DEVELOPMENT OF WEANER MEAL FOR DAIRY CALVES USING FISH WASTES FROM NILE PERCH (*Lates niloticus*) AND CASSAVA (*Manihot esculenta*) ROOT MEAL

BY

ABDUL AHMED SELEMANI KATAKWEBA

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ABSTRACT

Growth, blood parameters and *in sacco* degradability studies were run concurrently to evaluate the effects of cassava root meal (CRM) and fish waste (FW) as energy and protein substitutes for respectively hominy meal (HM) and cotton seed cake (CSC) in formulation of weaner meals for dairy calves. The FW were derived from processing of Nile perch (*Lates niloticus*) while CRM (*Manihot esculenta*) was purchased in fresh form and dried for compounding. In experiment I the effects of CRM and FW as substitutes for HM and CSC were evaluated in growth, blood parameters and intake trials lasting for 56 days using 20 Ayrshire weanner heifers ranging in weight from 88-194 kg. The heifers were allotted at random in four treatments rations (TR_1 – TR_4) of 5 animals each. The four treatments were: TR_1 66.5 % HM and 31.5 % CSC; TR_2 = 50 % CRM and 48 % CSC; TR_3 67.5 % HM and 30.5% FW and TR_4 = 51.5 % CRM and 46.5 % FW. Data was collected on daily DMI and weight changes were recorded fortnightly. In Experiment II *in sacco* degradability studies were made to assess the degradability characteristics of the individual feed ingredients as well as the compounded rations used in Experiment I. Four fistulated cows with an average weight of 314.25 kg were used. Rumen pH and NH_3-N were also measured. No ($P > 0.05$) differences in weight gain were observed between heifers on TR_1 and TR_3. Heifers on TR_2 gained ($P < 0.05$) faster than those on TR_1, TR_3 and TR_4 (620 vs 490, 460 and 420 g respectively). TR_2 had ($P < 0.05$) superior feed efficiency (0.129) followed in a descending order by TR_1, TR_3 and TR_4 (0.116, 0.113 and 0.106 kg gain /kg feed respectively). Feed costs per kg gained for TR_1 – TR_4 were $ 0.338, 0.418, 0.332 and 0.496 respectively. Blood parameters were ($P < 0.05$) influenced by protein and energy sources as well as their interactions. Fish

wastes supplementation to heifers increased (P<0.05) blood plasma minerals compared to CSC for TR_1. TR_4 Heifers on CRM and CSC combination had (P < 0.05) higher levels of total plasma protein and plasma glucose (97.07g/l and 3.3 mmol/l) compared to those of CRM and FW (94.86 g/l and 3.0 mmol/l) respectively. DM degradability at 48h for CRM was (P < 0.05) higher than HM (920 vs 835 g/kg) while CP for HM was (P < 0.05) higher than that of CRM (946 vs 837 g/kg) respectively. Both DM and CP for CSC were (P < 0.05) higher than that of FW (739 and 887 vs 367 and 598 g/kg). Hay had DM and CP of 322 and 749 g/kg respectively. The degradability of DM and CP at 48h in TR_1 and TR2 were (P < 0.05) higher than in TR3 and TR_4 (801and 799 vs 727 and 616 g/kg DM and CP of 828 and 825 vs 667 and 605 g/kg) TR_2 having apparently higher rates of DM and CP degradability. The pH and NH_3-N ruminal values were (P < 0.05) different between treatment rations and treatments with FW component had (P < 0.05) higher NH_3-N than that of CSC (284.7 and 203.7 vs 135.8,and 183.9 mg/l). It was concluded that CRM and FW could be used cost effectively in weaners rations, but best results are obtainable where CRM is combined with CSC.

DECLARATION

I, ABDUL AHMED SELEMANI KATAKWEBA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and it has not been submitted for a higher degree in any other University.

Signature.....

Date.....16/09/2002.....

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DEDICATION

This work is dedicated to my parents, my wife JAZIRA and my beloved children

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ABBREVIATIONS AND SYMBOLS

a, b, c (Bolded)	Degradability characteristics
a, b, c, d, e	Super script $^{a, b, c, d, e}$; means within each row bearing same letter are not significantly different at $P<0.05$
AA	Amino acids
AAS	Atomic absorption spectroscopy
ADF	Acid detergent fibre
ADG	Average daily gain
ADP	Adenosine diphosphate
AMP	Adenosine monophosphate
ANOVA	Analysis of variance
APF	Animal protein factor
ARC	Agriculture research council
ATP	Adenosine triphosphate
CF	Crude fibre
CP	Crude protein
CPD	Crude protein degradability
CRD	Complete randomised design
CRM	Cassava root meal
CSC	Cotton seed cake
DASP	Department of animal science and production
DM	Dry matter degradability
DMI	Dry matter intake
DOMD	Dry organic matter digestible

e	Natural logarithm
EE	Ether extracts
ERD	Effective rumen degradability
FAO	Food and agriculture organization
FE	Feed efficiency
FM	Kilogram
LWG	Live weight gain
MDB	Marketing development bureau
ME	Metabolizable energy
mg/dl	Milligram per decilitre
MJ	Megajule
mmol/l	Mill moles per Litre
N	Nitrogen
NADH2	Nicotinamide adenosine diphosphate
NDF	Neutral detergent fibre
NFE	Nitrogen free extract
NH_3	Ammonia
NH_3-N	Ammonia nitrogen
NORAD	Norwegian Agency for Development Cooperation
NPN	Non protein nitrogen
NRC	National research council
NS	Non significant
NSC	Non-structural carbohydrates
OM	Organic matter

Pi	In organic Phosphate
RDP	Ruminal degradable protein
RNA	Ribose nucleic acid
RUDP	Ruminal undegradable protein
RSD	Residual standard deviation
SAS	Statistical package
SC	Structural carbohydrates
SEM	Standard error of the mean
SIG	Significance
SUA	Sokoine University of Agriculture
t	Time
TDMI	Total dry matter intake
TDN	Total digestible nutrients
TFP	Tanzania fish production
TR_1	Treatment ration one
TR_2	Treatment ration two
TR_3	Treatment ration three
TR_4	Treatment ration four
US$	United State Dollar
VFA	Volatile fatty acids
$W^{0.75}$	Metabolic body weight

CHAPTER ONE

1.0 INTRODUCTION

The productivity of cattle in the tropics is considerably lower than those in temperate climates. Many factors contribute towards this low productivity. In many developing countries feed availability in terms of quality and quantity accounts for the poor nutritional status of livestock. The problem is more severe especially for dairy cattle of all classes. During periods of feed shortages farmers resort to the use of poor quality crop residues (Shem, 1993; Aregheore and Ikhetua, 1999). It has been estimated that ruminants in the tropics consume as much as 56 % of their annual ME intake from crop residues (Aregheore and Ikhetua, 1999). Consequently, intake of other nutrients is limited, particularly protein and minerals (Kimambo *et al.*, 1990; Kasongo *et al.*, 1995). Supplementation with energy and protein concentrates is therefore necessary.

Protein and energy sources for dairy cattle in the tropics are from oil seed cakes (from milling industries) including cotton seed cake and cereal brans respectively. Other protein sources include sunflower and copra cakes. Sunflower cake however, is not used extensively because of its high fibre content and relatively low digestible protein. Copra cake on the other hand, is characterized by high residual oil content making it a rather unstable product (Lyimo 1983; Kofi, 1999).

The cost and availability of concentrates is a major constraint for their limited utilization in ruminant rations in Tanzania. At current market prices, cotton seed cake included at 30 percent in the ration contributes about 46 percent of the total cost of

the rations (Kimbi, 1997). Nearly 60 percent of cotton in Tanzania is grown in Shinyanga and Mwanza regions. However cotton seed cake fetches higher prices in Kenya and Uganda than in Tanzania. This factor and unreliable supplies due to frequent cotton diseases and pests outbreaks affect the availability and insufficient amount of cotton seed cake to the local dairy industry (Israel, 1992; Kakwemeire, 1999). It is therefore imperative that other alternative protein source are sought to ensure that rations compounded for dairy animals are cost effective and of acceptable nutritional quality.

Fish wastes have been shown elsewhere to be suitable protein sources in dairy rations but have not been well studied in Tanzania (Ngate, 1997; Mohamed, 1998). Research done using non-ruminants show that feeding of Tanzanian fish wastes resulted in positive growth rates, and high feed conversion efficiency (Mbamba 2000). Ngate (1997) reported fish wastes (Nile perch) from processing plants in Mwanza to be a potential source of protein supplement containing nearly 60 % CP. Ruminants in Tanzania can effectively utilize fish wastes being a good source of protein. This is based on the findings from other countries despite the fact that fish meal was used in stead of fish wastes.

Major sources of energy for livestock in Tanzania are Maize and wheat brans (Lekule, 1990). However due to unpredictable weather their production is low. In most seasons, grains are not de-hulled but milled to produce flour only resulting in low bran production. There is also high competition for brans between ruminants and

non-ruminants (pigs and poultry) (Lekule, 1990; Israel, 1992). This problem guarantees to find another source of energy such cassava root meal.

Cassava root meal has been shown elsewhere to be excellent energy source for livestock. It is low in dry matter, protein, fat and mineral contents, but it is rich in energy due to a high content of starch. Due to its high amylopectin content in relative to maize makes cassava a suitable source of energy for ruminants (Lekule, 1990). In Tanzania, Lekule (1990) and Israel (1992) pointed out that in properly balanced rations, cassava could completely replace cereals as a source of energy for pigs. In ruminants findings by Kanjanapruthipong *et al.* (2001) show cassava to be an excellent source of fermentable total non-fibre carbohydrates, which is an important substrate for the microbial growth in the rumen. The synthesis of rumen microbial protein is thus more efficiently achieved than when sugars are fed. In Tanzania cassava root meal has been used as a source of energy for lactating dairy cows with good results (Kurwijila, 1976). However, very little work has been carried out using weaners, a class of ruminants that costs farmers substantial resources to rise up to breeding age.

Quantities of milk offered to calves before weaning are usually less than the recommended amounts. The main reason for this is the temptation among farmers to sale as much milk as possible. Calves are almost always underfed and reared for periods longer than necessary before they can be weaned. The overall effects are high pre-weaning mortalities (8-20 %) and poor post-weaning performance (Mohamed 1998). Mohamed (1998), attempted to develop a calf-starter feed that

could be used to wean calves off milk early enough to maximize milk crop from their dams. However the studies by Mohamed (1998) limited the focused on early weaning, without paying attention to the post weaning performance.

Delayed puberty and age at first breeding in Tanzania has been linked to the poor post-weaning nutrition of heifers. The common practice of exposing weaned calves to poor quality pastures accounts for the delayed age at first breeding.

This study therefore was carried out with general objective of comparing the efficiency of fish wastes and oil seed cakes as protein sources; hominy meal and cassava root meal as sources of energy to the weaned growing dairy cattle with the view to suggesting an optimal FW and CRM combination that can support rapid post weaning growth.

The specific objectives were:

(a) To determine the nutrient composition of fish waste (Nile perch) and cassava root meal.

(b) To evaluate the growth performance of weaned dairy calves supplemented with or without fish wastes and cassava root meal.

(c) To compare the economics of replacing cotton seed cake and hominy meal by fish wastes and cassava root meal respectively.

(d) To determine protein, glucose and mineral levels in blood of supplemented weaners.

(e) To determine degradabilities of feed ingredients and treatment rations.

It was hypothesised that: -

(a) The inclusion of fish wastes and cassava root meal in weaned dairy calves meals increased live body weight, feed intake and daily gain.

(b) Inclusion of fish wastes and cassava root meal did not reduce costs of production.

(c) There are no enough fish wastes in Tanzania for livestock feeding.

CHAPTER TWO

2 0 LITERATURE REVIEW

2.1 Growth of heifers and their nutrition

Growth is a biological synthesis or production of new biological cell units with increase in living protoplasm. It includes cell multiplication, enlargement and incorporation of materials from the environment. Growth can be expressed as live weight gain, carcass weight or tissue (muscle, bone and fat) gain per unit time. The age curve is sigmoid in shape with the inflection point showing the minimum velocity of growth and age at puberty (Lawrence and Fowler 1997). Growth of calves is one of the factors, which affect the viability of dairy farm enterprises (Tomer *et al.*, 1985). Postnatal growth is affected by many factors which include, disease, general management practices, nutrition, parity of dam, weaning age, parasitic burden and genetic composition of the calf (Place *et al.*, 1998).

Nutrition is a critical constraint responsible for growth rate and low production and is a key factor for improving animal productivity. In the tropics, during the dry season the level of protein in the natural pastures could be as low as 3.4 % (Adepise and Oyedipe, 1985). Therefore, feeds for maintenance of growing heifers should include adequate crude protein and energy thereby allowing earlier breeding and reduction in feed costs for early return on investments (Gardner *et al.*, 1988). The plane of nutrition can vary from that which will just maintain body weight to that which will allow the maximum rate of gain. The maximum rate of gain is limited by voluntary productive energy intake of the animal while the optimum rate of weight gain is mainly an economic decision, which is determined by the end product required, the

relative cost of the productive energy from different nutrient sources and the desired rate of turnover of capital. The maximum development of an organism is fixed by heredity and nutrition is an essential factor in determining whether this potential or maximum will be reached (Kasongo *et al.*, 1995; Lawrence and Fowler 1997; NRC, 2001).

The most important considerations for the growth of dairy heifers are those that influence reproduction and lactation. Therefore an optimal growth pattern for dairy heifers is one that allows a heifer to develop to full lactation potential at a desired age with minimal expenses. The growth process is important to understand because growth controls the time of first breeding as well as age and body weight at first calving. Proper calf and heifer management allows heifers to be sexually mature at 13 months of age and to be bred to conceive at 15 months (Tomer *et al.*, 1985; Place *et al.*, 1998). Heifers with high plane of nutrition also have high conception rates than heifers on medium and low planes of nutrition (Gardener *et al.*, 1988; Amir *et al.*, 1967). Experiments conducted at Cornell University (Schmidt and Van Vleck 1974) on Holstein heifers revealed that over fed animals maintained their weight through out their lives. The overfed animals attained puberty at an average of 9.2 months, normally fed group attained puberty at 11.2 months; and the underfed group attained puberty at 20.2 months. The only problems reported due to rapid growth include adipose tissue in the mammary glands, several services before conception and large size of the calf (Amir *et al.*, 1967). Mgongo *et al.* (1989) reported that over feeding of heifers causes infertility because of fat deposition around the ovaries. Mujuni *et al.* (1990) reported that animals with above average feeding management;

age at first calving could be reduced to 900 days without adversely affecting subsequent reproductive performance.

Stress due to inadequate nutrition causes a reduction in fertility, delay maturity of heifers, reduction in ovarian formation and irregular oestrus cycles and calving difficulties (Kearl, 1982). Milk production during the first lactation is affected although improvement can be observed in later lactations (Kurwijila, 1991).

2.1.1 Need for supplementation in the tropics

In many developing countries feed availability in terms of quality and quantity accounts for the poor nutrition status of animals. Information on the nutritive value of most ingredients used in feed formulations and the minimum nutrient requirements of dairy cattle is well documented (Kimambo *et al.*, 1990; Sarwatt and Mtengeti, 1990; McDonald *et al.*, 1998). Intake of the nutrients by cattle in the tropics is however limited and seasonal particularly for protein and minerals (Kimambo *et al.*, 1990; Kasongo *et al.*, 1995). In Tanzania this poor nutritional environment is the result of a seasonal distribution of the annual rainfall that falls in October to December and February to May. Green forages are therefore absent for the rest of the year except on marshy areas. The standing hay during the dry season has an average 1-4 % crude protein and is high in crude fibre. There is also a decline in nutritive value of hay with maturity of pastures (Göhol 1981; Sarwatt and Mtengeti, 1990). This type of hay as well as crop residues have been shown to be inadequate to provide animals with enough energy and protein for maintenance and production. Protein from such low energy feeds has also been inefficiently utilized

(Shem, 1993). Supplementation with energy and protein concentrates is therefore necessary to cover for nutrient deficits.

Protein and energy supplementations from different sources increase the voluntary intake of poor quality forages by cattle. Supplementation corrects a depressed intake back to normal (Leng, 1990; Mero, 1997) and supplements improve protein: energy ratio in nutrients absorbed by cattle fed on low quality forages (Ørskov and Ryle, 1990).

Types of supplementation influence intake and digestibility responses of low quality roughages. In case of proteins a good supplement should contain both degradable and undegradable protein to balance for the protein quality required by the animal and ruminal microbes (Jones, 1994). Starches and sugars are more rapidly fermented than cellulose and hemi cellulose. This is one of the reasons for the greater microbial (N) synthesis observed with mixed roughage and concentrate rations than with poor quality roughages (Ørskov and Miller, 1988). High rates of fermentable energy enable bacteria to grow more rapidly and to minimize the proportion of energy used for their maintenance (McDonald *et al.*, 1998). It has been shown that the use of high-energy rations up to a certain limit results in improved efficiency of gain and growth rate as well as improvements in reproductive and productive performance (McDonald *et al.*, 1998).

2.1.2 Protein supplementation in ruminants

Protein supplementation plays an important role in making energy available and is a factor in stimulating intake of the basal forage (Kearl, 1982). Higher levels of proteins above 7 % are normally needed to enhance digestibility and energy availability from the primary forage (Khan *et al.*, 1998). Church (1984) reported that the important factors in protein source used, whether preformed protein (such as plant protein) or as non-protein nitrogen (NPN) are the levels needed in a supplement and quantity needed.

The protein level and source have been found to have an effect on feed intake and growth. Sighn *et al.* (1991) evaluated two rations containing 13.5 % and 16.3 % CP for their effect on feed intake, growth and digestibility of organic matter rations. The authors observed that feed intake and growth were higher in 16.3 % than 13.5 % protein diet. ARC (1990) reported that dry matter digestibility, intake and growth rate rose at an average of 0.01 units for each unit change in crude protein percentage for rations containing at least 16 % crude protein.

The protein value of a feed stuff for ruminants may be determined by the ability of the feed to promote microbial synthesis in the rumen, the extent to which the feed protein escapes degradation by the rumen micro organisms, provides protein and essential amino acids for absorption in the small intestines, glucose precursors and by a variable combination of these separate attributes (Ørskov and Miller, 1988; Klusmeyer *et al.*, 1990; Hoover and Stokes, 1991).

Protein requirements for ruminants are not constant as requirements vary in relation to changing productive or physiological status of the animal. Ruminants require less protein for maintenance, slow growth, early pregnancy, late growth and late lactation (Kempton *et al.*, 1977; Sighn *et al.*, 1991). Provided metabolizable energy is non-limiting the rumen microbes appear to be able to provide sufficient protein to the above physiological states by utilizing low protein sources e.g. urea (Hoover and Stokes, 1991).

However in early growth, late pregnancy, early lactation and peak lactation in ruminants the amino acids requirements are high and the protein produced by rumen microbes cannot meet these demands. Minimum levels of protein which are adequate for good performance differ with different physiological categories; heifers 11 % CP, dry cows 9 % CP and lactating cows 13-16 % CP (Kearl, 1982); McDonald *et al.*, 1998). It is therefore necessary to add exogenous amino acid supply to the small intestines by feeding dietary protein that passes intact from the rumen to duodenum known as by pass proteins. Animal by-product meals are good undegraded protein sources. These include fishmeal, blood meal, bone and meat meal (Barlow and Windsor, 1984). It is also generally believed that the microbial protein produced by microbes is not available as amino acids to the animal. Therefore the supply of by-pass protein is appropriate. Fish meal/wastes are some of the best sources of by-pass proteins (Hussein and Jordan, 1991 a.b; Grigsby *et al.*, 1991; Guthrie and West, 1993).

Ruminants always feed on many types of proteins of plants and animal origin protein. Digestibility of protein nitrogen in the small intestine varies with protein sources. For example; cotton seed cake, fish meal/wastes, sunflower cake, and microbial protein have digestibility of 0.75, 0.87, 0.74 and 0.85 respectively (Ørskov and Miller, 1988; Sampth, 1990). Protein is fermented to volatile fatty acids, methane, Co_2 and ammonia. Ammonia is either absorbed directly across the rumen wall or passes out of the rumen with the fluid phase of digesta or incorporated into microbial protein (Ørskov and Miller, 1988). Dietary protein is however, not totally degraded and some passes intact into abomasum and duodenum where it is digested by enzymatic hydrolysis. Microbial, dietary and endogenous protein leaving the rumen is subjected to digestion and absorption in the small intestines. Any protein leaving the small intestine may be fermented by microorganisms in the caecum and colon or excreted in the faeces (Taminga, 1979; Sampth, 1990; NRC 2001).

2.1.3 Energy supplements in ruminants

Carbohydrates are the major energy source and make up the largest nutrient component in dairy rations, accounting for greater than 65 % of ration dry matter. Carbohydrates are present in the diet in two distinct forms: structural and non-structural (Hoover and Stokes, 1991). Compatible combinations of carbohydrates are important in the diet to promote strong ruminal digestion (thus yielding high levels of energy), support high yields of microbial protein synthesis, and maintain a stable fermentation. Consequences of a carbohydrate imbalance include inefficient ruminal digestion, body weight loss, and animal health complications (acidosis, displaced abomasums, and laminitis) (Hoover and Stokes, 1991).

The major energy source for ruminants is forages. However additional energy needed may be provided in many forms. The decision on the form of energy, i.e. grain or forage; is based on several factors including quality of forage, why and by how much energy is needed in addition to cost (Pyne, 1990; Kurwijila, 1991; McDonald *et al.*, 1998).

The performance of growing heifers is mostly limited by the shortage of energy content in the rations. Kearl (1982) reported that low quality feeds contributes to energy shortages in heifers. They are poorly digested and remain longer in the digestive system and thus reducing dry matter intake (DMI). Uses of high-energy rations improve efficiency of gain and growth rate as well as productive performance (Smith *et al.*, 1991; McDonald *et al.*, 1998).

Klusmeyer *et al.* (1990) and Church (1984) showed that the utilization of forage energy is impaired and its digestion reduced when the level of concentrate supplementation is above 50 % and or addition of grain energy, this is because of the change on rumen pH and fermentation. Therefore, the addition of grain energy to low quality forage will not cause problems except for a possible reduction in intake and digestibility of the forage (ARC, 1990; Stump and Lopez, 1994).

Feed preparation methods affect the feeds metabolizable energy. Grinding and pelleting of roughages in ruminants leads to an increase in energy losses in faeces (Kearl, 1982), while increased levels of feeding in ruminants reduces the digestibility of their food and hence its energy value. For finely ground roughages, mixed

roughages and concentrate rations, ME is reduced by increase in level of feeding (Ørskov and Ryle, 1990; Stump and Lopez 1994).

There are increases in live weight gains, milk production in response to increased quantity of energy supplied. When energy intake is increased animals retain more either partly as protein if nitrogen intake is adequate, or entirely as fat, and the animals' live weight gain increases. According to McDonald *et al.*, (1998), energy intake is the pace maker of production since animals tend to show a continuous response to changes in the quantities supplied.

Essential substrates fermented in the rumen are carbohydrates, protein and fats. Carbohydrates are by far the most important as a source of energy for microbes under the anaerobic conditions prevailing in the rumen. The rate at which carbohydrate is fermented is also important as high rates of fermentable enable bacteria to grow more rapidly and to minimize the proportion of energy used for their maintenance. Production of volatile fatty acids, methane and carbon dioxide also depends on the rate at which most edible carbohydrates are fermented (Ørskov and Miller, 1988; Hoover and Stokes, 1991; Khan *et al.*, 1998).

2.1.4 Protein and energy interaction in ruminants

Proteins and carbohydrates have a significant interaction within the rumen at the sites of absorption and ultimately through nutrient utilization of the tissues. Increasing the crude protein of isocaloric rations from 11-20 % of the ration dry matter increase the energy value of the ration by overriding the expected depression of digestibility due

to increased intake (Noceck and Russel, 1988; Khan *et al.*, 1998). The stimulating effect of protein appears to involve a cycle of improved efficiency of microbial protein synthesis, increased dry matter digestibility, dilution rate, food intake and finally energy intake. Other factors such as increased intestinal supply of amino acids and improved amino acid balance play a minor role to energy intake (Noceck and Russel, 1988).

Loerch (1983) reported that increased protein to energy ratio, the body gain of calves decreased and suggested that the optimum protein to estimated net energy would be 1:46 or slightly less. Furthermore animals on high ME low protein rations consumed less feed than those on high ME and high proteins rations. The utilization of nitrogen has been observed to be poor with low energy levels. Hoover and Stokes (1991) reported responses of additional energy when ration contained 12 % crude protein but no benefit was obtained by feeding additional energy when the basal diet contained only 5-8 % crude protein. Additional protein increases the digestibility of protein and crude fibre (Loerch, 1983; Hoover and Stokes, 1991; McDonald *et al.*, 1998).

All the energy for microbial growth is derived from the fermentation of dietary carbohydrates and nitrogenous constituents provide the nitrogen requirements of the microorganisms. Nitrogen-carbohydrates interrelation occurring with in the rumen is of considerable importance to over all rumen metabolisms. Rations low in metabolizable energy have been shown to result in a smaller synthesis of microbial protein (Nocek and Russel, 1988; Lykos *et al.*, 1997).

2.2 Protein requirements of weaned dairy calves

Protein requirements are compiled from estimates of the inevitable losses of protein from the body, the retention of protein during growth and the biological value of the protein. The requirement of the protein is considered to be the sum of the needs for maintenance and tissue protein deposition. The amount of nitrogen stored per kg gain varies from 26-34 g, but it appears to be higher for calves gaining weight very slowly and for calves gaining weight very rapidly if the diet contains a high concentration of protein (McDonald *et al.*, 1998; NRC, 2001).

Requirement for apparently digestible protein are slightly higher for the ruminant calf than for the pre-ruminant calf. There is a considerable wastage of nitrogen in the ruminant calf, owing to the absorption of NH_3 produced in the rumen and subsequently excreted in the urine as urea. Feeding calves with rumen undegradable proteins can reduce this loss of nitrogen (McDonald *et al.*, 1998).

2.2.1 Sources of proteins in ruminants

Protein supplements for ruminants can either be from plant or animal sources. For plant sources, oil cakes and seed meals are mainly used. These are residues remaining after the removal of oil from oil seeds or rejected oil seeds. Although the biological value of these oil cakes as protein sources are lower compared to that of animal protein sources, they are still valuable in the feeding of animals because they are cheaper compared to the animal protein sources (McDonald *et al.*, 1998).

The oil cakes commonly used for livestock feeding in Tanzania include, sesame meal, cottonseed, sunflower, soybean, groundnut and coconut cakes (Kimbi 1997). Cottonseed cake is the most abundant vegetable protein available that could be utilized for ruminant feeding. The nutritive value of cottonseed cake depends on the variation in composition of the seed and condition of processing. Processing influences all variable composition such as fibre, oil, protein content as well as gossypol content and availability of amino acids (Lyimo, 1983). For hydraulic processing oil content of the cakes is 4-8 %, screw processing 3-5 % and solvent extracted 3 %. Gossypols content also follow the same trend, 0.05-0.2, 0.02-0.06, and 0.05 % for hydraulic, screw and solvent extracted processing of processing cakes respectively (Lyimo, 1983; McDonald *et al.*, 1998).

Although gossypol has been shown to have no effect in adult ruminants, young calves have been shown to be injured by appreciable amounts of gossypol and it is therefore unwise to feed cottonseed cake to calves under 3-4 months. Free gossypol contents of 0.029 % in cottonseed cake could form up to 60 % of the concentrate mixture for calves with no ill effect. Cottonseed cake should be fed with good quality hay, silage or green pasture because it has a low carotene content that can be supplied by the former (McDonald *et al.*, 1998).

Among animal protein sources for ruminants include meat meal, blood meal, bone meal and fish products as fishmeal and fish wastes (Guthrie and Waste, 1993; Kjos, 2001). With exception of fishmeal and fish wastes, availability of animal proteins in large quantities in Tanzania for ruminants is not possible. This is due to a high

demand by humans and low production potential of these animal by products. Fishmeal and fish wastes are however abundant due to fishing activities in lake Victoria and the Indian Ocean (Mbamba 2000).

2.2.2 Fish meal (FM)

Fishmeal (FM) is made from whole fish (fish caught specially for making fish meal or from fish caught for food i.e. that unacceptable for human consumption) including fish by-products like viscera, heads, tails and back bones (Hussein and Jordan, 1991 a; Kjos, 2001). About 90 % of world's FM is from fish species with high and low fat content e.g. from Anchovy, Capelin, Menhaden (< 10 % fat) and from white fish, e.g. Cod and Haddock (< 1 % fat) and other sources e.g. whales and shell fish (Hussein and Jordan, 1991 a b; Kjos, 2001). Fish are transported to the processing factories either fresh or chemically preserved with small amount of formaldehyde and/or sodium nitrate. Preservation may be accomplished with ice or refrigerated water. Because fish are highly perishable, preservation becomes important if fish do not reach the factory soon after being caught (Hussein and Jordan, 1991 a).

2.2.2.1 Processing of fish meal

Processing of FM involves cooking, pressing, drying and grinding of fish. Fish are cooked to coagulate their protein, to free water and fat from the tissues. Cooked fish then are pressed to remove some of the water and fat and to produce what is called a pressed meal. This pressed meal is dried to about 90 % DM ground to the desired particle size and packed. The liquid removed by pressing is centrifuged to remove the fat known as stick water; the remaining solution is evaporated to thick syrup

containing 30-50 % solids (mostly protein) and is added back to the pressed meal to form the whole meal. Almost all fish are subjected to these processing stages except for pressing, which can be omitted for those species of fish that have low fat content, such as white fish (Hussein and Jordan, 1991 a; Kjos, 2001). Fishmeal may also be produced by simple methods. In a project conducted by the Agricultural University of Norway in Eritrea, FM was processed by sun drying of by-catch from schrimp trawlers. A combination of small fishes and a hot and dry climate made it possible to dry the fish in 2-3 days (Kjos, 2001).

2.2.2.2 Quality of fishmeal

Fishmeal is a brown product and the intensity of the colour is attributed to several factors, including fish species, particle sizes, fat and moisture contents, and the nutritional background of the fish (Hussein and Jordan, 1991a). Barlow and Windsor (1984) summarized chemical composition data of various types of FM and indicated that FM has high CP (60.4-72 %); fat (3.4-11.3 %) that is higher in long chain (20 carbon atoms or more) polyunsaturated fatty acids than vegetable fat. Ash content of various FM also is high (10.1-20 %) and is composed primarily of Ca and P. Fish meal is rich in essential amino acids, particularly lysine and sulphur containing amino acids (i.e. cystine and methionine) (Kjos, 2001). They also reported that despite the wide differences in CP content between FM of different origins, amino acid profiles were quite similar.

Johson and Savage (1987) and Kjos (2001) reported several factors for variations observed in the quality of FM and these include: 1. Meals made from fish scraps

contain a higher ash and a lower protein contents than meals made from whole fish. 2. Fish spoilage due to autolysis, degraded fresh that coagulates poorly during cooking, causing difficulties during pressing and leading to meals with low protein and high fat content. 3. Crude protein levels are affected by amounts of stick water added to the meal. 4. Evaporator temperatures as high as 150 ^{0}C used to condense stick water, may affect protein quality of the whole meal. 5. Time and temperature used to dry the pressed fish alter cystine, histidine, lysine and tryptophan amino acids that are susceptible to destruction during heat treatment. 6. Storage of FM without stabilization of fat leads to fat-protein autoxidation that decreases the solubility, digestibility, and availability of proteins. These changes are associated with destruction of labile amino acid residues such as cystine, histidine lysine and methionine.

2.2.2.3 Fish meal as a source of protein in ruminants

Fishmeal is considered as an excellent protein source for poultry, pigs and ruminants. For the non-ruminant animals, the high content of protein and the good amino acid composition, and the high digestibility of amino acids, is of importance. For ruminants, especially high yielding cows some qualities of fishmeal with low ruminal degradation values for protein (high contents of rumen escape protein) has been of special interest. However, fishmeal has also shown good results when used for young ruminants and sheep (Hussein and Jordan, 1991 a, b; Kjos, 2001).

2.2.3 Fish wastes (FW)

Fish wastes are materials resulting from industrial fish processing operations from either wild stock or aquaculture. They consist of particles of left over dead fish; flesh, heads, skin, tails, bone entrails, shells, internal organs, or liquid stick water (IOM, 2001; Kjos, 2001).

Fish wastes pose a potential hazard to the environment because the organic components of FW have a high biological oxygen demand and if not managed properly, can cause aesthetic problems and strong odours as a result of bacterial decomposition if not stored properly or disposed quickly. Further processing of wastes to animal feeds is considered a viable alternative. It is essential that the waste be fresh (Kjos, 2001; IOM, 2001).

2.2.3.1 Processing and quality of FW

Processing of FW into animal feeds is similar to that of FM. The main process used is hydrolysis, a process that can successfully reduce fish by-products to a high protein source acceptable for animal feeds (Hussein and Jordan, 1991 a). The quality of FW is relatively lower than that of FM (Table 2.1) because of fish parts that are incorporated in FM compared to FW. FM is mainly composed of whole fish although other fish industrial by-products can be included. FW are mainly the end products of the fish industries after removing fillet part from the fish (Hussein and Jordan, 1991 a; Anderson *et al.*, 1993; McDonald *et al.*, 1998; Kjos, 2001). McDonald *et al.*, (1998) observed that a wide variety of fish wastes/meal are available depending upon the country of origin, the raw material and the process used to prepare them.

