feeds for TSHZ in ranches. The main objective of the present study was to assess the relationship between diet digestibility and changes of morphology of the digestive system of TSHZ fattened on diets based on agro processing by products.

The specific objectives of the study were

i. To assess the effect of diets on the length and width of ruminal papillae of fattened cattle.
ii. To assess the effects of diets on crypts and depth of intestinal villi of fattened cattle.
iii. To assess the relationship between digestibility of diets and morphology of the gut.
iv. To assess the effect of diets on the carcass, liver weight and glycogen level of cattle fattened with diets based on agro processed by products.

CHAPTER TWO

2.0 LITERATURE REVIEW

The purpose of this review is to collect the available information on digestibility and way in which diet affects the morphology of the digestive system. The focus of the review is centered on digestibility of different feed and their effect on the morphology of the digestive system. This review gives detailed information on the way in which digestibility of feeds brings changes to ruminal and intestinal structures that is papillae, villi, and crypt. In addition, the way in which feed digestibility affects carcass, liver weight and glycogen level.

2.1 Morphology of Ruminant Digestive System

Understanding the anatomy and physiology of digestive system is useful in conceptualizing the effect of diet on morphology of digestive system of ruminants (Fisher, 2002). Performance of animals under feedlot is derived from the type of diet, morphology of the digestive system through which the nutrients passes and digestion processes that include absorption of nutrients. Ruminant animals have four compartmentalized stomach. The reticulum, rumen and omasum are classified as the non-glandular fore-stomach. These compartments are the site of anaerobic microbial fermentation and function to store and regulate the passage of digesta. The abomasum is the forth compartment of the stomach and is the only glandular compartment. The esophagus empties into the reticulum and rumen. The reticulum is classified as a blind sac and is noted for its “honeycomb” like mucosal surface. It is muscular and often is considered part of the rumen (ruminoreticulum). The rumen is

the largest compartment of the stomach. It is characterized for its finger like projections called papillae (Van Soest, 1994). These papillae increase surface area for nutrient absorption. The length and size of the papillae largely depend on the type of diet being consumed and which affects the type of volatile fatty acids (VFA) produced.

When a feedstuff is in the ruminoreticulum, smooth muscular contractions allow it to continuously churn until the feed particles are small enough to enter the opening into the omasum. The omasum is composed of muscular leaflets with papillae, and water is absorbed in this compartment. If digesta comes out of the rumen small enough it may bypass the omasum and directly enter the abomasums (Van Soest, 1994; Fisher, 2002).

The abomasum is considered to be the "true" stomach in ruminant animals. The mucosal lining of the abomasum is arranged in folds known as abomasum or gastric folds. The abomasum environment is very acidic due to the secretion of hydrochloric acid and other digestive enzymes. The abomasum connects to the small intestine at the pyloric sphincter.

The duodenum, the first part of the three sections of the small intestine, is where bile and pancreatic secretion enter the gastro-intestinal tract. The duodenum is relatively short in length and connects with the jejunum; the longest section of the small intestine. In the jejunum the largest quantity of nutrients absorption take place. From the jejunum the small intestine transitions into the ileum. Like the duodenum, the

ileum is relatively short. The thicker mucosal tunica of the entire small intestine contains finger like projections called villi which facilitate absorption and are similar to the papillae of the rumen (Banerjee, 1991). The villi decrease in size distally in the small intestine.

Succeeding the small intestine in ruminant animals is the hindgut, which is functionally similar to that of other mammals. It is comprised of the large intestine, the cecum, colon and the rectum. Unlike the small intestine, the hindgut does not have villi. The rectum is the final storage point for digesta before defecation from the anus. Absorption of inorganic ions and water takes place in the large intestine, consequently, faecal materials are drier as they move through the large intestine. The large intestine is also a major site for microbial fermentation.

2.1.1 Effect of diet on morphology of digestive system

Nutrient acquisition begins with dry matter intake (DMI), which is the dominant process for assessing animal productivity followed by digestibility of the DM and then absorption. Nocek *et al*. (1984) found that the ruminal epithelial lining is thicker and shows more vaculation of stratum granulosum in concentrate – fed animals and has more mucosa to muscles compared to the rumen of cattle fed ground or chopped hay. In forage-fed animals, the processes that occur in the rumen play a determinant role in the amount and type of nutrients absorbed (Tamminga and Van Vuuren, 1996). The nutrients absorbed are derived from digestion of the dry matter that is consumed by the animals. The rate of changes as well as the development and stabilisation of the physiological functions of the digestive tract and dry matter intake

are related to the physical structure of feed (Greenwood *et al*., 1997; Baldwin *et al*., 2000). It is known that physical structure of the feed affects its digestibility. On the other hand, there are direct relationships between papillae, villi and crypt development and digestibility of forage (Villalba and Provenza, 1999).

Zitnan *et al.* (2003) studied the length of intestinal villi in cattle fed intensively on barley straw and pelleted concentrate at a ratio of 28: 72 and found that, the length of duodenal villi significantly increased (P = 0.026) whereas that of jejunal villi approached the limits of significance (P = 0.052) when compared to the extensive group which grazed on natural pasture. There was no significance difference observed in the length of ileal villi.

In the intensive group, the crypts were deepest in the duodenum (309 μm), this value approaching the limits of significance (P = 0.065) when compared to the extensive group (285 μm) which grazed on natural pasture. In jejunal and ileum the differences were very small, however, higher in the intensive group, as shown on Table 1 and 2.

Table 1: Morphometrical parameters of papillae of the ventral ruminal sac

	n	Length (mm) ±SE	Width (mm) ±SE	Number per cm^2	Surface area (mm^2/cm^2)
Intensive rearing	7	6.54 ± 0.56	2.33 ± 0.24	55 ± 6	1 677 ± 191
Extensive rearing	7	5.23 ± 0.40	1.82 ± 0.14	55 ± 3	1 044 ± 80
P values		0.0002	0.001	0.85	0.00002

Source: Zitnan *et al.* (2003)

Table 2: Height of villi and depth of crypts in the small intestine

	n	Villi (µm) ±SE			Crypts (µm) ±SE		
		duodenum	jejunum	ileum	duodenum	jejunum	ileum
Intensive rearing	7	550 ± 44	585 ± 44	509 ± 42	309 ± 21	296 ± 23	303 ± 15
Extensive rearing	7	501 ± 58	527 ± 56	502 ± 32	285 ± 21	282 ± 22	302 ± 23
P values		0.026	0.052	0.54	0.065	0.104	0.83

Source: Zitnan *et al.* (2003)

Study in cattle calves conducted by Strusnska *et al.* (2009) indicated that at 90 days of age, the bulls of experimental group (supplemented with whole maize grains followed by oat grain) were characterized by thinner ($P<0.01$) ruminal epithelium, including a thinner cornified layer (17.50 vs 33.39 µm). The same calves had thicker duodenal epithelium ($P<0.01$) and thicker jejunal mucosa ($P<0.05$). Moreover, the calves of experimental group had regular length, shape and tall intestinal villi, which were irregular in the calves of control group which were supplemented with ground cereal grains. The physical structure of the diet has been reported to affect papillary, villi and crypts depths in size and shape, but does not influence the muscle thickness of rumen (Beharka *et al*., 1998). Roughage in adequate amounts and consistency is required to maintain the growth of the rumen epithelium and papillae in mature cattle, whose effect is diminished if the roughage is ground (McGavin and Morrill, 1976). However, the difference from observations made by the above authors might arise due to differences in types of feedstuffs used for fattening animals and probably differences in environmental conditions. Therefore, there is a need to establish that relationship of digestibility and morphology of digestive system for Tanganyika Short Horn Zebu as there is no similar study that has been conducted in Tanzania.

2.1.1.1 Effects of diet and diet digestibility on rumen papillae and intestinal villi

Digestibility of feed determines the nutrients that might be available for absorption into animal's body to cater for various body functions. Scocco *et al*. (2007) observed morphometric variation of rumen papillae according to variation in forage digestibility and nutrient supply. Type of feed and digestibility also account for development of rumen papillae as reported by Dirksen *et al*. (1985) that grain feeding increases length of the rumen papillae in comparison to feeding only poorly digestible roughages. Study in heifer calves conducted by Harrison *et al.* (1960) where by at 16 and 35 weeks of age, twelve Holstein Heifer calves were sacrificed in which six had voluntarily consumed a high – concentrate diet and other six a high roughage diet.

The ratios of hay to concentrate were 1:9 and 9:1 respectively. Rumen papillae length and width were greater ($P<0.03$) in the faster growing (high concentrate) calves compared to high roughage one. Apparently, both rapid growth and papillary development were due to the highest energy levels consumed by these animals. Kromann and Meyer (1972) studied the influence of the ration's energy contents and physical form on rumen morphology. Twelve ruminant animals were fed on 2 feeds, ration 1 consisted of 98% alfa alfa hay and 2% animal fat (low energy) and ration 2 consisted of 20 alfa alfa, 2% animal fat and 78% barley (high energy). The rations were of two physical forms, milled and pelleted. The lambs fed the high energy diets had a higher ($P< 0.05$) rumen morphology score than those fed low energy. The pelleted physical form had the most score ($P< 0.05$) on papillae length

and width particularly with high energy diet, compared with milled and low level energy.

Mixing of concentrate with forage may affect digestibility of forage and consequently affect development of rumen papillae due to shift in volatile fatty acids (VFA) from that of cellulose origin to VFA from concentrate. (Scocco *et al*., 2007) observed that grass diet promotes the development of rumen papillae due to the effect of VFA produced by cellulose digestion.

Wang *et al.* (2009) studied the changes in the morphology of the digestive system of 18 old Guanzhong wether goats (body weight 28.5±16kg) assigned to three treatments of dietary starch levels. (1) Low Starch (LS, 28%), (2) Medium Starch (MS, 35%) and (3) High Starch (HS, 46%) after 35days of experiment, he observed the following; MS diet significantly stimulated the development of rumen by increasing the papillae height ($P<0.01$). It also enhanced villus height and crypt depth of duodenum ($P<0.01$). HS diet significantly decreased the ruminal pH, compared with its effect on rumen morphology. This experimental study indicates that starch level in diet plays an important role in rumen development, as shown in Table 3. Villi and crypts are the functional units of the small intestine, assuming the role of digestion and absorption. Changes in the development of the enterocytes and in the structure of villi determine the digestive and absorptive capacity of the small intestines.