Table 2.1: Chemical composition of fishmeal and fish wastes in % DM

Fishmeal	DM	CP	EE	ASH	P	Ca
Herring meal (a)	98.00	58.80	33.30	9.30	1.35	1.42
Menhaden meal (a)	96.20	67.70	10.70	21.50	3.65	6.89
Anchovy meal (a)	89.06	70.40	11.40	17.50	2.60	4.13
Tanzania fish meal (b)	89.10	69.10	15.50	25.20	2.05	6.50
Fish wastes						
Tanzania fish wastes (b)	90.60	52.20	8.60	43.60	2.10	13.04
Tanzania fish wastes (c)	75.50	59.96	25.09	40.13	2.52	11.34
Tanzania fish wastes (d)	96.70	42.70	9.00	45.20	2.80	9.60

(a) Anderson *et al.* (1993) (b) Mbamba, (2000) (c) Ngate, (1997)

(d) Thomke and Macha, (1986)

2.2.3.2 Quantity of Fish wastes from Nile perch (*Lates niloticus*) obtained from Lake Victoria.

Ngate (1997), showed an enormous potential of fish wastes as a protein source for livestock in Tanzania. The author reported that 18726 tons of fresh fish were landed from which an average of 990 tons of fish offals were obtained, although actual amounts are likely to be higher (Table 2.2) The same author reported that when unmarketable fish were included over 300 tons of wastes were generated every month.

Table 2.2: Amount of fish harvested and quantity of fish wastes produced at some fish processing plants (1993-1996) Mwanza

Year	Wt of fish (tons)	Average of fish offal (%) of body weight	Qt. of fish offal (tons)	Qt. of DM offal (tons)	Qt. of CP (ton)
1993	16,078	5.58	849	641	384
1994	16,107	5.58	850	642	385
1995	18,596	5.58	982	741	445
1996	24,121	5.58	1274	962	577

Source: Ngate (1997).

Komba (Personal Communication, 2000) studied the production potential of fish wastes from 8 Nile perch processing factories in Mwanza city. The factories included, Vick Fish, Tanzania Fish Production (TFP), TAN Perch, Mwanza Fishing industries, Omega and Nile perch fisheries. The author reported that one kg of fish fillet produced 67 % fish wastes as shown in Table 2.3 below.

Table 2.3: Fish fillets and fish wastes produced by Nile perch processing industries form lake Victoria

Year of production	Fish fillets produced (kg)	Fish wastes produced
1995	12404	25186
1996	13724	27866
1997	16230	32953
1998	26018	52824
1999	16561	33622
2000	29377	59643

Source: Komba, (2000)

2.2.3.3 General characteristics of fish wastes

In general fish is considered as a superior feed for all kinds of domestic animals, in terms of protein value, mineral and vitamin contents. Therefore, the nutritive value of aquatic by-product is generally good. Feeds of fish origin are rich in protein and amino acids, ranking close to milk protein (Kjos, 2001). The amino acid composition of FW is usually very high and protein digestibility is also high. However, there might be some variations in the contents of amino acids due to the origin of the by-products. Fish muscles in general have the most favourable amino acid composition, while the proteins found in bone marrow and skin has lower contents of the amino acids lysine, methionine and cystine. The contents of fat may also show some variation. If the fat (oil) content is high, it is necessary to remove the oil before

feeding it to animals, to avoid fishy taste of the products (McDonald *et al.*, 1998; Kjos, 2001). Fish products are good sources of calcium, phosphorus and other trace minerals. Both in practice and in animal experiments, feeds made with fish show good results especially for poultry, pigs and all classes of ruminants. In aquaculture and for fur bearing animals, fish is the superior feed ingredient (McDonald *et al.*, 1998; Kjos, 2001). Fish wastes contain unknown growth factors known collectively as the animal protein factor (APF) (McDonald *et al.*, 1998). They are also free from toxins and have an acceptable bacterial content and composition. However nitrite residues, if present at high enough levels, can form nitroamines, which are particularly toxic to mink. Pigs, poultry, cattle and sheep are less susceptible to nitroamines (McDonald *et al.*, 1998; DeBoer and Bickel, 1988; Anderson *et al.*, 1993).

2.2.3.4 Effect of fish wastes on growth of weaned dairy calves

Fish waste/meal contains over 60 percent crude protein with an excellent amino acid profile and is about 65 percent rumen undegradable. However, considerable variability in rumen degradability may occur due to different fish by-product components and processing methods. Because of smell and taste, acceptance of fishmeal may be a problem, so ruminants should be adapted slowly (Guthrie and West, 1993; Mbamba, 2000).

Performance responses of growing heifers to FM/FW supplementation have been variable. Such variability is surprising because FM/FW is a protein source with high

rumen escape and, when processed correctly, it is well digested in the small intestines (Anderson *et al.*, 1993).

2.2.3.5 Physiological and dietary factors of FM/FW on growth

Hussein and Jordan (1991 a, b) reported gains to be higher in males followed by castrate males and then females when ruminants were supplemented with FM/FW. Young castrated calves (113 kg) grew faster when fed corn silage-based rations supplemented with FM/FW than with urea. This response was attributed to increased amino acid flow to the small intestines (Hussein and Jordan, 1991 a, b). Grigsby *et al.* (1991) reported higher gains when weaned calves fed FM/FW and corn supplements on ryegrass than ryegrass mixed with maize and rye grass pastures alone. Ørskov and Miller (1988) also reported greater average daily gain for young growing heifers less than 200 kg fed rations supplemented with FM/FW than those fed rations supplemented with urea and soybean meal. In contrast yearling dairy heifers fed straw based rations supplemented with FM/FW, soybean meal, or whey plus urea had similar average daily gain. Lopez *et al.*, (1999) observed a higher daily gain of 495.67 g when 500g fish meal was supplemented daily to growing Holstein heifers compared to 337.54 g for those fed with maize meal on chopped Bermuda grass.

Hussein and Jordan (1991 a, b) concluded that the potential for ruminally undegraded protein sources to improve rate and efficiency of gain and N balance may be greatest in young, growing ruminants in which the ruminal microbial amino acids supply may

be insufficient to meet metabolic amino acids requirement for maintenance and rapid growth.

Several dietary factors influence the response of growing ruminants to FM/FW supplementation. Such factors include the concentrate level, grain and forage sources (Hussein and Jordan, 1991 a, b). Replacing a low ruminal escape protein source such as cottonseed meal with FM/FW in corn-based rations fed to Holstein steers did not improve average daily gain or feed efficiency (Thonney and Hogue, 1985). The ruminally-undegraded protein of FM/FW may have no advantage because the basal rations in these studies were mostly corn, which has 40 % escape of ruminal degradation (Ørskov, 1986; Therdchai, 1987). Miller (1978) replaced urea with fishmeal in early- weaned growing calves from 50 to 110 kg live weights as supplements to barley rations and reported increased growth rates of young calves. In another study, Pham Kim Cuong *et al.* (2001) fed 20 young bulls with FM/FW and cotton seed cake using rice straw as basal ration. Bulls supplemented with FM/FW had greater average daily gain (557 g) than those supplemented with cotton seed cake (474 g). Bulls fed on urea treated rice straw with FM/FW had the highest average daily gain (688 g) and bulls fed on treated rice straw with cotton seed cake had the lowest average daily gain (607 g).

However FM/FW illustrates inconsistence of responses when supplemented to ruminant rations. (Hussein and Jordan (1991a,b) suggested several points to be considered when formulating FM/FW rations for ruminants if an improvement in animal performance is to be expected. These include the following: 1) FM/FW

supplemented rations seem to be most effective when fed to young sheep or cattle during the rapid phase of growth (i.e. shortly after weaning). The response may be greater for males than for females or castrated males. 2) FM/FW has little or no advantage when in combination with high corn rations and fed to growing finishing ruminants because microbial protein and the ruminally-undegraded fraction of corn protein meet the protein requirements of such animals. 3) Supplementation may be more effective in enhancing ruminal fermentation and ruminal performance with high quality silage rations than with hay and straw rations. The magnitude of the response may be greater with silages of medium or poor quality. 4) Ruminal degradation of FM/FW protein is a vital factor that should be considered when formulating ruminant diet because it has shown to be affected negatively or positively by processing. 5) FM/FW has no advantage over less expensive seed meals (soybean, cottonseed, groundnut and sunflower meals) in rations of ruminants in later phases of growth when protein requirements can be met by microbial protein plus escape feed protein because of their lower protein requirements.

2.2.3.6 Limitation of fish wastes as an animal feed

The major practical limitation to the use of fish waste in animal feeding is based on its handling, processing and preservation. The moisture and fat content of the fresh fish waste are normally very high, 70 % and 12 % respectively depending on the type of fish (Barlow and Windsor, 1984).

The high moisture and fat content also bring rapid deterioration and difficulties of preservation in fresh forms. The high content of polyethlenic acids makes fish oil in

the fishwaste highly susceptible to oxidation (DeBoer and Bickel, 1988). Treatment with antioxidants may slow the rate of rancidity but could have the negative effects of transferring the oxidative rancidity and fish off flavours into the body lipids and other animal products (Clucas, 1981).

2.3 Energy requirements of weaned dairy calves

Energy requirements can be divided into energy required for maintenance and that required for growth, both of which are influenced by body size, age, sex, type and level of growth, activity and environmental conditions. Energy for maintenance consists of the energy utilized for its basal metabolism, including a small loss of energy in the urine, together with the heat produce by voluntary activities. The efficiency of utilization of ME for maintenance depends on the energy concentration in the diet. With high roughage rations containing 8.8 MJ ME/kg DM efficiency is 68 % where as with high concentrate rations containing 14.2 MJ ME/kg DM the efficiency of utilization of ME for growth is much lower than that for maintenance (McDonald *et al.*, 1998).

2.3.1 Sources of energy in ruminants

Carbohydrates as source of energy for ruminants can be obtained from different sources. These include; cereals (corn, wheat, oats rice and barley). Other sources of energy are cereal by products that include; brans from maize, wheat, rice and barley, cereal husks and hominy meal. Roots, stems and tubers; cassava, sweet potatoes, sugar canes and their products like cassava fibre (pomace) and sugar cane molasses (Guthrie and West, 1993; McDonald *et al.*, 1998) are major energy sources. Apart

from cereals, roots, tubers and their products, ruminants can get their energy from pastures in the form of green crops, or dry as hay and straw also as processed like silage (Ørskov and Ryle, 1990; Payne, 1990; Van Soest, 1994).

Carbohydrates are grouped into structural carbohydrates (SC) and non-structural carbohydrates (NSC). The microorganisms living in the rumen allow the ruminants to obtain energy from fibrous carbohydrates (cellulose and hemicellulose) that are bound with lignin in plant cell walls or fibre. Since fibre is bulky it is retained in the rumen where the cellulose and hemicellulose are fermented slowly. As plants mature, the lignin content of fibre increases and the extent of cellulose and hemicellulose fermentation in the rumen decreases. Fibre in the form of long particles is essential to stimulate rumination. Rumination enhances the breakdown and fermentation of fibre. It stimulates ruminal contraction, and it increases the flow of saliva to the rumen. Saliva contains sodium bicarbonate (baking soda) and Phosphate salts that help to keep the acidity (pH) of the rumen content almost neutral. The non-fibrous carbohydrates (present in many concentrates) promote the production of propionic acid whereas the fibrous carbohydrates (present primarily in forages) stimulate the production of acetic acid in the rumen. In addition, the non-fibrous carbohydrates yield more VFA (i.e., more energy) because they are fermented faster and more completely (McDonald *et al.*, 1998; NRC 2001).

The common carbohydrates used in Tanzania to feed ruminants are milling by-products that include hominy meal, molasses, brans of maize and wheat. Cereals are faced with low production and competition between livestock and humans. Among

livestock there is also a competition between ruminants and non-ruminants (Lekule, 1990; Israel, 1992). The latter authors proposed the use of cassava as a potential alternative source of energy for domestic livestock that could solve this problem. Cassava is low in dry matter, protein, fat and mineral contents, but the DM is rich in energy due to a high content of starch. Starch that is contained in the cassava tuber makes the synthesis of rumen microbial protein more efficient when it acts as the main dietary source of fermentable carbohydrate compared to sugars (Sommart *et al.*, 2000 b). Findings by Kanjanapruthipong *et al.* (2001) concluded that cassava is an excellent source of fermentable total non-fibre carbohydrates for ruminants.

2.3.2 Cassava toxicities

Cassava is famous for the presence of free and bound cyanogenic glucosides, linamarin and lotaustralin. According to Stephen (1998) they are converted to HCN in the presence of linamarase, a naturally occurring enzyme in cassava. Linamarase acts on the glucosides when the cells are ruptured. All plant parts contain cyanogenic glucosides with the leaves having the highest concentrations. In the roots, the peel has a higher concentration than the interior. In the past, cassava was categorized as either sweet or bitter, signifying the absence or presence of toxic levels of cyanogenic glucosides. Sweet cultivars can produce as little as 20 mg of HCN per kg of fresh root, while bitter ones may produce more than 50 times as much. The bitterness is identified through taste and smell. This is not totally valid system, since sweetness is not absolutely correlated with HCN production ability (Rehm and Espis, 1991; Stephen, 1998).

2.3.3 Processing of harvested cassava roots and leaves

Buitago (1990) as sited by Nguyen (1996) reported that the greatest limitation to the use of cassava as animal feed is its content of cyanogenic glucoside. Ikediobi *et al.*, (1980) have shown that cassava containing 144 to 164 ppm HCN after processing can be used for feeding of livestock in Nigeria. According to Tewe (1992); the lethal dosage of HCN varies with species of animal, and amount consumed and has not been established.

Presence of HCN presents a problem to cassava utilization in domestic livestock. Therefore processing of the roots and leaves is inevitable. Apart from HCN also the shelf life of cassava is only a few days unless the roots receive special treatment (Rehm and Espis, 1991; Stephen, 1998). Several methods have been employed to make use of cassava as feed for livestock. Removing the leaves two weeks before harvest lengthens the shelf life to two weeks. Other methods include fermentation, sun drying boiling and roasting. The most common processing method for ruminant feeds is sun drying followed by ensiling and fermentation (Bakrie, 1997; Stephen, 1998; Bui Van Chinh and Le Viet Ly, 2001). In the drying process unpeeled roots can be grated and dried while leaves can be harvested and sun dried. Drying period can range between 2-4 days (Wanapat, 1999).

Fermentation of both roots and leaves is another process used. The process involves using microorganisms commonly *Aspergillus niger* (*A.niger*) and it is known as a solid-state fermentation. The method used in fermentation is as follows: 1). The roots and leaves are sliced into small pieces and steamed for 30 minutes. 2). Mixture of

urea and minerals are added to each kg of steamed roots with the following composition: 16.7g urea, 32.2 g ammonium sulphate. 6.25 g NaH2PO4, 2.08 g MgSO4, 0.63g KCL and 0.31g FeSO4. Minerals are required to precipitate the chemical compound that would prohibit growth of microorganisms. 3). The mixture is then left to cool down, after which 2 g of *A.niger* is added to each kg of the mixture. 4). It is then transferred into a plastic tray, and is well spread over the tray with a 2-3 cm thickness then covered with a similar size tray. 5). The tray is kept in a room temperature for 5 days, and then dried in a 60 ^{0}C oven for 24 hours. 6). The dried fermented cassava roots may be fed directly to ruminants (Bakrie *et al.*, 1995). Ensiling process involve cassava tops (30-60 cm pieces including green leaves) which were collected when harvesting roots. The cassava tops are chopped (2-4) cm) and pressed before ensiling. After 60 days the product can be ready to be fed to animals as HCN will be at lowest concentration (Bui Van Chinh and Le Viet Ly, 2001).

This processing technique has been found to have several advantages when domestic livestock utilizes cassava by-products. Fresh cassava tops have an HCN content of 863 mg/kg DM that is reduced to 90.5 mg/kg DM after sun drying for three days and to 32.5 mg/kg DM after ensiling for 60 days. Ensiled cassava tops can substitute green grass in ruminant rations (Bui Van Chinh and Le Viet Ly, 2001).

Bioprocess (fermentation) has caused an increase in crude protein contents of cassava root through solid-state fermentation from 3 % to 18-42 %; cassava leaves

from 19 % to 26 %. Apart from increase in protein content also crude fibre decreased and the palatability increased (Bakrie *et al.*, 1995).

2.3.4 Cassava as animal feed

In Asia, where rice is the most popular staple feed, commercial cassava production has focussed on animal feed, mainly in the form of chips and pellets for export. Over the past 30 years Thailand has led the way. In 1995, Thailand exported 3.3 million tones of cassava pellets, mostly to the European Union. In Africa and Latin America, the domestic market for cassava-based animal feed shows potential for growth. More than 30 % of cassava production in Latin America is used for domestic animal feed, compared to less than 2 % in Africa (FAO, 2000).

Both fresh and dried cassava roots are consumed by ruminants in different forms (sliced, chopped, ground). Dried cassava roots have given satisfactory results as the principle energy source for dairy cattle intensive beef fattening and lamb growth. Cassava can replace almost all of the grain in the rations with little reduction in performance. Inclusion level of up to 65 %, preferably pelleted, do not seem to affect health, carcass quality, or overall performance when the rations are carefully balanced (Wanapat, 1999). Cassava leaf and stem meal has been used at the 35 % level in dairy cow concentrates advantages. The forage has been used to provide by-pass protein to ruminants fed urea and molasses. The intake of cassava forage was about 5 kg per day, and about two months of adaptation was required before full production was obtained (Wanapat, 1999).

2.3.5 Nutritive value of cassava root

Cassava roots contribute basically carbohydrates (energy) to the rations of human and animals. Out of 100 % of dry root only 80 % is nitrogen free extract (NFE). NFE fraction of cassava consists of approximately 80 % starch of which 20 % is amylase. In the starch component, 60 % is amylopectin and the remaining 20 % is made up of sugar (sucrose) and amides (Khajarem and Khajarem., 1984; Lekule, 1990; Rehm and Espis, 1991; Israel, 1992).

Cassava is low in dry matter, but the DM is rich in energy due to a high content of starch (Kanjanapruthipong *et al.*, 2001). High amylopectin content in cassava relative to maize makes it a more suitable source of energy for ruminants than for monogastric animals (Lekule, 1990). Cassava is very low in protein, and the protein is of poor quality. The nitrogenous substances vary from 0.7-4.6 %. Lysine, methionine and tryptophan are very low. In this aspect the amino acid profile compares unfavourably to that of cereal grains (Therdchai and Mikled, 2001). Cassava is also poor in lipids, leading to deficiency problems in certain animal rations. The range is 0.3 to 1.2 % ether extract. Most animals require 1-2 % lipids in their rations and ruminants can tolerate 5 to 7 % fat. Thus the low lipid content, together with the possibility of being limiting in some essential fatty acids vital for normal body function renders cassava deficiency in lipids (McDonald *et al.*, 1998). Although cassava contains very small amounts of minerals there is great variation due to different soil types and processing methods. Cassava has a range of 0.04 to 0.12 % calcium and phosphorus (Wanapat, 1999). The chemical composition of

cassava root meal compared with other energy sources is as shown in Table 2.6 below.

Table 2.4: Chemical composition of cassava root meal compared to other feeds (DM%)

Feed	DM	CP	EE	CF	ASH	Starch
Whole maize grain	86.4	10.6	4.9	2.4	1.5	15.3 *
Hominy meal	87.9	13.3	14.1	6.3	4.2	15.8 *
Wheat feed	93.6	15.9	2.6	16.5	7.3	14.7 *
Cassava root meal	90.0	3.5	0.9	4.3	3.0	89.2 *
Cassava chips	89.6	3.1	0.9	4.3	3.0	87.8**
Broken rice	89.3	9.1	1.7	0.5	0.9	87.8***
Ground paddy	90.7	7.2	1.9	0.3	0.2	69.9**

Sources: - * Thomke and Macha, (1986); Lekule *et al*; (1988).

** Therdchai and Mikled, 2001

*** Kriangsak *et al.* 1990.

2.3.6 Effect of cassava root meal in ruminants

There are no deleterious effects that have been reported in ruminants by partial or total substitution of cereal grains with detoxified cassava tuber meal (Fomuyam and Meffeja, 1987). Cassava is easily digested by all categories and species of animals and is a good energy source in ruminants and monogastric animals. Its digestibility has been reported to be comparable to that of maize and other cereals (Khajarem and Khajarem, 1984; Lekule, 1990). Like oats, wheat and barley cassava root contain high soluble fraction of starch and sugar (Taminga, 1979) and can be added to rations to increase utilization of ruminal NH_3-N for microbial proteins synthesis. Although it is generally accepted that cassava is highly palatable feed, effect of inclusion rates in cattle rations on intake reported is not consistent (Zinn and DePeters, 1991;

Kanjanapruthipong *et al.*, 2001). For example inclusion of cassava in low quality roughage rations without an additional source of N will impair microbial growth efficiency (Permaratne *et al.*, 1998) due mainly to an insufficient supply of N for microbial synthesis. An adequate supply of N is therefore necessary when cassava is used as a source of total non-fibre carbohydrate (Kanjanapruthipong *et al.*, 2001).

Sommart *et al.*, (2000 a) observed that cassava fed at a rate of 15, 30 and 45 % and combined with different roughage sources (ruzi grass, rice straw and urea treated rice straw); improves animal weight gain and milk production without any adverse effects on rumen function or milk fat. The mentioned parameters increased linearly with increasing levels of cassava inclusion.

Starch that is contained in the cassava tuber makes the synthesis of rumen microbial protein more efficient when it acts as the main dietary source of fermentable carbohydrate compared to sugars (Rowe *et al.*, 1980). Jalaludin (1977) reported that when Holstein male calves (150-200 kg) were fed on rations containing 75 % cassava gained as fast or faster than those on the feeds devoid of cassava. The latter author further reported that a mixture of 37 % cassava and urea gave the best gain compared to wheat combined with cottonseed meal. Muller *et al.*, (1974), reported that a simple ration with composition of 85 % cassava root meal, 6 % molasses, 8 % urea and 1 % mineral supplement would much up well with tropical grasses. Sanda and Methu (1992) reported that total substitution of maize meal with cassava had no significant effect on *in vivo* digestibility of either dry matter (DM) or organic matter (OM).

Smith *et al.* (1992) in his review on the response of ruminants to a diet of cassava and its products reported tubers and peels to be good energy sources, which when supplemented with nitrogen, minerals, vitamins and roughage promote good performance in dairy and beef cattle, sheep and goats. The authors pointed out the constraints to increased utilization of cassava products in ruminant feeds to be the difficulty of obtaining sufficient quantities and the cyanide content. Krishna and Ramana (1991) reported that cheap sources of energy for ruminants in increasing expenses are rice bran, cassava peelings, wheat bran, sorghum then maize. Efficiency of crude protein (CP) utilization was higher in the cassava peel-based rations than from corn-based diets (Lakpini *et al.*, (1997). Stump and Lopez (1994) fed Napier grass (*Pennisetum purpureum*) hay to sheep supplemented with 0, 15, 30 and 45 % peeled and dried cassava root as a source of starch. Total organic matter intake was highest at 30 % cassava, and decreased thereafter. Increase in dietary starch decreased hay intake and protein and cell wall digestibility.

Aregheore (1992) using dairy calves aged 12 to 16 months and fed on cassava flour or maize corn and forage, reported high daily live weight gain and blood glucose levels in calves fed cassava. In another study Therdchai and Mikled (2001) fed White Lamphun cattle with concentrates containing cassava at 0, 50, 75, and 100 % substituting maize as energy sources with rice straw as a basal ration. The total DMI intake was 5.54, 8.83, 5.37 and 5.23 kg/day while average daily gain was 794, 866, 779 and 965 g/day with respectively.

2.4 Effect of protein and energy supplements on ruminal pH, NH_3-N and VFA

The rumen environment is controlled by the type and quantity of feed eaten, periodic mixing through contraction of the rumen, salivation and rumination, diffusion or secretion into the rumen, absorption of nutrients from the rumen and passage of material down the digestive tract (Preston and Leng, 1987; Herrera-Saldana *et al.*, 1990; Lyskos *et al.*, 1997).

The microbial ecosystem in the rumen is complex and highly dependent on fed diet. The vast majority of ruminants consume a mixture of carbohydrates, of which cellulose and hemi cellulose are the largest components. However, at times the diet can contain large amounts of soluble carbohydrates or starch (e.g. Molasses or grain) (Preston and Leng, 1987). The potentially fermentable pool of protein includes feed proteins plus the endogenous parts of salivary glands, sloughed epithelial cells, and the remains of lysed ruminal micro-organisms (Herrera-Saldana *et al.*, 1990; NRC, 2001).

Ruminal bacteria can incorporate amino acids into microbial protein or ferment them as energy source. The fermentation of amino acids also gives rise to ruminal NH_3. Protein is usually more expensive than carbohydrates. Therefore utilization of protein as an energy source will have a negative impact on the economics of ruminant production (Noceck and Russel, 1988). Crude protein can most easily be fractioned into soluble and insoluble parts. In forages most soluble CP is actually NPN but grains contain a considerable amount of soluble N that is true protein amino acid.

NPN is rapidly converted to ruminal NH_3 (Noceck and Russel, 1988). Approximately half of ruminally degraded protein N enters the NH_3 pool and that only half of the NH_3-N is used for microbial protein synthesis. Microbial growth is dependent on the supply of fermentable carbohydrates and the end products of protein metabolism are influenced by the availability of carbohydrates. When ATP (primarily from carbohydrate fermentation) is available, amino acid entering the microbes can be incorporated into microbial protein. If ATP is not sufficient to drive protein synthesis, all amino acids will be fermented as and energy source HN_3 will accumulate (Noceck and Russel, 1988).

Some proteins are more soluble in rumen fluid and are degraded more easily by rumen microbes than are others. Differences in the concentration of NH_3 in ruminal fluid may be due to differences in solubility of protein or microbial activity in the rumen. A lower rumen pH would be expected when a high concentrate diet is fed compared to a normal diet. Thus more NH_3 in the rumen would be in the ionised form that will result in less NH_3 diffusing across the rumen wall. Increase in the concentration of rumen fluid NH_3-N shortly before feeding may be due to endogenous metabolism of non-growing microbes releasing NH_3 when soluble carbohydrate is deficient or cytolytic bacteria digesting other rumen organisms with the release of NH_3. Salivation may be a contributing factor to the increase in the concentration of NH3-N in the rumen (Satter, 1986; Nocek and Russell, 1988).

The magnitude of proteins and carbohydrates fermentation in the rumen is controlled by the inherent rate of protein hydrolysis, the uptake rate of peptides and amino acids (AA) into ruminal micro organism, the availability of carbohydrates to provide ATP

for microbial protein synthesis and the presence of methanogenic bacteria to provide a sink (CH4) for excess reducing equivalent (NADH2) (Nocek and Russell, 1988).

2.4.1 Effect of protein and energy supplement on ruminal pH

Ruminal pH can vary from above 7 to less than 5 depending on the type of diet fed to an animal as well as the rate and frequency of feeding (Erfle *et al.*, 1982). The pH of the rumen contents is near neutral on a predominantly forage diet and can reach pH near or below 5 when high grain diet are fed. Low pH (i.e. <6) results in low ammonia concentration in continuous mixed rumen fermentations. Low ammonia concentration could affect the growth of certain rumen bacteria that require ammonia (Erfle *et al.*, 1982). Change in ruminal pH changes the ruminal fermentation by products. The latter author reported the following changes when pH changed from 7 to 5; volatile fatty acids (VFA) 80 to 50mmoles/day, butyric acid 10 to 5 mmoles/day, propionic constant 12 to 20 mmoles/day, acetic acid and prop ionic ratio 4.3 to 0.9 and lactic acid increase as pH reaches 5 leading to ruminal acidosis. The major effect of pH appear to be on the ability of mixed rumen cultures to liberate NH_3 from amino acid, diaminase and protease activity and total bacterial number show significant decrease when pH drops to 5. The optimal ruminal pH for fibre digestion ranges between 6.7 and 7.1. Fibre digestion is decreased greatly when ruminal pH declines below 6 (Klusmeyer *et al.*, 1990).

Pham King Cuong *et al.* (2001) carried a study on ruminal pH using FM and cotton seed cake (CSC) with untreated rice straw using fistulated animals. The pH for cotton seed cake fed animals was 6.9 and that of FM fed animals was 6.8. When

treated rice straw with 4 % urea was fed the pH dropped to 6.7 for both FM and CSC.

Sommart *et al.* (2000 a) *in vitro* study observed the proportion of cassava in the substrate and its affected on pH. The pH ranged between 6.88 and 6.79 when cassava root meal was included at the rate of 13 to 45 % respectively. Sommart *et al.*, (2000 b) when studying ruminal environment in dairy cows reported the decrease in ruminal pH with increase in cassava root meal inclusion. The pH ranged between 6.5 and 6.7 on 13.5 to 54 % inclusion. These data suggest that inclusion of cassava root up to 54 % of the total ration did not alter ruminal pH. Muller *e al.* (1977) reported 85 % substitution of grains with cassava root meal while Wanapat, (1999) reported 65 % substitution with pelleted cassava with no affect on health, carcass quality, or overall performance when the rations were carefully balanced.

2.4.2 Effect of protein and energy supplements on ruminal NH_3-N

Ruminal NH_3-N concentration is affected by both source and amount of crude protein (CP) in the diet. Protein supplements of different origin vary in the rate and potential extent of degradation. Animal proteins such as blood, fish meal/wastes or meat and bone meal are slowly degraded in comparison with most vegetable proteins. A diet with low CP produces low ammonia and that with high CP produce high ammonia in the rumen. NH_3-N in excess of 5mg/100ml had no effect on protein content of the fermentor effluent even when ammonia concentration was in excess of 80 mg NH_3-N/100ml (Satter and Roffler, 1975). Hoover (1986) reported that 3.3 to 8 mg/dl NH_3-N optimised microbial growth and organic matter digestion; however,

actual values ranged from 1 to 76mg/dl and depended on dietary proteins as well as fermentable carbohydrates.

There are marked differences between carbohydrate supplements in their effects on ruminal NH_3 concentration and these differences arise through changes in ruminal microbial populations. Cellulolytics that are highly dependent on NH_3-N, thus low NH_3 can reduce structural carbohydrate digestion and ultimately feed intake (Taminga, 1979). Sommart *et al.* (2000 a) reported the decrease of NH_3-N concentration with inclusion of high levels of cassava chips at 15 % (3.92 mg/100.ml), 30. 5 % (3.72 mg/100.ml), 45 %) (3.52 mg /100 ml). In another study by Sommart *et al.* (2000 b) NH_3-N result gave 13.42 mg/100ml at 13.5% and 10.9 mg/100ml at 54 % inclusion rate of cassava root meal. Pham King Cuong *et al.* (2001) observed the effects of FM and CSC on ruminal NH_3 with untreated and treated rice straw. Concentrations of 149.3 and 133.5 mg/l against 256.1 and 226.2 mg/l of CSC and FM on untreated and treated rice straws respectively were observed. CSC had high NH_3 than FM.

Many strains and species of bacteria, protozoa, and anaerobic fungi participate by elaborating a variety of proteases, peptidases, and diaminases that act on feed crude protein to liberate peptides, AA, and NH_3. When protein degradation exceeds the rate of AA and NH_3 assimilation into microbial protein, peptide and AA catabolism leads to excessive ruminal NH_3 concentrations (Hoover and Stokes, 1991). Some of the peptides and AA not incorporated into microbial protein may escape ruminal degradation to NH_3 and become sources of absorbed AA to the host animal. Protozoa

are more active in degrading insoluble feed proteins (Soyabean and fishmeal) than more soluble feed proteins (casein) (Klusmeyer *et al.*, 1990; NRC, 2001).

2.4.3 Effect of protein and energy supplements on VFA production

The rumen environment is controlled by the type and quantity of feed eaten. Carbohydrates can be fermented in the rumen to yield volatile fatty acids (VFA's: acetate, propionate, and butyrate) and lactic acid. Some carbohydrates are digested post ruminally, while others pass through the animal undigested (Herrera-Saldana *et al.*, 1990). Non-ruminants lack the enzymes necessary to digest structural carbohydrates, but they can digest non-structural ones.

However ruminants are unique in that rumen microorganisms can digest both structural and non-structural carbohydrates in plants. They degrade carbohydrates into simpler sugar components such as oligosaccharides, disaccharides, and monosaccharides and rumen microorganisms utilize these products to form VFA's that the host animal can digest and utilize (Herrera-Saldana *et al.*, 1990).

Ruminal changes include pH, NH_3 and VFA (Erfle *et al.* 1982; Sommart *et al.* (2000 a, b). Erfle *et al.* (1982) reported the following changes when pH changed from 7 to 5; volatile fatty acids decreased from 80 to 50 mmoles/day, butyric acid from 10 to 5 mmoles/day, propionic constant increased from 12 to 20 mmoles/day. Change in VFA concentration is related with the type of feed ingredient supplemented and the roughage fed (Pham King Cuong *et al.* (2001). The latter author has observed changes from 74 and 88 against 94.3 and 104.2 mmol/l VFA when young bulls were supplemented with CSC and FM on untreated and treated rice straw respectively.

Sommart *et al.* (2000 a, b) studied the influence of cassava levels and type of roughage on total concentration and production of VFA, acetic, propionic and butyric acids and acetic: propionic in dairy cattle ratios. Mean total VFA concentration and proportion of propionic acid increased linearly but the proportion of acetic and acetic to propionic (C_2:C_3) ratio decreased with high cassava inclusion. There was substantial decrease in the ratio at the higher levels of cassava inclusion. When dried Ruzi grass was included there was proportional high decrease of these substrates confirming literature reports of changes in VFA concentration proportions with increase in the roughage (Sommart *et al.*, 2000 a). Rice straw also caused molar changes in VFA production between roughage sources. The values obtained by Sommart *et al.* (2000 a, b) (Table 2.6) are similar to concentration in both rumen fluid and *invitro* systems, suggesting no acid inhibition of microbial growth that can occur when cassava root meal is used. Increased inclusion of cassava resulted in a substantial increase in total VFA production and these increases were simultaneous with a decrease in pH.

Table 2.5: Levels of cassava root meal (%), total VFA, acetic, propionic, butyric acids (mmol/l) and C_2: C_3 in *invitro* system and rumen fluid of dairy cows

Cassava root meal (%)	Total VFA	Acetic acid	Propionic acid	Butyric acid	C_2:C_3
***In vitro* system**					
15	53.18	63.97	27.35	6.85	2.36
30	64.71	62.69	28.70	6.97	2.22
45	61.55	61.55	29.39	7.38	2.11
Ruzzi grass	61.79	62.01	28.97	7.25	2.15
Rice straw	56.38	63.33	27.98	6.95	2.28
Rumen fluid					
13.5	63.6	65.3	20.2	11.4	
27	66.4	65.4	20.2	11.3	
40.5	78.7	61.9	23.5	11.2	
54	56.9	64.7	19.5	12.3	

Source Sommart *et al.* (2000 a, b)

2.5 Estimation of digestibility of feed ingredients

Digestibility is the proportion of a feed or nutrient in the feed that has been apparently absorbed by the animal relative to the quantity consumed. In analytical terms it represents the difference in nutrient value between the feed eaten and the material voided by the animal (McDonald *et al.*, 1998).

There are several methods used in estimation of digestibility of a given feedstuff. However, regardless of the technique applied, a true value of digestibility of a feed should represent the extent to which chemical constituents of the feed become available to the animal (McDonald *et al.*, 1998). The techniques range from *in vivo* trial, *in vitro* and *in sacco* (nylon bag). Use of a given technique depends on the objective, feedstuff type under study, feasibility and cost related factors. However the degree of accuracy in determining the true value of digestibility varies, but all the

techniques provide apparent digestibility rather than true values due to technicalities within each method.

The *in sacco* degradability has now become a routine analysis in most ruminant feed evaluation studies. Application of scientific principles in animal nutrition necessitates the need for rapid evaluation of feedstuffs. Chemical analysis do not provide sufficient information as basis for prediction of actual feeding values of a feedstuff. The most useful measure of the nutritional value of a feedstuff is its apparent dry matter digestibility.

Although the nylon bag technique is now the standard process in many laboratories, the need for frequent replacement of the bags, the costs involved in maintaining fistulated animals, and lack of repeatability of results put into question its long term use in the feed evaluation. In principle this technique provide a good measure of disappearance of feed components from the rumen into the lower tract (McDonald, 1981). Such property should give a good indication of a natural tendency of a given feed for degradation in the rumen and there is an indication of its potential digestibility.

2.5.1 Prediction of dry matter and protein degradation of feed ingredients by *in sacco* method.

The nylon bag technique involves incubation for variable length of time of bags with porosity of 40-60 μm containing a test feed in the rumen of a fistulated animal. This technique is a modification of the one reported by Quin *et al.* (1938) who used silk

bags (Ørskov *et al* 1980). The method requires that the porosity of the cloth and the ratio of sample weight to surface area of the bag be standardized. The practice involves the retrieval of samples at set interval usually 6, 12, 24, 48, 72, 96 and 120 h to quantify the material that has disappeared by that particular moment. The amount of DM disappearance is regarded to be equivalent to digestibility.

The proportionate disappearance is described by the mathematical model developed by Ørskov and McDonald, (1979): $\mathbf{P = a+b\ (1-e^{-ct})}$. Where **P** is the amount of DM/CP disappearance at time **t**, **a** is the measure of solubility (i.e. degradation at time zero) **b** is the potential degradability of the component of the DM/CP, **c** is the rate constant of degradation, **e** is the natural logarithm and **a+b** is the total degradation of the sample; hence the component **100-(a+b)** describes the residue resistance to the rumen degradation.

The residue will inevitably contain microbial debris, thus the measure obtained by the nylon bag give only the apparent and not true degradability of the feed. Van Soest (1994) suggests that a subsequent treatment of the residues with neutral detergent should provide an estimate of true digestibility.

Fishmeal/wastes are relatively undegradable. The degradability of fishmeal/wastes depends on processing conditions and on whether the soluble stick water factor is included in the fishmeal for ruminants (Ørskov and Miller 1988). Considering rumen out flow rate of 0.08 which is used for high growth rate and high producing lactating cows, degradability of protein at 48h from different sources was 41 % for meat and

bone meal, 48 % for Fish meal/wastes and 63 % for cottonseed meal. From the above observations fishmeal/wastes has high by-pass protein than vegetable proteins. Khan *et al.*, (1998) conducted degradability trials and revealed that at 48h soya bean (plant protein) was highly degraded in rumen (99.1%) while Fishmeal (animal protein) was less degraded (76.8 %). In another study Pham Kim Cuong *et al.* (2001) used untreated rice straw as the basal diet and reported 48h crude protein degradability of 85.9 % and 65.6 % when cottonseed meal and fishmeal were respectively used. The latter authors concluded that generally animal proteins were lowly degraded in the rumen than vegetable proteins.

It is often assumed that all starch is readily available and soluble in the rumen. This is not true, as best demonstrated by an uncooked potato or stale bread, both forms of starches (Ørskov, 1986). The latter author reported that although at least 90 % of starch in small grains is fermentable in the rumen, up to 40 % of cornstarch could escape rumen fermentation. Therdchai (1987) reported escape that exceeds 40 %. Starch can be broken down and absorbed in the small intestine via pancreatic amylase, but this capacity is limited in ruminants. Large quantities of starch in the small intestine will overwhelm this process, resulting in starch passing through the animal undigested. A complex matrix in the seed coat of cereal grains contributes to rumen by pass. Processing methods such as steam flaking and grinding and high moisture fermentation ruptures the matrix, releasing starch and enhancing rumen fermentation of the starch (Herrera-Saldana *et al.*, 1990).

Therdchai and Mikled, (2001) reported on the site and extent of cassava starch digestion in ruminants. Cassava starch was completely digested in the gastro-intestinal tract of ruminants of which 94 % was digested in the rumen, 5 % in the small intestine and only 1 % in the large intestine. Digestibility of cassava starch was relatively high compared with cereals. Kanjanapruthipong *et al.* (2001) also found that total non fibre carbohydrates in cassava to be easily degraded within the rumen of cattle two to three times and more degraded *in vitro* and *in sacco* than those of corn. In an earlier study Smith *et al.* (1991) reported 48h dry matter degradability of 81 % and 83 % for maize bran and cassava peels respectively while Ørskov *et al.* (1992) observed 48h degradability of cassava peels from Ghana to be 71.1 %.

2.6 Effect of protein and energy supplements on blood parameters

Blood analysis has become a major tool that reveal pathological and physionutritional state in animals. This is possible because the parameters are kept within relatively narrow limits in plasma or serum. In addition to this, blood samples are easily obtained and analysed. This is advantageous and time saving in relation to analytical studies of feeds (Kasongo *et al.*, 1995; McDowell, 1996).

2.6.1 Plasma Glucose

Glucose concentrations in whole blood from dairy cattle have been used extensively as an indicator of energy status. Normal plasma glucose concentration range between 2.5 and 4.16 mmol/l as per (Table 2.7).

Table 2.6: - Blood glucose levels in ruminant animals

Species of animal	Glucose level mg/dl	Glucose level mmol/l
Sheep	50-80	2.8-4.4
Goat	50-75	2.8- 4.2
Cattle	45-75	2.5-4.2

Source Kaneko, (1989)

Most animal feeds contain 18.5MJ/kg DM (McDonald *et al.*, 1998). This energy from the feed is obtained by digestion and glycolysis to glucose in the body and utilized for productive and reproductive purposes by the animals (Lehninger, 1982). The latter reported that in ruminants, lactic acid provides another source of energy via lactic acid cycle. Part of the glucose requirements in ruminants can therefore be met from this source, but it is probably minimal since excess of lactic acid in the rumen is toxic (Mgasa and Mbasa, 1988).

McDonald *et al.* (1998), observed that the amount of glucose absorbed from the digestive tract of ruminants is relatively small and that a blood glucose levels show little relation to feeding behaviour. It would therefore seem unlikely that a glucostatic mechanism of intake control could apply to ruminants. Various factors determine the concentration of blood glucose. The net balance of equilibrium between the rates of entry and of removal of glucose in the circulation gives the glucose concentration in blood at any particular time. The supply of blood glucose can be by intestinal absorption and other dietary glucose, hepatic production from glycogen and other carbohydrates such as galactose and fructose or amino acids (Kaneko, 1989).

Aregheore (1992) using dairy calves aged between 12 and 16 months and fed on cassava flour or maize concentrates and forage, reported high daily live weight gain and blood glucose levels in calves fed on cassava showing cassava to be a good source of energy and carbohydrate in calf nutrition compared with maize.

2.6.2 Plasma proteins

Serum or plasma proteins constitute a portion of the amino acid pool of the body and the concentration of protein in the plasma at any given time is a function of the hormonal balance, nutritional status, water balance and other factors affecting the state of health of the animal (Doornenbal *et al.*, 1988). There is no storage of protein in times of dietary excess. Any excess of amino acids over that necessary to maintain the circulating pool is quickly converted to carbohydrates or fats and utilized for energy (Kaur and Arora, 1995). Normal plasma protein concentration in cattle is between 68-85 g/l (Schalm *et al.*, 1975). Kaneko (1989) reported plasma concentration to be 5-7 % (50-70 g/l) or 5-7 g/dl; if hemoglobin is included. Whole blood is composed of about 20 % or more protein.

The potentially fermentable pool of protein includes feed proteins plus the endogenous parts of saliva, sloughed epithelial cells, and the remains of lysed ruminal microorganisms (Ørskov and Miller, 1988; Sampth, 1990). Some of the peptides and amino acids not incorporated into microbial protein may escape ruminal degradation and converted to ammonia and become sources of absorbed amino acids to the host animal (NRC, 2001). Veira *et al.* (1994) reported increased plasma

albumin concentration without effect on plasma glucose when they fed steer calves with fishmeal in increasing levels.

2.6.3 Mineral requirement of weaned calves

Animals can obtain their mineral requirements from their food under natural conditions but the mineral contents of tropical pastures are very low. Under these conditions mineral deficiency symptoms occur and these retard growth and cause skeletal abnormalities and other pathological conditions that may be fatal. Supplementation is inevitable in case of deficiency in feed ingredients (McDowell, 1996). Mineral elements provide structural support to the body in the form of the skeleton, catalyses numerous enzymatic reactions essential for metabolism and cell division. Calcium (Ca) and Phosphorus (P) are the major constituents of bones in a complex salt protein matrix. Magnesium (Mg) and Sodium (Na) Potassium (K) together with some trace elements such as Cobalt (Co), Zinc (Zn), Molybdenum (Mo), Manganese (Mn) and Iron (Fe) are present as structural components (McDowell, 1996). Lehninger (1982), McDonald *et al.* (1998) and Payne (1990) reported that Ca, Mg, Fe, Co, Mn, Mo, and Zn are involved in complex biochemical reactions such as enzyme activity. Fe is essential constituent of haemoglobin in the blood and myoglobin muscle tissue. Co is a constituent of a vitamin B_{12}. Iodine is a component of thyroid hormone. Ca, K, Mg, and Na are involved in maintenance of normal physiological states in cells, nervous system and conduction of nerve impulses at neuromuscular junction. Na, K and Cl are necessary for the regulation of intracellular intravascular and extravascular pressure, pH of blood, lymph and gastrointestinal fluids.

2.6.3.1 Major mineral elements in the body of growing heifers

Calcium and Phosphorus serve as constituents of bones, teeth and give strength and rigidity to the skeletal structures. The amount of Ca and P deposited in each kg of live weight gained during growth depend on the age and previous nutrition of the animal. For maximum utilization of Ca and P the ratio of Calcium to Phosphorus must be similar to that of bone and it has been shown that a ration of 2:1 to 7:1, Ca: P is satisfactory (McDowell, 1992; McDowell 1996; NRC 2001). When there is a plenty of vitamin D in the ration the ratio becomes of importance and more efficient utilization in made of the amounts of element present (McDowell 1996).

2.6.3.2 Calcium (Ca)

Ca is the most abundant mineral element in the animal's body, comprising 1-2 % of total body composition (Johnson 1999). About 99 % of the animal body Ca is stored in bones and teeth (McDonald *et al.*, 1998). The remaining 1 % is distributed in soft tissues and body fluids (Ballantine and Herbein 1991). Ca is important in reproduction. Hypocalcaemia has been associated with poor reproductive performance (McDowell, 1992). Studies have shown that cows requiring only one service per pregnant had an average serum Ca concentration of 2.27 mmol/l, compared with 2.17 mmol/l in cows requiring more services (Schrap, 1980). Ca is essential nutrient that influences resistance to diseases (McDowell, 1992) and Ca is involved in antioxidant systems that maintain the integrity of phagocytic cells and lymphoid tissues (Hogan *et al.*, 1996). Ca is also important in energy metabolism-hypocalcaemia (negative energy balance) (Daniel, 1983).

Plasma or serum Ca concentration may give an overall indication of Ca status, but ionized Ca concentration gives a better estimate of the amount available for uptake and utilization by tissues (Ballantine and Herbein 1991). Ca is precisely regulated in blood plasma. In cattle the normal total range is 2.43-3.1 mmol/l (Kaneko 1989). Ca needed for maintenance, growth, pregnancy and lactation in dairy cattle is 0.43-.77 %/kg DM (McDowell, 1992).

Ca in pastures, seeds and other sources has variation in concentrations. The average Ca contents in pasture grasses examined in Tanzania range from 0.26-0.78 % (Mwakatundu, 1977; Mtengeti, 1984; Sendalo, 1986 and Muhikambele, 1990). Ca in grains range from 0.05-0.2 % (Phiri 1995), oil seeds Ca averaged 0.3 % (Thomke and Macha, 1986). In fish wastes it ranges from 9.6-13.04 % (Ngate, 1997; Mbamba, 2000) and in cassava root meal it ranges from 0.04 to 0.12 % (Lekule, 1990).

Calcium form inorganic sources appear to be utilized more efficiently than that from plant origin (Bondi, 1987). Availability of Ca from different sources for cattle can be classified in two groups i.e. Ca from bone meal mono or dicalcium phosphate and fish meal/wastes being highly available and that from hay and forages being of lowest availability (Under Wood and Suttle, 1999).

McDonald *et al.* (1998) and Kjos, (2001) reported that fish products are good source of calcium, phosphorus and some of the trace minerals. Both in practice and in experiments, a feed made from fish meal has shown good results in rations for

poultry, pigs and ruminants. Cassava has low mineral contents and supplementation from other sources for animal feeds is very important.

2.6.3.3 Assessment of Ca balance in animals

A number of response criteria have been used to evaluate Ca status in livestock and human beings. These responses include growth rate, feed intake and feed efficiency, serum/plasma Ca concentrations bone alkaline Phosphate levels as well as dimensional, compositional and mechanical criteria for bones (Ballantine and Herbein 1991). Many factors have been identified that might reduce Ca absorption. An excess of P or Mg interference reduces Ca absorption by binding themselves on the protein responsible for binding Ca (Horst, 1986).

2.6.3.4 Ca toxicities and interaction with other minerals

Under normal conditions dietary Ca is considered to be non-toxic when animals consume single large doses because it is under homeostatic regulation, i.e. the element is absorbed according to need and the excess is excreted (NRC 2001). Excess of Ca may cause bone disorders and reduce feed consumption (McDowell, 1992). Feed intake was reduced by 3.2 % weight gain by 1.8 % and feed efficiency by 1.59 % when feedlot cattle received rations containing more than 1 % Ca (Bondi, 1987). Maximum tolerance levels of Ca for cattle are 2 % when adequate dietary P is provided (McDowell, 1992). Dietary calcium at levels of 4.4 % may cause significant depression in protein and energy digestion, whereas high incidences of bone and joint abnormalities has been reported in bulls fed three to five times the recommended Ca levels (McDowell, 1992). Grazing animals in several parts of the

world develop calcinosis, a disease characterized by deposition of Ca salts in soft tissues (McDowell, 1992). The addition of excess Ca to other wise adequate diet may result in a deficiency of other essential elements such as Mg, Fe I, Cu, Zn, Mn and reduces energy or protein the animal might better utilize for increased production (NRC 2001). In every case it appears that injurious effect of Ca is attributed to an interaction with these elements rather than to a harmful effect of Ca itself (McDowell, 1992).

2.6.3.5 Phosphorus (P)

Phosphorus is the second most abundant mineral element found in the body of cattle (Ternouth, 1990). Approximately 80 % of body P is present in bones and teeth. The remainder is distributed in tissue of body fluids. Phosphorus is involved in a great variety of vital functions probably more than any other mineral (Corbridge, 1985). P is involved in feed metabolism and utilization of fat, carbohydrates, proteins, and other nutrients in the body (Bondi, 1987). As a major constituent of cell walls, phospholipids are involved in maintaining the structure and integrity of all cells in the body. Phospholipids allow fatty acids to be transported through the body. It is part of DNA involved in the determination of the genetic characteristics of the animal and in the expression of those characteristics through P in RNA. P is involved in many enzyme reactions involving energy metabolism in cells (e.g. in ATP, ADP, cyclic AMP and creatine Phosphate). P is important in the formation of protein, nucleoprotein and phosphoproteins (Corbridge, 1985). P is essential for proper function of the rumen microorganisms especially those that digest plant cellulose. Microbial activities are reduced when inorganic P levels are less than 50-80 mg/l in

the rumen (McDowell, 1985). Feed intake and utilization is affected as P is involved in the control of appetite and in the efficiency of feed utilization (Under Wood, 1984). Low ruminal P results in reduction on fibre digestion by limiting microbial activity, reduces amino acid (AA), so the animal becomes AA deficient, and metabolically active tissues (muscle and liver) results in reduced RNA synthesis affecting the metabolic activities of cells (McDowell, 1992). P is involved in body weight gain. P supplementation experiment has shown benefits in live weight gain (McDowell, 1992). Heifers receiving higher dietary P of 0.2 % versus 0.12 % has higher gains (257 kg vs 205 kg) per year and produce calves with greater birth weight (26.9 kg vs 22.7 kg), respectively (McDowell, 1992).

Lameness and stiffness of gait, bending, deformation or fractures of the pelvis and long bones, arching of the back, facial enlargements, malformed teeth and jaws are characteristics of P deficiency (Underwood, 1981). The basic defect is a failure or reduction in the mineralization process so that the bones contain insufficient mineral to develop or maintain normal shape and strength and therefore to sustain mechanical functions. Stiffness in the joints and reluctance to stand exacerbate the P deficiency as they reduce the ability of the animal to look for food (Ternouth, 1990). Rickets as in case of Ca deficiency is a manifestation of long-standing dietary deficiency in young animals (Jones and Hunt, 1983).

Poor reproduction has been a regular feature of herds confined to P deficient grazing pastures (Underwood and Suttle, 1999). The subnormal fertility is associated with wide range of conditions including low ovarian activity low conception rate,

abortions, retained placenta and long calving interval (Underwood and Suttle, 1999). However there is no evidence to show whether these are primarily effects of the P deficiency *per se* or secondary effects of a reduction in feed intake (Ternouth, 1990).

Phosphorus requirements are highly dependent on the level of productivity and the physiological status of the animal (NRC, 2001). Young, pregnant animals that are lactating and still growing have high P needs (McDowell, 1992). The amount of P absorbed by the body of animal depends on the source of the P, the amount of intake, the Ca to P ratio, intestinal pH, the age of the animal and dietary levels of Fe, Al, Mn, K, and fat (McDowell, 1992). The normal range of P recommended on dairy cattle is 0.28-0.48 %/kg DM (McDowell, 1992).

A number of factors can affect the absorption of P. It is known that high levels of Ca in the diet may reduce the absorption of P when P levels are low (Tenuoth 1990). This reduction is due to either precipitation of P in non –absorbable forms within the intestine as pH rises or to the homeostatic mechanism concentrating or regulating plasma Ca (Schneider *et al.*, 1985). Large intakes of iron, aluminium and magnesium salts interfere with the absorption of P by forming an insoluble Phosphate (Bondi, 1987). Parasitism may also reduce absorption of P (Wilson and Field, 1983).

Plasma inorganic Phosphate (Pi) levels of 1.8-2.9 mmol/l are considered normal in cattle while levels of 1.25-1.75 mmol/l Pi are considered marginal and below 1.25 mmol/l are considered low (Ternouth, 1990; Underwood and Suttle, 1999). McDowell (1992) suggested a higher level of over 1.45 mmol/l.P in pastures, seeds

and other sources as in case of Calcium has also a certain range. The average P contents in pasture grasses examined in Tanzania range from 0.06-0.67 % (Mwakatundu, 1977; Mtengeti, 1984; Sendalo, 1986 and Muhikambele, 1990). Ca in grains range from 0.14-0.4 % (Phiri 1995), whereas oil seeds P averaged 0.2-1.5 % (Thomke and Macha 1986), cassava root meal, 0.04-0.12 % (Lekule, 1990; Israel, 1992) and fish wastes 2.1-2.8 % (Ngate, 1997; Mbamba, 2000).

2.6.3.6 Assessment of P balance in animals

Strong positive relationship has been found between plasma inorganic phosphate (Pi) and dietary P intake levels in both cattle and sheep (Tenouth, 1980). Serum Pi is a good indicator of P status of ruminants only if stress factors, time of sampling and blood preparation are handled in good order (McDowell, 1992). Protein and P deficiencies commonly occur concurrently in the dry season under tropical conditions. Under these conditions food intake is reduced, cattle loose weight and bones resorption results in elevation of plasma Pi (Ternouth, 1990). As in calcium status evaluation, Williams *et al.*, (1991) analysed P concentration in blood, milk, faeces, bones, saliva, rumen liquor various tissues and hair of growing cattle fed adequate (0.2 %) or deficient (0.12 %) of dietary P. Of the parameters studied, rib bones P concentration best reflect the dietary P intake.

2.6.3.7 P toxicity

P is not considered to be toxic when single larger doses are administered or consumed by animals, however mild diarrhoea may occur. Prolonged consumption of high P rations may cause severe hypocalcaemia because of disorders associate

with Ca absorprion and metabolism. High P intake predisposes animals to urinary calculus (McDowell, 1992; NRC 2001).

2.6.3.8 Summary of the review

The use of fish wastes and cassava root meal in Tanzania has been mainly limited to monogastrics. Performance respective to both fish waste and cassava root meal have been inconsistent, varying widely depending on type of stock, form of waste and levels of inclusion. The few existing reports on use of fish wastes were centred on laboratory evaluation (without feeding trials) and on exclusive use of marine fish. In all these studies fish waste meals were compounded based largely on whole fish deemed unfit for human consumption. In Asia, North Africa and Latin America fish waste and cassava root meal have been extensively used in lactating ruminants diets. The responses are varied but there is a general consensus that the two components are valuable low cost supplements. Variation responses are mainly due to variability in chemical composition and un-standardized properties because of different processing procedures, type of fish and by-product components of fish waste and cassava root used in processing. Other factors included concentrate level, grain and forage sources used together with fish wastes and cassava root. Apart from the study by Mohamed (1998), there are no repots on the use of fish waste in and cassava root meal for post waning heifers. However, the positive growth performance reported by Mohamed (1998) was indicative of the potential of fish waste on pre-weaning ruminants. The present study aims at development of a mixed compound that would utilize an energy supplement to enhance a protein supplement (based fish waste) in promoting growth performance of dairy heifers.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experiment I: The effect of treatments rations on live weight changes, average daily gain and blood parameters of weaner heifers under study

3.1.1 Study location and duration

All experiments were carried out at Magadu dairy farm, Sokoine university of Agriculture (SUA) in Morogoro region (Tanzania) between January and May 2001. Morogoro lies about 550m above sea level and experiences a hot climate throughout most of the year. The average humidity is about 78 % and the temperature range between 20 ^{0}C and 35 ^{0}C. The duration of experiment was preceded by a 21-day preliminary period to acclimatize the animals to the treatment rations. This was then followed by data collection period of 60 days Data collection was supposed to be done for 90 days but due to the amount of funds allocated collection was done for 60 days and still positive responses were observed for that period.

3.1.2 Experimental animals and their management

A total of 20 weaned Ayrshire heifers from Magadu dairy farm were used in this study. The heifers weighed between 88 to 194 kg with an average weight of 144.55 kg. Heifers were dewormed monthly using Levamisole (Hoonspraten Ltd Belgium) injectable solutions (1ml/10 kg live weight). External parasites mainly ticks were controlled by pour on acaricide (pyrethrins) (Coopers Ltd Nairobi Kenya) (1ml/20 kg live weight) at the interval of 3 weeks and were given multivitamins (Hoonspraten Ltd Belgium) (1ml/10 kg live weight). The animals were kept and fed in individual pens and had free access to water.

3.1.3 Feeds and feeding

Ration formulation was based on the literature sited in Table 3.1. Feed ingredients used were; Cottonseed cake (CSC), Fish waste (FW), hominy meal (HM) and cassava root meal (CRM). Ingredients were milled and then used to compound the treatment rations.

Table 3.1: Chemical composition of feed ingredients (DM%)

Feed	DM	CP	EE	CF	ASH	ME (MJ/kg)	Starch sugar (g)
Hominy meal	87.9	13.3	14.1	6.3	4.2	12.7	15.8
Cassava root meal	90.0	3.5	9.0	4.3	3.0	12.8	69.2
Fish wastes	92.2	39.1	9.0	1.0	45.2	12.6	-
Cotton seed cake	90.0	38.1	9.4	15.7	7.0	12.3	-
Hay	80.0	5.5	1.6	38.0	7.0	7.0	-

Sources: Thomke and Macha, (1986); Lekule *et al*; (1988).

3.1.3.1 Fish wastes (FW)

Fresh FW were obtained from Nile perch processing factories around Mwanza city and fish originated from lake Victoria. The factories included; Vick Fish, Tanzania Fish production (TFP), TAN Perch, Mwanza Fishing Industries, Omega, and Nile perch fisheries. Type of fish that is allowed by the Tanzanian government to be processed by fish factories into fish fillets and fish maw is Nile perch (*Lates niloticus).* The FW obtained included factory by products (pp 64-69) comprising of heads, tails, skins, backbones and intestines (Plate 1). Fish fillet (Plate 2) and fish maws (air bladder) (Plate 3) retained by factories for export and local human consumption.

Collected FW were sorted by small traders (especially women) (Plate 4) at Mkolani village in Mkuyuni division into edible portions (heads) (Plate 5) and intestines were sold to pig farmers (Plate 6). The skins (Plate 7) were sold to leather processing industries. The rest of FW were sun dried on wooden rakes (Plate 8). Drying time depends on the seasons of the year. During the rainy season drying time was 7-10 days while during the dry season it ranges from 3-5 days. Dried FW was then collected, stored (Plate 9) and sold to traders (Plate 10) who milled and packed them (Plate 11) ready for sale distribution to the wider local and the export market.

3.1.3.2 Cassava root meal

Cassava roots (CR) (Plate 12) (pp 69-71) were collected from Mikese village in Morogoro rural district (40 km from SUA) and processed at Sokoine University of Agriculture (SUA). Before processing CRM were washed to remove soil. After washing unpeeled CR were chopped into small slices (Plate 13) and sun dried. The drying process (Plate 14) was facilitated by turning the slices on a concrete floor upside down three to four times a day for a period of 3-5 days. The dry root meal was then milled and packed using normal hammer mills (Plate 15).

Plate 1: Fresh fish wastes

Plate 2: Fish fillets

Plate 3: Fish maw (air bladder)

Plate 4: Sorting of fish wastes

Plate 5: Fish heads for human consumption

Plate 6: Fish intestines for feeding pigs

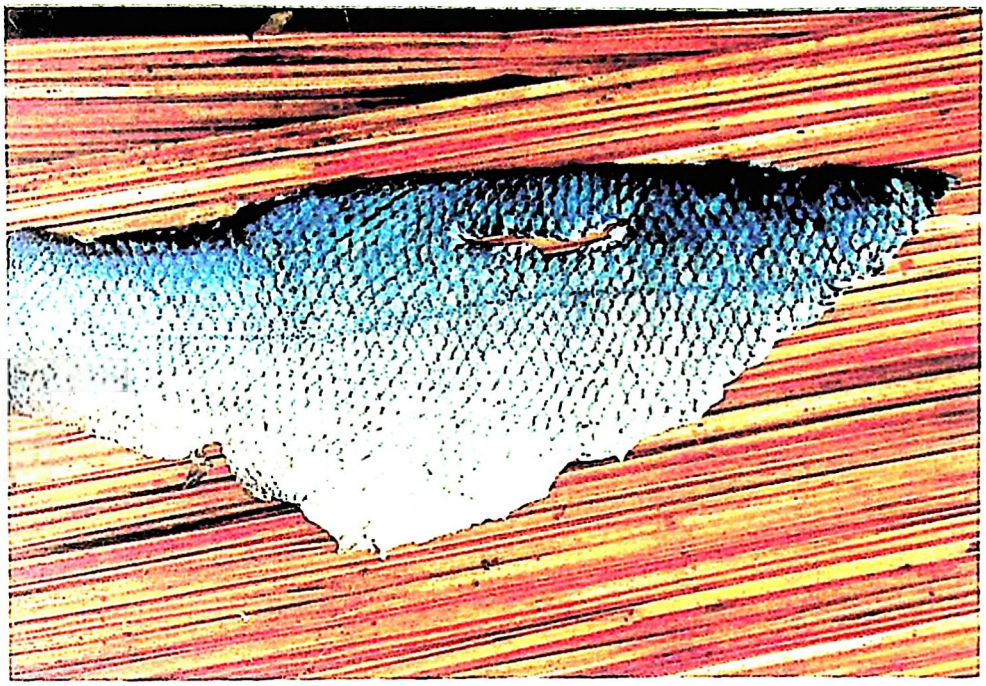

Plate 7: Fish skin for leather making

Plate 8: Sun drying of fish wastes

Plate 9: Dried fish wastes put in store

Plate 10: Transportation of fish wastes

Plate 11: Milling and parking of fish wastes

Plate 12: Uprooted cassava roots

Plate 13: Chopping of cassava roots

Plate 14: Drying of cassava chips

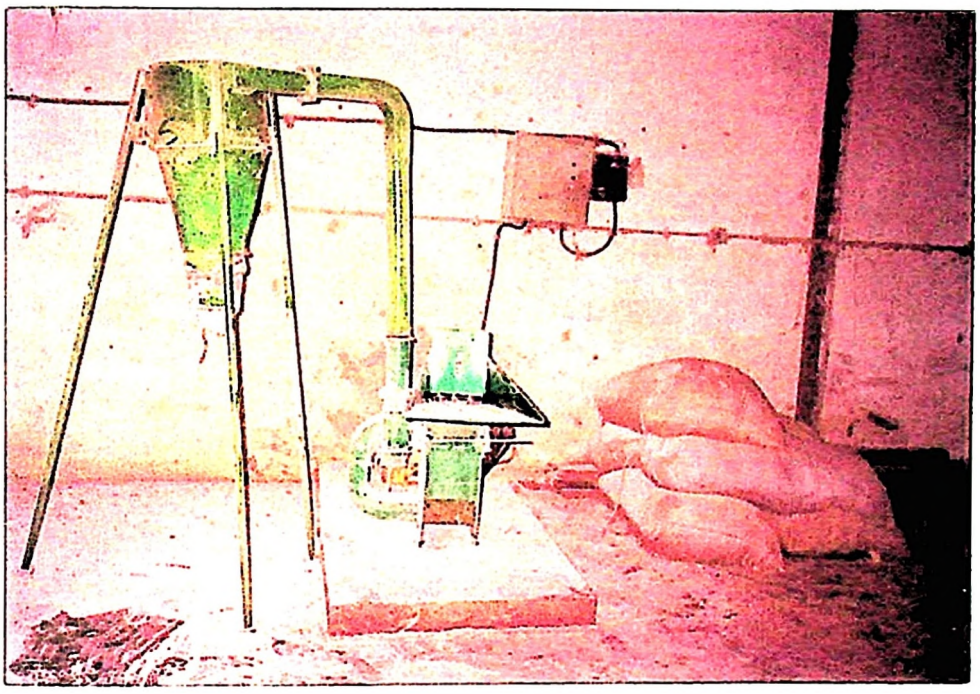

Plate 15: Milling and parking of cassava roots

Plate 16: Weaner heifers feeding on TR_4 composed of cassava root meal and fish wastes

3.1.3.3 Cotton Seed Cake (CSC), Hominy Meal (HM) and Minerals

Cotton seed cake originally from Shinyanga region was purchased from Dar es Salaam and milled using a normal hammer mill before mixing it with other feed ingredients. Hominy meal was purchased from local maize milling machines in Morogoro and hay was purchased from Morogoro in Mazimbu campus (SUA).

3.1.3.4 Basal diet

Standing hay dominated by *Brachiaria brizatha* from Mazimbu campus (SUA) was cut during dry season baled and transported to Magadu dairy farm.