Table 3: Influence of Dietary Starch Level on Rumen Morphology

	Dietary Starch Level			SEM	P -Value
	Low	**Medium**	**High**		
Papillae Height μm	2025[a]	2060[a]	1620[b]	844.1	0.005
Papillae Width μm	424	413	402	66.6	0.054
Wall surface μm²	612 030[b]	756 549[a]	21 412[c]	20 371	0.0032
Papillae density n/cm²	85	86	87	5.43	0.447

Source: Wang *et al.* (2009)

Hampson (1986) reported that by measuring the villous height and studying villous shape one can estimate the number of enterocyte in the villous. In other words, if the villi are longer and flatter, the enterocyte surface will be longer and consequently, higher absorptive ability. Villous height (VH), crypt depth (CD) and the ratio of VH/CD reflect intestinal health (Wang *et al*., 2009). Sharifi *et al.* (2007) reported that a reduction in VH caused by soluble non-starch polysaccharide can reduce values of nutrient digestibility. On the other hand, feeding of poor digestible diet may cause poor development of villi in small intestine due to limited supply of nutrients required for villi development. Study by Baldwin *et al.* (2000) on effect of dietary protein levels on viscera tissue mass and intestinal morphology of cattle. Thirty two beef steers (285 ±3kgBW) were used, steers were assigned to; diet 1 10% CP and diet 2 13% CP.

After 84 days, steers were slaughtered and viscera organ removed separated and were observed; Rumen and abomasums weights and small intestinal length were greater ($P<0.04$) in steers fed 13% CP diet than those fed 10% CP diet on both absolute weight basis and percentage of empty BW. Increasing the dietary CP also increased

the villus height in duodenum (P = 0.02) and the crypts depth of jejunal (P = 0.03) sections.

2.2.2 Diet digestibility and it's measurement

Nutritive value of feeds is determined by a number of factors, including composition, odor, texture and taste (Schneider and Flat, 1975). These factors are generally measurable in the case of the animal as digestibility and intake. Digestibility is simply a measure of the availability of nutrients from the offered feeds to the animal. There are several techniques used in measuring digestibility, one among them is: Marker technique.

There has been considerable interest among animal nutritionists, in methods of reducing the time and expense involved in digestion experiments, by the use of methods where total faeces are not collected and weighed but are merely analyzed. This departure from the former method of determining digestibility has been designated as the indicator or index method (Kotb and Luckey, 1972). In this method, in addition to the chemical analysis of the usual proximate nutrients, the content in the feed and faeces of an indigestible reference substance is determined. The substance may be a natural constituent of the feed (internal indicator) or it may be added to the feed (external indicator). Substances used for this purpose include ferric oxide, chromic oxide, lignin, silica, chromogen, acid-insoluble ash (Van Keulen and Young, 1977) and indigestible acid detergent fibre (Waller *et al*., 1980). A good marker must be strictly non absorbable, must not affect or be affected by the gastrointestinal tract or its microbial population, must be physically similar to or

intimately associated with feed material and its method of estimation in digesta, samples must be specific and sensitive and not interfere with other analyses. Apart from the way of measuring digestibility, feed digestibility tend to be affected by several factors which lead to affect morphology of digestive system, some of those factors are:-

a) Feed intake

The plane of nutrition is one of the primary factors that affect digestibility of any feed. Experiments have shown that livestock usually, digest a larger percentage of the nutrients in their feed when fed restrictedly than when they receive full feed (Okin and Mathison, 1991; Faichney, 1993). Most data indicate some depression in apparent digestibility as level of intake is increased. This may be due to a more rapid movement of feed through the tract, thus allowing less time for digestion and absorption, which tend to affect the growth of digestive system morphology (Kromann and Meyer, 1972).

b) Chemical composition

One of the most significant factors, that affect diet digestibility and morphology of digestive system, is the chemical composition of the feeds (Luginbuhl *et al*., 1994; Sarwar *et al*., 1994). Digestibility of one feed is believed to differ from that of a similar feed because each may contain different contents of certain chemical entities, particularly since some of these diminish the opportunity for the digestive enzymes to come in contact with their respective substrates. On the other hand, digestibility of complete feeds can be enhanced by the additions of relatively small quantities of

specific nutrients such as protein or soluble carbohydrates, which lead to stimulation of papillae and villi development (Swift *et al*., 1994) while forage digestibility is dependent on the cell wall (neutral detergent fibre) content and its availability is determined by lignifications and other factors.

c) Diet composition

Optimization of the rumen function is of major importance for the digestibility of diet and morphology of digestive system, especially the one which is based on low quality roughages (Galyean and Goetsch, 1993). There are strong relationships between diet composition, digestibility and growth of digestive morphology (Kromann, 1973). Rumen microbial ecosystem and activity are influenced by the supplement type and level in the diet, which determine the availability of minerals, nitrogen and glucogenic precursors (Berge and Dulphy, 1991). Special attention is given to ce1l wall concentration in the ration as it is related to feed efficiency (Van Soest, 1994), inter ingredient relationships determine the occurrence of associative effects (Archimede *et al*., 1996). Rations should then be formulated not only to meet ruminant nutrient requirements but also to stimulate positive interactions among ingredients (Sauvant and Giger, 1989). The latter interactions may improve the feed value by enhancing feed intake, microbial synthesis and fibre degradation later on papillae and villi development.

d) Feed processing

Processing of feedstuffs is conducted in an attempt to enhance digestibility (Sarwar *et al*., 1994). Changes in physical form can influence digestibility of the dry matter,

energy, protein or any of the organic substances in feed products. Such processes as drying, grinding, pelleting and wafering all act to generally affect digestibility. Chemical, biological treatments and chopping improve the digestibility of fibrous feeds (Sarwar *et al*., 1994). Much data exist indicating that forage digestibility is depressed by grinding to a very fine particle size (Galloway *et al*., 1993) Fine grinding also apparently increases rate of passage that consequently reduces the digestibility and growth of digestive system morphology.

There is strong relationship between diet digestibility and morphology of digestive system. Well digested diet lead to high improvement of morphology of digestive system that has been observed by different authors.

The study by Safiétou *et al*. (1998) showed that *In vitro* DM and OM digestibility were significantly ($P<0.05$) influenced by diet type and was higher ($P<0.01$) in diet which contained more concentrate compared to the straw based diet, also that diet performed well in papillae and villi length due to high concentrate proportion that supplied readily fermentable carbohydrate, which increased rumen microbial population.

Terje *et al*. (1996) studied the influence of diet digestibility on morphology of digestive system and reported that DM and OM digestibility was higher in group which was fed experimental diet compared to free ranging group. Experimental diet showed highest ($P<0.01$) overall papillae length and density, resulting in the surface enlargement factor (SEFs) 25% higher than overall 3 group of free ranging. These

indicated that, the low ability of fermentation with high content of cellulose lead to poor digestibility and growth of morphology of digestive system.

Study conducted by Hristov *et al.* (2001) on fermentation characteristics in cattle fed medium and high concentrate barley – based diets, observed DM digestibility and N contents to be higher ($P < 0.05$) and concentrations of NDF and ADF to be lower ($P < 0.05$) in the high barley than in the medium barley diet. When fed the high barley diet, the steers had higher ($P < 0.05$) intakes of DM and N and lower ($P < 0.05$) intakes of NDF and ADF. The concentration of soluble protein in the rumen was generally higher ($P < 0.05$) with the high barley diet than with the medium barley diet. Higher ruminal concentrations of total VFA ($P < 0.001$) propionate ($P < 0.001$), acetate and butyrate ($P < 0.05$) were observed in high barley than in the medium barley diet. The higher concentrations of ruminal VFA led to high development of ruminal papillae and intestinal villi.

2.2.3 Effects of VFA concentration on ruminal and intestinal morphology

A diet rich in concentrate is generally associated with high concentration of short chain fatty acid (SCFA) (Dirksen *et al.,* 1985), this will consequently lead to increased transport of SCFA across the ruminal wall (Gäbel *et al*., 1987), stimulating some aspects of rumen morphologic and metabolic development (Lane and Jesse, 1997). Such diet will lead to stronger development of rumen papillae and intestinal track than that observed with diet based on forage, but it also depend on the physical structure of that diet (Zitnan *et al*.,1999).

It has been shown that under standard conditions the mitotic index of the epithelial basal cells of the rumen does not exceed 1.0% (McGavin and Morrill, 1976) and that increases significantly after intraruminal administration of butyrate, propionate and acetate (Sakata, 1995). In addition, the acetate-propionate ratio can also influence the development of the rumen mucosa (Zitnan *et al*., 1999). However, both propionate and butyrate stimulate much more papillary growth than did acetate (Sakata, 1995). Nevertheless, butyric acid is far more effective than propionic acid in development and stimulation of papillae growth (Kauffold *et al*., 1977). The difference between these two fatty acids could mainly be explained by different apoptotic rates, which is only one third for propionate compared to butyrate (Mentschel *et al*., 2001). Therefore, this explains the differential effect on papillary length caused by the two fatty acids (Mentschel *et al*., 2001).

Butyrate in particular appears to be the most potent SCFA in promoting the development of rumen epithelium (Tamate *et al.*, 1977). This finding has also bee supported by the demonstration of an increased mitotic index and a decreased cell deletion (apoptosis) in sheep fed barley (Tamate *et al.,* 1977). Nevertheless, the opposite is found in animals fed hay (Tamate *et al.*, 1977). Hofmann and Schnorr (1982) described changes in the barrier layer (flattened horn cells) in relation to diet. The barrier layer of the rumen epithelium becomes thicker in winter or in dry seasons when animals eat food with large amounts of fibre. It is evident that there is a close relationship between type of feed consumed by ruminants and morphology of the digestive system. Since TSHZ belong to the group of ruminant animals, they might indicate similar relationship.

Other authors observed that volatile fatty acids (in particular propionic acid and butyric acid) produced during nutrient fermentation are essential for inducing physiological changes in the functions of the stomach in calves, evolving from those typical of monogastric animals (at birth) to those characteristic of adult ruminants (Warner, 1991; Lesmeister and Heinrichs, 2004). The stimulation of rumen development by volatile fatty acids is indicative of a correlation between anatomical changes in the rumen (including the growth of ruminal papillae) and microflora growth (Baldwin, 1998; Beharka *et al*., 1998; Lane *et al*., 2000).

It is known from literature that concentrate-rich diets cause an increase in VFA (mainly propionic and butyric acid) production thus stimulating the metabolism of the rumen epithelium, the structural development and absorptive activity (Jesse *et al.,* 1995; Lane and Jesse, 1997; Zitnan *et al.,* 1999). Therefore, the end products of digestion have correlation with morphology of digestive system in ruminants. The growth of the papilla, villi and crypts depth was dictated by the type of diet ingested: the more digestible the diet (i.e. higher concentrate) the longer the papillae, villi and crypts depth for increased surface area for absorption of the increased VFAs produced while the less digestible the diet, the shorter the papillae. This entails the need for assessing digestibility of feedlot rations provided to Tanganyika Short Horn Zebu during fattening in relation to morphology of digestive system of TSHZ.

2.3 Effect of Diet on Carcass and Liver Weight and Glycogen Level

Dietary energy in particular affects tissue depots in growing animals as a result, carcass traits and meat quality are also influenced (Oddy *et al*., 2001; Purchas *et al*.,

2002). Research has shown that the finishing diet for beef cattle can greatly impact growth performance and carcass traits. Cattle finished on high-concentrate or high-energy diets have superior carcass quality attributes, such as heavier hot carcass weights (HCW), higher quality grades and marbling scores than carcasses from cattle finished on lower-energy or forage-based diets (McMillin *et al*., 1990; Mandell *et al*., 1997).