3.1.3.5 Feeding of experimental animals

The basal diet (hay) was offered *ad libitum* while supplementary rations were offered twice a day (one half at 0800 and the other one at 1500 h) at the rate of 11.6 g/kg body weight to meet protein and energy requirement of heifers. The daily amount consumed per heifer (basal and supplements) was recorded as the difference between amount offered and that refused. Feeds offered were adjusted for weight after every two weeks to accommodate for changes in weight.

3.1.4 Treatment rations and experimental design

The treatments rations were formulated in such that FW replaced CSC and CRM replaced HM as protein and energy sources respectively (Table 3.2). Treatment 1 ($\mathbf{TR_1}$) was composed of hay, cotton seed cake and hominy meal. Treatment 2 ($\mathbf{TR_2}$) contained hay, cotton seed cake and cassava root meal; treatment 3 ($\mathbf{TR_3}$) contained hay, fish wastes and hominy meal and treatment 4 ($\mathbf{TR_4}$) containing hay, fish wastes

and cassava root meal. All treatment rations were balanced to meet the nutrient requirements of the experimental animals basing on the estimated chemical composition in feed ingredients (Table 3.1).

Table 3.2: Ingredient composition of treatment rations (kg DM)

Ingredients	Treatments			
	TR_1	TR_2	TR_3	TR_4
Cotton seed cake (CSC)	315	480	-	-
Fish wastes (FW)	-	-	305	465
Hominy meal (HM)	665	-	675	-
Cassava root meal (CRM)	-	500	-	515
Minerals	20	20	20	20
Total	1000	1000	1000	1000

Minerals (Super lick) (Abcon Chemicals Ltd Dar-Es-Salaam Tanzania) were purchased from K.V animal health center in Morogoro town and inclusion level was 2 %. The composition was as per guaranteed minimum stated by the manufacture shown in Table 3.3 below.

Table 3.3: Mineral composition (%) of cattle mix (Super lick) used in formulation of treatment rations

Type of minerals	Composition (%)
Calcium	17.50
Phosphorus	12.00
Sodium chloride	25.00
Magnesium	0.30
Iron	0.19
Zinc	0.25
Copper	0.05
Manganese	0.30
Selenium	0.02
Potassium	0.13
Iodine	0.04

Source: Abcon Chemicals Ltd Dar-Es-Salaam Tanzania

Treatment rations were formulated by the trial and error method and Feed metabolizable (ME) was determined using formula developed by MAFF, (1975) as cited by Shem *et al* (1995) (3.2.5.3)

The heifers were randomly allocated to four treatments. The design used was complete randomised design (CRD) and each treatment ration was allocated to five heifers.

3.1.5 Data collection

The data collection depended on the particular parameter, as there was daily weekly and 14 days interval collection.

3.1.5.1 Dry matter intake (DMI) and growth performance study

Daily DMI per heifer (basal and supplements) was recorded as the difference between amount offered and that refused (on DM bases). Refusal were collected and weighed before next feeding. The average DMI per treatment ration was computed at the end of the study

Before commencement of the experiment all heifers were weighed for three consecutive days to establish initial weight using a weighbridge, and thereafter at an interval of 14 days. Weighing was carried out between 0600h and 0700h before morning feeding. The weight recorded at every end of 14 days was taken, as the initial weight for next 14 days.

3.1.5.2 Blood plasma parameters

Blood samples were collected from all the experimental animals weekly and analysed for plasma Ca, P, Glucose and proteins. Blood samples for glucose analysis were collected in sodium fluoride containing vacutainer tubes. Sodium fluoride acted both as an anticoagulant and as glucose preservative. In the laboratory samples were centrifuged at 2000 rpm for 10 minutes and the clear plasma siphoned into other labelled tubes. In order to avoid glycolysis, plasma was frozen at (-15 ^{0}C-20 ^{0}C) until analysis for glucose (Kaneko, 1989).

Blood samples for total protein, phosphorus and calcium, determinations were collected in heparin containing vacutainer tubes. The samples were then centrifuged at 2000 rpm for 10 minutes to obtain plasma. The clear plasma was then siphoned and collected into other labelled tubes and frozen at (-15 ^{0}C-20 ^{0}C) until analysis (Kaneko, 1989).

Blood plasma analysis was carried in the department of Veterinary physiology and Toxicology at SUA. For Ca and P the spectrophotometer model CECIL C 2041 2000 from Cecil instruments limited was used. Plasma total protein was determined using RANDOX reagent kit from Randox laboratories from United Kingdom (Henry *et al.*, 1974) as described by RANDOX Laboratories (1995). Plasma glucose was determined using RANDOX reagent kit from Randox laboratories from United Kingdom (Teuscher *et al.*, 1971) as described by RANDOX Laboratories (1991). The wavelengths used were 574 nm for Ca, 420 nm for P, 540 nm for proteins and 540 nm for glucose.

3.1.6 Chemical composition analysis

Chemical compositions of the feed ingredients, treatment rations and hay were determined according to A.O.A.C, (1990). Proximate analysis process was done on feed ingredients, treatment rations and hay. Samples were fractionated into dry matter (DM) Ash, and crude fibre (CF). Crude protein (CP) was determined using a semi automatic Kjeldatech method (NX6.25) and ether extract (EE) was determined by using soxhlet extraction technique. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents were also analysed according to the method of Van Soest (1994). Minerals were analysed by atomic absorption spectroscopy (AAS) using AAS UNICUM model 919.Wave lengths were 422.5 for Ca, 884 for P, 285 for Mg while Na and K flame photometer technique was used.

3.1.7 Cost /benefit analysis of experimental rations

All the current costs for the feed ingredients were recorded. Total costs for each treatment rations and the respective live weight gained for entire period of the study were also recorded. The cost of the feed per kg gained was calculated by dividing total feed cost for each treatment ration by respective live weight gained. The ratio obtained was a base for comparing the costs of treatment rations; since the animals were not slaughtered at the end of the study.

3.1.8 Statistical analysis

3.1.8.1 Dry matter intake and growth performances

Data collected for the total dry matter intake live weight gain average daily gain and feed efficiency were analysed using the GLM Procedures of the SAS statistical

package (SAS, 1990). Covariance analyses to remove the effect of initial body weights were used as described by Snedecor and Cochran (1989). The model was as following: -

$$Y_{ij} = \mu + T_i + b\ (X_{ij} - X) + e_{ij}$$

Where by:

Y_{ij} = General response in terms of live weight change (kg/day) of the j^{th} animal in i^{th} dietary treatment.

μ = Overall mean

T_i = Effect of i^{th} dietary treatment

Xij = Initial body weight of an individual heifer

X = Overall mean of initial body weights

b = Regression of live weight change on initial body weight

b $(X_{ij}-X)$ = Covariate factor for adjustments of live weight change from initial body weight of animal

e_{ij} = Error term peculiar to an individual animal.

3.1.8.2 Blood plasma parameters

Blood plasma parameter data were analysed using the GLM procedures of the SAS statistical package (SAS, 1990) according to the following model

$$Y_{ij} = \mu + A_i + e_{ij}$$

Where by: -

Y_{ij} = General response of the j^{th} animal to i^{th} dietary treatment,

μ = Overall mean

A_i = Effect of i^{th} dietary treatment on the observed changes

e_{ij} = An error term.

3.2 Experiment II: - Effect of cassava root meal and fish wastes on ruminal pH, NH_3-N, DM and CP degradability

3.2.1 Study location duration

All experiments were carried out at Magadu dairy farm, Sokoine university of Agriculture (SUA) in Morogoro region (Tanzania) between January and May 2001. The duration of experiment was 14 days for DM and CP degradability. Seven days were used for acclimatization to the diets and another seven days were used for data collection, after which pH and NH_3-N were determined for 44 days (11 days per treatment ration).

3.2.2 Management of the fistulated animals

Four fistulated Friesian–Zebu crossbreed cows with a mean weight of 309.22 kg were used in rumen pH, NH_3-N and degradability of both feed ingredients and treatment diets. Prior to commencement of the experiment the animals were dewormed using Levamisole injectable solution (1ml/10kg live weight) (Hoonspraten Ltd Belgium) and given multivitamins at the rate of (1ml/10kg live weight) (Hoonspraten Ltd Belgium). To control ectoparasites pour on acaricide (pyrethrins) (Coopers Ltd, Nairobi Kenya) at the rate of (1ml/20kg live weight) was used.

3.2.3 Feeds and feeding

The cows were put in individual pens and were fed on hay *ad libitum* used in experiment one and had free excess to water. Before starting data collection on DM and CP degradability, the rumen environment was stabilized by feeding the animals 3 kg daily of a concentrate mixture composed of 0.3, 0.3, 0.2 and 0.2 parts CSC, FW, CRM and HM respectively. Minerals were supplied at the rate of 2% of total ration. For the rumen pH, NH_3-N cows were fed rations used in experiment one at the same rate of 11.6g/kg body weight once every morning.

3.2.4 Feed ingredients, treatment rations and experimental design

Feed ingredients tested for DM and CP degradability were CSC, FW, HM, CRM and Hay while treatment rations included TR_1-TR_4 (3.1.4). Ruminal pH and NH_3-N parameters were determined for the treatment rations only in a Latin square design.

3.2.5 Data collection

The data for rumen pH and NH_3-N were collected before feeding the cows and thereafter at interval of 2 hours for a period of 24 hours. Collection was done every 11^{th} day for each treatment ration after a period of 10 days used for acclimatization.

3.2.5.1 Rumen pH

Rumen liquor was obtained by squeezing ruminal contents collected 15 cm beneath the fistula opening. The fluid was then strained using surgical gauze into four 100 ml plastic jars, one for each cow. The pH was recorded immediately using a portable electronic pH meter.

3.2.5.2 Rumen NH_3-N concentration

After the pH readings were done two to three drops of concentrated sulphuric acid were added to the rumen liquor samples to avoid N losses and were ice parked in a cool box immediately transported to the laboratory and stored into a deep freezer at temperature between –15 ^{0}C and –20 ^{0}C before being analysed for NH_3-N. Before freezing the samples were centrifuged at 3000 rpm for 15 minutes. NH_3-N content was analysed using the Kjeltec distillation unit. A strong alkali (NaOH) was used during distillation instead of a weaker Magnesium oxide (MgO). NH_3-N was estimated using the general formula as described by Kimambo *et al.*, (1999).

[N x (V - Blank) x Molecular weight of NH_3 X 1000 mg/l

Where N= Normality of hydrochloric acid (HCL) used during titration

V= Volume of HCl acid used for titration of sample (ml).

Blank = Volume of HCl acid used for titration of blank (ml).

3.2.5.3 Rumen degradability study

Rumen studies was carried to evaluate the degradability of the individual feed ingredients composed of cotton seed cake (CSC), fish wastes (FW), cassava root meal (CRM), hominy meal (HM) and hay and formulated treatment diets (TR_1-TR_4).

Experimental procedure used was the nylon bag. (*in sacco*) technique (Ørskov *et al.* 1980) to determine degradability characteristics of feed ingredients and feed rations. Nylon bags of size 40 to 50 µm were labelled to identify different samples and different incubation times. Two bags containing 2 g of each sample were used per

animal per incubation time. Each feed sample was incubated in four animals. The samples were incubated at different time interval of 6, 12, 24, 48, 72 and 96 h for feed ingredients and up to 72 h for treatment rations. For each incubation period the bags were removed from the rumen and washed in running tap water until the water was clear. The samples were then run through a stomacher (Model 400 Lab Blender) to minimize microbial contamination. The samples were stored in a deep freezer at a temperature of between –15 ^{0}C and –20 ^{0}C to stop further microbial activity. The samples were filtered on labelled N-free filter papers. The filter paper were folded over the sample and dried at 100 ^{0}C for 24 hours then weighed to determine residual weights. Samples were finally digested and distilled using the Kjeltec system unit to determine nitrogen.

The percentage of DM and CP degraded (**p**) after time, **t**, was determined according to the mathematical model $\mathbf{P= a + b\ (1-e^{-ct})}$ (McDonald, 1981). Where **P** is percentage degradation at time **t, a** is the zero time intercept (of degradation curve at time zero), **b** is potentially rumen degradable portion of DM, **c** is the rate constant at which b is degraded, **a + b** is the potential rumen degradability (asymptote).

Effective rumen degradability (ERD) was calculated according to the equation **P=a+bc/(c+k)** (Ørskov and McDonald, 1979), where **P** = effective rumen degradability and **k** is passage rate constant.

Degradability characteristics **a, b,** potential degradability **(a+b),** DM and CP degradability at 48-hours and degradation rate **c** (h^{-1}) were calculated from raw data

using NAWAY computer programme developed by the Rowett Research Institute, Aberdeen, U.K, (Shem, 1993).

Dry matter degradability (DMD) (g/kg) DM and crude protein degradability (CPD) (g/kg) DM were calculated from the DM and CP disappearance from the bags using the following formulas:

$$\text{DMD (g/kg DM)}: -\frac{\text{Wt DM incubated (g)} - \text{Wt of residue (g) (after incubation)}}{\text{Wt DM incubated (g)}} \times 100$$

$$\text{CPD (g/kg DM)}: -\frac{\text{CP incubated (g)} - \text{CP in residue (after incubation)}}{\text{CP incubated (g)}} \times 100$$

Feed metabolizable energy (ME) was calculated according to the following formulae:

ME (MJ/kg DM) = 0.15 or 0.16 DOMD % (MAFF, 1975 cited by Shem *et al.* (1995).

DOMD = 0.98 DMD %-4.8

Where DOMD %= Dry organic matter digestible and DMD % (g/kg DM) = in this case was the 48h degradability.

The coefficient was varied according to the class of feed; 0.15 was used for hay and 0.16 for supplementary rations according to MAFF, (1975) cited by Shem *et al.* (1995).

3.2.6 Statistical analysis

The data collected from, DM and CP degradability, ruminal pH and NH_3-N parameters were analysed using the General Linear Model Procedure (GLMP) of SAS statistical package (SAS, 1990). The following model was used.

$$Y_{ij} = \mu + A_i + e_{ij}$$

Where by: -

Y_{ij} = General response of the j^{th} animal to i^{th} treatment ration/feed ingredient.

μ = Overall mean.

A_i = Effect of i^{th} treatment ration/feed ingredient on the observed changes.

e_{ij} = Error term.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment I

4.1.1 Chemical composition of experimental feeds

The chemical composition of the experimental feeds; cotton seed cake (CSC), fish wastes (FW) cassava root meal (CRM), hominy meal (HM) and hay used in the experimental rations are presented in Tables 4.1 and 4.2.

Table 4.1: Chemical composition of experimental feeds (g/kg DM)

Feed type	DM	CP	EE	ASH	NDF	ADF
Fish wastes						
Rainy season FW (SD) *	961	396	151	347		
Dry seasons FW (SD)	985	397	218	344		
Freshly processed	939	503	91	358		
Skin (SD)	944	865	79	83		
Intestines (SD)	950	798	97	62		
Heads (SD)	927	428	213	260		
Tail and back bones (SD)	935	423	208	400		
Cassava root meal						
Whole CRM *	921	43	8	51		
Peeled	933	20	5	45		
Peels	950	93	7	82		
Other experimental feeds						
Cotton seed cake *	9575	373	75	63	51	347
Hominy meal *	964	139	85	46	630	80
Hay (Brachiaria brizantha)	967	42	5	89	794	554

DM = Dry matter, CP = Crude protein, EE = Ether extract, CF = crude fibre, SD=sun dried NDF = Neutral detergent fibre, ADF = Acid detergent fibre, ASH = Ash, * = Feed ingredients used to formulate treatment rations.

Table 4.2: Mineral composition of experimental feeds (g/kg DM)

Experimental feeds	Ca	P	K	Na	Mg
Fish wastes (rainy season)	98.1	39.8	4.8	5.4	2.
Fish wastes (dry season)	136	71.4	4.5	6.4	2.1
Hay (*Brachiaria brizantha*)	5.2	1.3	12.3	3.2	1.5
Cassava root meal	0.9	4.5	2.9	4.1	3.7

The crude protein (CP) of fish waste (Table 4.1) ranged from 396 g/kg DM for sun dried FW to 865 g/kg DM for FW skins. Ash ranged from 347 g/kg DM for mixed FW to 62 g/kg DM for FW intestines. Freshly processed FW had higher CP (503 g/kg DM) than sun dried FW (396 g/kg DM). Crude fat (EE) was lower in Freshly processed FW (91 g/kg DM) compared to that in sun dried FW (151 g/kg DM). The Ash component was higher in freshly processed FW than in sun dried FW. The sun dried FW processed during dry season had higher crude fat than that from the rainy season. In case of minerals Na, Ca and P were higher in FW processed during dry season compared to that in the wet season (Table 4.2). The CP, EE, and Ash of FW component were higher than that of CSC (Table 4.1).

Cassava peels had the higher CP content (93 g/kg DM) compared to cassava root meal (43 g/kg DM) and peeled cassava root meal (20 g/kg DM). Ash was highest for cassava peels (82 g/kg DM) and lowest for peeled cassava root meal (49 g/kg DM). The CF, EE CP contents of CRM were lower than that of hominy meal (HM) as another energy source Cotton seed cake had lower CP, ASH and EE than that of both sun dried and freshly processed FW. DM for CSC was higher than that of freshly processed FW. Hay had the lowest CP but highest NDF and ADF.

4.1.2 Chemical composition of the treatment rations

Chemical composition of the treatment rations are summarised in Table 4.3.and Table 4.4. Average dry matter (DM) content of the treatment rations were above 960g/kg DM. Crude proteins content was almost the same ranging from 201-206 g/kg DM in TR_1 to TR_4 respectively. Crude fat (EE) was highest in TR_3 (94 g/kg DM) and lowest in TR_2 (26 g/kg DM). Ash content was highest in TR_4 (240 g/kg DM) and lowest in TR_1 (69 g/kg DM). Energy content was highest in rations with CSC (TR_1 and TR_2) and lowest in rations with FW (TR_3 and TR4). The rations containing FW (TR_3 and TR4) had higher Ca and P contents than TR_1 and TR_2 while TR_1 and TR_2 had higher K than in other two treatment rations (Table 4.4).

Table 4.3: Chemical composition (g/kg DM) and energy ME (MJ/ kg DM) of treatment rations

TR	DM	CP	EE	ASH	CF	NDF	ME
TR_1	969	201	76	69	113	449	13
TR_2	967	202	26	74	116	426	12
TR_3	973	203	94	167	51	470	11
TR_4	972	206	58	240	63	601	9

DM = Dry matter, CP = Crude protein, EE = Ether extract, CF = crude fibre,
NDF = Neutral detergent fibre, ASH = Ash, ME = Metabolizable energy

Table 4.4: Mineral composition (g/kg DM) of treatment rations

Teatment (TR)	Ca	P	K	Na	Mg
TR_1	4.6	6.4	12.9	4.3	3.6
TR_2	6.3	2.6	17.0	6.4	3.1
TR_3	44.2	17.8	9.3	5.4	3.0
TR_4	61.9	28.9	11.0	4.7	1.8

4.1.3.Growth performance study results

4.1.3.1 Total dry matter intake feed efficiency and average daily gain

LSMeans of dry matter intake (DMI) are shown in Table 4.5, (ANOVA is in Appendix 1 while individual values are in Appendix 2). The average DMI was ($P<0.05$) different with TR_2 having higher intake values followed by TR_1, TR_3, and TR_4 with average intakes of 5.35, 5.09, 4.95 and 4.89 kg/day respectively. Supplementation with different protein and energy sources was ($P<0.05$) affected DMI between treatment diets. In case of protein sources heifers supplemented with FW had lower DMI than those on CSC. On the other hand energy feeds had ($P<0.05$) DMI varying between protein sources. CRM combined with CSC (TR_2) had higher DMI than that of HM (TR_1) while on FW based rations HM (TR_3) had higher DMI than CRM (TR_4). The average daily gain (ADG) was ($P<0.05$) different among four rations. Heifers on TR_2 had the highest weight gain (620 g/day) and TR_4 the lowest weight gain (420 g/day). Feed efficiency (FE) was ($P<0.05$) different between treatment rations. TR_2 had the highest (0.129 g/kg) FE while TR_4 the lowest (0.106 g/kg). A combination of CRM as energy source and CSC as protein source had ($P<0.05$) higher values in DMI, FE, and ADG than CSC combined with HM and FW combined with both energy sources.

Table 4.5: The LSMeans ± SEM, Total dry matter intake, dry matter intake per metabolic body weight, average daily gain average daily gain per metabolic body weight and feed efficiency (FE) of dairy heifers fed on different treatment rations

ITEM	TREATMENTS				SEM	Pr > F	SIG
	TR_1	TR_2	TR_3	TR_4			
DMI (kg)	5.09^{b}	5.35^{a}	4.95^{c}	4.89^{d}	0.029	0.0001	***
DMI/ $W^{0.75}$	0.119^{b}	0.125^{a}	0.114^{c}	0.113^{c}	0.001	0.0001	***
ADG (g/day)	490^{b}	620^{a}	460^{b}	420^{c}	0.015	0.0001	***
ADG/ $W^{0.75}$	0.013^{b}	0.015^{a}	0.012^{b}	0.011^{c}	0.0003	0.0001	***
FE (g/kg)	0.116^{b}	0.129^{a}	0.113^{bc}	0.106^{c}	0.003	0.0001	***

*** = Highly significant at P <0.0001

Super script $^{a, b, c, d,}$; means within each row bearing same letter are not significantly different at P<0.05

4.1.3.2 Live weight changes

LSMeans of the changes in live weight (kg) of weaned heifers fed on different treatment ratios are shown in Figure 4.1. (ANOVA on live weight changes is in Appendix 1, all LSMeans are in Appendix 3 while individual values are in Appendix 4). All animals in the four treatments gained weight throughout entire experimental period. The changes in live weight between treatment rations were (P<0.05) different. TR_2 had the highest change (32 kg) followed by TR_1 and TR_3 with 29 kg each and TR_4 had the lowest gain of 26 kg (Figure 4.1). TR_2 had the highest average live weight change compared to other treatments and there was (P<0.05) difference between treatments from week 2 to week 8. Heifers in TR_2 had the highest average body weight change at the end of the experiment although there was (P>0.05) difference between treatments. Live weight changes and ADG were (P>0.05) between TR_1 and TR_3.

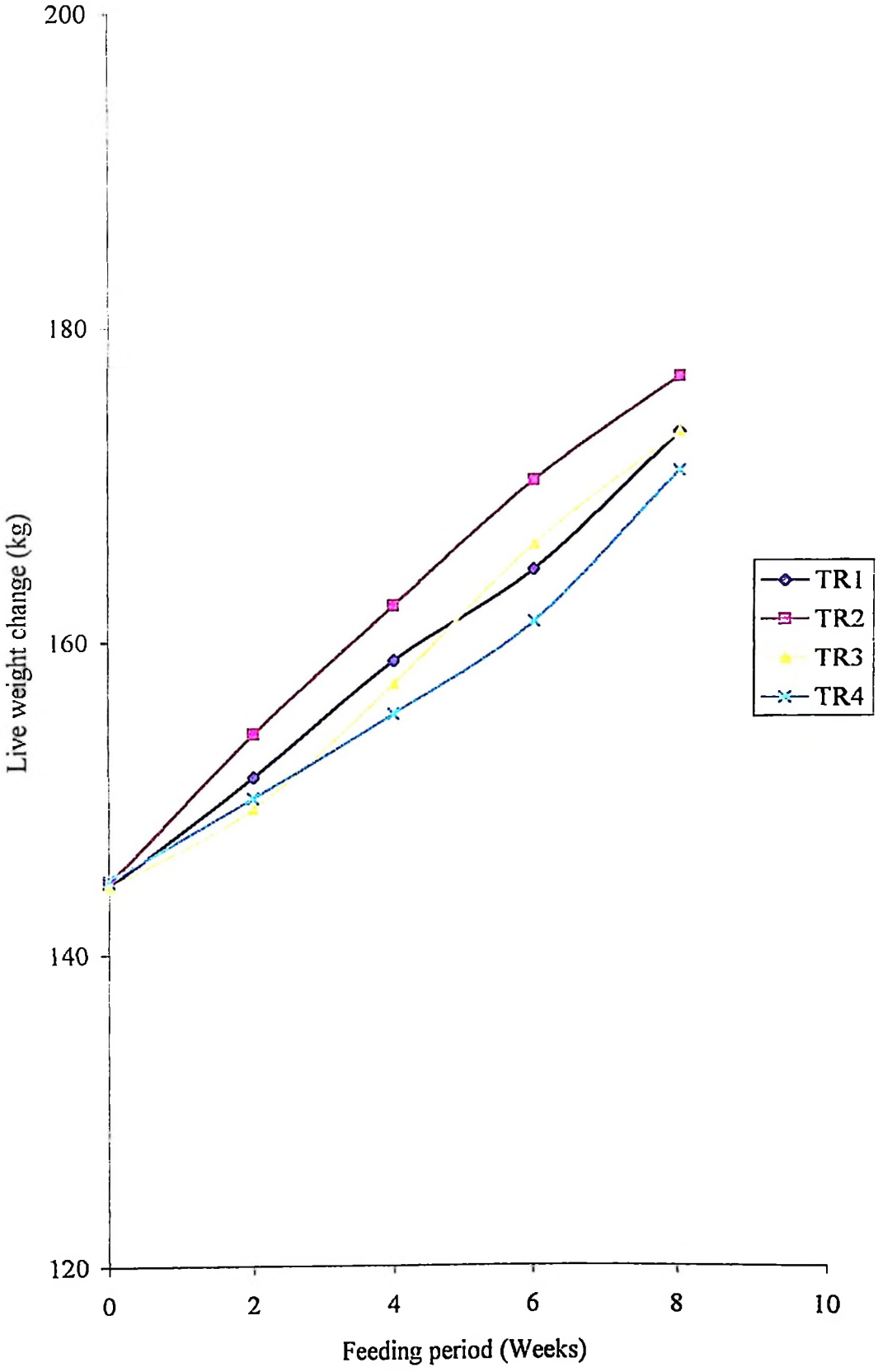

Figure 4.1: Live weight change of weaned dairy heifers

4.1.4 Blood parameters

Blood parameters included Ca, Pi, plasma glucose and total plasma proteins are shown in Table 4.6. Individual values for all parameters are presented in Appendix 5 while ANOVA results are in Appendix 1. There were ($P<0.05$) differences between treatments in all the blood parameters measured.

4.1.4.1 Plasma Proteins

Total plasma proteins were determined in the study. TR_2 had ($P<0.05$) higher levels of protein (97.1g/l) compared with other treatments and was followed by TR_4 (95g/l), TR_3 (92.3 g/l) and TR_1 (90.5 g/l). Protein and energy sources had ($P<0.05$) influenced protein concentration in blood plasma. For energy sources treatment rations with CRM (TR_2 and TR_4) had higher plasma blood protein levels than those on HM (TR_1 and TR_3). In case of protein sources CSC (TR_2) had higher protein than FW (TR_4).

Table 4.6: LSMeans ±SEM for the effect of treatment rations on different blood parameters

Treatment	Protein (g/l),	Glucose (mmol/l)	Ca (mmol/l)	Pi (mmol/l)
TR_1	90.5^{c}	3.15^{b}	2.28^{c}	1.21^{c}
TR_2	97.1^{a}	3.30^{a}	2.36^{ab}	1.26^{c}
TR_3	92.3^{bc}	3.14^{b}	2.40^{a}	1.38^{b}
TR_4	95.0^{ab}	3.0^{c}	2.34^{b}	1.60^{a}
SEM	0.989	0.165	0.018	0.046
Pr>F	0.0001	0.0001	0.0001	0.0001
Significance	***	***	***	***

NS = Not significant

*** = Highly significant at P <0.0001

Super script $^{a, b, c,}$; means within each column bearing same letter are not significantly different at P<0.05

4.1.4.2 Plasma Calcium (Ca)

Maximum and minimum levels of calcium contents were ($P<0.05$) different between rations (Table 4.6). Heifers on TR_3 had the highest calcium concentration while TR_1 had the lowest. TR_2 had higher levels of calcium than TR_4 and chemical composition of treatment rations indicated TR_3 and TR_4 to contain Ca six times more than that of TR_1 and TR_2 (Table 4.1).

4.1.4.3 Plasma inorganic Phosphate (Pi)

Plasma Pi in four treatments rations are shown in Table 4.6. Levels of TR_1 and TR_2 were ($P>0.05$) different while TR_3 and TR_4 were ($P<0.05$) different. Plasma Pi was highest in TR_4 and lowest in TR_1. The average Pi concentrations were 1.6mmol/l, 1.38mmol/l, 1.26mmol/l and 1.21mmol/l in treatments TR_4, TR_3, TR_2 and TR_1 respectively. Treatment rations with FW had higher levels of Pi than those with CSC. Among treatment rations with FW, TR_4 had higher level of Pi than TR_3.

4.1.4.4 Plasma Glucose

Plasma glucose concentration was ($P<0.05$) different between treatment rations (Table 4.6). The overall concentrations were 3.15mmol/l, 3.3mmmol/l 3.14mmol/l and 3.0mmol/l for TR_1, TR_2, TR_3 and TR_4 respectively. TR_1 and TR_3 had ($P>0.05$) different glucose concentration levels while TR_2 had ($P<0.05$) higher glucose level than TR_1 and TR_4.

4.2 Experiment II

4.2.1 Effect of treatment rations on ruminal pH and NH_3-N

Ruminal parameters studied included pH and NH_3-N. Appendix 1 presents ANOVA results while individual values for both parameters are presented in Appendix 6.

4.2.1.1 Ruminal pH

Ruminal pH for all treatment rations decreased ($P<0.05$) from 2h to 6h after feeding and then increased and attained highest level at 24h after feeding (Figure 4.2 and LSMeans in Appendix 3). Overall means values indicated that there was ($P<0.05$) difference between ruminal pH with TR_1 having ($P<0.05$) higher level (6.4) than other treatment rations. There was ($P>0.05$) difference between treatments at 10, 12, 18, 20, 22, and 24 hours after feeding. However the difference between treatments was ($P<0.05$) at 0, 2, 4, 6, 8, 14 and 16 hours after feeding.

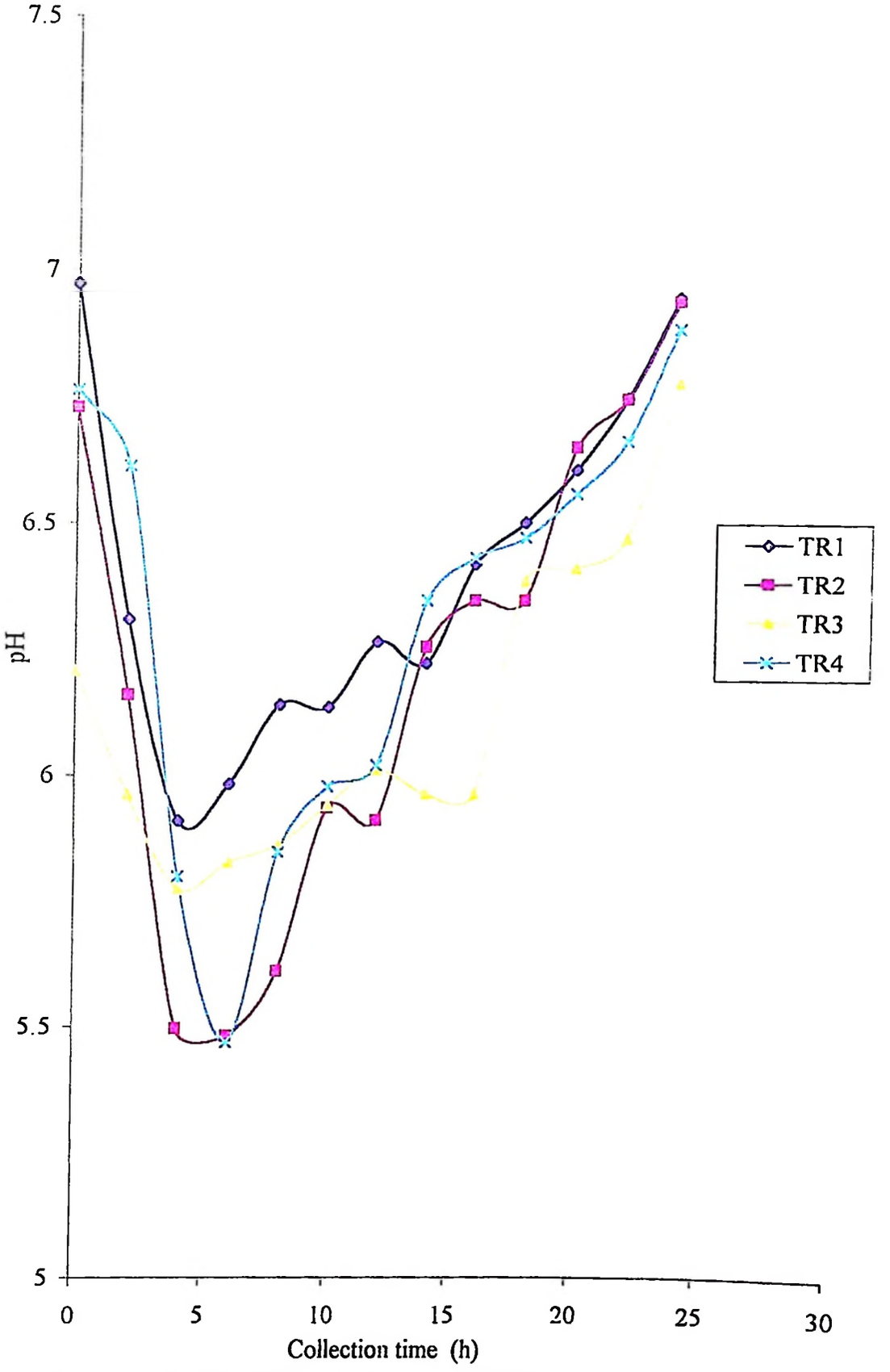

Figure 4.2: Ruminal pH levels of treatment rations

4.2.1.2 Effect of treatment rations on ruminal NH_3-N

Levels of NH_3-N are shown in Figure 4.3 (LSMeans in Appendix 3). For the entire period of 24 hours; TR_3 had ($P<0.05$) the highest NH_3-N level followed by TR_4 then TR_2 and finally TR_2. There was an increase in NH_3-N in all treatments at 2, 20, 22, and 24 hours after feeding. With exception of 2 and 12 hours treatment ration were ($P<0.05$) different in NH_3-N levels. Overall there was ($P<0.05$) difference in NH_3-N levels between treatments; TR_3 (283.7 mg/l), TR_4 (203.7 mg/l), TR_2 (183.9mg/l) and TR_1 (135.8 mg/l). Treatments with FW had ($P<0.05$) higher levels of NH_3-N than those with CSC. TR_3 had ($P<0.05$) higher levels of NH_3-N than TR_4.