Warner *et al.* (2002) conducted an experiment on sixty Hereford-types steers of approximately 400 kg live weight and age of 16 to 27 months. Experimental animals fed on pasture of low nutrition value and other on hay supplement (high level of nutrition) for three weeks prior to slaughter. The cattle of high level of nutrition had a positive and higher live weight change over the three week period ($P < 0.001$) and were 6% heavier in final mean live-weight ($P < 0.01$) than those on low level of nutrition, although mean carcass weight was similar ($P > 0.05$). The cattle on low level of nutrition lost more weight over the three weeks, had a lower final live weight and lower loin muscle glycogen than on high level of nutrition. Cattle in the low level of nutrition had lower muscle glycogen than the other treatment ($P<0.01$). It was concluded that, high nutrition diet is needed for better carcass weight and glycogen level. Although increasing roughage in the diet may appear beneficial, there is concern that feeding forages at high levels may depress growth rates, carcass and meat quality due to depressed feed intakes and energy dilution of the diet. Cattle finished on forage typically take longer to reach market weight, and often have decreased average daily gains (ADG) than concentrate-fed cattle because of the low energy of the forage feeding (Bennett *et al*., 1995). The gut and liver have a

considerable impact on the partitioning of metabolizable energy between heat energy loss and net tissue energy gain (Reynolds and Maltby, 1994). In fact, the gut and liver account for 45 to 50% of whole-body heat energy production but comprise only 10 to 13% of whole-body tissue mass (Seal and Reynolds, 1993). This implies that energy rich diets in feedlots might influence liver mass through energy deposition in form of glycogen. The study conducted by Ferrell *et al.* (1986), examined further the relationship between body weight gain and viscera organ. The lambs were fed on various levels of diets and kept for different period, as shown on Table 4.

Table 4: Influence of diet on visceral organ

Treatments	Liver	Heart	Kidney
Period 1			
HG	788	173	138
MG	628[e]	140[d]	112[d]
LG	668[f]	155[de]	121[e]
Period 2			
HG	409[d]	141[d]	92[d]
MG	433[d]	121[e]	94[e]
LG	291[d]	120[d]	74[d]
Residue	45	13	12

Where HG – High gain lambs, MG - Middle gain lambs. LG - Low gain lambs
Source: Ferrell *et al.* (1986).

At the end of experimental period, when comparisons were made among groups of lambs of similar weight, had been fed to gain more rapidly (HG) had greater weights or proportions of visceral organs (liver, heart and kidney) than lambs fed to gain less rapidly (LG).

Jenkins *et al*. (1986) reported data from a study involving non pregnant, non lactating cows previously characterized as having high or low milk production potential, A sample of cows was killed initially. The remaining cows were fed at either a high or low level for 84 days, and then killed. Weights of lung and liver were greater in high-milk-producing cows than in low-milk-producing cows, and weights of all organs measured (heart, lung and kidney) were greater relative to metabolic body size in cows fed at the high level compared with those fed at the low level, or those killed initially.

The glycogen stored in the muscle is dependent on the nutrition of the animal before its slaughter. High energy feed, such as a feedlot ration or grain supplementation, provides enough energy to support general body function (or its maintenance requirements) as well as an excess, which is stored as glycogen in the muscles. This glycogen reserve is available to the animal when the need arises, such as when it is stressed. Alternatively, if an animal has been on low energy feed (e.g. poor quality hay or dry grass), most of the energy from this feed is used up for maintenance with only a small reserve in the muscle to be used if stress occurs (Brian, 2006).

Other studies suggest that heat production by the portal-drained viscera (PDV) increases with dietary fibre content (Reynolds *et al*., 1991). This causes loss of energy that might be deposited in body tissues as stored energy. On the other hand, Reynolds *et al*. (1991) demonstrated that the partial efficiency of ME for tissue gain was greater in heifers fed 75% concentrate than in heifers fed 75% forage at equal ME intake, primarily due to lower PDV heat production. These demarcate the reason

why concentrate feeding is normally preferred in feedlots as the basic need for fattening of animals. However, enough time is required to demonstrate changes in alimentary and liver mass due to improvement of diet.

2.4 Conclusion

It has been revealed from the review that, various studies demonstrated that type and quality of diet contribute in morphological changes in gut tissues and changes in visceral organ mass of animals. However, little attention has been given to the effect of diet digestibility on morphological changes in gut tissues and visceral organs of beef cattle particularly TSHZ in feedlots production system. The aim of the current research was to investigate the relationship between diet digestibility and morphology of digestive system of local zebu cattle finished on agro processing by products. The information obtained could encourage efficient utilization of locally available agro processing by product which is currently unutilized local resource for local zebu especially in feedlot.

CHAPTER THREE

3.0 MATERIALS AND METHODS

A study was carried out with the major objectives of assessing the digestibility of diets and changes of the morphology of the digestive system of TSHZ fattened on diets based on agro processing by products.

3.1 Location of the Study

The study was carried out at Kongwa Ranch, which is located in Dodoma region, Central Tanzania. Kongwa ranch lies between latitude 5° 55’ and 6° 10’ South and from longitude 36° 15’ to 36° 46’ East. The area is a typical representative of semi – arid areas of Tanzania where the majority of livestock are kept. The digestibility studies were conducted at Kongwa ranch while samples for morphology of the digestive system were collected after slaughtering of the animals at Dodoma abattoir.

3.2 Experimental Design and Treatments

The experimental layout was based on an ongoing feedlot experiment. Forty five (45) Tanganyika Short Horn Zebu (TSHZ) cattle aged two to three years with average weight of 200kg were allocated to five dietary treatments in a feedlot experiment, nine animals per treatment in a complete randomized design (CRD) and other nine animals grazed on natural pasture as a control group, which made a total of 54 animals.

3.3 Management of experimental animals and feeding

The feedlot animals were confined in individual pens that enabled collection of faecal samples from each animal. The diets were compounded as indicated in Table 5. The feedlot animals were fed *ad libitum*, for both hay and concentrate. The control group grazed on natural pasture.

Table 5: Diet ingredients and proportions (%) of the formulated concentrate diets

Diet ingredient	T1	T2	T3	T4	T5
Maize bran	0	33	50	0	0
Maize meal	38	0	38	0	30
Rice polishing	0	0	0	41	51
Molasses	47	47	0	47	0
Cotton seedcake	13	18	10	10	09
Mineral mix	1	1	1	1	1
Salt	0.5	0.5	0.5	0.5	0.5
Urea	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100

3.4 Digestibility Trial

Digestibility study was conducted during the last two weeks of the feeding experiment. Acid Insoluble Ash which is a natural constituent of the diet was used as internal marker according to the procedure of Van Keulen and Young (1977). The daily allowance was given twice per day at 0730 and 1830hours, with hay to concentrate ratio of 1:5. The faecal samples were collected immediately after faecal dropping during the collection time. They were collected at an interval of 4 hours for a period of 12 hours, which made a total of three samples per animal per day. Faecal

samples for all animals were weighed and sun dried for several hours, partially ground and stored in plastic bags until the end of the collection period. Diet refusal for feedlot animals were collected every morning. Similarly for the control group, It's faecal samples were collected in grazing area immediately after drop, also samples from grazing pasture were collected every day during grazing time.

3.4.1 Sample preparation

At the end of the collection period, the collected samples (diet, refusal and faeces) of known partial sun dried weight were dried to a constant weight in a forced air oven at the Department of Animal Science laboratory at Sokoine University of Agriculture. The dried daily faecal samples from each animal, three times per day were mixed together and then ground, making one faecal sample per animal per day; thus led to 10 samples per animal per experimental period of ten days. Diet and refusal samples were also ground and five composite samples were made at an interval of two days for the 10 days.

3.4.2 Chemical analysis

The collected diet, refusal and faecal samples were analyzed for DM and ash contents according to the standard procedures described by AOAC (1990). The Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) contents of diet, refusal and faecal material were analyzed according to Van Soest *et al*. (1991).The DM content of the samples was determined by drying duplicate samples of known weight in oven set at 60 – 70 ºC for 48 hours and raised to 105ºC for 24 hours.

3.4.3 Estimation of digestibility coefficients

The 2N HCI Acid Insoluble Ash (AIA) analytical procedure was used for determination of acid insoluble ash content of diet, refusal and faeces (Van Keulen and Young 1977).

A duplicate sample of 5-g each of the dried and ground diet, refusal and faeces were weighed into a 50 ml crucible and dried in a forced air oven (135ºC) for 2 hours. There after the samples were cooled in a desiccator to room temperature, re-weighed (Ws) and then ashed for 3 hours at 450ºC. The ash was weighed and transferred to a 600 ml Berzelius beaker (without spout) and 100 ml of 2N HCI was added. The mixture was boiled on a hot plate for 5-min. The hot hydrolysate was filtered using ash free filter paper of known weight and washed free of acid with hot (85 to 100ºC) distilled water. The ash and filter paper were transferred into a crucible of known weight and were ashed for 3hours at 450º C. The crucibles and their contents were cooled in a desiccator to room temperature, weighed while containing ash (Wf) and re-weighed immediately after emptying (We). Percentage AIA was calculated from the equation: (Wf - We)/Ws * 100, where Wf = weight of crucible with ash, We = weight of empty crucible and Ws = weight of sample dry matter. The same procedures were applied for the pasture grazed by the control group.

3.4.3.1 Calculation of digestibility coefficients

Apparent Digestibility (%) =100 – {100(%Ifd/% Ifc) * (% Ntfc /%Ntfd)}. Where I represents the “indicator “,fd is “ in diet,” fc is “in faecal” and Nt represents the “nutrient”

Ntfd = (fd*Nt) – (fr*Nt)/ (fd – fr) * 100. Where Ntfd = Nutrient concentration in feed intake,'' fd – diet offered,'' fr – refusal,'' Nt - nutrient.''

3.4.4 Measurements of Gut Morphology

3.4.4.1 Collection of tissue samples

The animals on feeding trial were slaughtered after 90 days of experimental period. After slaughter, animals were bled, skinned eviscerated and digestive tract removed. The weights of the carcass and liver were recorded. Ruminal and intestinal contents were removed from the gastro intestinal track immediately after evisceration. Tissue samples of rumen, intestinal and liver from all animals were collected from different compartments within 30 minutes after slaughter before washing the gut. Samples of the rumen wall intended for morphological examination were obtained from identical sites of the ventral ruminal sac (approximately 30cm caudal of the cranial pillar). Small pieces of rumen about 3 by 3 cm in size were taken from the sampling point. The duodenal tissue samples (about 10 cm length) were taken from a site about 50 cm distal of the pyloric sphincter, while jejunal ones from the mid-jejunum (approximate centre of the jejunum). Ileal samples were obtained at 50 cm proximal to the ileo-caecal junction. A small piece of liver was also cut. All the samples of tissue were fixed in 10% neutral buffered formalin for subsequent laboratory assessments.

3.4.4.2 Measurements of papillae, villi, crypt and liver

Three papillae were dissected from each rumen piece, where by the length and width of rumen papillae were measured using a ruler. Tissue samples from the liver and

intestinal which were fixed in 10% formalin solution, rinsed with water to remove the chemical. Five straight villi were randomly selected on each section of duodenal, jejunal, ileum and measured by using light microscope. The slides which had tissue samples were fixed in microscope and viewed at a 10× magnification, which corresponds to 12.05 μ microns. The tip of the villi before the fold measured the length and the bottom of the fold before submucosal was taken as a measure for the depth of the crypts. Samples of the liver also taken and glycogen levels of the Periodic Acid Schiff (PAS) of stained liver sections, were estimated by comparing the level of pinkish color on the stained sections after fixing tissue slide on microscope. Deep pink color was scored 100 – 80%, pink color 80 – 60% and light pink score 60 – 40%, very faint pinkish color was scored 40 – 20% and lack of pinkish staining was scored 20 – 0%. This procedure was taken due to lack of automatic machine for glycogen level measurement. Panasonic digital camera was used to take some slide pictures.

3.5 Statistical Analysis

The obtained data on digestibility values, morphological characteristics, carcass and liver weight and glycogen levels were statistically analysed using GLM procedure of SAS (1990).

3.5.1 Model for digestibility, rumen morphology, carcass and liver weight and glycogen level

$$Yij = \mu + Ti + eij \quad \ldots\ldots(1)$$

Where as

Yij = Response of j^{th} animal belongs to i^{th} treatment (diet)

Ti = Effect due to i^{th} treatment (diet)

μ = Overall mean

eij= Random error

3.5.2 Model for villi and crypt depth

Yijk = μ+ai +bj +ck+ (ab)ij + e ijk.....(2)

Where

Yijk = Response of k^{th} (villi and crypt of animal) belongs to i^{th} treatment (diets) and j^{th} gastro – intestinal compartment.

μ = Overall mean

ai = Effect due to i^{th} treatment (diet)

bj = Effect due to gastro - intestinal compartment (duodenum, jejunum and ileum)

(ab)ij =An interaction effects of i^{th} diet and j^{th} compartment

eijk = Random error.

Main effects of means were further examined using Duncan's Multiple Range Test. The dependent variables assessed were digestibility and morphology of digestive system. i.e length and width of papillae, villi length and crypt depth that arise due to diets digestibility for the ijk^{th} in individual cattle.

CHAPTER FOUR

4.0 RESULTS

4.1 Chemical Composition of the Dietary Treatments

Table 6 shows the chemical composition and Metabolizable Energy (ME) of dietary treatments and hay used to feed the experimental animals. All dietary treatments had dry matter content of about or above 90%. Crude protein contents of the diets ranged from 128 to 169 g/kg DM, whereas the hay that was used as basal diet had very low crude protein content (43 g/kg DM). Dietary Treatment T3 had the highest crude protein content followed by treatments T5, T2, and T1 and lowest in Treatment T4.

Table 6: Chemical composition (g/kg DM) and Metabolizable energy (ME MJ/kg DM) of dietary treatments and Hay

Chemical composition	Treatments					
	T1	**T2**	**T3**	**T4**	**T5**	**Hay**
Dry matter	920	922	917	919	912	898
Crude protein	138	145	169	128	148	43
Ether extract	50	75	89	71	65	73
Neutral detergent fibre (NDF)	180	208	308	378	401	852
Acid detergent fibre (ADF)	96	117	162	201	271	577
Metabolizable energy	13.1	12.0	11.9	11.2	10.0	8.8

The ether extract content was highest in Treatment T3 followed by Treatment T2 whereas the content in hay was higher than that of treatments T4, T5 and T1. Hay had the highest amount of NDF and ADF followed by treatments T5, T4, T3, T2 and

T1. The metabolizable energy was highest in Treatment T1 followed by treatments T2, T3, T4 and T5. Hay had the lowest amount of metabolizable energy.

4.2 Digestibility Coefficients

The Lsmeans of apparent digestibility of various treatments are presented in Table 7. Analysis of variance showing the influence of treatment on digestibility values is presented in Appendices 1, 2, 3 and 4.

Table 7: Lsmeans ± SEM of the DM, OM, NDF and ADF digestibility of different dietary treatments

Treatment	Apparent Digestibility (% DM)			
	DM	OM	NDF	ADF
Control	35.7^{d}	32.6^{d}	24.8^{d}	18.4^{e}
T1	62.2^{ab}	55.3^{ab}	54.3^{a}	50.0^{b}
T2	63.9^{a}	58.8^{a}	57.4^{a}	54.8^{a}
T3	58.7^{b}	51.2^{b}	49.7^{b}	47.3^{bc}
T4	54.9^{bc}	48.6^{bc}	45.4^{b}	44.2^{c}
T5	50.3^{c}	43.6^{c}	40.9^{c}	39.2^{d}
SEM	1.388	1.608	1.596	1.715
P - Value	0.0001	0.0001	0.0001	0.0001

Means bearing same superscript along the same column are not statistically different at (P>0.05)

Treatment T2 had significantly (P<0.05) higher DM and OM digestibility than other treatments, but did not statistically differ (P>0.05) from that of Treatment T1. The Control diet, had lowest (P<0.01) DM digestibility value as shown in Table 7.

Treatment T3 had higher NDF digestibility than that of Treatment T5 and control diet (P<0.01). Treatment T2 had higher (P<0.05) fraction of ADF digestibility followed by treatments T1, T3, T4, T5 and Control diet.

4.3 Gut Morphology

4.3.1 Effect of treatments on ruminal papillae length and width

Table 8 shows the Lsmeans ± SEM of papillae length (mm) and width (mm) for the rumen of the experimental animals. Analysis of variance (ANOVA) showing the influence of treatments on ruminal papillae length and width are shown in Appendices 5 and 6, respectively.

Table 8: Lsmeans ± SEM of papillae length (mm) and width (mm) for the rumen of the experimental animals

Treatment	Papillae length (mm)	Papillae width (mm)
Control	10.5^{c}	1.70^{c}
T1	14.3^{ab}	2.89^{ab}
T2	16.1^{a}	3.44^{a}
T3	12.5^{b}	2.21^{b}
T4	13.2^{b}	2.70^{b}
T5	12.1^{b}	2.30^{b}
SEM	1.014	0.433
P - Value	0.0045	0.0265

Means bearing the same superscript along the same column are not statistically different (P>0.05).

The mean length of rumen papillae of cattle fed on Treatment T2 was significantly (P<0.01) longer than those on the other treatments except for T1. The mean difference between treatments T1, T3, T4 and T5 was not significant (P >0.05).

Cattle on the control group exhibited the lowest rumen papillae length (Table 8 and Plate 1).

(a) (b)

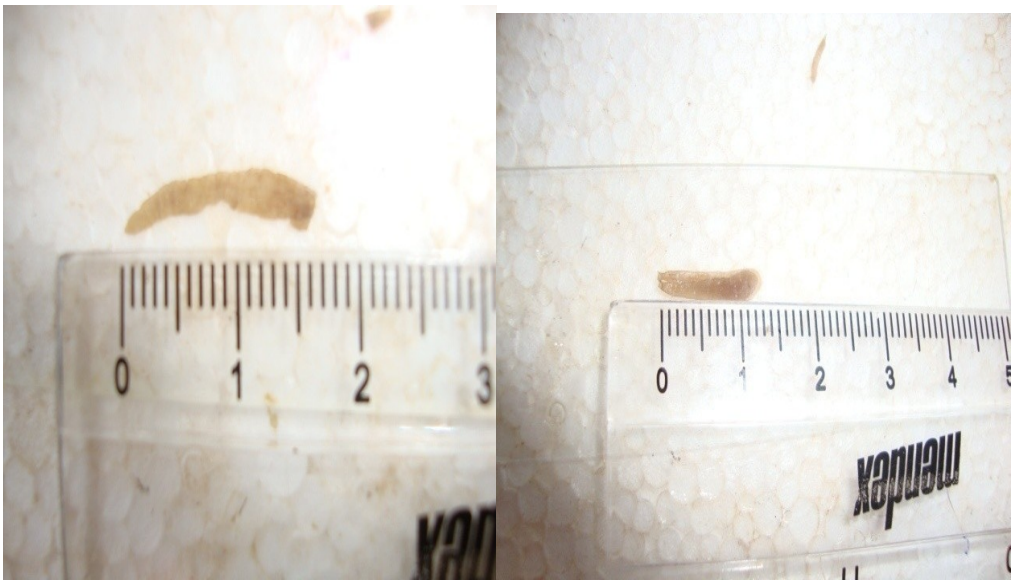

Plate 1: Pictures of papillae length (mm) of cattle on Treatment T2 (a) and control (b) as taken by a ruler

The mean rumen papillae width of cattle fed on Treatment T2 was wider ($P<0.01$) than rumen papillae of cattle in other treatments except Treatment T1. The rumen papillae of cattle fed on Treatment T1 were the second wider, although the width did not differ significantly ($P>0.05$) from those of cattle from other treatments except those on the control. Cattle on the control group had the lowest rumen papillae width (Table 8 and Plate 2).

(a) (b)

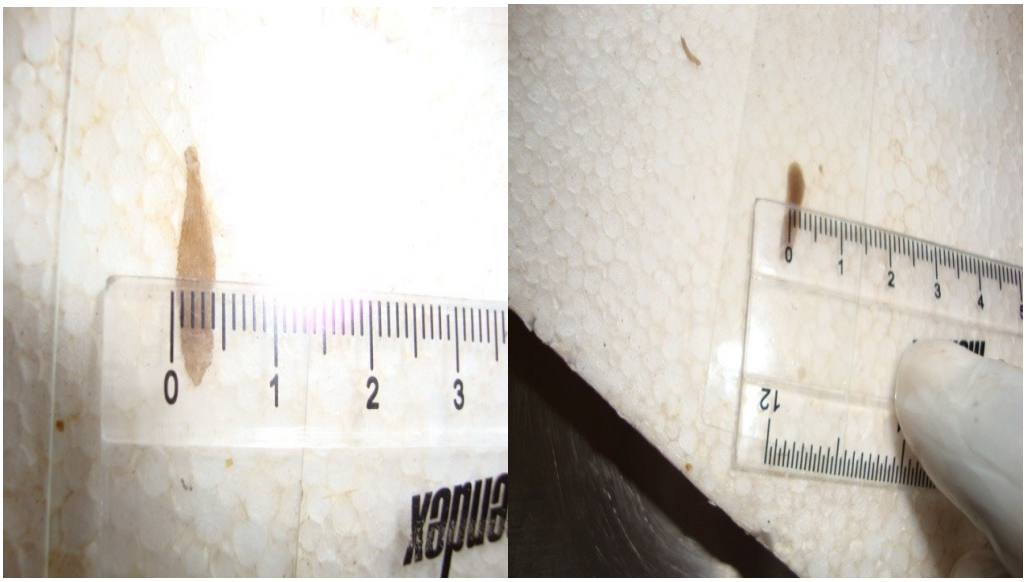

Plate 2: Picture of papillae width (mm) of cattle fed on Treatment T2 (a) and control (b) as measured by a ruler

4.3.2 Effect of dietary treatments on villi length and crypts depth

Table 9 presents the Lsmeans of villi length (µm) and crypts depth (µm) of intestinal track (IT) of animals on different dietary treatments. Generally, dietary treatments and IT compartments and their interactions significantly ($P<0.01$) influenced the villi length and crypts depth. The effect of treatments on villi length and crypts depth in duodenum, ileum and jejunum are demonstrated in Figures 1 and 2.