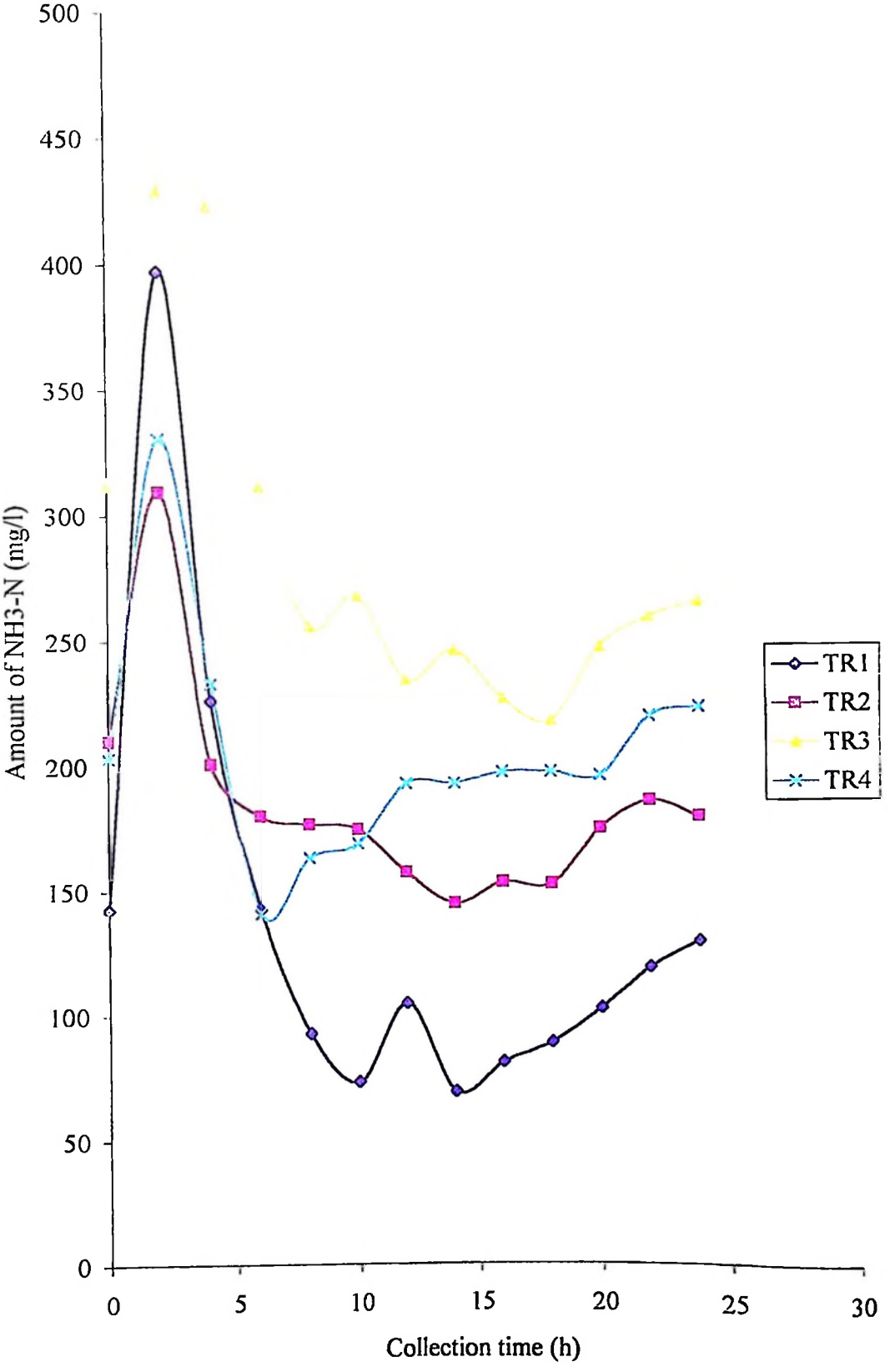

Figure 4.3: Ruminal NH3-N levels of treatment rations

4.2.2 Degradability experiment results

DM and CP degradability data are presented in Appendix 1 (ANOVA) Appendix 3 (LSMeans) while individual data in Appendix 6.

4.2.2.1 DM Degradability of experimental feeds

Potential degradability characteristics (**a**, **b**, and **c**), 48h degradability, ME (estimated basing on 48h degradability values) are presented in Figure 4.4. CSC had ($P<0.05$) higher degradability values for **a**, **b**, and 48h characteristics than FW. Fish waste had higher **c** (h^{-1}) value (0.069 h^{-1}) than CSC (0.046 h^{-1}). Energy content (ME) was ($P<0.05$) higher in CSC (10.8 MJ/kg DM) than in FW (5.5 MJ/kg DM). The 48h DM, **a**, **c** and ME values were ($P< 0.05$) higher in CRM than HM. The **b** value was ($P<0.05$) higher in HM (622 g/kg DM) than CRM 322 g/kg DM.

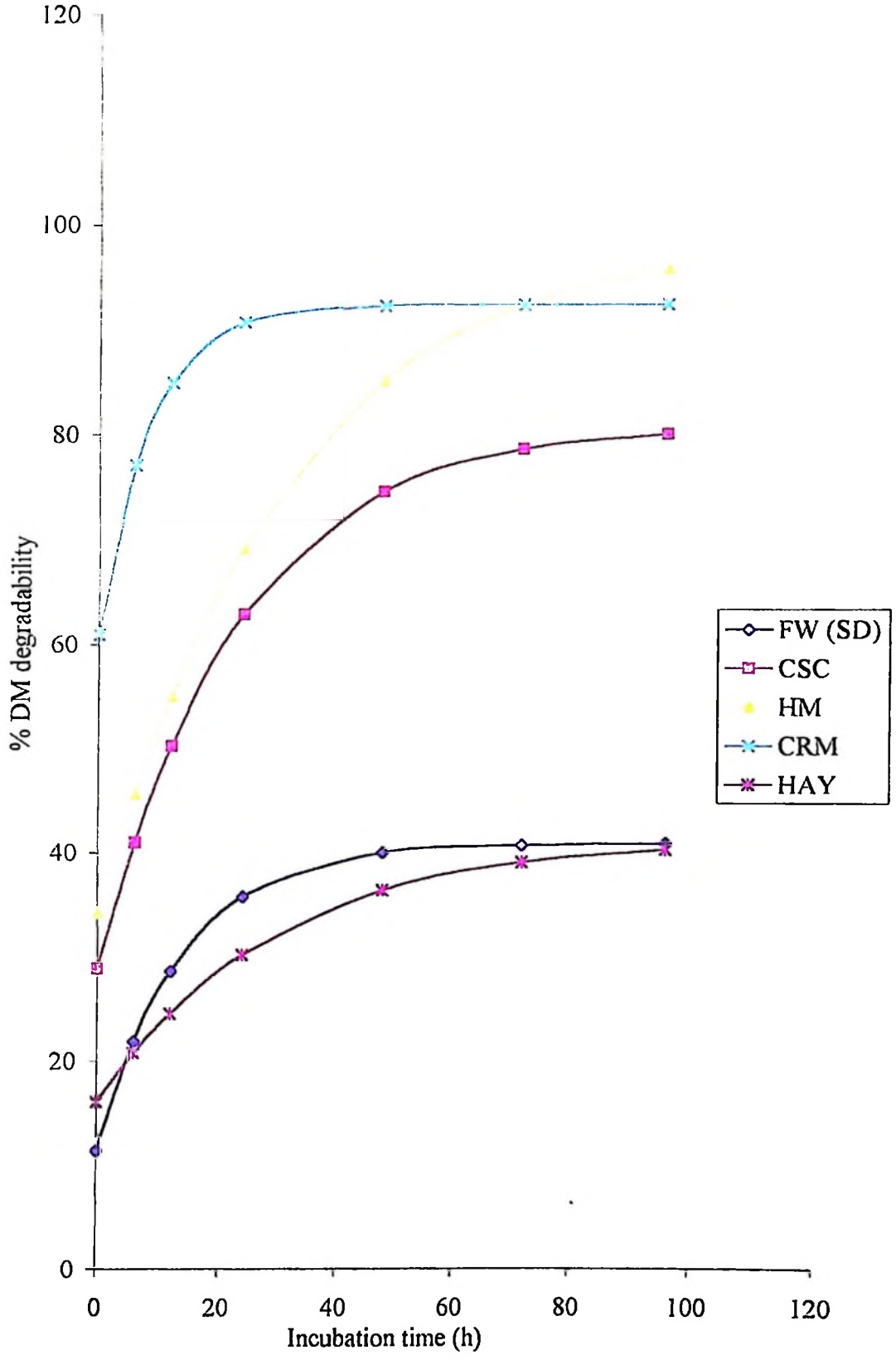

Figure 4.4: DM degradability of experimental feeds

4.2.2.2 CP degradability of experimental feed ingredients

The 48h degradability of crude protein (CP), degradability characteristics **a**, **b**, **c**, and potential degradability **(a+b)**, are presented in Figure 4.5. The CP degradability characteristics (**a** and **b**) and 48h degradability varied ($P<0.05$) between feeds while the **c** values were ($P>0.05$) between feeds. CSC had ($P<0.05$) higher degradability values in **a**, **b**, **c**, and 48h CP than FW. CSC had the highest potential degradability (**a+b**) (921g/kg DM) and FW had the lowest potential degradability (635 g/kg DM). HM had ($P<0.05$) higher **b** and 48h CP degradability values than CRM while **a**, and **c** values were ($P<0.05$) higher in CRM than HM.

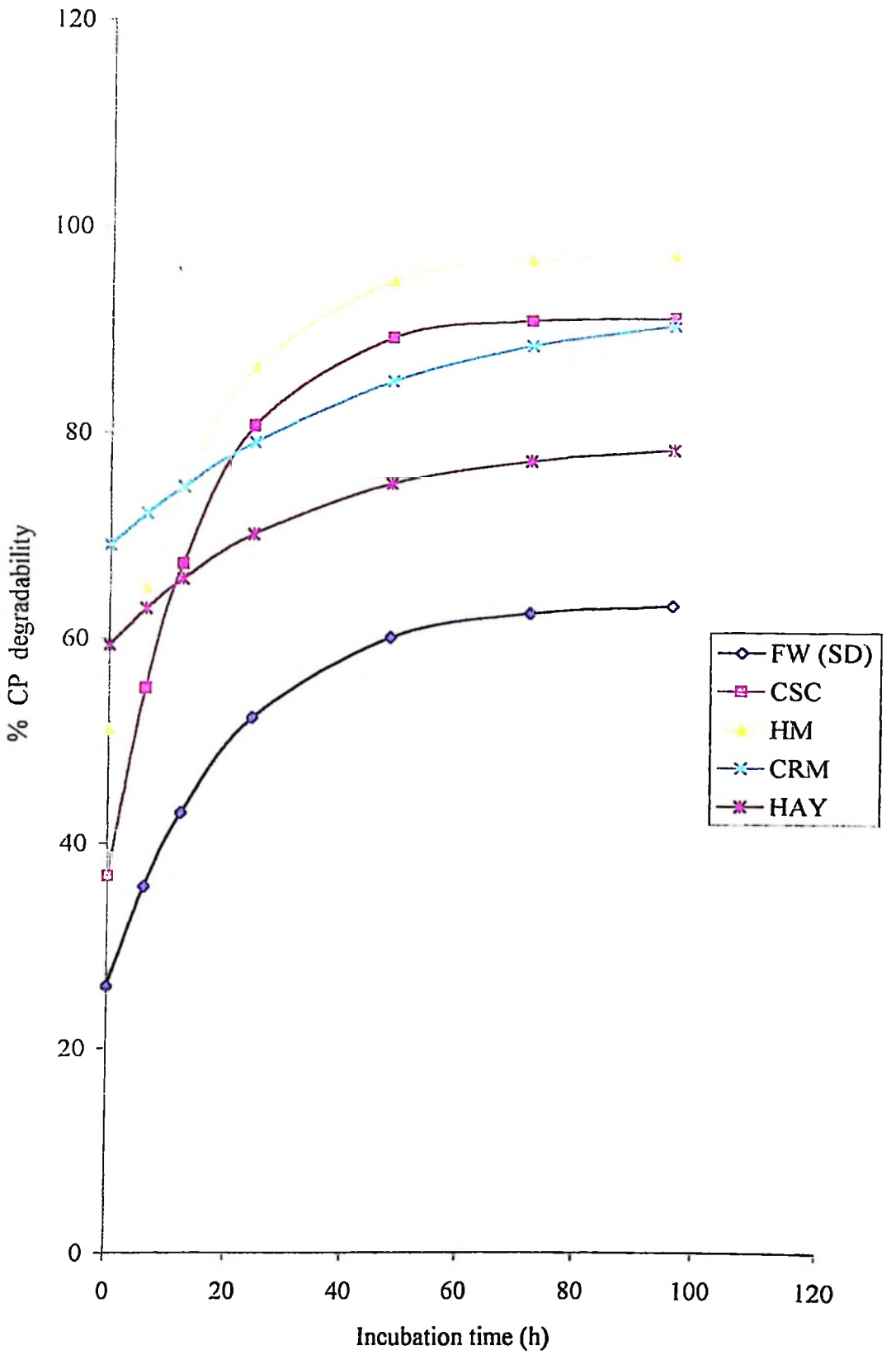

Figure 4.5: CP degraradability of experimental feeds

4.2.2.3 DM degradability of treatment rations

The 48h DM degradability (g/kg DM) and degradability characteristics (**a**, **b**, and **c**) of treatment rations are presented in Figure 4.6. (ANOVA tables in Appendix 1, LSMeans in Appendix 3 and Individual values are presented in Appendix 6). DM degradability characteristics **a**, **b**, potential degradability (**a+b**) and 48h DM degradability as well as the degradation rate constant **c** (h^{-1}) were ($P<0.05$) different between treatment rations. The degradation rate constant (**c**) was ($P<0.05$) higher for TR_2 ($0.089h^{-1}$) while TR_3 had the lowest degradation rate ($0.019\ h^{-1}$). The insoluble but potentially degradable fraction (**b**), 48h DM degradability and potential degradability (**a+b**) were lowest for TR_4 compared to the other treatments. Metabolizable energy (ME) was ($P<0.05$) higher in TR_2 (11.65 MJ/kg DM) and lower in TR_4 (8.91 MJ/kg DM). Protein sources influenced degradability characteristic **a**, **c**, 48h DM degradability and ME contents in the treatments. For TR_3 and TR_4 having FW as protein source had higher degradability characteristics **a** than TR_1 and TR_2 with CSC as protein source. 48h DM degradability, **c** and ME were ($P<0.05$) higher in rations containing CSC than those with FW. Energy sources also influenced potential degradability (**a+b**) as treatment rations with HM had ($P<0.05$) higher **a+b** value than CRM.

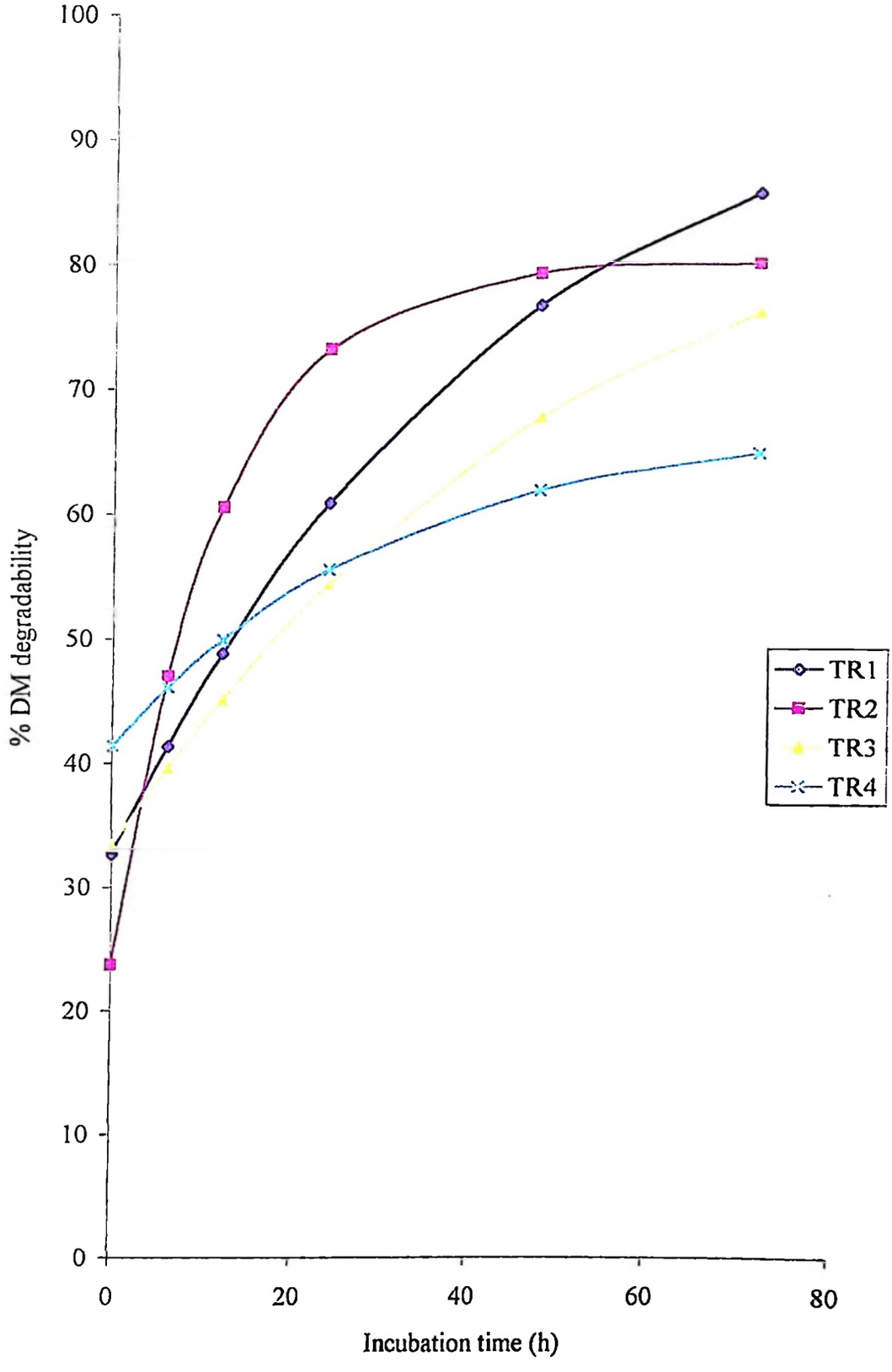

Figure 4.6: DM degradability of treatment rations

4.2.2.4 CP degradability of treatment rations

The 48h degradability data for CP (g/kg DM) in the treatment rations are presented in Figure 4.7, LSMeans in Appendix 3 and individual values are presented in Appendix 6. With exception of (**b**), other degradability characteristics (**a** and **c**) and 48h for CP were ($P<0.05$) different between treatment rations. Potential degradability (**a+b**) varied ($P < 0.05$) between the treatments rations. For the insoluble but potentially degradable fraction (**b**), TR_3 had a highest fraction degraded (616 g/kg DM) and TR_4 had the lowest degraded fraction (487g/kg DM). Protein sources had influence on **a**, **c**, and 48h degradability of CP. The degradation for CP values was ($P<0.05$) higher in CSC than for FW containing rations.

4.2.3 Correlation between some of the parameters in Experiment I and II.

Observed levels in Experiment II and I are summarized in Table 4.7. Correlation between TDMI and INW on FE were ($P > 0.5$) the rest of parameters were ($P < 0.5$) correlated. TDMI and INW had ($P < 0.5$) higher correlation than other parameters. In Experiment II, NH_3-N and DM degradability (DMD) were ($P > 0.5$) correlated and had a negative correlation. Regression between NH_3-N and DMD was also negatively correlated as per Figure 4.8 below.

Table 4.7: Partial correlation coefficients of parameters in Experiment I and II

	INW	TDMI	ADG	FE	NH_3-N	DMD
INW	.	0.76^{***}	0.38^{***}	0.18^{NS}		
TDMI		.	0.39^{***}	0.14^{NS}		
NH^3-N					.	-0.02^{NS}

NS = Not significant, *** = Highly significant at P <0.0001

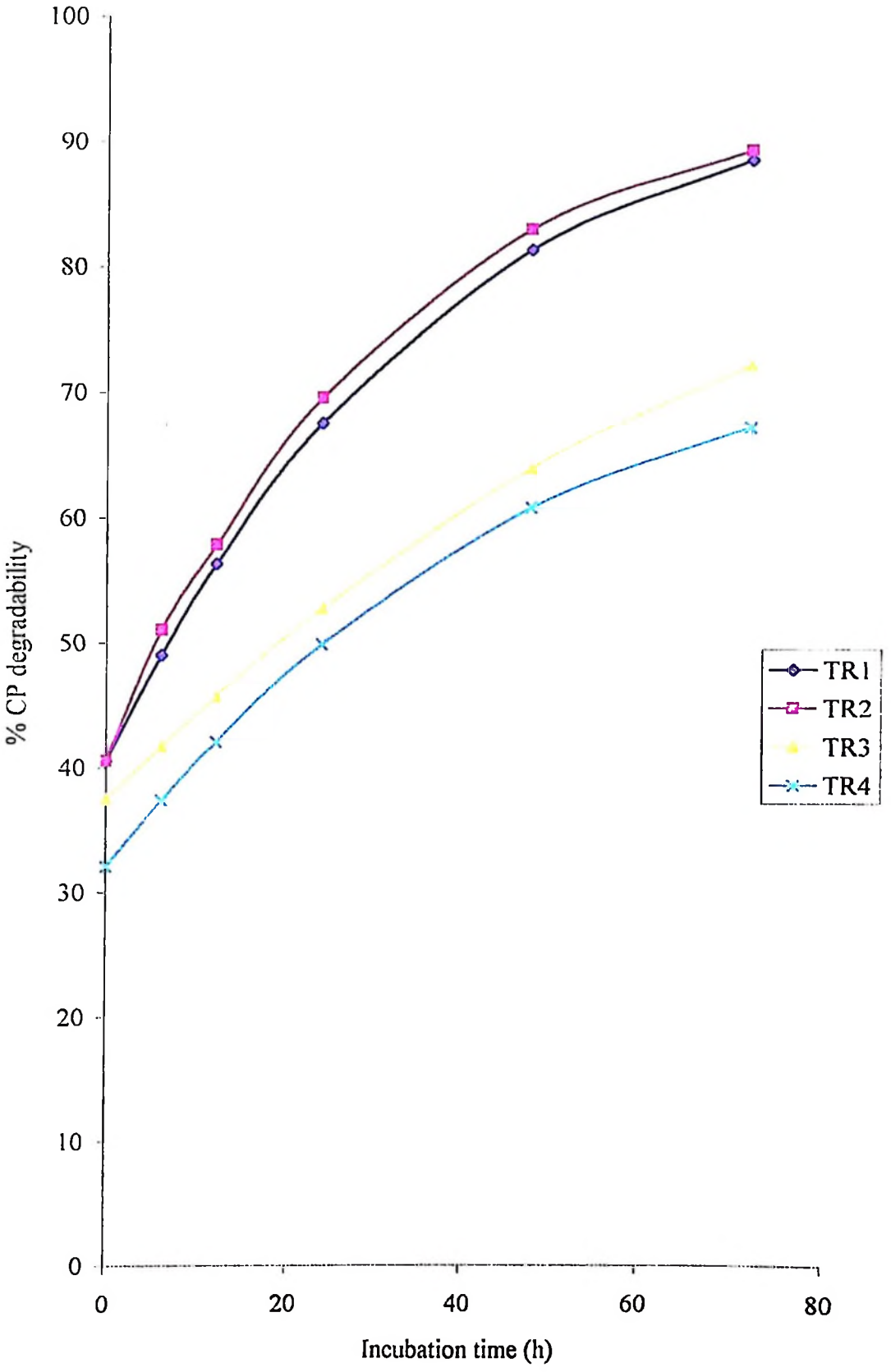

Figure 4.7: CP degradability of treatment rations

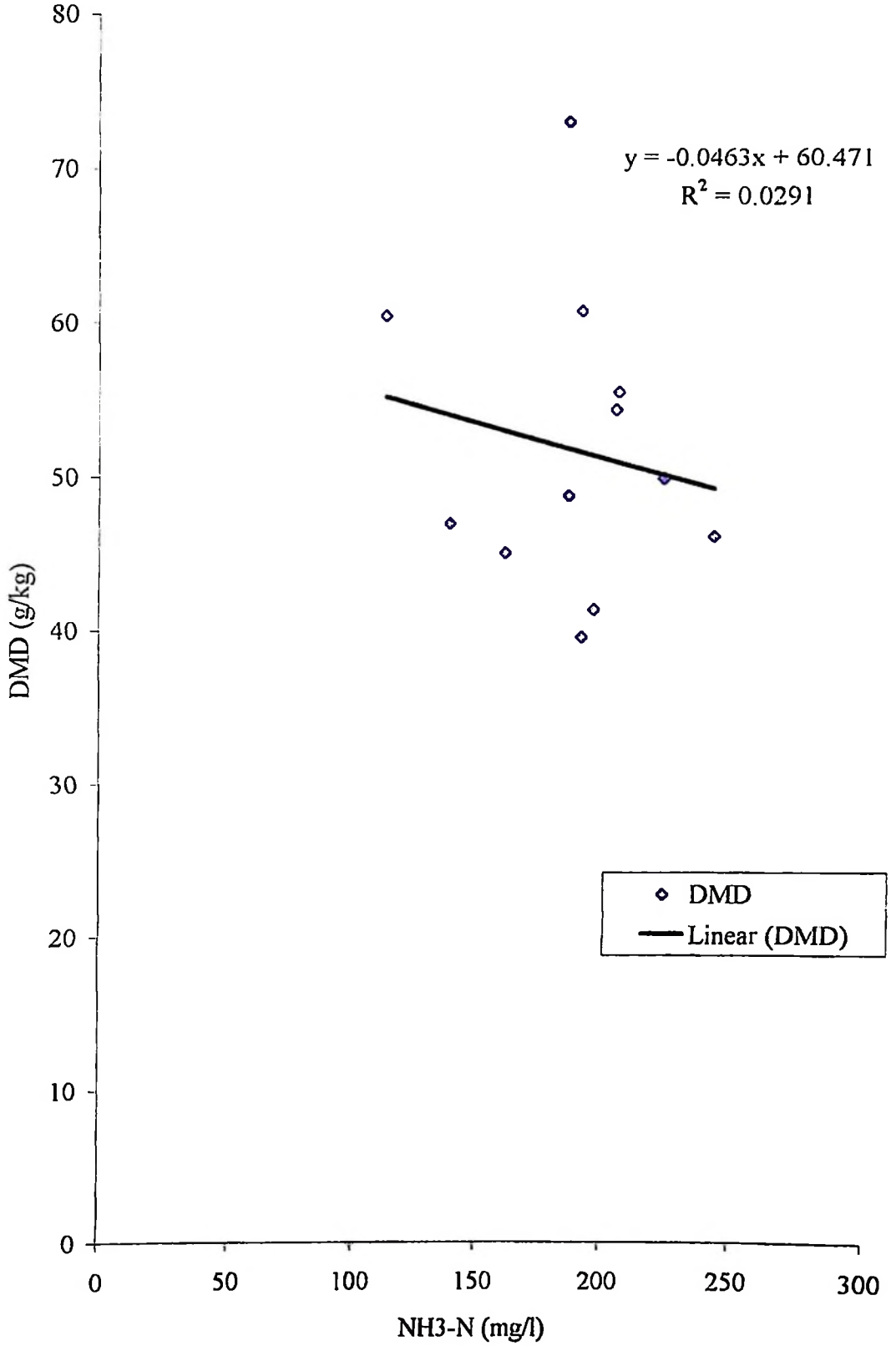

Figure 4.8: Regression between DMD and NH3-N

4.2.4 Cost /benefit analysis of experimental rations

The average costs of concentrates used per 1-kg gain in live weight for the different treatment rations is shown in Table 4.8. The cost of concentrates used per 1kg gained was highest in TR_4 followed by TR_2 then TR_1 and finally TR_3 (US$.0.496, 0.418, 0.338 and 0.332) respectively. Treatments with CRM (TR_2 and TR_4) were expensive compared to HM containing rations (TR_1 and TR_3) but weight gained was higher in TR_2 with CRM than in other treatments.

Table 4.8: Weight gained (kg), concentrate fed (kg), costs of individual experimental feeds (US$) and cost of 1kg gained (US$)

ITEM	Cost/kg feed (US$)	TR_1	TR_2	TR_3	TR_4
Mean weight gained (kg)		29	32	29	26
Mean concentrate fed (kg)		100.5	102.5	99.2	99.3
CSC (%)		31.5	48	-	-
FW (%)		-	-	30.5	46.5
CRM (%)		-	50	-	51.5
HM (%)		66.5	-	67.5	-
Cost of CSC	0.140	4.50	7.03	-	-
Cost of FW	0.140	-	-	4.30	6.53
Cost of CRM	0.123	-	6.43	-	6.47
Cost of HM	0.076	5.20	-	5.20	-
Total costs (US$)		9.70	13.46	9.50	13.00
Cost/ kg gained (US$)		0.338	0.418	0.332	0.496

5.0 DISCUSSION

5.1 Chemical Composition of feed ingredients

The crude protein, NDF and ADF values (Table 4.1) observed in the hay were all within ranges commonly reported for poor quality tropical forages (Göhl, 1981; Adepise and Oyedipe, 1985; Mtengeti, 1995). Such low CP values justified the need for supplementation in the present study. The CP value of FW (Table 4.1) was lower than values previously reported by Ngate, (1997) and Mbamba, (2000), whereas the P value was higher. In Ngate's (1997) studies the FW used included a significant proportion of whole fish that were regarded as unfit for human consumption. Mbamba (2000) on the other hand was centred on offals derived from marine fish. In the present study, the FW were mostly derived from by-products of filleting factories. By-products of filleting usually contain less flesh and more of the skeletal tissues (Hussein and Jordan, 1991a; Kjos, 2001). In addition, no partitioning was done for the various carcass components remaining after filleting. This would mean that the CP value and the P value noted here also could have been increased or decreased by inclusion of N and minerals contents derived from the keratinised tissues e.g. scales and skin. Johson and Savage (1987) and Kjos (2001) reported several reasons for variation observed in the quality of FM/FW. They observed that meals made from fish scraps contain a higher ash and a lower protein contents than meals made from whole fish. Freshly processed FW had significantly higher content of CP and lower fat content than sun dried FW collected during both dry and rainy seasons (Table 4.1). An industrial processing, involving mechanized drying and press extraction of oil was used for the freshly processed FW. This process minimizes decomposition and reduces the dilution effect of fat on CP content (Hussein and

Jordan, 1991, a, b; Kjos, 2001). The CSC and hominy meal values obtained in this study (Table 4.1) were within the range reported by Thomke and Macha, (1986) and by Lekule *et al.* (1988). Cassava root meal had higher values of CP, ash and crude fibres (Table 4.1) than those reported by Lekule *et al.* (1988). The difference could be attributed to variation in soil types, processing methods and stage of maturity at the time of harvesting (Wanapat, 1999). The Cassava root meal appeared to have a high CP value (Table 4.1) principally because of the peels that were included. It could be noted that peels analysed separately had twice the value of CP in CRM. This value however, exaggerates the true worth of CP in the meal because the peels are known to contain the N containing HCN (Lekule, 1990; Nguyen, 1996). The HCN is of limited feed value that necessitates cassava processing (Nguyen, 1996; Bui Van Chinh and Le Viet Ly, 2001). It was intended in this study to compound meals that would provided 20 % CP and 10 MJ /kg DM) daily intakes of respectively protein and energy. Levels obtained after compounding the treatment rations were within the range recommended for growing heifers (Table 4.3) (Sighn *et al.*, 1991; ARC, 1990; McDowell (1992). The compounded rations were consumed at acceptable levels as evidence by the voluntary intakes (Table 4.5). The feed efficiency and possible interactive effects of changing the energy and protein sources are discussed in sections (5. 2 .1 and 5.2 .2).