Cattle fed on Treatment T2 had higher ($P<0.05$) villi length and crypts depth than those under the other dietary treatments (Table 9, Figs 1 and 2). Cattle under Treatment T3 was the second in the order of having longer villi length although it did not differ significantly ($P>0.05$) from those assigned to Treatments T4 and T1. Cattle on the Control group had the shortest ($P<0.05$) villi length.

Table 9: Lsmeans ± SEM of Villi length (µm) and Crypts depth (µm) of GIT of animals on different dietary treatments

Treatment	Villi length (µm)	Crypts depth (µm)
Control	678[d]	218[e]
T1	872[bc]	334[b]
T2	981[a]	371[a]
T3	890[b]	316[c]
T4	861[bc]	286[d]
T5	815[c]	252[de]
SEM	1.3717	0.7633
P - Value	0.0003	0.0185

Means bearing the same superscript along the same column are not statistically different (P>0.05)

The crypts had higher depth in cattle on Treatment T2 than those on other treatments. Cattle fed on Treatment T1 had the second higher crypts depth. There were no statistical difference in crypts depth of cattle on treatments T4 and T5, and those on Treatment T5 and the Control group (Table 9).

Cattle on Treatment T2 had longer ($P<0.05$) duodenum villi than their counter parts, although did not differ significantly from those fed on treatments T3 and T4, but was significantly higher than those fed on treatments T1, T5 and the control. The mean length of duodenum villi from cattle fed on treatments T1 and T5 were not significantly different but they were longer ($P < 0.05$) than those of control group (Figure 1 and Plate 3).

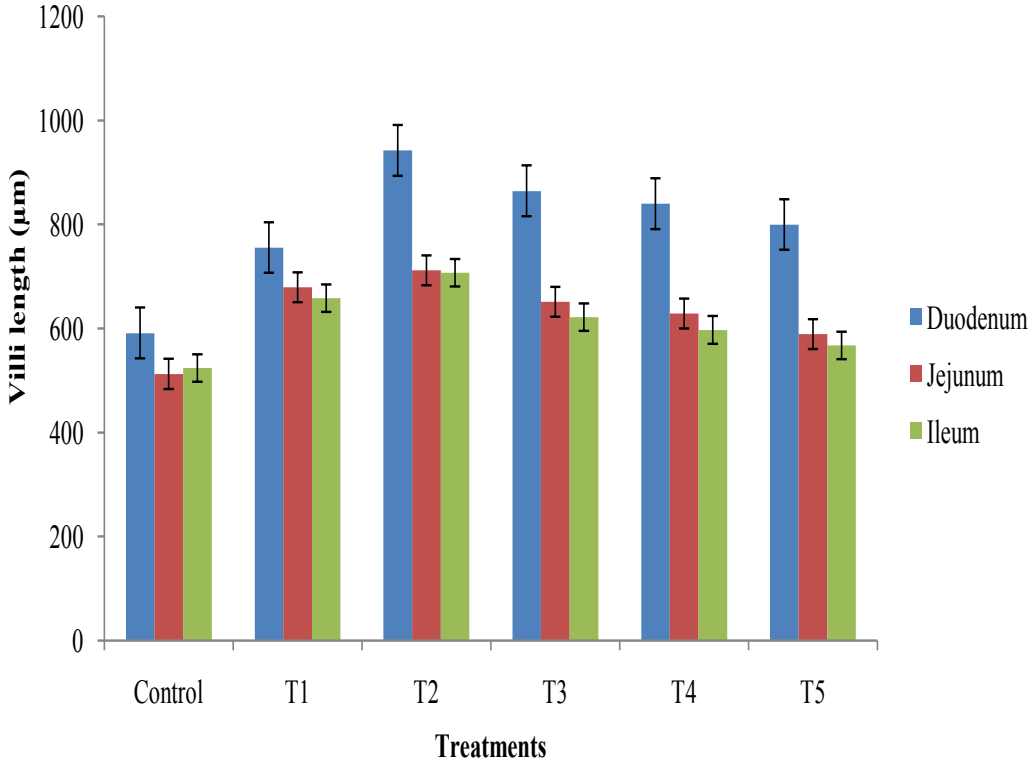

Figure 1: Effects of treatments on Villi length in various compartments

The jejunum villi of the cattle on Treatment T2 were longer ($P<0.05$) than those on Treatment T5 and Control though not significantly ($P>0.05$) different from those of cattle under Treatments 1, 3 and 4 (Figure 1 and Plate 4). Cattle fed on Treatment T2 had longer ($P<0.05$) ileum villi length than those on treatments T4, T5 and Control group but did not differ ($P>0.05$) from those on treatments T1 and T3 (Figure 1 and Plate 5). Cattle on Treatment T2 had higher crypts depth in duodenum (379 µm) than those on treatments T1 and T5 but were not significantly different ($P>0.05$) from those on treatments T3 and T4.

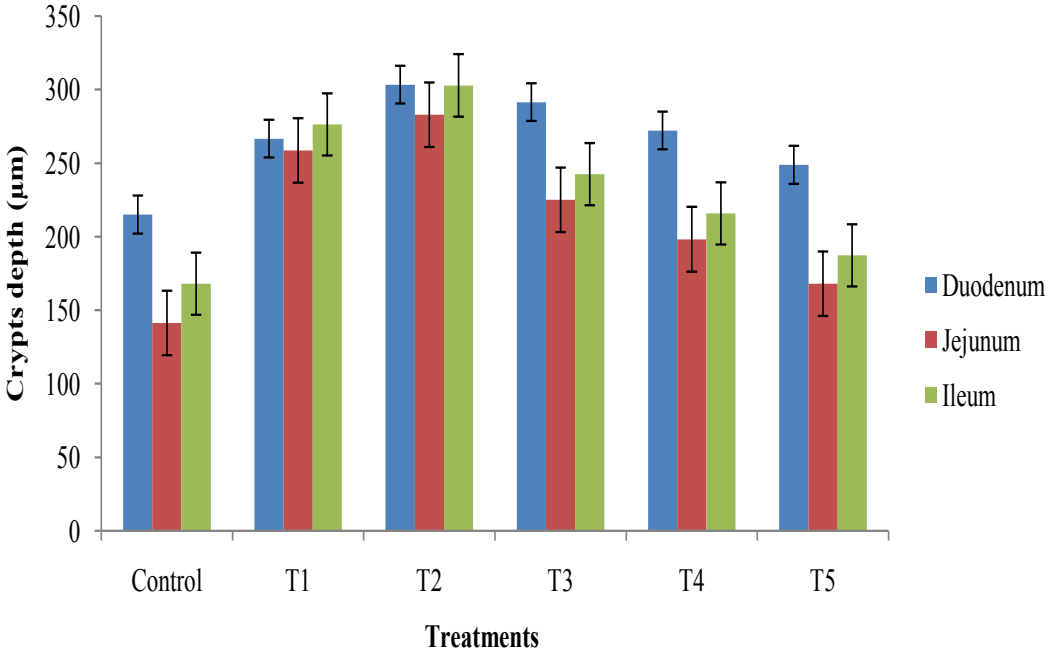

Figure 2: Effect of treatments on Crypts depth in various GIT compartments

Cattle under Control group had the lowest (P<0.05) crypts depth (Figure 2 and Plate 3). Jejunum of cattle on Treatment T2 had highest (P<0.05) crypt depth followed by those on Treatment T1, which differed significantly (P<0.05) from cattle on treatments T3, T4 and T5. The Control group had the lowest (P<0.05) crypts depth (Figure 2 and Plate 4).

Ileum of cattle on Treatment T2 had highest (P<0.05) crypts depth followed by cattle on Treatment T1, which differed significantly (P<0.05) from those on treatments T3 and T4. The lowest crypts depth was observed in cattle on Treatment T5 and in the control group (Figure 2 and Plate 5).

(a) (b)

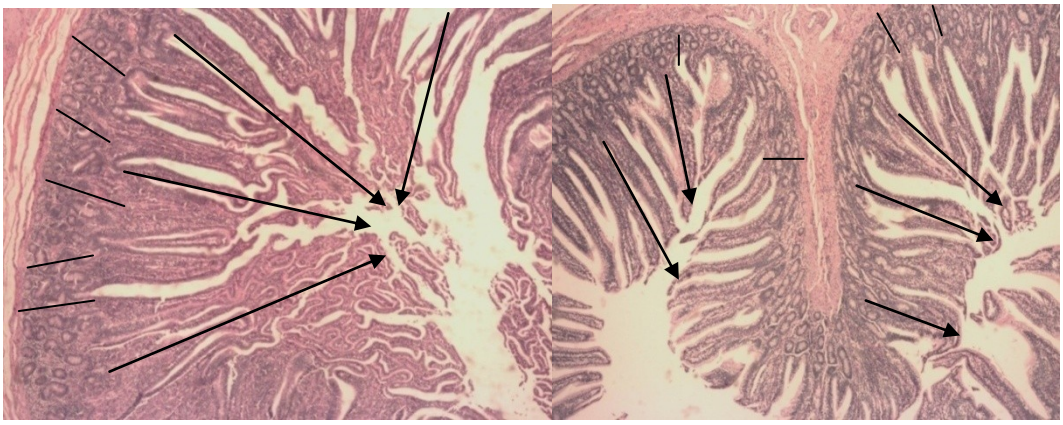

Plate 3: Pictures of duodenum showing villi (arrows) and crypt (lines) of cattle on Treatment T2 (a) and control (b) as taken by light microscope

(a) (b)