5.2 Total dry matter intake (DMI)

Table 4.5 shows average DMI per each treatment ration. The minimum total dry matter intake observed in the present study was 4.89 kg/day while published DM requirements ranges from 4.2 to 5.6 kg/head/day for growing heifers weighing 150-

200 kg and gaining 0.5 kg/day (Kearl, 1982). The DMI recorded in this study was sufficient to support growth of heifers as reported by previous studies in which cattle weighing from 150 to 200 kg and fed on different diets containing slowly degradable protein (FW) or moderate degradable protein (CSC) had DMI ranging from 2.6 to 4.6 % (Rocha *et al.*, 1995). Good interaction between CRM and CSC led TR_2 to have high DMI. Cassava root meal has been reported to increase DMI in dairy cattle when included at 15 % of the diet DM consisted of cassava root meal (Silvester *et al.*, 1977; Zinn and DePeter, 1991). Therdchai and Mikled (2001) substituted maize with CRM at 0, 50, 75and 100 %, and reported total DMI of 4.49, 6.24, 5.85 and 5.83 kg/day respectively. The total DMI consumed by growing heifers provided sufficient nutrients in terms of CP, ME and minerals (Table 4.3).

5.3 Live weight changes and average daily gains

Figure 4.1, Table 4.7 and Appendix 3 present the treatment effects of the experimental rations on growth performance of the heifers. Heifers receiving all rations showed a consistent weight increment of between 5 and 9 kg per fortnight. Heifers raised on CRM with CSC showed superior daily weight gain than all other groups. Those given CRM with FW apparently had lower gains during the first four weeks but seemed to recover over the last two weeks. In all groups the final weight attained by all heifers was similar. The highest gain was observed in TR_2. This observation concurs with similar findings by Silvester *et al.* (1977) who reported that cassava meal promotes higher gains because of its effects on improved intake. Similarly the studies by Nocek and. (1984) showed that CRM increases live weight gain whenever included in ruminant feeds. LuzMeyeles and Preston (1977) noted

nearly 30 % increase in weight in cattle fed CRM at 15 % of the DMI. Cassava Root Meal offered to cattle at 50, 75 and 100 % of the daily ration combined with low quality roughages (rice straw) has been shown to promote weight gain of as much as 866, 779 and 695 g/d respectively (Therdchai and Milked, 2001). Zinn and DePeter. (1991), found that daily weight gain was significantly greater when 15 % of the diet DM consisted of cassava root meal and uses of high-energy diets improve efficient of gain and growth (Smith *et al.*, 1991; McDonald *et al.*, 1998). No ($P > 0.05$) difference in daily gain was noted when FW replaced CSC in rations where energy was derived from HM (TR_1 and TR_3). Replacing a low ruminal escape protein source such as cottonseed meal with FM/FW in corn-based diets does not improve average daily gain or feed efficiency (Thonney and Hogue, 1985). This contrary was also true where CRM was used as source of energy (TR_2 and TR_4). Animals receiving CRM combined with CSC (TR_2) showed superior gain than those fed CRM combined with FW (TR_4). This would suggest apparent interactions that exist between CRM and the protein sources. The CSC was expected to provide a slowly ruminal degradable protein (RDP), hence improving total rumen digestible organic matter (Pham Kim Cuong *et al.*, 2001). Such a scenario would provide more energy to the animal and possibly also a higher rate of gain (Table 4 5). The FW on the other hand is an excellent source of ruminal undegradable protein (RUDP). Animals fed on low quality roughages while receiving a high proportion of RUDP may experience low DMI and high plasma total protein (Hussein and Jordan, 1991 a b; Veira *et al.* (1994)). Tables 4.6 and Appendix 3 show that there was little difference among the treatment groups in both plasma total protein and rumen pH profiles. This would suggest that CSC was only partially rumen degradable while most of the FW was

RUDP (Pham Kim Cuong *et al.*, 2001). Thus the superior performance by animals on TR_2 was due mostly to the positive interaction between CSC and CRM, high DM degradation and higher ME (Appendix 3) whereas TR_4 could not effectively support rumen organic matter digestion and some of RUDP escape intestinal digestion, absorption and pass out in faeces while undigested.

5.4 Feed efficiency (FE)

Feed efficiency was correlated with TDMI and ADG indicating higher significance with ADG (Table 4.7). TR_2 had high feed efficiency compared to other treatments (Table 4.5). Comparison between TR_1 and TR_2, show that the cause of changes was due to energy sources as protein source was the same (CSC). Cassava is low in dry matter, but the DM is rich in energy due to a high content of starch. High amylopectin content in cassava relative to maize makes it a more suitable source of energy for ruminants than for monogastric animals (Kanjanapruthipong *et al.*, 2001). The latter author concluded that cassava is an excellent source of fermentable total non-fibre carbohydrates that are energy yielding substrates for the microbial population in the rumen. Starch that is contained in cassava tuber makes the synthesis of rumen microbial protein more efficient when it acts as the main dietary source of fermentable carbohydrate compared to sugars (Rowe *et al.*, 1980).

5.5 Plasma Protein

The normal range for blood plasma protein in grazing animals is 68-85g/l (Jain, 1986). This level has been noted to increase in animals receiving high protein concentrates (Sawadogo *et al.*, 1991). Values obtained in the present study were

above the range for non -supplemented grazing animals (Table 4.6). High total plasma protein noted in TR_3 and TR_4 suggests that FW was mostly digested in the lower gut after escaping ruminal breakdown. These further supports the earlier observation noted in section (5.2.1). Veira *et al.* (1994) reported increased plasma albumin concentration when steers were fed with increasing levels of fishmeal. The significantly higher concentration of plasma protein in animals on TR_2 could be due to the sparing effect of the readily available energy from cassava. Hoover and Stokes (1991) have shown that when energy is readily available the animal is spared from using protein as an energy source, hence increasing the quantity mobilised into protein accretion. The amount of NH_3-N in the rumen could also have had an influence on the total protein concentration in the blood since ruminal NH_3-N obtained in this study was more than that required by rumen microorganisms for microbial protein synthesis, the excess could therefore have been converted into body proteins through body circulation process (NPN) (Sighn *et al.*, 1991; Hoover and Stokes, 1991).

5.6 Blood Minerals

The use of FW provides opportunities for reducing costs of supplementing animals with inorganic mineral sources, particularly Ca and Pi (Mbamba, 2000). Observations were made to evaluate the availability of these two minerals to the animals when FW was included in the rations. Table 4.6 show that animals on both TR_3 and TR_4 had significantly higher blood levels of Ca than those on TR_1 as also reflected in Table 4.1 The high plasma Ca in TR_2 was not expected. Chemical composition of the FW and that of the compounded rations (Tables 4.1 and 4.3)

showed that the animals on TR_3 and TR_4 were receiving at least twice the recommended daily allowance for Ca. This amount appeared to be only poorly available when judged by the plasma levels of Ca. However, no attempt was made to assess urinary losses, neither was it possible to quantify amount retained. In any case the blood levels noted suggest that FW could not provide adequate quantities as was expected. Kaneko (1989) reported that cattle should have between 2.43-3.1 mmol/l of Ca. However, this level is known to be variable depending on many factors, e.g. age of the animals, physiological status and corresponding levels of Pi (McDowell, 1996). All animals in the present study did not show any symptoms of low Ca intake.

Inorganic phosphate (Pi) is needed for the primary functions of growth, energy metabolism and reproduction (Corbridge, 1985; McDowell, 1992). The Pi levels observed in all treatments in this study (Table 4.7) were lower than the recommended daily allowance (1.8 and 2.9 mmols/l) (Under Wood and Suttle, 1999). Animals on TR_3 and TR_4 had levels approaching the recommended levels but were still about 0.42 to 1.3 mmols/l below the recommended allowances. It was expected that at 30-46.5 % inclusion of FW there would be adequate quantities of Pi in the rations. Indeed, the chemical analysis of the rations (Table 4.1) showed that all animals received sufficient supply of Pi in the rations. The low plasma levels would suggest that uptake or availability of the Pi was poor. It may be speculated that the high oil content in FW presumable containing high Vitamin A (Table 4.1) might have interfered with Ca and Pi metabolism. It has been shown that high Vitamin A could negatively affect Vitamin D uptake and therefore Pi metabolism (McDowell, 1996; McDonald *et al.*, 1998).

5.7 Plasma Glucose

The level of plasma glucose is indicative of energy supply at tissue level. Animals starved on rapidly available energy would normally show high levels of ketones i.e. Non-esterfiried Fatty Acids, triglycerides and Beta-hydroxybutyrate. Adequate glucose levels indicate that the animal receives sufficient energy supply from the diet. Results in Table 4.6 suggest that animals in all the four treatment rations had glucose levels within the normal values for ruminants (Kaneko (1989. Animals on CRM were expected to show high values of glucose (Aregheore, 1992). However, this superiority was inconsistent, suggesting that energy from CRM was best utilized when the diet contained CSC than FW.

5.8 Ruminal pH and NH_3-N

The pH value of the rumen liquor observed in this study was within the ranges recommended for normal functioning of the microbes in animals on diets based on low quality roughages (Priego *et al.*, 1977; Erfle *et al*, 1982; Klusmeyer *et al.*, 1990; Kimambo *et al.*, 1999). Inclusion of CRM adds to rapidly fermentable sugars, compounds that are known to lead to low pH (Sommart *et al.*, 2000 a, b). However, despite the CRM inclusion in TR_2 and TR_4 the pH ranges remained within similar levels as in diets containing HM (Figure 4.2 Appendix 3). At pH 6 or thereabout rumen functions are not likely to be severely interfered (Klusmeyer *et al.*, 1990). Findings by Sommart *et al.* (2000 a, b) showed that CRM inclusion does bring down rumen pH because of high production of volatile fatty acids, but even at 54 % inclusion, the deviation from neutrality is still insignificant, an observation that is in agreement with data from the present study.

The trends observed on rumen NH_3-N were in contrast to findings by other workers (Pham King Cuong *et al.*, 2001). Animals on TR_3 and TR_4 were expected to show low rumen NH_3-N (Pham King Cuong *et al.* (2001), but the contrary was observed. This would suggest that FW was partially degraded in the rumen, a factor that is further corroborated with the findings on plasma protein (Table 4.6). It may also be to the high requirement of rumen NH_3-N for diets with high CP content (Odle and Schaefes, 1986). When CRM replaced HM as energy substrate in TR_2, the levels of rumen NH_3-N were significantly raised. This probably arises from the fact that there was an increased energy supply in the rumen activating the rumen microbes, and that the CSC was likely to have been degraded at a faster rate (Appendix 3). Figure 4.3 supports this assertion.

5.9 Degradation of CSC and FW

DM and CP degradability values for the present study are summarized in Figures 4.4 and 4.5 (LSMeans Appendix 3) Cotton seed cake had both high DM and CP degradation rates than FW. This was expected as CSC is a plant material, which normally would have higher RDP than a material of animal origin (Barlow and Wind son, 1984; Khan *et al.*, 1998; Kimambo *et al.*, 1999; Pham Kim Cuong *et al.*, 2001). Possible explanations for the difference in DM and CP rumen degradability of FW and CSC include, differences in solubility, chemical characteristics and presence of cross linked disulphide bonds or cyclical structures of the protein (Mahadevan *et al.*, 1980; Preston and Leng, 1987; Pham Kim Cuong *et al.*, 2001).

5.10 Degradation of CRM and HM

Figures 4.4 and 4.5 show that DM degradability of CRM were grater than HM. Over 94 % of CRM was degraded in the rumen (Therdchai and Mikled (2001). Carbohydrates in cassava are degraded twice or thrice faster than those of corn (Smith *et al.*, 1991; Kanjanapruthipong *et al.*, 2001). In corn over 40 % of the carbohydrates can escape rumen degradation (Ørskov, 1986; Therdchai, 1987). The apparent low CP degradability in CRM may have resulted form an increase in CP value of the residues following the solid-state fermentation of the root meal. Supriyati *et al.* (1995) and Barkrie *et al.* (1997) reported that multiplication of rumen microbes could be significantly increased following inclusion of CRM as an energy substrate. Through this method, Barkrie *et al.* (1997) were able to produce "Cassapro"(fermented cassava roots) via solid-state fermentation using CRM and *Aspergilus niger*. Cassapro is currently a popular ingredient in ruminants' diets in Indonesia (Supriyati *et al.*, 1995; Barkrie *et al.*, 1997).

5.11 Degradation of treatment rations

The trends of the treatment rations on DM and CP degradation were summarised in Figures 4.6, 4.7 (LSMeans Appendix 3). Treatment rations with CSC had higher ME, DM and CP degradation than the rations with FW component. Good interaction between protein and energy sources mentioned previously (5.2.1) of TR_2 (CSC and CRM) still had good results on ruminal degradation. The main difference in DM and CP degradation between treatment rations with FW compared to that of CSC was due to the by pass protein of FW in TR_3 and TR_4 (Barlow and Windsor, 1984) as explained above in section 5.5.1. There was positive correlation between DM and CP

degradation (Table 4.7) indicating that both components were inter dependant to the microbes for their proper feed utilization. Any kind of increase in NH_3-N as in FW feeds was hindering the degradation of DM component of the feed as DM degradability was negatively correlated with NH_3-N (Appendix 3).

5.12 Economic analysis of treatment rations

From the results (Table 4.8) the production cost of TR_4 and TR_2 were higher compared to TR_2 and TR_3. This was largely due to the inclusion of CRM and the associated higher levels of protein sources. CRM currently sells at a high price (0.123 US$) compared to HM (0.076 US$) principally because its production has not been commercially exploited and that supplies are very seasonal (MDB, 1998).

When FW substituted CSC both feed cost and performance in live weight gain were unaffected, suggesting that FW can successfully replace CSC without additional cost, as the cost of FW was the same as that of CSC (0.14 US$). However, feed efficiency could be best retained where FW was combined with HM than with CRM (Table 4.5). Assuming that the rate of gain remains constant over a period of 72 weeks (i.e. from weaning to 24 months) it may be expected that the total cost of rearing a heifer on diets based on FW and HM would amount to about $45.45. This sum is $ 1.69 cheaper than where the conventional CSC is used (See Appendix 8).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 CONCLUSIONS

This study was undertaken to investigate substitution of CSC by FW and HM by CRM as protein and energy sources respectively and their effect on growth performance of weaned dairy heifers.

Result from this study show that CRM can successfully replace HM as an energy source and that FW could replace CSC as a protein source. Best results were obtainable where CRM was mixed with CSC. Apparently higher rate of FW inclusion may have led to low intake, probably because of the fishy smell of the feed.

From this study CRM can be used wholly as energy source without being combined with other energy sources. In case of FW can successfully be combined with energy sources that have high crude proteins (i.e. HM and wheat feed) and inclusion level of FW not exceeding 30 %. Once low CP energy sources are used (i.e. CRM), then a combination of FW with other sources of protein (i.e. CSC) will be preferred in order to reduce fishy smell.

6.2 RECOMMENDATIONS

1). Further studies are required on FW from lake Victoria as protein source for dairy cattle due to little information currently available. FW is undegradable crude protein that escapes ruminal degradation. There is a need to carry out digestibility studies to ascertain amount of N from FW that is lost in faeces and urine. The maximum

inclusion level of FW to dairy cattle feeds has to be determined as inclusion level above 30 % indicated reduced performance of weaned heifers. Fish wastes have a good source of minerals especially Ca and P. Levels of supplementing with or without other mineral sources when using FW have to be determined.

2). Currently high demand and low supply of CRM makes high production cost/kg gain when CRM is included in ration formulation. Deliberate efforts have to be made in order to find the means of producing more cassava that will be able to meet the current market. Any high production and supply of CRM will automatically stabilize and reduce the input cost of CRM in ruminant feeds and finally will be comparable to HM as energy sources.

3). Current inclusion levels that can be recommended are 50 and 30 % for CRM and FW when respectively used alone as energy and protein sources. Above those levels stated then a combination of other energy and protein sources will be required to be included.

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APPENDICES

Appendix 1: ANOVA tables for feed ingredients, feed rations, feed intake, body weights ruminal pH and NH_3-N and blood plasma parameters

DM DEGRADABILITY OF FEED RATION INGREDIENTS.

1.Fish wastes (FW)
2.Cotton seed cake (CSC)
3.Hominy meal (HM)
4.Cassava root meal (CRM)
5.Hay

1 ANOVA table for DM degradability at 48hrs

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	7936.714	1587.342	257.02	0.0001
Feed ingredients	4	7858.593	1964.648	318.11	0.0001
Error	9	55.584	6.176		
Corrected total	14	7992.298			
R-Square=0.993	CV=3.821	Root MSE=2.485	DM mean=65.045		

2 ANOVA table for dependant variable A

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	4527.064	905.413	509.47	0.0001
Feed ingredients	4	4517.282	1129.321	635.46	0.0001
Error	9	15.994	1.777		
Corrected total	14	4543.058			
R-Square=0.996	CV=4.408	Root MSE=1.333	A mean= 30.245		

3 ANOVA table for dependant variable B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	3429.215	685.843	69.44	0.0001
Feed ingredients	4	3367.810	841.953	85.24	0.0001
Error	9	88.896	9.877		
Corrected total	14	3518.112			
R-Square=0.975	CV=7.815	Root MSE=3.143	B mean=40.215		

Appendix 1 cont.

4 ANOVA table for dependant variables A+B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	9718.973	1943.795	247.31	0.0001
Feed ingredients	4	9696.801	2424.2	308.44	0.0001
Error	9	70.736	7.859		
Corrected total	14	9789.709			
R-Square=0.993	CV=3.979	Root MSE=2.803	A+B mean=70.46		

5 ANOVA table for dependant variable C

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	0.0281	0.0056	3.31	0.057
Feed ingredients	4	0.0276	0.0069	4.05	0.378
Error	9	0.0153	0.0017		
Corrected total	14	0.0434			
R-Square=0.6476	CV=57.78	Root MSE=0.0412	C mean=0.0714		

6 ANOVA table for dependant variable ME

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	193.202	48.3	147.3	0.0001
Feed ingredients	4	193.202	48.3	147.3	0.0001
Error	10	3.279	0.328		
Corrected total	14	196.482			
R-Square=0.983	CV=6.072	Root MSE=0.573	ME mean=9.43		

CP DEGRADABILITY OF FEED INGREDIENTS

7 ANOVA table for CP degradability at 48hrs

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	2248.792	449.758	106.48	0.0001
Feed ingredients	4	2208.069	552.017	130.69	0.0001
Error	9	38.014	4.224		
Corrected total	14	2286.806			
R-Square=0.683	CV=2.558	Root MSE=2.055	CP mean=	80.337	

Appendix 1 cont.

8 ANOVA table for dependant variable A

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	3225.898	645.179	62.97	0.0001
Feed ingredients	4	3211.305	802.827	78.36	0.0001
Error	9	92.205	10.245		
Corrected total	14	3318.103			
R-Square=0.972	CV=6.704	Root MSE=3.201	A mean=47.746		

9 ANOVA table for dependant variable B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	2700.576	540.115	9.4	0.0022
Feed ingredients	4	2661.806	665.451	11.58	0.0013
Error	9	517.279	57.476		
Corrected total	14	3217.855			
R-Square=0.839	CV=20.735	Root MSE=7.581	B mean=36.563		

10 ANOVA table for dependant variable A+B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	2140.357	428.071	18.16	0.0002
Feed ingredients	4	2134.566	533.341	22.64	0.0001
Error	9	212.162	23.574		
Corrected total	14	2352.519			
R-Square=0.909	CV=5.758	Root MSE=4.855	A+B mean=84.321		

11 ANOVA table for dependant variable C

SOV	DF	SS	MS	F VALUE	Pr >F
Model	5	1.452	0.290	1.21	0.3794
Feed ingredients	4	1.444	0.286	1.19	0.3793
Error	9	2.168	0.241		
Corrected total	14	3.620			
R-Square=0.401	CV=256.21	Root MSE=0.491	DM mean=0.192		

DM AND CP DEGRADABILITY OF TREATMENTS RATIONS

12 ANOVA table for DM degradability at 48hrs

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	899.622	224.907	12.78	0.0004
Treatment ratios	3	897.259	299.086	16.99	0.0002
Error	11	193.989	17.602		
Corrected total	15	1093.248			
R-Square=0.823	CV=5.708	Root MSE=4.196	DM mean=73.518		

Appendix 1 cont.

13 ANOVA table for dependant variable A

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	629.416	157.354	202.43	0.0001
Feed ingredients	3	627.212	209.071	268.96	0.0001
Error	11	8.551	0.777		
Corrected total	15	637.967			
R-Square=0.987	CV= 2.699	Root MSE=0.882	A mean=32.759		

14 ANOVA table for dependant variable B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	3612.989	903.247	57.97	0.0001
Feed ingredients	3	3541.849	1180.616	75.77	0.0001
Error	11	171.399	15.582		
Corrected total	14	3784.388			
R-Square=0.955	CV=7.607	Root MSE=3.947	B mean=51.893		

15 ANOVA table for dependant variable A+B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	2218.247	554.562	44.88	0.0001
Feed ingredients	3	2119.856	706.619	36.19	0.0001
Error	11	135.913	12.356		
Corrected total	15	2354.160			
R-Square=0.942	CV= 4.125	Root MSE= 3.575	A+B mean=84.651		

16 ANOVA table for dependant variable C

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	0.013	0.003	39.81	0.0001
Feed ingredients	3	0.012	0.004	39.52	0.0001
Error	11	0.001	0.0001		
Corrected total	15	0.014			
R-Square= 0.935	CV= 21.841	Root MSE=0.009	C mean= 0.041		

17 ANOVA table for dependant variable ME

SOV	DF	SS	MS	F VALUE	Pr >F
Model	3	21.815	7.271	18.26	0.0001
Feed ingredients	3	21.815	7.271	18.26	0.0001
Error	12	4.778	0.398		
Corrected total	15	26.59			
R-Square=0.8203	CV=5.862	Root MSE=0.631	ME mean= 10.764		

Appendix 1 cont.

18 ANOVA table for CP degradability at 48hrs (TREATMENTS)

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	1594.992	398.748	12.94	0.0004
Feed ingredients	3	1529.903	509.968	16.55	0.0002
Error	11	339.039	30.822		
Corrected total	15	1934.031			
R-Square=0.825	CV=7.593	Root MSE=5.552	CP mean=73.12		

19 ANOVA table for dependant variable A

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	191.384	47.846	28.22	0.0001
Feed ingredients	3	191.226	63.742	37.59	0.0001
Error	11	18.652	1.696		
Corrected total	15	210.036			
R-Square=0.911	CV=3.457	Root MSE=1.302	A mean=37.669		

20 ANOVA table for dependant variable B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	457.203	114.301	3.51	0.0444
Feed ingredients	3	338.155	112.718	3.46	0.0548
Error	11	358.625	32.602		
Corrected total	15	815.828			
R-Square=0.560	CV=10.327	Root MSE=5.709	B mean=55.289		

21 ANOVA table for dependant variable A+B

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	932.616	233.154	8.92	0.0018
Feed ingredients	3	822.095	274.032	10.49	0.0015
Error	11	287.472	26.134		
Corrected total	15	1220.088			
R-Square=0.764	CV=5.499	Root MSE=5.112	A+B mean=92.958		

22 ANOVA table for dependant variable C

SOV	DF	SS	MS	F VALUE	Pr >F
Model	4	0.001	0.0002	7.62	0.0034
Feed ingredients	3	0.001	0.0003	9.92	0.0018
Error	11	0.0003	0.00003		
Corrected total	15	0.0013			
R-Square=0.735	CV=24.5	Root MSE=0.0056	C mean=0.023		

Appendix 1 cont.

FEED INTAKE, WEIGHT GAIN AND FEED EFFICIENCY OF EXPERIMENTAL ANIMALS

23 ANOVA table for Total (Hay +Concentrates) dry matter intake per day (TDMI)

SOV	DF	SS	MS	F VALUE	Pr>F
Model	36	117.914	3.275	95.28	0.0001
Treatments (T)	3	7.797	2.599	75.6	0.0001
Replications	4	92.345	23.084	671.5	0.0001
Weeks (WK)	7	10.469	1.496	43.51	0.0001
Initial body Weight	1	5.669	5.669	164.9	0.0001
T*WK	21	1.644	0.078	2.28	0.0028
Error	123	4.228	0.034		
Corrected Total	159	122.142			
R-Square= 0.965		CV= 3.66	Root MSE= 0.185	TFID= 5.073	

24 ANOVA table for Total (Hay +Concentrates) dry matter intake (TDMI)/$W^{.75}$

SOV	DF	SS	MS	F VALUE	Pr>F
Model	36	0.0068	0.0002	8.19	0.0001
Treatments (T)	3	0.0027	0.0009	39.36	0.0001
Replications	4	0.0016	0.0004	17.06	0.0001
Weeks (WK)	7	0.0011	0.0002	7.08	0.0001
Initial body Weight	1	0.00004	0.00003	1.55	0.2158
T*WK	21	0.0013	0.00006	2.74	0.0003
Error	123	0.0028	0.00002		
Corrected Total	159	0.0096			
R-Square= 0.706		CV= 4.23	Root MSE=0.0048	TFID= 0.113	

25 ANOVA table for Average daily gain (ADG)

SOV	DF	SS	MS	F VALUE	Pr>F
Model	36	2.261	0.063	6.67	0.0001
Treatments (T)	3	1.028	0.343	36.41	0.0001
Replications	4	0.722	0.181	19.18	0.0001
Weeks (WK)	7	0.025	0.004	0.038	0.9135
Initial body Weight	1	0.214	0.214	22.74	0.0001
T*WK	21	0.271	0.013	1.37	0.1451
Error	123	1.158	0.009		
Corrected Total	159	3.418			
R-Square= 0.661		CV= 19.584	Root MSE= 0.097	WGD= 0.495	

26 ANOVA table for Average daily gain (AVD) /$W^{.75}$

SOV	DF	SS	MS	F VALUE	Pr>F
Model	36	0.0008	0.00002	5.16	0.0001
Treatments (T)	3	0.0004	0.00013	28.03	0.0001
Replications	4	0.0003	0.00007	15.49	0.0001
Weeks (WK)	7	0.00001	0	0.37	0.9172
Initial body Weight	1	0.00001	0.00001	2.59	0.1102
T*WK	21	0.00015	0	1.64	0.0503
Error	123	0.0006	0		
Corrected Total	159	0.0014			
R-Square= 0.602		CV= 16.29	Root MSE= 0.002	WGD= 0.013	

Appendix 1 cont.

27 ANOVA table for Feed Efficiency (FE)

SOV	DF	SS	MS	F VALUE	Pr>F
Model	36	0.055	0.0015	4.14	0.0001
Treatments (T)	3	0.014	0.0046	12.5	0.0001
Replications	4	0.031	0.0078	21.25	0.0001
Weeks (WK)	7	0.001	0.0002	0.46	0.8605
Initial body Weight	1	0.001	0.0014	3.92	0.0498
T*WK	21	0.007	0.0003	0.92	0.5714
Error	123	0.045	0.0004		
Corrected Total	159	0.099			
R-Square= 0.548		CV= 16.46	Root MSE= 0.019	FE mean= 0.116	

RUMINAL pH AND RUMINAL AMMONIA NITROGEN (NH_3-N)

28 ANOVA table for Ruminal pH

SOV	DF	SS	MS	F VALUE	Pr>F
Model	54	33.219	0.615	15.99	0.0001
Treatments (T)	3	2.249	0.750	19.48	0.0001
Replications	3	0.359	0.119	3.11	0.0281
TIME (hrs)	12	27.197	2.26	58.9	0.0001
T*TIME	36	3.413	0.095	2.46	0.0001
Error	153	5.887	0.038		
Corrected Total	207	39.106			
R-Square= 0.849		CV= 3.167	Root MSE= 0.196	PH mean= 6.254	

29 ANOVA table for Ruminal Ammonia Nitrogen (NH_3-N)

SOV	DF	SS	MS	F VALUE	Pr>F
Model	54	1349390.743	24988.717	9.9	0.0001
Treatments (T)	3	521040.458	173680.153	68.83	0.0001
Replications	3	114745.788	38248.596	15.16	0.0001
TIME (hrs)	12	588935.124	49077.927	19.45	0.0001
T*TIME	36	124669.374	3463.038	1.37	0.0973
Error	153	386095.679	2523.5012		
Corrected Total	207	1735486.422			
R-Square= 0.778		CV= 25.159	Root MSE= 50.234	NH3N= 199.67	

30 ANOVA table for total blood plasma Proteins

SOV	DF	SS	MS	F VALUE	Pr>F
Model	35	8020.48	229.16	5.72	0.0001
Treatments (T)	3	1107.86	369.29	9.21	0.0001
Treatments*WK	24	2202.93	91.79	2.29	0.0014
Weeks (WK)	8	4709.69	588.71	14.69	0.0001
Error	144	5771.26	40.08		
Corrected Total	179	13791.74			
R-Square= 0.5815		CV= 6.76	Root MSE= 6.33	Protein mean = 93.70	

Appendix 1 cont.

31 ANOVA table for blood plasma Phosphorus

SOV	DF	SS	MS	F VALUE	Pr>F
Model	35	6.62	0.189	20.45	0.0001
Treatments (T)	3	3.95	1.32	142.22	0.0001
Treatments*WK	24	0.81	0.033	3.63	0.0001
Weeks (WK)	8	1.87	0.233	25.25	0.0001
Error	144	1.33	0.009		
Corrected Total	179	7.95			
R-Square= 0.833		CV= 7.06	Root MSE= 0.096	Phosphorus mean = 1.362	

32 ANOVA table for blood plasma Calcium

SOV	DF	SS	MS	F VALUE	Pr>F
Model	35	2.66	0.076	5.68	0.0001
Treatments (T)	3	0.35	0.116	7.96	0.0001
Treatments*WK	24	0.51	0.021	1.58	0.0528
Weeks (WK)	8	1.81	0.226	16.83	0.0001
Error	144	1.93	0.013		
Corrected Total	179	4.595			
R-Square= 0.580		CV= 4.94	Root MSE= 0.116	Calcium mean = 2.344	

33 ANOVA table for blood plasma Glucose

SOV	DF	SS	MS	F VALUE	Pr>F
Model	35	5.49	0.157	1.62	0.0267
Treatments (T)	3	1.99	0.664	6.84	0.0002
Treatments*WK	24	1.95	0.081	0.84	0.6871
Weeks (WK)	8	1.55	0.194	1.99	0.0511
Error	144	13.98	0.097		
Corrected Total	179	19.47			
R-Square= 0.282		CV= 9.89	Root MSE= 0.312	Glucose mean = 3.151	

Appendix 2: Total dry matter intake (TDMI), Average daily gain (ADG) and Feed efficiency (FE)

TR	REP.	WK	INW.	F/D CO	F/D HAY	TDMI	ADG	FE
1	1	1	97	1.090	2.648	3.738	0.2857	0.105
1	1	2	101	1.090	2.596	3.686	0.2857	0.106
1	1	3	101	1.135	2.531	3.666	0.3929	0.135
1	1	4	108	1.135	2.709	3.844	0.3929	0.129
1	1	5	108	1.214	2.582	3.796	0.2857	0.103
1	1	6	109	1.214	2.676	3.890	0.2857	0.100
1	1	7	109	1.224	2.503	3.728	0.4375	0.144
1	1	8	121.5	1.224	2.450	3.674	0.4375	0.146
1	2	1	137	1.540	2.846	4.386	0.4286	0.121
1	2	2	143	1.540	3.020	4.560	0.4286	0.116
1	2	3	143	1.607	3.233	4.840	0.5000	0.123
1	2	4	151	1.607	3.435	5.041	0.5000	0.118
1	2	5	151	1.697	3.106	4.803	0.5238	0.128
1	2	6	159	1.697	3.280	4.977	0.5238	0.124
1	2	7	159	1.786	3.495	5.281	0.4911	0.111
1	2	8	164.5	1.786	3.395	5.180	0.4911	0.113
1	3	1	141	1.584	3.051	4.635	0.4643	0.121
1	3	2	147.5	1.584	3.216	4.801	0.4643	0.117
1	3	3	147.5	1.657	3.185	4.842	0.4643	0.116
1	3	4	154	1.657	3.502	5.159	0.4643	0.109
1	3	5	154	1.730	3.443	5.173	0.4762	0.111
1	3	6	161	1.730	3.223	4.953	0.4762	0.116
1	3	7	161	1.809	3.435	5.244	0.5000	0.113
1	3	8	169	1.809	3.392	5.201	0.5000	0.114
1	4	1	153	1.719	3.422	5.141	0.6786	0.145
1	4	2	162.5	1.719	3.475	5.194	0.6786	0.144
1	4	3	162.5	1.826	3.651	5.477	0.5714	0.120
1	4	4	169	1.826	3.614	5.440	0.5714	0.121
1	4	5	169	1.711	3.567	5.279	0.5000	0.113
1	4	6	174	1.711	3.404	5.116	0.5000	0.116
1	4	7	174	1.954	3.657	5.611	0.5000	0.106
1	4	8	181	1.954	3.686	5.640	0.5000	0.105
1	5	1	194	2.179	3.700	5.879	0.5714	0.112
1	5	2	202	2.179	3.837	6.016	0.5714	0.109
1	5	3	202	2.269	4.330	6.599	0.6071	0.104
1	5	4	211	2.269	4.317	6.587	0.6071	0.104
1	5	5	211	2.371	3.960	6.330	0.5952	0.107
1	5	6	219	2.371	4.023	6.394	0.5952	0.106
1	5	7	219	2.460	4.485	6.945	0.6339	0.102
1	5	8	229.5	2.460	4.298	6.758	0.6339	0.105
2	1	1	120	1.346	2.665	4.011	0.6429	0.179
2	1	2	129	1.346	3.144	4.490	0.6429	0.160
2	1	3	129	1.446	3.135	4.581	0.5893	0.147

Appendix 2 continued

2	1	4	136.5	1.446	2.973	4.419	0.5893	0.152
2	1	5	136.5	1.530	3.095	4.625	0.5595	0.140
2	1	6	143.5	1.530	3.080	4.610	0.5595	0.140
2	1	7	143.5	1.610	2.701	4.311	0.4732	0.132
2	1	8	146.5	1.610	3.144	4.754	0.4732	0.120
2	2	1	139	1.558	3.301	4.859	0.8929	0.189
2	2	2	151.5	1.558	3.531	5.090	0.8929	0.180
2	2	3	151.5	1.699	3.541	5.240	0.6786	0.143
2	2	4	158	1.699	3.461	5.160	0.6786	0.145
2	2	5	158	1.772	3.385	5.157	0.7262	0.153
2	2	6	169.5	1.772	3.479	5.251	0.7262	0.150
2	2	7	169.5	1.901	3.734	5.635	0.6607	0.130
2	2	8	176	1.901	3.605	5.505	0.6607	0.133
2	3	1	142	1.592	3.361	4.954	0.9286	0.191
2	3	2	155	1.592	3.723	5.316	0.9286	0.178
2	3	3	155	1.738	3.739	5.477	0.7679	0.150
2	3	4	163.5	1.738	3.937	5.676	0.7679	0.145
2	3	5	163.5	1.834	3.632	5.466	0.6786	0.137
2	3	6	170.5	1.834	3.512	5.346	0.6786	0.140
2	3	7	170.5	1.912	3.707	5.619	0.6518	0.129
2	3	8	178	1.912	3.584	5.496	0.6518	0.132
2	4	1	154	1.727	3.512	5.239	0.3571	0.088
2	4	2	159	1.727	3.621	5.348	0.3571	0.086
2	4	3	159	1.783	4.012	5.795	0.4643	0.097
2	4	4	167	1.783	4.204	5.987	0.4643	0.094
2	4	5	167	1.873	3.969	5.842	0.4405	0.093
2	4	6	172.5	1.873	4.012	5.885	0.4405	0.092
2	4	7	172.5	1.935	3.940	5.875	0.4911	0.100
2	4	8	181.5	1.935	4.081	6.016	0.4911	0.098
2	5	1	168	1.884	3.989	5.873	0.5714	0.112
2	5	2	176	1.884	4.214	6.098	0.5714	0.108
2	5	3	176	1.974	4.277	6.252	0.6429	0.115
2	5	4	186	1.974	4.197	6.171	0.6429	0.116
2	5	5	186	2.086	4.181	6.267	0.6429	0.115
2	5	6	195	2.086	4.250	6.336	0.6429	0.113
2	5	7	195	2.187	4.309	6.496	0.6071	0.106
2	5	8	202	2.187	4.250	6.437	0.6071	0.107
3	1	1	88	0.994	1.651	2.645	0.1429	0.088
3	1	2	90	0.994	1.256	2.249	0.1429	0.103
3	1	3	90	1.016	2.302	3.318	0.2679	0.112
3	1	4	95.5	1.016	2.169	3.185	0.2679	0.117
3	1	5	95.5	1.078	2.481	3.560	0.3929	0.139
3	1	6	104.5	1.078	2.600	3.678	0.3929	0.135
3	1	7	104.5	1.180	2.375	3.554	0.4464	0.154
3	1	8	113	1.180	2.462	3.641	0.4464	0.150
3	2	1	135	1.524	2.530	4.054	0.2857	0.096

Appendix 2 continued

3	2	2	139	1.524	2.392	3.916	0.2857	0.100
3	2	3	139	1.569	3.042	4.611	0.4643	0.122
3	2	4	148	1.569	2.994	4.563	0.4643	0.123
3	2	5	148	1.671	3.171	4.842	0.5595	0.134
3	2	6	158.5	1.671	3.284	4.955	0.5595	0.131
3	2	7	158.5	1.790	3.482	5.271	0.6071	0.130
3	2	8	169	1.790	3.426	5.216	0.6071	0.132
3	3	1	149	1.525	2.841	4.365	0.4286	0.121
3	3	2	155	1.525	2.962	4.487	0.4286	0.118
3	3	3	155	1.750	3.162	4.912	0.4286	0.108
3	3	4	161	1.750	3.183	4.933	0.4286	0.107
3	3	5	161	1.818	3.149	4.967	0.4762	0.115
3	3	6	169	1.818	3.237	5.055	0.4762	0.113
3	3	7	169	1.907	3.505	5.413	0.4464	0.101
3	3	8	174	1.907	3.516	5.424	0.4464	0.101
3	4	1	163	1.632	3.370	5.001	0.3929	0.099
3	4	2	168.5	1.632	3.553	5.185	0.3929	0.096
3	4	3	168.5	1.903	3.672	5.575	0.4464	0.098
3	4	4	175.5	1.903	3.471	5.373	0.4464	0.102
3	4	5	175.5	1.981	3.428	5.409	0.4762	0.106
3	4	6	183	1.981	3.593	5.575	0.4762	0.103
3	4	7	183	2.066	3.696	5.762	0.4643	0.098
3	4	8	189	2.066	3.725	5.791	0.4643	0.097
3	5	1	187	2.111	3.500	5.611	0.4643	0.100
3	5	2	193.5	2.111	3.631	5.742	0.4643	0.098
3	5	3	193.5	2.185	4.183	6.368	0.6607	0.115
3	5	4	205.5	2.185	4.386	6.571	0.6607	0.112
3	5	5	205.5	2.320	4.141	6.461	0.6548	0.113
3	5	6	215	2.320	4.276	6.596	0.6548	0.110
3	5	7	215	2.427	4.374	6.801	0.5982	0.100
3	5	8	220.5	2.427	4.305	6.732	0.5982	0.101
4	1	1	108	1.156	2.219	3.375	0.4643	0.167
4	1	2	114.5	1.156	2.607	3.763	0.4643	0.149
4	1	3	114.5	1.145	2.429	3.574	0.3929	0.139
4	1	4	119	1.145	2.557	3.703	0.3929	0.134
4	1	5	119	1.341	2.603	3.944	0.3333	0.111
4	1	6	122	1.341	2.472	3.813	0.3333	0.115
4	1	7	122	1.375	2.723	4.098	0.4732	0.139
4	1	8	134.5	1.375	2.653	4.028	0.4732	0.142
4	2	1	139	1.568	2.600	4.168	0.4643	0.135
4	2	2	145.5	1.568	2.886	4.454	0.4643	0.126
4	2	3	145.5	1.641	3.214	4.854	0.5000	0.122
4	2	4	153	1.641	3.301	4.941	0.5000	0.120
4	2	5	153	1.725	3.138	4.863	0.3810	0.100
4	2	6	155	1.725	3.247	4.972	0.3810	0.098
4	2	8	164	1.747	3.531	5.279	0.4464	0.143

Appendix 2 continued

4	3	1	146	1.583	2.800	4.383	0.5357	0.130
4	3	2	153.5	1.583	3.220	4.803	0.5357	0.109
4	3	3	153.5	1.731	3.267	4.998	0.4464	0.105
4	3	4	158.5	1.731	3.454	5.185	0.4464	0.098
4	3	5	158.5	1.787	3.178	4.965	0.3810	0.099
4	3	6	162	1.787	3.091	4.878	0.3810	0.099
4	3	7	162	1.965	3.383	5.349	0.4286	0.099
4	3	8	174	1.965	3.412	5.378	0.4286	0.029
4	4	1	158	1.951	2.780	4.730	0.0714	0.034
4	4	2	159	1.951	2.162	4.113	0.0714	0.029
4	4	3	159	1.770	2.940	4.710	0.0714	0.028
4	4	4	160	1.770	3.231	5.001	0.0714	0.089
4	4	5	160	1.804	3.414	5.218	0.3571	0.087
4	4	6	173	1.804	3.526	5.330	0.3571	0.094
4	4	7	173	1.951	3.656	5.606	0.4286	0.093
4	4	8	182	1.951	3.740	5.691	0.4286	0.115
4	5	1	173	1.990	3.201	5.191	0.5000	0.107
4	5	2	180	1.990	3.546	5.536	0.5000	0.107
4	5	3	180	2.092	3.310	5.402	0.4821	0.102
4	5	4	186.5	2.092	3.567	5.659	0.4821	0.108
4	5	5	186.5	2.193	3.410	5.602	0.5119	0.111
4	5	6	194.5	2.193	3.284	5.477	0.5119	0.099
4	5	7	194.5	2.266	3.570	5.836	0.4821	0.101
4	5	8	200	2.266	3.450	5.716	0.4821	0.102

TR = Treatment.
REP = Replication
WK = Week
= INW = Initial weight
FE = Feed efficiency

F/D HAY = Feed intake/day Hay
F/D CO = Feed intake/day Concentrates
TDMI = Total dry matter intake
ADG = Average daily gain

Appendix 3: LSMeans of Live weight changes, ruminal H and NH3-N, DM and CP degradability of feed ingredients and treatment rations

1: The LSMeans ±SEM of live weight changes (LWC) (kg) of dairy heifers fed on different treatment ratios

Weeks	TREATMENTS				SEM	Pr > F	SIG.
	TR_1	TR_2	TR_3	TR_4			
2 (kg)	151.31^{ba}	154.09^{a}	149.31^{b}	149.98^{b}	0.986	0.0362	*
4 (kg)	158.70^{b}	162.19^{a}	157.21^{b}	155.30^{b}	1.072	0.0112	*
6 (kg)	164.50^{b}	170.19^{a}	166.10^{b}	161.18^{c}	0.761	0.0002	***
8 (kg)	173.22^{ba}	176.78^{a}	173.22^{ba}	170.76^{b}	1.408	0.0937	NS
LWC	29^{ba}	32^{a}	29^{ba}	26^{b}	1.408	0.0856	NS

NS = Not significant
* = Significant at P < 0.05
*** = Highly significant at P <0.0001
Super script $^{a, b, c}$; means within each row bearing same letter are not significantly different at P<0.05

2: LSMeans ±SEM of ruminal pH from fistulated cows fed on treatment rations

HOUR	TREATMENTS				SEM	Pr > F	SIG
	TR_1	TR_2	TR_3	TR_4			
0	6.9^{a}	6.7^{bc}	6.2^{c}	6.8^{a}	0.117	0.0040	**
2	6.3^{b}	6.2^{bc}	5.9^{c}	6.6^{a}	0.084	0.0011	**
4	5.9^{a}	5.5^{b}	5.8^{a}	5.8^{a}	0.077	0.0156	*
6	5.9^{a}	5.5^{b}	5.7^{a}	5.5^{b}	0.097	0.0058	**
8	6.1^{a}	5.6^{b}	5.9^{ba}	5.8^{ba}	0.106	0.0302	*
10	6.1^{a}	5.9^{a}	5.9^{a}	6.0^{a}	0.117	0.5997	NS
12	6.3^{a}	5.9^{b}	6.0^{a}	6.0^{ba}	0.092	0.0931	NS
14	6.2^{a}	6.3^{a}	6.0^{b}	6.4^{a}	0.084	0.0387	*
16	6.4^{a}	6.4^{a}	6.0^{b}	6.4^{a}	0.089	0.0083	**
18	6.5^{a}	6.4^{a}	6.4^{a}	6.5^{a}	0.070	0.3914	NS
20	6.6^{a}	6.7^{a}	6.4^{a}	6.6^{a}	0.113	0.4861	NS
22	6.7^{a}	6.8^{a}	6.7^{a}	6.5^{a}	0.126	0.3902	NS
24	6.9^{a}	6.9^{a}	6.9^{a}	6.8^{a}	0.110	0.6841	NS
Mean	6.4^{a}	6.2^{c}	6.1^{d}	6.3^{b}	0.099	0.0001	***

NS = Not significant
* = Significant at P < 0.05
** = Significant at P < 0.01
*** = Highly significant at P <0.0001
Super script $^{a, b, c, d}$; means within each row bearing same letter are not significantly different at P<0.05

Appendix 3 continued

3: LSMeans ±SEM of ruminal NH_3-N (mg/l) from fistulated cows fed on treatment rations

HOUR	TREATMENTS				SEM	Pr > F	SIG
	TR_1	TR_2	TR_3	TR_4			
0	142.5^{c}	210.0^{b}	312.1^{a}	203.2^{b}	19.24	0.0004	***
2	397.2^{ba}	309.5^{b}	429.2^{a}	330.6^{b}	30.67	0.0561	NS
4	226.0^{b}	200.7^{b}	422.5^{a}	232.8^{b}	37.08	0.0041	**
6	142.5^{b}	179.5^{b}	311.2^{a}	140.8^{b}	26.77	0.0021	**
8	92.8^{b}	176.3^{ba}	255.5^{a}	163.0^{b}	28.85	0.0143	*
10	73.4^{b}	174.2^{ba}	267.3^{a}	168.6^{ba}	34.29	0.0144	*
12	104.6^{b}	156.9^{ba}	233.6^{a}	192.3^{ba}	30.98	0.0663	NS
14	69.2^{c}	144.2^{bc}	245.4^{a}	192.3^{ba}	26.46	0.0034	**
16	81.0^{c}	152.6^{b}	226.0^{a}	196.5^{ba}	20.8	0.0020	**
18	88.6^{c}	151.8^{bc}	216.8^{a}	191.5^{ba}	20.89	0.0046	**
20	102.0^{c}	173.7^{b}	246.2^{a}	196.8^{ba}	19.61	0.0019	**
22	118.1^{c}	184.7^{b}	258.1^{a}	218.4^{ba}	14.84	0.0002	***
24	128.2^{d}	177.9^{c}	264.0^{a}	221.8^{b}	12.36	0.0001	***
Mean	135.8^{d}	183.9^{c}	283.7^{a}	203.7^{b}	24.81	0.0001	***

NS = Not significant
* = Significant at P < 0.05
** = Significant at P < 0.01
*** = Highly significant at P <0.0001
Super script $^{a, b, c, d}$; means within each row bearing same letter are not significantly different at P<0.05

4: LSMeans ± SEM DM degradation characteristics a, b, (g/kg DM), c (h^{-1}) 48h and metabolizable energy (ME) (MJ/kg DM) of the experimental feeds

Feed ingredient	a	b	a+b	48h	c	ME
FW	116^{c}	2967^{c}	413^{c}	397^{d}	0.069^{b}	5.5^{d}
CSC	285^{c}	537^{b}	822^{b}	739^{c}	0.046^{b}	10.8^{c}
HM	356^{b}	622^{a}	978^{a}	835^{b}	0.031^{b}	12.3^{b}
CRM	603^{a}	322^{c}	925^{a}	920^{a}	0.153^{a}	13.7^{a}
Hay	152^{d}	234^{d}	386^{c}	362^{d}	0.058^{b}	4.9^{d}
SEM	0.770	1.815	1.619	1.435	0.024	0.328
Pr > F	0.0001	0.0001	0.0001	0.0001	0.0378	0.0001
Significance	***	***	***	***	*	***

ME= 0.16*DOMD% and DOMD%= 0.98 DMD%-4.8 and DMD%= 48h DM
* = Significant at P< 0.05
*** = Highly significant at P <0.0001
Super script $^{a, b, c, d}$; means within each column bearing same letter are not significantly different at P<0.05

Appendix 3 continued

5: LSMeans ± SEM CP degradation characteristics a, b, (g/kg DM), 48.h and c (h^{-1}) of the experimental feeds

Feed ingredient	a	b	a+b	48.h	c
FW	277^{e}	378^{bc}	635^{c}	598^{c}	0.053^{a}
CSC	400^{d}	551^{a}	921^{a}	887^{b}	0.068^{a}
HM	510^{c}	464^{ba}	974^{a}	946^{a}	0.061^{a}
CRM	657^{a}	236^{dc}	893^{a}	837^{c}	0.743^{a}
Hay	594^{b}	199^{d}	794^{b}	749^{d}	0.031
SEM	1.848	4.377	2.803	1.186	0.283
Pr > F	0.0001	0.0013	0.0001	0.0001	0.3793
Significance	***	*	***	***	NS

NS = Not significant

* = Significant at P < 0.05

*** = Highly significant at P <0.0001

Super script $^{a, b, c, d,}$; means within each column bearing same letter are not significantly different at P<0.05

6: LSMeans ± SEM DM degradation characteristics a, b, (g/kg DM), 48.h, c (h^{-1}) and Metabolizable energy (ME) (MJ/kg DM) of the treatment rations

Feed	a	b	a +b	48h	c	ME	DMD■	OMD■
TR1ons	328^{b}	656^{a}	983^{a}	807^{a}	0.024^{cb}	11.9^{a}	684	736
TR_2	237^{c}	566^{b}	803^{c}	791^{ba}	0.089^{a}	11.7^{a}	733	793
TR_3	333^{b}	586^{b}	920^{b}	727^{b}	0.019^{c}	10.6^{b}	639	77
TR_4	418^{a}	268^{c}	682^{d}	616^{c}	0.034^{b}	8.9^{c}	719	840
SEM	0.473	2.478	2.209	2.021	0.005	0.209		
Pr > F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Significan	***	***	***	***	***	***		

ME= 0.16*DOMD% and DOMD%= 0.98 DMD%-4.8 and DMD%= 48h DM

*** = Highly significant at P <0.0001

■= Invitro: 48h Dry matter digestibility (DMD) and Organic matter digestibility (OMD)

Super script $^{a, b, c, d,}$; means within each column bearing same letter are not significantly different at P<0.05

Appendix 3 continued

7: LSMeans ± SEM CP degradation characteristics a, b, (g/kg DM), 48h and c (h^{-1}) of the treatment rations

Feed rations	a	b	a +b	48h 48	c
TR_1	406^{a}	562^{ba}	968^{a}	828^{a}	0.028^{ba}
TR_2	406^{a}	547^{ba}	953^{a}	825^{a}	0.032^{a}
TR_3	375^{b}	616^{a}	990^{a}	667^{b}	0.012^{c}
TR_4	321^{c}	487^{b}	808^{b}	605^{b}	0.020^{c}
SEM	0.626	3.155	2.879	2.902	0.003
Pr > F	0.0001	0.0882	0.0030	0.0002	0.0013
Significance	***	NS	*	***	**

NS = Not significant
* = Significant at P < 0.05
** = Significant at P < 0.01
*** = Highly significant at P <0.0001
Super script $^{a, b, c, d,}$ denote means within each column bearing same letter are not significantly different at P<0.05

Appendix 3 continued

7: LSMeans ± SEM CP degradation characteristics a, b, (g/kg DM), 48h and c (h^{-1}) of the treatment rations

Feed rations	a	b	a +b	48h 48	c
TR_1	406^{a}	562^{ba}	968^{a}	828^{a}	0.028^{ba}
TR_2	406^{a}	547^{ba}	953^{a}	825^{a}	0.032^{a}
TR_3	375^{b}	616^{a}	990^{a}	667^{b}	0.012^{c}
TR_4	321^{c}	487^{b}	808^{b}	605^{b}	0.020^{c}
SEM	0.626	3.155	2.879	2.902	0.003
Pr > F	0.0001	0.0882	0.0030	0.0002	0.0013
Significance	***	NS	*	***	**

NS = Not significant
* = Significant at P < 0.05
** = Significant at P < 0.01
*** = Highly significant at P <0.0001
Super script [a, b, c, d.] denote means within each column bearing same letter are not significantly different at P<0.05

Appendix 4: Live weight gained of weaner heifers

TR	IDN	CODE	IA(MO)	WKO	WK2	WK4	WK6	WK8	WTG
TR_1	2012	TR_1-1	7	97	101	108	109	121.5	24.5
TR_1	9908	TR_1-2	19	137	143	151	159	164.5	27.5
TR_1	9929	TR_1-3	19	141	147.5	154	161	169	28
TR_1	9930	TR_1-4	13	153	162.5	169	174	181	28
TR_1	9922	TR_1-5	17	194	202	211	219	229.5	35.5
TR_2	9902	TR_2-1	11.5	120	129	136.5	143.5	146.5	26.5
TR_2	2009	TR_2-2	9.5	139	151.5	158	169.5	176	37
TR_2	2004	TR_2-3	12.5	142	155	163.5	170.5	178	36
TR_2	9920	TR_2-4	18	154	159	167	172.5	181.5	27.5
TR_2	9907	TR_2-5	20	168	176	186	195	202	34
TR_3	2015	TR_3-1	4	88	90	95.5	104.5	113	25
TR_3	2011	TR_3-2	7	135	139	148	158.5	169	34
TR_3	2002	TR_3-3	13	149	155	161	169	174	25
TR_3	9906	TR_3-4	20	163	168.5	175.5	183	189	26
TR_3	9925	TR_3-5	15	187	193.5	205.5	215	220.5	33.5
TR_4	2010	TR_4-1	8	108	114.5	119	122	134.5	26.5
TR_4	2003	TR_4-2	13	139	145.5	153	155	154	25
TR_4	9928	TR_4-3	14	146	153.5	158.5	162	174	28
TR_4	9735	TR_4-4	13.5	158	157	160	173	182	24
TR_4	9910	TR_4-5	19	173	180	186.5	194.5	200	27

TR = Treatment WK = Week WTG = Weight gained in 8 weeks

IDN = Identification number IA = Initial age in months.

Appendix 5: Blood plasma parameters

TRM	REP	WK	PROTEIN (g/l)	P (mmol/l)	Ca (mmol/l)	SUGAR (mmol/l)
1	1	0	82.2	1.2	2.26	2.75
1	1	1	90.3	1.3	2.23	3.32
1	1	2	104	1.22	2.39	2.47
1	1	3	89.4	1.23	2.36	3.3
1	1	4	84.6	1.15	2.41	2.96
1	1	5	103	1.21	2.33	3.18
1	1	6	85.5	1.19	2.44	2.65
1	1	7	83.1	1.16	2.4	2.76
1	1	8	76.4	1.23	2.33	3.08
1	2	0	81.4	1.15	2.27	3.74
1	2	1	96.5	1.15	2.08	2.92
1	2	2	97.2	1.23	2.18	3.07
1	2	3	87.5	1.24	2.13	3.43
1	2	4	88.5	1.17	2.17	3.49
1	2	5	97.7	1.1	2.3	3.47
1	2	6	85.2	1.05	2.31	3.5
1	2	7	86.8	1.14	2.17	3.2
1	2	8	87	1.27	2.38	2.97
1	3	0	85.4	1.05	2.28	3.06
1	3	1	97.2	1.25	2.15	3.16
1	3	2	84.3	1.24	2.32	3.68
1	3	3	93.1	1.29	2.23	3.17
1	3	4	91.7	1.02	2.36	3.45
1	3	5	89.8	1.1	2.32	3.43
1	3	6	86.6	1.25	2.06	3.54
1	3	7	88.4	1.23	2.43	3.55
1	3	8	82.1	1.28	2.26	3.3
1	4	0	73.4	1.27	2.33	2.86
1	4	1	93.6	1.3	2.27	3.06
1	4	2	107	1.26	2.26	2.85
1	4	3	102	1.28	2.28	2.93
1	4	4	98.4	1.01	2.37	2.94
1	4	5	95.1	1.05	2.32	3
1	4	6	88.9	1.3	2.39	3.08
1	4	7	88.9	1.26	2.39	3.25
1	4	8	87.2	1.3	2.36	3.08
1	5	0	83.4	1.24	2.07	3.43
1	5	1	85.9	1.4	2.08	3.22
1	5	2	91.9	1.24	2.13	2.63
1	5	3	103	1.3	2.13	3.36

Appendix 5 cont.

1	5	4	98.4	1.02	2.21	2.85
1	5	5	104	1.18	2.45	3.52
1	5	6	87.5	1.2	2.2	2.46
1	5	7	92.7	1.48	2.36	3.34
1	5	8	88	1.46	2.4	3.45
2	1	0	93.4	1.19	2.2	3.57
2	1	1	92.3	1.46	2.04	3.63
2	1	2	100	1.22	2.27	2.93
2	1	3	109	1.3	2.23	2.95
2	1	4	92.9	1.12	2.51	3.49
2	1	5	94.4	1.17	2.38	3.76
2	1	6	90.5	1.23	2.3	3.75
2	1	7	99.3	1.26	2.4	3.51
2	1	8	88.9	1.36	2.31	3.39
2	2	0	94.2	1.03	2.22	3.6
2	2	1	91.4	1.36	2.18	3.56
2	2	2	103	1.26	2.43	2.83
2	2	3	86.2	1.29	2.48	2.84
2	2	4	97.9	1.07	2.56	2.87
2	2	5	96.5	1.2	2.48	3.65
2	2	6	86.9	1.22	2.66	3.18
2	2	7	87.5	1.2	2.6	2.92
2	2	8	79.5	1.37	2.46	2.91
2	3	0	83.9	1.07	2.09	3.45
2	3	1	103	1.31	2.27	3.7
2	3	2	108	1.29	2.47	3.12
2	3	3	104	1.22	2.46	3.24
2	3	4	112	1.03	2.42	3.28
2	3	5	97.3	1.16	2.48	3.51
2	3	6	97	1.14	2.28	3.11
2	3	7	99.6	1.22	2.66	2.97
2	3	8	90.7	1.4	2.46	3.32
2	4	0	85.5	1.24	2.16	3.82
2	4	1	90.2	1.45	2.08	3.29
2	4	2	106	1.32	2.28	3.09
2	4	3	104	1.4	2.35	3.94
2	4	4	99.2	1.16	2.33	3.26
2	4	5	112	1.21	2.47	3.66
2	4	6	99.6	1.15	2.28	3.41
2	4	7	107	1.21	2.54	3.53
2	4	8	91.3	1.38	2.42	3.05
2	5	0	86.2	1.1	2.29	3.31

Appendix 5 cont.

2	5	1	86	1.3	2.25	3.35
2	5	2	115	1.46	2.08	2.99
2	5	3	110	1.53	2.23	3.12
2	5	4	106	1.22	2.3	3.1
2	5	5	114	1.27	2.46	3.18
2	5	6	86.7	1.25	2.38	2.81
2	5	7	94.2	1.33	2.58	3.41
2	5	8	96	1.42	2.37	3.15
3	1	0	78.7	1.03	2.25	3.06
3	1	1	97.3	1.23	2.36	3.37
3	1	2	102	1.44	2.18	3
3	1	3	97.7	1.37	2.43	3.26
3	1	4	103	1.4	2.31	2.88
3	1	5	89.3	1.4	2.75	3.4
3	1	6	85.1	1.36	2.65	3.15
3	1	7	71.8	1.46	2.61	3.35
3	1	8	81.2	1.52	2.44	3.24
3	2	0	84.5	1.09	2.31	3.51
3	2	1	96	1.28	2.23	3.29
3	2	2	103	1.32	2.04	2.9
3	2	3	94	1.46	2.4	3.51
3	2	4	98.3	1.3	2.51	3.24
3	2	5	84.1	1.31	2.71	3.54
3	2	6	90.2	1.42	2.5	3.49
3	2	7	85.4	1.4	2.64	2.7
3	2	8	78.5	1.56	2.51	3.46
3	3	0	85.7	1.07	2.31	2.89
3	3	1	92	1.46	2.25	2.78
3	3	2	93.5	1.42	2.27	2.72
3	3	3	99.7	1.53	2.35	2.95
3	3	4	93.1	1.41	2.52	3.04
3	3	5	80.4	1.35	2.5	3.28
3	3	6	84.9	1.52	2.67	3.6
3	3	7	86	1.52	2.3	3.5
3	3	8	81	1.38	2.53	2.92
3	4	0	87.7	1.05	2.27	2.83
3	4	1	93.4	1.4	2.41	2.77
3	4	2	93.9	1.32	2.14	3.42
3	4	3	100	1.32	2.21	2.93
3	4	4	102	1.21	2.46	2.94
3	4	5	100	1.26	2.33	3.37
3	4	6	95.5	1.4	2.38	3.5

Appendix 5 cont.

3	4	7	97.2	1.42	2.53	3.25
3	4	8	83.7	1.51	2.5	3.12
3	5	0	86.8	1.06	2.3	2.81
3	5	1	102	1.52	2.09	3.31
3	5	2	100	1.53	2.29	3.45
3	5	3	105	1.54	2.15	2.7
3	5	4	112	1.52	2.37	3.42
3	5	5	94.9	1.43	2.72	3.03
3	5	6	100	1.48	2.4	2.95
3	5	7	97.1	1.46	2.54	3.25
3	5	8	86.8	1.7	2.42	2.54
4	1	0	93	1.06	2.37	2.71
4	1	1	101	1.76	2.11	2.94
4	1	2	105	1.7	2.08	2.74
4	1	3	94.4	1.9	2.12	2.55
4	1	4	95.3	1.6	2.11	3.22
4	1	5	87	1.8	2.38	3.68
4	1	6	82.3	1.73	2.31	3.37
4	1	7	82	1.7	2.38	3.61
4	1	8	109	1.7	2.27	2.85
4	2	0	88.5	1.28	2.05	2.77
4	2	1	105	1.56	2.38	3.05
4	2	2	111	1.52	2.26	3.11
4	2	3	90.2	1.62	2.2	2.95
4	2	4	93.7	1.62	2.29	3.36
4	2	5	103	1.42	2.76	3.44
4	2	6	93.1	1.56	2.61	3.51
4	2	7	89.1	1.59	2.5	3.03
4	2	8	89.6	1.9	2.41	3.24
4	3	0	89.6	1.11	2.17	2.09
4	3	1	118	1.84	2.01	3
4	3	2	100	1.85	2.21	3.55
4	3	3	98.7	1.83	2.28	3.2
4	3	4	88.7	1.72	2.18	2.9
4	3	5	84.9	1.71	2.3	3.06
4	3	6	85.1	1.75	2.38	3.21
4	3	7	84.2	1.67	2.47	2.98
4	3	8	85.2	1.92	2.37	2.62
4	4	0	87.9	1.05	2.08	3.09
4	4	1	105	1.52	2.37	2.76
4	4	2	103	1.48	2.35	2.76
4	4	3	87.5	1.72	2.28	2.63

Appendix 5 cont.