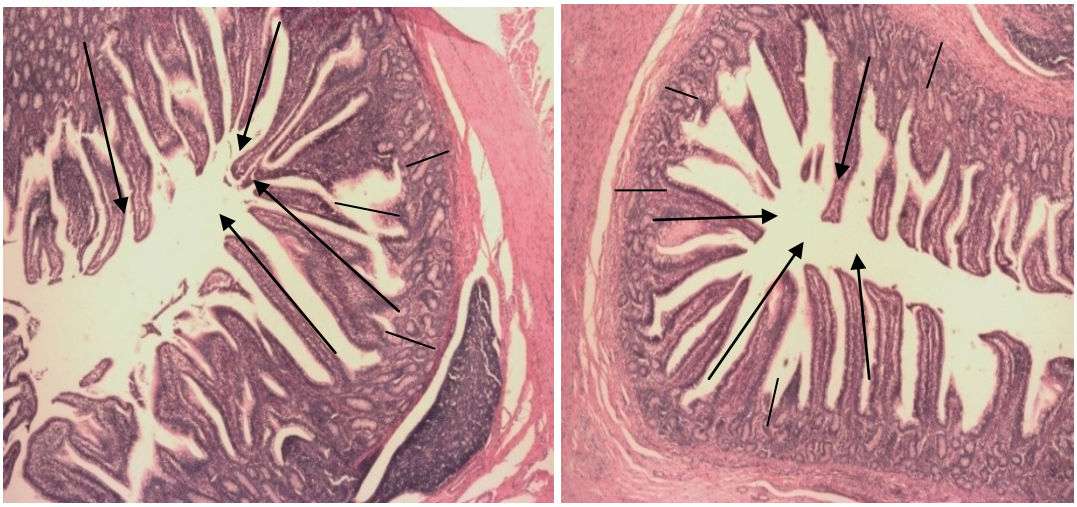

Plate 4: Pictures of jejunum showing villi (arrows) and crypt (lines) of cattle on Treatment T2 (a) and control (b) as taken by light microscope

(a) (b)

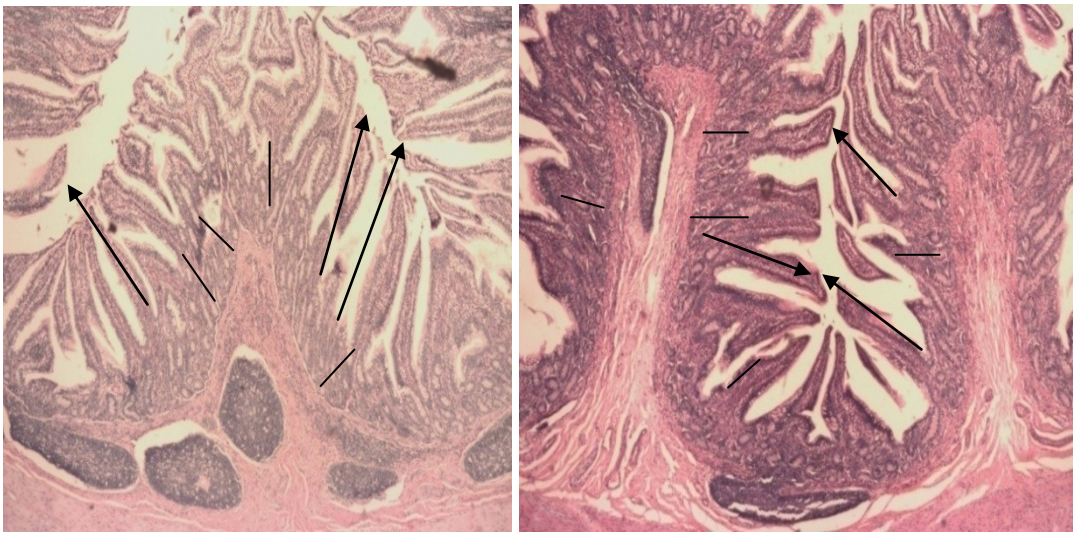

Plate 5: Pictures of ileum showing villi (arrows) and crypt (lines) of cattle on Treatment T2 (a) and control (b) as taken by light microscope

4.3.3 Effect of treatments on carcass weight, liver weight and glycogen level

The mean carcass weight of the cattle fed on Treatment T2 was heavier than those from the other treatments (P< 0.01), followed by those in cattle under Treatment T1. The mean carcass weight of cattle fed on Treatment T3 was higher than those on treatment T5 but similar to those of treatments T1 and T4.

Table 10: Lsmeans ± SEM for carcass weight, liver weight (kg) and glycogen content

Treatment	Carcass weight (kg)	Liver weight (kg)	Glycogen content (%)
T1	143^{ab}	3.63^{ab}	43.4^{ab}
T2	153^{a}	3.86^{a}	55.1^{a}
T3	140^{b}	3.32^{b}	39.0^{b}
T4	135^{bc}	3.10^{b}	36.4^{b}
T5	133^{c}	3.03^{b}	33.0^{b}
SEM	1.9312	0.1525	5.3415
P- Value	0.0033	0.0002	0.0438

Means bearing the same superscript along the same column are not statistically different (P>0.05)

The mean weight of liver from cattle on Treatment T2 was higher (P <0.05) than those on the other treatments except for Treatment T1. There was no difference (P >0.05) in the mean weight of liver from cattle on treatments T1, T3, T4 and T5. Cattle on Treatment T5 had lowest mean liver weight. Mean glycogen content in cattle fed on Treatment T2 was highest (P < 0.05) as shown by the deep pink colour in plate 6 and Table 10, although it was not significantly different (P>0.05) from the glycogen level in cattle on treatments T1, T3, T4 and T5.

(a) (b)

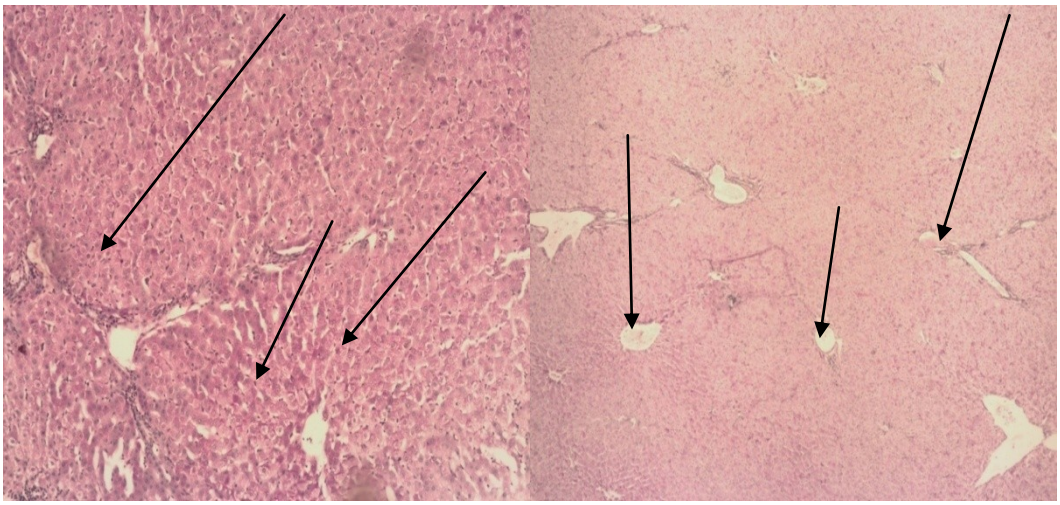

Plate 6: Picture of liver showing glycogen level by pinkish granule (arrows) of Treatment T2 (a) and T5 (b) as taken by light microscope.

4.4 Relation Between Diet Digestibility and Carcass, Liver Weight (kg) and Glycogen Level (%)

Table 11 shows that, there was a positive correlation between value of DM and OM digestibility with carcass, liver weight and glycogen level. Values of DM and OM digestibility were significantly (P<0.05) correlated with carcass, liver weight and

glycogen level. The digestibility of NDF was significantly (P<0.05) correlated with carcass weight, whereas that of ADF was correlated (P<0.05) with liver weight.

Table 11: Relation between digestibility values of diet and carcass, liver weight (kg) and glycogen level (%)

Apparent digestibility (%)	Correlation	Carcass wt (kg)	Liver wt (kg)	Glycogen (%)
DM	R	0.223672	0.07448	0.138456
	P	0.01598	0.0335	0.0388
OM	R	0.015645	0.084596	0.05527
	P	0.04715	0.0299	0.007314
NDF	R	0.086685	0.05634	0.183365
	P	0.0342	0.7264	0.8512
ADF	R	0.120681	0.152979	-0.185675
	P	0.4523	0.0396	0.2451

Where R is regression and P (probability) significant different

4.5 Relationship Between Digestibility Values and the Ruminal and Intestinal Morphology

The simple correlation coefficient between value of gut morphological and series of apparent DM, OM, NDF and ADF digestibility are given in Table 12. The correlation values showed that, there is positive correlation between DM digestibility and duodenum villi length, jejunum villi length, ileum crypts depth and papillae width, similarly OM digestibility correlated (P<0.05) with jejunum crypt depth and ileum crypt depth. The values of NDF and ADF digestibility were positively correlated (P<0.05) with duodenum villi length and papillae length.

Table 12: Relation between diet digestibility and morphology of digestive system

Apparent Digestibility (%)	Correlation	Duodenum villi length (µm)	Jejunum villi length (µm)	Ileum villi length (µm)	Duodenum crypt depth (µm)	Jejunum crypt depth (µm)	Ileum crypt depth (µm)	Papillae length (mm)	Papillae width (mm)
DM	R	0.175474	0.155002	0.055917	0.201588	0.250219	0.329722	0.084517	0.22389
	P	0.0027	0.0028	0.0702	0.1648	0.0829	0.0207	0.5637	0.0122
OM	R	0.187594	0.12287	0.146695	0.224354	0.435667	0.325835	0.07038	0.077309
	P	0.1968	0.4003	0.3145	0.1212	0.0018	0.0223	0.6308	0.5975
NDF	R	0.259407	0.00692	0.114189	0.268841	0.189965	0.120018	0.189242	-0.112232
	P	0.0419	0.9624	0.4347	0.0618	0.1911	0.4114	0.1928	0.4426
ADF	R	0.066623	0.07088	-0.055618	0.119526	0.207414	0.35192	0.037164	0.049672
	P	0.6492	0.6284	0.7043	0.4133	0.1527	0.0731	0.0399	0.7347

Where R is regression and P is probability

CHAPTER FIVE

5.0 DISCUSSION

5.1 Nutritive Value of the Dietary Treatments

a) Chemical composition

The dietary treatments had crude protein contents that ranged from 128 to 169 g/kg DM and ME values that ranged from 10.0 to 13.1 MJ/kgDM. The CP values exceeded the threshold level for rumen microbial activity requirements of 70g/kgDM and also meet the requirement for finishing cattle as reported by Robson (1996). Similarly the ME content of the six diets that ranged from 10.0 to 13.1 MJ/kgDM met the requirement for finishing cattle (Robson, 1996). The variations in the chemical composition of experimental diets could be attributed to difference in nutritive value of feed ingredients actually used to formulate the treatment diets and the values that were obtained in the literature.