4	4	4	95.2	1.6	2.21	2.97
4	4	5	86.2	1.69	2.65	2.69
4	4	6	90	1.52	2.44	3.12
4	4	7	91.6	1.44	2.78	3.26
4	4	8	94	1.7	2.29	2.56
4	5	0	89.1	1.23	2.29	3.45
4	5	1	110	1.74	2.44	3.16
4	5	2	101	1.52	2.3	2.41
4	5	3	97.2	1.56	2.32	3.15
4	5	4	108	1.45	2.36	2.99
4	5	5	96.5	1.54	2.54	2.46
4	5	6	103	1.48	2.62	2.48
4	5	7	85.3	1.45	2.46	3.55
4	5	8	91.7	1.68	2.38	2.89

Appendix 6: Ruminal pH and Ruminal ammonia nitrogen (mg/l)

TREAT	REP	TIME	PH	NH_3-N
1	1	0	6.83	148.42
1	1	2	6.4	381.17
1	1	4	6.04	192.27
1	1	6	6.05	121.43
1	1	8	6.23	104.57
1	1	10	6.31	84.33
1	1	12	6.3	80.96
1	1	14	6.22	77.58
1	1	16	6.48	101.19
1	1	18	6.57	104.57
1	1	20	6.66	114.69
1	1	22	6.66	128.18
1	1	24	6.84	148.42
1	2	0	6.57	256.36
1	2	2	6.04	195.64
1	2	4	5.43	101.2
1	2	6	5.43	158.54
1	2	8	5.52	151.79
1	2	10	5.78	131.65
1	2	12	6.04	141.67
1	2	14	6.3	138.3
1	2	16	6.48	128.18
1	2	18	6.48	104.57
1	2	20	6.48	148.42
1	2	22	6.65	145.05
1	2	24	6.83	134.93
1	3	0	5.58	377.79
1	3	2	6.03	414.9
1	3	4	5.69	49.22
1	3	6	6	374.42
1	3	8	5.76	337.31
1	3	10	5.68	411.52
1	3	12	5.94	337.31
1	3	14	5.76	360.93
1	3	16	5.76	263.1
1	3	18	6.3	252.99
1	3	20	6.03	273.22
1	3	22	5.85	252.99
1	3	24	6.38	246.24
1	4	0	6.65	226
1	4	2	6.4	354.18

Appendix 6 continued

1	4	4	5.95	236.12
1	4	6	5.68	134.3
1	4	8	5.87	156.16
1	4	10	6.13	178.57
1	4	12	5.96	188.9
1	4	14	6.3	246.24
1	4	16	6.39	229.37
1	4	18	6.39	242.87
1	4	20	6.64	222.63
1	4	22	6.64	222.63
1	4	24	6.73	239.49
2	1	0	7.02	131.55
2	1	2	6.05	408.15
2	1	4	5.87	236.12
2	1	6	6.05	91.08
2	1	8	6.23	70.84
2	1	10	6.23	50.6
2	1	12	6.4	70.84
2	1	14	6.31	57.34
2	1	16	6.49	57.34
2	1	18	6.48	70.84
2	1	20	6.57	74.21
2	1	22	6.66	104.57
2	1	24	7.02	114.69
2	2	0	6.84	172.03
2	2	2	6.32	357.55
2	2	4	5.7	185.52
2	2	6	5.44	114.06
2	2	8	5.62	97.82
2	2	10	6.13	92.52
2	2	12	6.13	121.43
2	2	14	6.3	107.94
2	2	16	6.39	124.31
2	2	18	6.39	161.91
2	2	20	6.66	182.15
2	2	22	6.85	192.27
2	2	24	7.01	188.9
2	3	0	6.56	229.67
2	3	2	5.94	360.93
2	3	4	5.85	286.72
2	3	6	5.68	212.51
2	3	8	5.78	141.67

Appendix 6 continued

2	3	10	5.76	155.16
2	3	12	5.85	134.93
2	3	14	5.85	148.42
2	3	16	5.85	175.4
2	3	18	6.47	175.5
2	3	20	6.83	199.02
2	3	22	6.91	273.22
2	3	24	7.09	263.11
2	4	0	6.83	178.78
2	4	2	6.48	313.7
2	4	4	5.87	204.76
2	4	6	5.51	141.67
2	4	8	5.52	131.55
2	4	10	5.61	111.31
2	4	12	5.77	128.18
2	4	14	6.13	131.55
2	4	16	6.21	114.69
2	4	18	6.29	114.69
2	4	20	6.3	128.18
2	4	22	6.47	172.03
2	4	24	6.73	182.15
3	1	0	7.02	128.18
3	1	2	6.31	425.02
3	1	4	5.69	263.15
3	1	6	5.96	138.3
3	1	8	6.14	67.46
3	1	10	6.13	67.46
3	1	12	6.13	67.46
3	1	14	6.14	80.96
3	1	16	6.4	97.82
3	1	18	6.48	91.08
3	1	20	6.54	131.55
3	1	22	6.84	118.06
3	1	24	7.02	118.06
3	2	0	6.84	226
3	2	2	6.32	411.52
3	2	4	5.52	256.36
3	2	6	5.88	202.39
3	2	8	5.96	192.27
3	2	10	5.96	229.37
3	2	12	5.78	165.28
3	2	14	6.21	168.66

Appendix 6 continued

3	2	16	6.21	195.64
3	2	18	6.21	165.28
3	2	20	6.55	199.02
3	2	22	6.66	229.37
3	2	24	6.92	202.39
3	3	0	6.38	310.33
3	3	2	5.94	411.52
3	3	4	5.78	354.18
3	3	6	5.69	293.46
3	3	8	5.95	263.11
3	3	10	5.94	239.49
3	3	12	5.95	232.75
3	3	14	5.94	219.35
3	3	16	5.94	229.37
3	3	18	6.21	215.88
3	3	20	6.3	232.75
3	3	22	6.56	239.49
3	3	24	6.56	290.09
3	4	0	6.83	205.76
3	4	2	6.83	340.69
3	4	4	5.87	232.75
3	4	6	5.43	134.93
3	4	8	5.78	161.91
3	4	10	6.13	174.4
3	4	12	6.13	182.15
3	4	14	6.3	175.4
3	4	16	6.39	182.15
3	4	18	6.47	165.28
3	4	20	6.47	165.8
3	4	22	6.64	202.39
3	4	24	6.91	212.51
4	1	0	7.02	161.91
4	1	2	6.48	374.42
4	1	4	6.04	212.51
4	1	6	5.87	219.26
4	1	8	5.96	128.18
4	1	10	5.87	91.08
4	1	12	6.23	199.02
4	1	14	6.22	60.72
4	1	16	6.31	67.46
4	1	18	6.48	87.7
4	1	20	6.66	87.57

Appendix 6 continued

4	1	22	6.84	121.43
4	1	24	6.92	131.55
4	2	0	6.66	185.52
4	2	2	5.96	273.22
4	2	4	5.34	259.73
4	2	6	5.18	239.49
4	2	8	5.34	263.11
4	2	10	5.87	242.57
4	2	12	5.69	199.02
4	2	14	6.21	161.91
4	2	16	6.31	161.91
4	2	18	6.31	175.4
4	2	20	6.92	165.28
4	2	22	6.83	172.03
4	2	24	7.01	185.52
4	3	0	6.31	330.57
4	3	2	5.94	529.58
4	3	4	5.78	549.82
4	3	6	5.94	364.3
4	3	8	5.96	279.97
4	3	10	6.38	263.11
4	3	12	6.3	229.37
4	3	14	6.3	252.99
4	3	16	6.3	236.12
4	3	18	6.56	222.63
4	3	20	6.48	279.97
4	3	22	6.56	266.48
4	3	24	7.09	256.36
4	4	0	6.74	202.39
4	4	2	6.74	313.7
4	4	4	5.51	256.36
4	4	6	5.26	151.79
4	4	8	6.22	202.39
4	4	10	6.04	209.13
4	4	12	6.22	269.85
4	4	14	6.66	215.88
4	4	16	6.74	259.73
4	4	18	6.74	263.11
4	4	20	6.83	263.11
4	4	22	6.91	276.6
4	4	24	7.18	252.99

Appendix 7: Degradability characteristics of feed ingredients and treatment ratios

DM DEGRA.FW ANIMAL 1

A= 13.40	B= 24.55	C= .0398	RSD= 3.03				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		10.70	21.98	24.84	25.63	32.64	38.11	37.63
Fitted values		13.40	18.62	22.73	28.51	34.32	36.55	37.41
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		33.0	29.7	27.4	25.6	24.3	23.2	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		22.3	21.6	20.9	20.4	19.9	19.5	

DM DEGRA.FW ANIMAL 2

A= 12.08	B= 28.36	C= .0755	RSD= 2.89				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		10.70	24.87	29.74	33.35	36.42	42.69	41.99
Fitted values		12.08	22.42	28.99	35.82	39.69	40.33	40.43
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		37.1	34.5	32.4	30.6	29.2	27.9	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		26.8	25.9	25.0	24.3	23.6	23.0	

DM DEGRA.FW ANIMAL 3

A= 9.39	B= 36.03	C= .0917	RSD= 4.62				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		10.70	19.73	38.05	41.63	42.03	42.48	50.04
Fitted values		9.39	24.64	33.44	41.43	44.98	45.37	45.41
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		41.9	39.0	36.5	34.5	32.7	31.2	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		29.8	28.6	27.6	26.6	25.8	25.0	

DM DEGRA. CSC ANIMAL 1

A= 30.45	B= 54.22	C= .0253	RSD= 6.05				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		26.36	45.30	46.01	47.43	71.94	77.46	78.24
Fitted values		30.45	38.09	44.66	55.14	68.59	75.91	79.90
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		69.3	60.7	55.3	51.5	48.7	46.5	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		44.9	43.5	42.4	41.4	40.6	39.9	

DM DEGRA.CSC ANIMAL 2

A= 28.60	B= 52.33	C= .0423	RSD= 3.41				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		26.36	42.19	52.63	59.27	73.41	75.54	83.43
Fitted values		28.60	40.33	49.43	61.97	74.06	78.44	80.02
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		70.9	64.1	59.2	55.5	52.6	50.2	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		48.3	46.7	45.3	44.2	43.1	42.2	

Appendix 7 cont.

DM DEGRA.CSC ANIMAL 3

A= 26.50	B= 54.39	C= .0711	RSD= 1.67				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	26.36	45.86	57.02	72.18	77.24	79.55	82.97
Fitted values	26.50	45.40	57.73	71.03	79.11	80.57	80.84
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	74.2	69.0	64.8	61.3	58.4	56.0	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	53.9	52.1	50.5	49.1	47.9	46.7	

* *

DM DEGRA.HM ANIMAL 1

A= 36.92	B= 60.15	C= .0313	RSD= 2.87				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	35.60	48.17	58.73	64.63	85.71	89.81	94.36
Fitted values	36.92	47.21	55.74	68.67	83.66	90.74	94.08
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	82.5	73.6	67.6	63.3	60.1	57.5	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	55.5	53.8	52.4	51.2	50.2	49.4	

* *

DM DEGRA.HM ANIMAL 2

A= 34.22	B= 64.24	C= .0301	RSD= 2.27				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	35.60	42.08	55.53	65.62	85.44	90.48	94.48
Fitted values	34.22	44.82	53.68	67.24	83.29	91.09	94.88
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	82.4	72.8	66.4	61.8	58.3	55.7	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	53.5	51.8	50.3	49.1	48.0	47.1	

* *

DM DEGRA HM ANIMAL 3

A= 35.58	B= 62.20	C= .0306	RSD= 2.22				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	35.60	45.13	57.13	65.13	85.58	90.15	94.42
Fitted values	35.58	46.02	54.71	67.95	83.47	90.92	94.49
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	82.5	73.2	67.0	62.5	59.2	56.6	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	54.5	52.8	51.4	50.2	49.1	48.2	

* *

DM DEGRA. CRM ANIMAL 1

A= 61.34	B= 29.74	C= .1838	RSD= 2.19				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	60.96	83.52	84.41	90.31	91.25	91.40	92.47
Fitted values	61.34	81.21	87.81	90.72	91.08	91.08	91.08
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	89.5	88.2	86.9	85.8	84.7	83.8	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	82.9	82.1	81.3	80.6	79.9	79.3	

* *

Appendix 7 cont.

DM DEGRA. CRM ANIMAL 2

A= 58.60	B= 35.87	C= .0660	RSD= 4.19				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	60.96	63.96	81.65	89.31	91.50	92.43	95.99
Fitted values	58.60	70.33	78.22	87.11	92.96	94.17	94.41
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	89.8	86.1	83.3	80.9	79.0	77.4	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	76.0	74.8	73.8	72.9	72.1	71.3	

DM DEGRA. CRM ANIMAL 3

A= 60.91	B= 30.95	C= .2101	RSD= .63				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	60.96	82.72	90.13	90.96	91.47	92.04	92.32
Fitted values	60.91	83.08	89.37	91.66	91.86	91.86	91.86
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	90.5	89.2	88.0	86.9	85.9	85.0	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	84.1	83.3	82.6	81.9	81.2	80.6	

DM DEGRA. HAY ANIMAL 1

A= 14.79	B= 18.90	C= .0905	RSD= 6.32				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	15.06	23.52	23.92	34.52	37.09	39.10	23.90
Fitted values	14.79	22.71	27.31	31.53	33.44	33.66	33.68
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	31.8	30.3	29.0	27.9	27.0	26.2	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	25.4	24.8	24.3	23.8	23.3	22.9	

DM DEGRA.HAY ANIMAL 2

A= 16.27	B= 22.52	C= .0404	RSD= 1.45				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	15.06	22.29	26.47	28.70	34.91	37.69	38.88
Fitted values	16.27	21.12	24.92	30.25	35.55	37.56	38.32
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	34.3	31.3	29.2	27.6	26.3	25.3	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	24.5	23.8	23.2	22.8	22.3	21.9	

DM DEGRA. HAY ANIMAL 3

A= 14.64	B= 28.77	C= .0422	RSD= 1.37				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	15.06	21.46	23.98	34.22	40.37	41.25	42.91
Fitted values	14.64	21.07	26.06	32.95	39.61	42.02	42.90
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	37.9	34.2	31.4	29.4	27.8	26.5	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	25.5	24.6	23.8	23.2	22.6	22.1	

Appendix 7 cont.

CP DEGRA. FW ANIMAL 1

A= 26.73 B= 37.59 C= .0339 RSD= 2.16

Times	0.	6.	12.	24.	48.	72.	96.
Measurements	24.78	36.04	40.92	45.14	56.83	61.37	63.06
Fitted values	26.73	33.64	39.29	47.65	56.93	61.04	62.87
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	55.8	50.4	46.7	44.0	41.9	40.3	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	39.0	37.9	37.0	36.2	35.6	35.0	

CP DEGRA.FW ANIMAL 2

A= 25.79 B= 35.63 C= .0555 RSD= 3.23

Times	0.	6.	12.	24.	48.	72.	96.
Measurements	24.78	35.76	46.37	50.97	54.30	61.83	63.75
Fitted values	25.79	35.88	43.11	52.01	58.94	60.77	61.25
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	56.0	52.0	48.9	46.5	44.5	42.9	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	41.5	40.4	39.4	38.5	37.7	37.1	

CP DEGRA.FW ANIMAL 3

A= 24.58 B= 40.27 C= .0710 RSD= 5.60

Times	0.	6.	12.	24.	48.	72.	96.
Measurements	24.78	36.00	51.61	57.34	58.00	60.94	72.52
Fitted values	24.58	38.54	47.66	57.51	63.51	64.60	64.80
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	59.9	56.0	52.9	50.3	48.2	46.4	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	44.8	43.5	42.3	41.3	40.4	39.5	

CP DEGRA CSC ANIMAL 1

A= 39.68 B= 53.42 C= .0401 RSD= 6.15

Times	0.	6.	12.	24.	48.	72.	96.
Measurements	34.58	58.35	63.56	65.02	86.40	90.60	92.47
Fitted values	39.68	51.11	60.09	72.71	85.31	90.12	91.96
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	82.4	75.3	70.2	66.4	63.5	61.1	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	59.1	57.5	56.2	55.0	54.0	53.1	

CP DEGRA.CSC ANIMAL 2

A= 36.50 B= 53.98 C= .0756 RSD= 4.01

Times	0.	6.	12.	24.	48.	72.	96.
Measurements	34.58	59.20	70.90	76.32	87.99	89.32	94.44
Fitted values	36.50	56.17	68.68	81.68	89.04	90.24	90.44
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	84.2	79.2	75.1	71.8	69.0	66.6	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	64.5	62.7	61.1	59.7	58.5	57.4	

Appendix 7 cont.

CP DEGRA. CSC ANIMAL 3

A= 34.68	B= 57.89	C= .0896	RSD= 1.73				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	34.58	58.49	73.91	84.95	90.01	91.84	95.09
Fitted values	34.68	58.75	72.81	85.82	91.78	92.48	92.56
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	86.8	82.0	78.0	74.7	71.8	69.3	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	67.2	65.3	63.6	62.0	60.7	59.4	

CP DEGRA.HM ANIMAL 1

A= 51.50	B= 44.88	C= .0657	RSD= 2.16				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	50.11	68.31	77.09	84.41	93.43	96.24	97.84
Fitted values	51.50	66.12	75.97	87.10	94.46	95.99	96.30
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	90.5	85.9	82.3	79.4	77.0	75.0	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	73.2	71.7	70.4	69.3	68.3	67.4	

CP DEGRA. HM ANIMAL 2

A= 51.47	B= 46.62	C= .0675	RSD= 2.25				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	50.11	70.61	75.52	87.65	96.93	97.59	98.33
Fitted values	51.47	67.01	77.36	88.88	96.27	97.73	98.02
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	92.1	87.4	83.8	80.8	78.3	76.2	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	74.4	72.8	71.5	70.3	69.2	68.3	

CP DEGRA.HM ANIMAL 3

A= 50.02	B= 47.67	C= .0484	RSD= 1.83				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	50.11	60.49	73.79	81.10	93.27	95.73	97.77
Fitted values	50.02	62.02	71.00	82.75	93.01	96.22	97.23
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	89.5	83.7	79.4	76.1	73.5	71.3	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	69.5	68.0	66.7	65.6	64.6	63.7	

CP DEGRA. CRM ANIMAL 1

A= 69.39	B= 10.81	C= 2.0238	RSD= 2.25				
Times	0.	6.	12.	24.	48.	72.	96.
Measurements	69.39	80.30	78.30	78.45	79.30	81.22	83.62
Fitted values	69.39	80.20	80.20	80.20	80.20	80.20	80.20
K	.01	.02	.03	.04	.05	.06	
A+BC/(C+K)	80.1	80.1	80.0	80.0	79.9	79.9	
K	.07	.08	.09	.10	.11	.12	
A+BC/(C+K)	79.8	79.8	79.7	79.7	79.6	79.6	

Appendix 7 cont.

CP DEGRA. CRM ANIMAL 2

A= 58.21	B= 41.79	C= .0192	RSD= 8.44				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		69.39	53.74	56.70	80.18	84.77	89.14	94.95
Fitted values		58.21	62.75	66.79	73.62	83.35	89.49	93.36
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		85.7	78.7	74.5	71.7	69.8	68.3	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		67.2	66.3	65.5	64.9	64.4	64.0	

* *

CP DEGRA CRM ANIMAL 3

A= 69.42	B= 18.16	C= .1871	RSD= 2.46				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		69.39	81.60	86.57	83.60	86.67	88.92	90.11
Fitted values		69.42	81.67	85.66	87.38	87.58	87.58	87.58
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		86.7	85.8	85.1	84.4	83.7	83.2	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		82.6	82.1	81.7	81.3	80.9	80.5	

* *

CP DEGRA.HAY ANIMAL 1

A= 61.47	B= 19.35	C= .0243	RSD= 2.27				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		59.18	67.10	67.53	67.81	74.69	77.76	79.00
Fitted values		61.47	64.09	66.35	70.01	74.78	77.44	78.93
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		75.2	72.1	70.1	68.8	67.8	67.0	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		66.4	66.0	65.6	65.2	65.0	64.7	

* *

CP DEGRA HAY ANIMAL 2

A= 58.76	B= 18.64	C= .0349	RSD= .68				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		59.18	61.57	65.56	68.83	74.72	75.80	76.48
Fitted values		58.76	62.29	65.15	69.35	73.92	75.90	76.76
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		73.3	70.6	68.8	67.5	66.4	65.6	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		65.0	64.4	64.0	63.6	63.3	63.0	

* *

CP DEGRA.HAY ANIMAL 3

A= 57.99	B= 21.75	C= .0366	RSD= 1.35				
Times		0.	6.	12.	24.	48.	72.	96.
Measurements		59.15	60.33	65.71	71.59	76.53	77.18	79.42
Fitted values		57.99	62.27	65.71	70.69	75.98	78.18	79.09
K		.01	.02	.03	.04	.05	.06	
A+BC/(C+K)		75.1	72.0	69.9	68.4	67.2	66.2	
K		.07	.08	.09	.10	.11	.12	
A+BC/(C+K)		65.5	64.8	64.3	63.8	63.4	63.1	

* *

Appendix 7 Degradability characteristics of treatment rations

DM TR_1 ANIMAL I

Asymptote constrained to 100

A= 32.84	B= 67.16	C= .0221	RSD= 3.82			
Times	0.	6.	12.	24.	48.	72.
Measurements	32.17	42.20	51.43	54.34	79.99	86.34
Fitted values	32.84	41.18	48.48	60.48	76.75	86.32
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	79.1	68.1	61.3	56.7	53.4	50.9
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	49.0	47.4	46.1	45.0	44.1	43.3

* *

DM TR_1 ANIMAL 2

Asymptote constrained to 100

A= 32.11	B= 67.89	C= .0235	RSD= 3.66			
Times	0.	6.	12.	24.	48.	72.
Measurements	32.17	41.04	51.48	55.71	81.80	87.12
Fitted values	32.11	41.04	48.80	61.39	78.04	87.51
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	79.7	68.8	61.9	57.2	53.8	51.2
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	49.2	47.5	46.2	45.0	44.1	43.2

* *

DM TR_1 ANIMAL 3

Asymptote constrained to 100

A= 33.31	B= 66.69	C= .0195	RSD= 3.95			
Times	0.	6.	12.	24.	48.	72.
Measurements	32.17	43.14	49.20	52.02	77.38	83.49
Fitted values	33.31	40.69	47.25	58.28	73.90	83.67
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	77.4	66.3	59.6	55.2	52.0	49.7
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	47.9	46.4	45.2	44.2	43.4	42.6

* *

DM TR_1 ANIMAL 4

A= 32.43	B= 60.56	C= .0292	RSD= 5.00			
Times	0.	6.	12.	24.	48.	72.
Measurements	32.17	42.10	53.30	57.29	83.44	83.27
Fitted values	32.43	42.16	50.34	62.95	78.09	85.60
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	77.5	68.4	62.3	58.0	54.8	52.3
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	50.3	48.6	47.3	46.1	45.1	44.3

* *

DM TR_2 ANIMAL 1

A= 24.54	B= 54.53	C= .0860	RSD= 8.11			
Times	0.	6.	12.	24.	48.	72.
Measurements	20.93	54.86	59.17	62.25	80.35	82.39
Fitted values	24.54	46.51	59.63	72.14	78.18	78.95
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	73.4	68.8	65.0	61.7	59.0	56.7
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	54.6	52.8	51.2	49.7	48.5	47.3

Appendix 7 cont.

DM TR_2 ANIMAL 2

A= 25.10	B= 56.29	C= .0696	RSD= 7.40			
Times	0.	6.	12.	24.	48.	72.
Measurements	20.93	53.11	56.51	62.95	80.51	83.60
Fitted values	25.10	44.32	56.97	70.80	79.40	81.02
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	74.3	68.8	64.4	60.8	57.9	55.3
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	53.2	51.3	49.6	48.2	46.9	45.8

DM TR_2 ANIMAL 3

A= 22.90	B= 57.69	C= .0899	RSD= 4.56			
Times	0.	6.	12.	24.	48.	72.
Measurements	20.93	52.83	57.41	71.80	79.10	82.98
Fitted values	22.90	46.95	60.97	73.92	79.82	80.50
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	74.8	70.1	66.2	62.8	60.0	57.5
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	55.3	53.4	51.7	50.2	48.8	47.6

DM TR_2 ANIMAL 4

A= 22.19	B= 57.79	C= .1087	RSD= 5.10			
Times	0.	6.	12.	24.	48.	72.
Measurements	20.93	54.96	58.79	77.23	76.73	83.03
Fitted values	22.19	49.87	64.29	75.72	79.66	79.95
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	75.1	71.0	67.5	64.4	61.8	59.4
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	57.3	55.5	53.8	52.3	50.9	49.7

DM TR_3 ANIMAL 1

A= 34.74	B= 57.34	C= .0179	RSD= 1.68			
Times	0.	6.	12.	24.	48.	72.
Measurements	35.48	40.66	44.77	53.88	70.04	75.27
Fitted values	34.74	40.59	45.84	54.79	67.83	76.31
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	71.5	61.8	56.2	52.5	49.9	47.9
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	46.4	45.2	44.3	43.5	42.8	42.2

DM TR_3 ANIMAL 2

A= 33.03	B= 65.56	C= .0141	RSD= 3.34			
Times	0.	6.	12.	24.	48.	72.
Measurements	35.48	36.18	42.67	49.98	69.24	73.04
Fitted values	33.03	38.35	43.24	51.85	65.27	74.84
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	71.4	60.1	54.0	50.1	47.5	45.5
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	44.0	42.9	41.9	41.1	40.5	39.9

Appendix 7 cont.

DM TR_3 ANIMAL 3

A= 32.81	B= 60.20	C= .0224	RSD= 8.09			
Times	0.	6.	12.	24.	48.	72.
Measurements	35.70	37.70	48.14	50.90	82.80	76.08
Fitted values	32.81	40.36	46.97	57.80	72.42	80.96
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	74.4	64.6	58.5	54.4	51.4	49.1
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	47.4	46.0	44.8	43.8	43.0	42.3

* *

DM TR_3 ANIMAL 4

A= 32.67	B= 51.47	C= .0206	RSD= 3.70			
Times	0.	6.	12.	24.	48.	72.
Measurements	35.48	37.11	40.47	53.35	68.74	70.36
Fitted values	32.67	38.66	43.95	52.76	65.01	72.47
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	67.3	58.8	53.6	50.2	47.7	45.8
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	44.4	43.2	42.3	41.5	40.8	40.2

DM TR_4 ANIMAL 1

A= 40.49	B= 32.52	C= .0348	RSD= 3.04			
Times	0.	6.	12.	24.	48.	72.
Measurements	41.74	46.28	47.96	62.43	66.35	70.06
Fitted values	40.49	46.61	51.59	58.89	66.88	70.35
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	65.7	61.1	57.9	55.6	53.8	52.4
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	51.3	50.3	49.6	48.9	48.3	47.8

* *

DM TR_4 ANIMAL 2

A= 41.67	B= 30.74	C= .0183	RSD= .72			
Times	0.	6.	12.	24.	48.	72.
Measurements	41.74	44.33	48.62	51.99	59.92	64.11
Fitted values	41.67	44.87	47.73	52.60	59.65	64.19
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	61.6	56.4	53.3	51.3	49.9	48.9
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	48.0	47.4	46.9	46.4	46.1	45.7

* *

DM TR_4 ANIMAL 3

A= 42.18	B= 22.95	C= .0348	RSD= 1.17			
Times	0.	6.	12.	24.	48.	72.
Measurements	41.98	46.99	49.29	56.25	59.50	63.91
Fitted values	42.18	46.50	50.01	55.17	60.81	63.25
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	60.0	56.8	54.5	52.9	51.6	50.6
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	49.8	49.1	48.6	48.1	47.7	47.3

* *

Appendix 7 cont.

DM TR_4 ANIMAL 4

A= 41.13	B= 20.90	C= .0463	RSD= 1.01			
Times	0.	6.	12.	24.	48.	72.
Measurements	41.74	44.95	50.53	55.14	60.51	60.70
Fitted values	41.13	46.20	50.04	55.15	59.77	61.29
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	58.3	55.7	53.8	52.3	51.2	50.2
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	49.5	48.8	48.2	47.7	47.3	46.9

* *

CP TR_1 ANIMAL 1

A= 40.46	B= 57.17	C= .0337	RSD= 1.70			
Times	0.	6.	12.	24.	48.	72.
Measurements	39.45	52.93	59.22	70.63	87.34	92.20
Fitted values	40.46	50.91	59.45	72.13	86.26	92.56
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	84.5	76.3	70.7	66.6	63.5	61.0
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	59.0	57.4	56.0	54.9	53.9	53.0

* *

CP TR_1 ANIMAL 2

Asymptote constrained to 100

A= 38.88	B= 61.12	C= .0218	RSD= 4.77			
Times	0.	6.	12.	24.	48.	72.
Measurements	39.45	48.31	54.09	55.59	81.91	89.93
Fitted values	38.88	46.38	52.96	63.79	78.55	87.29
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	80.8	70.8	64.6	60.5	57.4	55.2
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	53.4	52.0	50.8	49.8	49.0	48.3

* *

CP TR_1 ANIMAL 3

A= 42.18	B= 50.80	C= .0286	RSD= 3.41			
Times	0.	6.	12.	24.	48.	72.
Measurements	39.45	55.08	55.93	66.35	79.27	87.31
Fitted values	42.18	50.20	56.95	67.42	80.12	86.51
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	79.8	72.1	67.0	63.4	60.7	58.6
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	56.9	55.6	54.4	53.5	52.7	52.0

* *

CP TR_1 ANIMAL 4

A= 40.73	B= 55.76	C= .0262	RSD= 2.61			
Times	0.	6.	12.	24.	48.	72.
Measurements	39.45	51.90	54.81	64.78	82.64	87.27
Fitted values	40.73	48.85	55.79	66.78	80.66	88.05
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	81.1	72.4	66.7	62.8	59.9	57.7
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	55.9	54.5	53.3	52.3	51.5	50.7

* *

Appendix 7 cont.

CP TR_2 ANIMAL 1

A= 41.08 B= 53.81 C= .0329 RSD= 5.01

Times	0.	6.	12.	24.	48.	72.
Measurements	38.91	55.77	57.61	66.04	88.37	87.94
Fitted values	41.08	50.73	58.65	70.48	83.82	89.87
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	82.4	74.6	69.2	65.4	62.5	60.2
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	58.3	56.8	55.5	54.4	53.5	52.7

CP TR_2 ANIMAL 2

A= 38.55 B= 60.65 C= .0279 RSD= .66

Times	0.	6.	12.	24.	48.	72.
Measurements	38.91	47.78	55.26	68.15	84.12	90.60
Fitted values	38.55	47.90	55.81	68.16	83.32	91.07
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	83.2	73.9	67.8	63.5	60.3	57.8
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	55.8	54.2	52.9	51.8	50.8	50.0

CP TR_2 ANIMAL 3

A= 41.18 B= 58.29 C= .0277 RSD= 2.58

Times	0.	6.	12.	24.	48.	72.
Measurements	38.91	53.42	57.85	68.57	82.66	92.55
Fitted values	41.18	50.10	57.65	69.47	84.03	91.53
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	84.0	75.0	69.2	65.0	61.9	59.6
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	57.7	56.2	54.9	53.8	52.9	52.1

CP TR_2 ANIMAL 4

A= 41.44 B= 46.14 C= .0407 RSD= 5.45

Times	0.	6.	12.	24.	48.	72.
Measurements	38.91	55.97	57.30	72.43	74.85	89.00
Fitted values	41.44	51.43	59.26	70.20	81.03	85.11
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	78.5	72.4	68.0	64.7	62.1	60.1
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	58.4	57.0	55.8	54.8	53.9	53.1

CP TR_3 ANIMAL 1

Asymptote constrained to 100

A= 37.43 B= 62.57 C= .0113 RSD= 2.01

Times	0.	6.	12.	24.	48.	72.
Measurements	39.02	41.60	43.06	51.45	66.24	71.35
Fitted values	37.43	41.54	45.39	52.33	63.68	72.33
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	70.7	60.1	54.6	51.2	49.0	47.4
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	46.1	45.2	44.4	43.8	43.3	42.8

Appendix 7 cont.

CP TR_3 ANIMAL 2

A= 39.46 B= 56.60 C= .0137 RSD= .98

Times	0.	6.	12.	24.	48.	72.
Measurements	39.02	43.62	49.44	54.72	66.24	75.13
Fitted values	39.46	43.91	48.01	55.27	66.66	74.87
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	72.1	62.4	57.2	53.9	51.6	49.9
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	48.7	47.7	46.9	46.3	45.7	45.2

CP TR_3 ANIMAL 3

Asymptote constrained to 100

A= 35.52 B= 64.48 C= .0162 RSD= 6.82

Times	0.	6.	12.	24.	48.	72.
Measurements	39.02	43.34	43.86	46.83	78.82	79.26
Fitted values	35.52	41.48	46.90	56.26	70.34	79.88
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	75.4	64.4	58.1	54.1	51.3	49.2
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	47.6	46.4	45.3	44.5	43.8	43.2

* *

CP TR_3 ANIMAL 4

Asymptote constrained to 100

A= 37.39 B= 62.61 C= .0067 RSD= 1.29

Times	0.	6.	12.	24.	48.	72.
Measurements	39.02	39.58	40.61	46.10	55.58	61.42
Fitted values	37.39	39.86	42.24	46.72	54.66	61.41
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	62.6	53.1	48.9	46.4	44.8	43.7
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	42.9	42.2	41.7	41.3	41.0	40.7

CP TR_4 ANIMAL 1

A= 31.98 B= 58.49 C= .0133 RSD= 3.26

Times	0.	6.	12.	24.	48.	72.
Measurements	34.58	34.71	36.99	50.86	60.11	67.53
Fitted values	31.98	36.47	40.63	48.00	59.63	68.08
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	65.4	55.4	50.0	46.6	44.3	42.6
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	41.3	40.3	39.5	38.9	38.3	37.8

* *

CP TR_4 ANIMAL 2

A= 32.35 B= 54.85 C= .0155 RSD= 3.32

Times	0.	6.	12.	24.	48.	72.
Measurements	34.58	36.01	37.74	52.73	61.20	68.91
Fitted values	32.35	37.23	41.68	49.43	61.19	69.29
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	65.7	56.3	51.1	47.7	45.4	43.6
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	42.3	41.3	40.4	39.7	39.1	38.6

* *

Appendix 7 cont.

CP TR_4 ANIMAL 3

A= 32.06 B= 39.61 C= .0268 RSD= 4.16

Times	0.	6.	12.	24.	48.	72.
Measurements	34.58	35.86	38.79	55.64	59.83	65.66
Fitted values	32.06	37.93	42.94	50.83	60.70	65.90
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	60.9	54.7	50.7	47.9	45.9	44.3
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	43.0	42.0	41.1	40.4	39.8	39.3

* *

CP TR_4 ANIMAL 4

A= 32.01 B= 41.68 C= .0253 RSD= 3.25

Times	0.	6.	12.	24.	48.	72.
Measurements	34.58	35.59	39.80	53.92	62.11	66.01
Fitted values	32.01	37.88	42.92	50.97	61.30	66.93
K	.01	.02	.03	.04	.05	.06
A+BC/(C+K)	61.9	55.3	51.1	48.2	46.0	44.4
K	.07	.08	.09	.10	.11	.12
A+BC/(C+K)	43.1	42.0	41.2	40.4	39.8	39.3

Appendix 8: Cost of 1 kg gained, days and cost to first service

Table 4.14: Weight gained (kg), concentrate fed (kg), costs of individual feed ingredients (US$) cost of 1kg gained (US$) and days and cost to 1st service

ITEM	Cost/kg feed (US$)	TR_1	TR_2	TR_3	TR_4
Mean weight gained (kg)		29	32	29	26.21
Mean concentrate fed (kg)		100.52	102.48	99.17	99.29
CSC (%)		31.5	48	-	-
FW (%)		-	-	30.5	47
CRM (%)		-	50	-	53
HM (%)		66.5	-	67.5	-
Cost of CSC	0.140	4.50	7.03	-	-
Cost of FW	0.140	-	-	4.30	6.53
Cost of CRM	0.123	-	6.43	-	6.47
Cost of HM	0.076	5.20	-	5.20	-
Total costs (US$)		9.70	13.46	9.50	13.00
Cost/ kg gained (US$)		0.338	0.418	0.332	0.496
Weight (kg) at 1st service		285	285	285	285
Weight reached at 56 days		173.22	176.78	173.22	170.76
Weight left to 1st service		111.78	108.22	111.78	114.24
Weight gain per day (kg)		0.49	0.61	0.46	0.42
Days left to 1st service		228.12	177.41	243	272
Total days to 1st service		284.12	233.41	299	328
Cost of feed per daily gain (US$)		0.166	0.255	0.152	0.208
Cost of feed to 1st service (US$)		47.164	59.520	45.446	68.224