The content of DM, NDF and ADF of the treatment diet, were within the range reported by Safiétou *et al.* (1998) and Hristov *et al.* (2001). However, the values for EE of the treatment diets used in the current study were slightly higher than those documented by Safiétou *et al.* (1998) and Hristov *et al.* (2001). At the same time treatment T4 and T5 showed high value of ADF and NDF, these could be due to the inclusion of rice polishing in the diets as shown in Table 5 which contains high fibre content, (Asimwe *et al*., 2015). This observation is in agreement with Jackson (2013), who observed that, the higher the fibre in the feed, the higher the ADF and NDF content.

a) Digestibility

Despite the highest Crude protein content for treatment diet T3, the feed had lower digestibility than treatment diet T2 and T1. The difference in digestibility levels between these treatment diets could be due to variation in digestibility of the feed ingredients used to compound the respective treatment diets. Treatment T1 and T2 contain molasses that is highly digestible (Asimwe *et al*., 2015). Luginbuhl *et al*. (1994) and Sarwar *et al*. (1994) reported that one of the most significant factors, that affect diet digestibility is the chemical composition of the feeds, also digestibility of one feed is believed to differ from that of a similar feed because each may contain different contents of certain chemical entities, particularly CP since some of these diminish the opportunity for the digestive enzymes to come in contact with their respective substrates. On the other hand Hugh – Jones and Peralta (1981) reported that digestibility of complete feeds can be enhanced by the additions of relatively small quantities of specific nutrients such as protein or soluble carbohydrates, while forage digestibility is dependent on the cell wall (neutral detergent fibre) content and its availability is determined by lignifications and other factors.

Also concentrate diet have a tendency of having high apparent digestibility compared to non concentrate diet (Terje *et al*., 1996). In the current study exhibited apparent DM and OM digestibility ranged from 63.9 - 35.7 and 58.8 - 32.6 respectively. The values obtained are within the range reported by other workers studying digestibility of industrial by products (Arias *et al*., 2003; Herrera *et al*., 1981). However, the apparent NDF and ADF digestibility values (54.82 - 18.38 and 57.4 - 24.8) obtained in the present study were higher than those reported by Ngo and Hans (2001) and

Tauqir *et al.* (2009) on ruminant animals where 36.6 - 27.7 and 28.1 - 19.5 ADF digestibility and 75.2 – 39.7 NDF digestibility values were observed. The difference could probably be due to variation on the basal diet used and ingredients used to formulate the concentrate. In currently study standing hay was used whereas in Ngo and Hans (2001) used cassava tops and Tauqir *et al*. (2009) jambo grass was used as basal diet.

On the other hand Treatment T4, T5 and control group had the lowest apparent digestibility which could be due to the lower metabolizable energy and higher NDF and ADF contents that could limit proper functioning of rumen microorganisms in degrading feed particles compared to other treatments (Treatment T1 - T3). Inclusion of rice polishing in T4 and T5 could account for poor performance on animals fed on these diets. Treatments which contained rice polishing had low apparent digestibility compared to diet with maize meal and maize bran. Poor diet digestibility for diet containing rice polishing has been reported by several studies. Jackson (2013) obtained values of 35 -40% digestibility values for rice polishing fed to cattle also Gadberry *et al.* (2007), Osmari *et al*. (2008) and Chae *et al.* (2002) obtained poor performance of cattle finished on rice polishing based diets due to poor diet digestibility. Similar observations of poor digestibility of diets containing rice polishing were reported for Heifers (Sanson *et al.,* 2003), for Steers (Pal *et al*., 2004, Toburan *et al*., 1990, Goncalves *et al*., 2007). The low digestibility and poor performance for animals fed diets based on rice polishing has been associated with high fibre content (10 – 15 %) (Göhl, 1982), high oil content (14 – 18%) which lead to rancidity (Chae *et al*., 2002). Also rice polishing has high content of silica and

oxalate (12 – 16 vs 3 – 5%) that interferes with the digestibility of rice polishing and formation of urinary calculi (Singh *et al*., 2000), both of which may cause problems in nutrient digestibility. Rice polishing differs more from maize bran and maize meal, which (the latter) was more palatable and it have low fibre. Also maize bran and maize meal have no major anti nutritional factors and can be fed with minimal processing. Ruminants efficiently consume whole, lightly cracked, rolled, or steam-flaked corn (Johnson, 2002).

The results obtained in the presents study, differ with the data obtained from other authors who have studied on the use of other industrial by products, this could be due to diet types, the type of diet which an animal is fed on have been reported to affect nutrient digestibility. Study by Safiétou *et al*. (1998) on apparent digestibility in cattle reported that, DM and OM digestibility were significantly influenced by diet type and particularly cell wall digestion was higher in straw based diets compared to other. Study by Arias *et al*. (2003) on vegetable wastes and sun-cured Lucerne which were used as forage sources in milk production, observed that, the digestibility coefficients of DM and OM were related positively with the crude protein content and in negative form with the fibre content. All of these studies showed that, each diet ingredients have it's own effect on diet digestibility. Feed intake is among the major determinant of ruminant diet digestibility. The increased intake is associated with fast digestion of the soluble fraction and higher rate of particle breakdown and passage through the rumen, leading to reduces digestibility. However, increase in digestibility when poor forage is supplemented with a high nitrogen containing feeds is due to the stimulation of the microbial activity (Niderkorn and Baumont, 2009).

5.2 Effect of Treatment Diets on Gut Morphology

5.2.1 Effect of treatments on ruminal papillae, villi length and width

The results shown that, when the apparent digestibility was high (Table 7) the ruminal papillae length and width and intestinal villi length also were high (Table 8 and 9). This is probably due to the increase in amount of nutrient supply towards the optimum level which supports feed utilization as well as morphological growth (ruminal papillae and intestinal villi). When concentrate diets are given to the animals they provide sufficient amount of nutrients for animal growth as well as production, concurrently have high impact on the ruminal and intestinal morphology (Duff *et al*., 2000).

The values of papillae length and width obtained in the current study (ranged from 16.1 – 10.5 mm and 3.44 – 1.70 mm, respectively) were higher than the papillae length of 6.54±0.56 mm and papillae width of 2.33±0.24 mm observed in an intensively reared cattle and 5.23±0.04 and 1.82±0.14, respectively for extensively reared cattle (Zitnan *et al.,* 2003). Highly concentrated diet, have efficiency in growth of ruminal and intestinal morphology. Study by Julius *et al.* (2011) on the effects of intensive fattening of bulls with a high – concentrate diet on ruminal mucosa, observed that ruminal papillae of bulls from the experimental group which fed on highly concentrate diet were better developed compared to the control group which fed on low concentrate.

The difference between these observations could probably be due to difference in cattle rearing systems used and concentrates used to feed the animals which

contained different nutrients. When animals are fed on concentrate diet, it leads to high digestibility value and morphological value being well developed, this could be due to the fact that diet rich in concentrate is highly digested and generally associated with high concentration of Short Chain Fatty Acids (Dirksen *et al*., 1985) that stimulate papillae growth. Zitnan *et al*. (1999) observed that short chain fatty acids are important in morphological development of gastrointestinal tract. Study conducted by Hristov *et al.* (2001) on fermentation characteristics in cattle fed medium and high concentrate barley – based diets, observed that, the higher concentration of ruminal VFA led to highly development of ruminal papillae and intestinal villi compared to diet which produced low VFA. Microbial fermentation of substrate in the rumen leads to the production of volatile fatty acids (VFA). The pool of VFA in the rumen is predominately made up of acetate, propionate, and butyrate. The same authors reported that rumen epithelial tissue metabolizes up to 90% of the butyrate produced in the rumen from microbial fermentation. Butyrate has a stimulatory effect upon rumen papillae development (Van Soest, 1994). This implies that feeding high concentrate substrates which promote butyrate production in the rumen have the possibility of enhancing rumen papillae and intestinal tissue development. However, results from the current study indicated that animals which were fed on Treatment diet T2, that contained molasses had higher apparent digestibility and morphological value, compared to others which were fed on other treatments diets.

Apart from the influence of concentrate on gut morphology, the use of molasses + maize bran without mixing with other energy ingredients was probably superior in

the production of butyrate that enabled proliferation of both rumen papillae and villi in the small intestine. Moreover the results from the current study also suggest that diets with proper balance of nutrients, such as proper proportion of molasses, maize bran and other nutrients lead to better performance in all parameters. This observation is in agreement with the study in heifer calves conducted by Harrison *et al.* (1960) on effect of concentrate to roughage ratio and observed that, rumen papillae length and width were greater in the faster growing (high concentrate) calves compared to high roughage one. Apparently, both rapid growth and papillary development were due to the highest energy levels consumed by these animals. Kromann and Meyer (1972) studied the influence of the ration‘s energy contents and physical form on rumen morphology and observed that, the lambs fed the high energy diets had a higher rumen morphology score than those fed on low energy. The pelleted physical form had the most score on papillae length and width particularly with high energy diet, compared with milled and low level energy at the same time.

The study conducted by Zitnan *et al.* (2003) on cattle, observed that, the length of duodenal villi significantly increased ($P = 0.026$) whereas that of jejunal villi approached the limits of significance ($P = 0.052$) for pelleted concentrate feed compared to the extensive group which grazed on natural pasture. So proper processed diets do better in digestibility compared to poor processed diets.

Ration balance affect growth and animal production, considerable high apparent digestibility and better performance in morphology of digestive system, ruminal papillae and intestinal villi observed in T2 than other treatments, could be attributed

to proper balance of ration, which made proper functioning of rumen microorganisms. Animals must receive sufficient amounts of all essential nutrients (water, energy, amino acids, vitamins and minerals) in proper balance to remain healthy, to have high growth rate and to produce more. Performance of ruminants is influenced by the proportion of balanced nutrients in their daily feed intake. Protein and energy are the main determinants in the ruminant feed that can alter the animal's performance. Ration formulation should involve proper combination of various ingredients in order to meet body nutritional requirements.

Lesmeister (2003) reported greater blood concentration of total VFA plus longer and wider rumen papillae in calves fed on 12% molasses diet than those fed on 5% molasses diet. The results from the currently study also concur with the study by Tamate *et al*. (1977) who observed rumen papillary growth being stimulated in cattle which received either propionate or butyrate directly into the rumen. Similar trend of results were also observed by Lane and Jesse (1997) who infused VFA in lambs, lambs infused with VFA had longer papillae and less papillae density than the lambs infused with saline, indicating that nutrients enhance rumen absorption site to grow. The increase in pappilae length and width in concentrate fed cattle could probably be due to butyrate and propionate produced which are used as energy sources by the rumen epithelium and subsequently have the greatest influence on epithelial development.

In contrast to the observation made by Lesmeister (2003), amount of molasses in T1, T2 and T4 in the current study were the same but the treatments exhibited difference

in ruminal papillae and intestinal villi proliferations. This could be attributed to differences in other solid ration ingredients that were included such as maize bran, maize meal and rice polishing. It has been reported that solid feeds differ in their efficacy to stimulate rumen development. Chemical compositions of the solid feeds, and the resultant microbial digestion end products, have the greatest influence on epithelial development (Stobo *et al*., 1966).

Chemical characteristics of solid feeds appear to influence rumen and intestinal epithelial growth. The difference observed between Treatment T2 and other treatments (treatments T1, T3, T4 and T5) could be attributed to the type and level of inclusion of solid energy ingredients (i.e., maize meal and rice polishing). Treatments effects showed similar trends in terms of papillae length and width, villi length, crypt depth and digestibility. This implies that digestibility of feeds contributes to some extent in proliferation of gastro-morphological structure in TSHZ cattle. Diets structures also tend to affect gut morphology. Study in cattle calves conducted by Strusnska et *al.* (2009), observed that, cattle which were supplemented with whole maize grains had thicker duodenal epithelium and thicker jejunal mucosa compared with others which were supplemented with ground cereal grain, characterized by thinner ruminal epithelium, including a thinner cornified layer (17.50 vs 33.39 μm).

Chemical characteristics of solid feed and diet manipulation have shown to increase butyrate concentrations which consequently affected positively rumen epithelial development. In the current study, diet manipulation was based on maize meal, maize bran and rice polishing that contain starch and molasses which contain soluble

sugars mainly sucrose from molasses in combination with different agro processing. Effects of feeding sucrose on rumen fermentation suggest an increase in ruminal butyrate concentration (Kellog and Owen 1969). Similarly, molasses supplementation as a source of 6% sucrose to lactating cows increased proportions of ruminal butyrate (Owen *et al*., 1967). Bartholome *et al*. (2004) reported that butyrate stimulates proliferation of villi in small intestine. Infusion of butyrate had a stimulatory effect at the enteroendocrine L cell) which could be due to chemicals which are in diets.

It is concluded that, for highly morphological improvement, animal should be given, concentrate diet which have proper ration and combination, chemical balance, and not to have high amount of fibre. Therefore diet should be formulated by considering the mentioned things (ration, combination, chemical balance, fibre content) to insure high growth of ruminal and intestinal morphology for better feed utilization so as to enhanced animal growth and production.

5.2.2 Relationship between diet digestibility and gut morphology

There were positive correlations between diet digestibility, ruminal and intestinal morphology. There is also a positive correlation between diet digestibility with carcass, liver weight and glycogen level. It is observed that, the increase in duodenum, jejunum, ileum and papillae in length, crypt depth and width, respectively was due to the higher apparent digestibility of the diet. Those results were similar to those of Zitnan *et al.* (2008) who observed that, the morphological differences of ruminal and intestinal tissue between cattle, adapt to increase in both length and

width of the absorptive surface due to the increase in nutrient digestibility associated in diets which lead to higher animal gain especially in carcass, liver and glycogen level.

These results also are in agreement with those of Andrieu (1984) who found a good correlation between both OM digestibility and energy value of maize silage and grain content with animal gain. Laforest *et al.* (1986) working with legume and grass silage, found that the DM digestibility was positively correlated with morphology of the animal digestive system.

From these results it is clearly shown that morphology of digestive system depends on diet digestibility. The well digested diet, lead to longer papillae length and width, with high villi length and crypt depth.

5.3 Influence of Digestibility of Diets on Carcass, Liver Weight and Glycogen Level

The observed higher carcass weight, liver weight and glycogen level of animals fed on Treatment diet T2 than their counter parts, could be due to relatively higher diet digestibility compared to other treatments. The carcass weight obtained in the present experiment ranged from 133 - 153 kg which was slightly higher than the value of 141 to 144 kg reported by Turki *et al.* (2011) and lower than 215 to 257kg reported by Esterhuizen *et al.* (2008). The existing differences between the results obtained from the present study and the previous ones could probably be due to differences in experimental feeds used and cattle breeds. In the current study Zebu cattle that have

low growth rate were used, while the study by Zitnan *et al*. (2003) Holsten breed were used, Turki *et al.* (2011) Charolais breed were used, Esterhuizen *et al.* (2008) Bonsmara breed were used and Terje *et al.* (1996) reindeers breed were used. Breed differences in ruminal papillae size and intestinal villi morphology have also been reported by Zitnan *et al*. (2008).

Liver weights obtained from the present study were within the range of 2.0 and 3.7 kg, which are similar to the other reporter's who fed their animals on industrial by product feed (Ferrell *et al.* 1986, Jenkins *et al.* 1986 and Brian 2006) and glycogen content obtained in the current study ranged from 30 – 60, which were similar with those reported by Warner *et al.* (2002) and Jenkins *et al.* (1986). The observed differences between the current results and related findings by other authors could be associated to nutritive value of experimental feeds used. These findings concur with those observed by Wood *et al*. (1986) who concluded that poorly digested diet lead to lighter body weight of animal which lead to smaller liver weight (average 10%) and contained less glycogen level.

A reduction in body and liver weight in animals which are fed on poorly digested diet has also been recorded by other workers (Jones *et al*., 1985; Moser *et al*., 1986; Mersmann *et al*., 1987). Data reported from the study with cattle by Murray *et al*. (2001) working with sheep and Winter *et al*. (1976) working with swine support the observation that weights of visceral organs, especially weights of liver and gut, vary in response to nutritional treatment especially on digestibility value, the better digested feed leading into higher weight of viscera organ. In addition, data reviewed

by Stangassinger and Giesecke (1986) reported that, liver weight was greater in sheep fed concentrates than in those fed hay and was greater in lambs of either group when refed, compared with fasting lambs. It is clear that liver weight gained was due to cell proliferation, as well as enlargement. The fact that the liver also receives arterial blood serves to coordinate the metabolism of absorbed nutrients under the influence of metabolites and hormones released from other tissues (Warriss 1982).

Generally, treatment effects showed the same trend in terms of carcass weight, liver mass and glycogen content to those of digestibility values. This observation implies that the more digestible diet in the current study was able to provide more energy that was partitioned for tissue production (carcass and liver weight) and storage (glycogen). It can be concluded that improvement of the diets of TSHZ's cattle in terms of protein, energy supply and digestibility enables gut development that in turn improves carcass and liver weights.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

It is concluded that, there is strong relationship between diets digestibility with ruminal and intestinal morphology, also diet digestibility with carcass, liver weight and glycogen level, so that the well digested diet, also led to high morphological (ruminal and intestinal) development, carcass, liver weight and glycogen level.

Treatment T2 is the well digested diet that performed well in all of the parameters investigated (papillae, villi, carcass, liver weight and glycogen level).

6.2 Recommendations

The following are recommended from the present study:

i) It was clearly observed that Treatment T2 had higher performance in terms of all parameters measured, thus, it is recommended for use in feeding TSHZ cattle that are reared under feedlot system.

ii) So further research should be conducted to determine the appropriate period of stay and economics of fattening using diet used in Treatment T2.

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APPENDICES

Appendix 1: ANOVA for effect of treatments on DM digestibility

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	48202.43	9640.49	55.56	0.0001
Replication	8	646.10	80.76	0.47	0.8804
Treatment*Replication	40	5019.68	125.49	0.72	0.8966
Error	486	84325.73	173.51		
Total Sum of Squares	539	138193.94			
	R-Square	CV	Root-MSE		DMD Mean
	0.39	24.27	13.17		54.27%

Appendix 2: ANOVA for effect of treatments on OM digestibility

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	65945.26	13189.05	49.83	0.0001
Replication	8	1693.06	211.63	0.80	0.6031
Treatment*Replication	40	8926.76	223.17	0.84	0.7416
Error	486	128626.53	264.66		
Total Sum of Squares	539	205191.62			
	R-Square	CV	Root-MSE		OMD Mean
	0.37	34.57	16.27		47.06%

Appendix 3: ANOVA for effect of treatments on NDF digestibility

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	37440.78	7488.16	32.67	0.0001
Replication	8	361.06	45.13	0.20	0.9913
Treatment*Replication	40	3173.73	79.34	0.35	0.9999
Error	486	111382.89	229.18		
Total Sum of Squares	539	152358.45			
	R-Square	CV	Root-MSE		NDFD Mean
	0.27	32.43	15.14		46.68%

Appendix 4: ANOVA for effect of treatments on ADF digestibility

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	74303.59	14860.718	63.89	0.0001
Replication	8	709.48	88.68	0.38	0.9306
Treatment*Replication	40	6956.53	173.91	0.75	0.8711
Error	486	113036.18	232.58		
Total Sum of Squares	539	195005.78			
	R-Square	CV	Root-MSE		ADFD Mean
	0.42	36.05	15.25		42.30

Appendix 5: ANOVA for effect of treatments on rumen papillae length

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	497.34	99.47	9.45	0.0045
Error	153	1610.33	10.53		
Total Sum of Squares	158	2107.67			
	R-Square	CV	Root MSE		Papillae length
	0.24	24.68	3.24		13.14 mm

Appendix 6: ANOVA for effect of treatments on rumen papillae width

Source of variation	Df.	SS	MS	F – Value	Pr>F
Treatment	5	49.22	9.84	6.07	0.0265
Error	153	248.18	1.62		
Total Sum of Squares	158	297.4			
	R-Square	CV	Root MSE		Papillae width
	0.17	50	1.27		2.55 mm

Appendix 7: ANOVA for effect of treatments on Villi length

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	28292.3	5658.5	33.7	0.0003
Compartment	2	43807.6	21903.8	130.4	0.0006
Treatment*Compartment	10	5878.8	587.9	3.5	0.0004
Error	654	109847.3	167.9		
Total Sum of Squares	671	202084.5			
	R-Square	CV	Root MSE		Villi length
	0.456	18.81	12.96		68.87 µm

Appendix 8: ANOVA for effect of treatments on Crypts width

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	5	9806.5	1961.3	31.88	0.0185
Compartment	2	3015.1	1507.6	26.48	0.0253
Treatment*Compartment	10	1170.4	117	1.86	0.0492
Error	654	41167.7	62.95		
Total Sum of Squares	671	55704.7			
	R-Square	CV	Root MSE		Crypts width
	0.26	33.09	7.93		23.97 µm

Appendix 9: ANOVA for effect of treatments on Carcass weight

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	4	2265.63	566.41	4.93	0.0033
Replication	8	994.8	124.35	1.08	0.3997
Error	32	3674.99	114.84		
Total Sum of Squares	44	6935.43			
	R-Square	CV	Root MSE		Carcass w
	0.47	7.62	10.72		140.61kg

Appendix 10: ANOVA for effect of treatments on Liver weight

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	4	4.4	1.1	7.84	0.0002
Replication	8	2.23	0.28	1.98	0.0809
Error	32	4.49	0.14		
Total Sum of Squares	44	11.12			
	R-Square	CV	Root MSE		Liver weight
	0.6	11.05	0.37		3.39kg

Appendix 11: ANOVA for effect of treatments on Liver Glycogen level

Source of variation	Df.	SS	MS	F - Value	Pr>F
Treatment	4	2637.47	659.37	0.97	0.0438
Replication	8	6115.2	764.4	1.12	0.3741
Error	32	21762.13	680.07		
Total Sum of Squares	44	30514.8			
	R-Square	CV	Root MSE		Glycogen level
	0.29	62.99	26.08		41.4