Degradation kinetics of carbohydrate fraction of commercial concentrate feeds for weaned calves, heifers, lactating and dry dairy cattle

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DECLARATION

I Agboola Olabisi Dorcas hereby declare that the dissertation, which I hereby submit for the degree of Master of science in agriculture at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution.

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DEDICATION

I dedicate this project to the source of wisdom and life, The Almighty God the creator of heaven and earth with everything within it. To you alone be all the glory now and forevermore.

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My profound appreciation goes to Almighty God for his provision, protection and guidance all through my research period. I wish to also express my unreserved gratitude to my supervisors Dr. O.A. Aiyegoro and Dr. F.V. Nherera-Chokuda for their parental advice, research supervision, constructive criticism and been there for me through the thick and thin period of my research.

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ABBREVATIONS

ADF	Acid detergent fiber
ADICP	Acid detergent insoluble crude protein
ADIN	Acid detergent insoluble nitrogen
ADL	Acid detergent lignin
AFMA	Animal Feed Manufacturers Association
ARC	Agricultural Research Council
Ca	Calcium
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
ED	Effective degradation
EE	Ether extract
GE	Gross energy
LRNS	Large ruminant nutrition system
ME	Metabolizable energy
MP	Microbial protein
N	Nitrogen
NDF	Neutral detergent fiber
NDICP	Neutral detergent insoluble crude protein
NDIN	Neutral detergent insoluble nitrogen
NSC	Non structural carbohydrate
OMD	Organic matter degradation
P	Phosphorus
RDP	Rumen degradable protein
RUP	Rumen undegradable protein
SA	South Africa
SC	Structural carbohydrate
TDN	Total digestible nutrient
TMR	Total mixed ration
VFA	Volatile fatty acids

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Summary
Title of dissertation

Degradation kinetics of carbohydrate fraction of commercial concentrate feeds for weaned calves, heifers, lactating and dry dairy cattle

Variations in composition and disappearance of nutrients in dairy cattle feeds are dictated by ingredients, methods of processing, storage while milk production levels depend on the animal, environmental factors and largely on pools of available carbohydrates, proteins, vitamins and minerals in the concentrate feeds. There is a wide variety of concentrates for dairy cattle on the formal and informal markets and dairy farmers need to be astute in selecting feeds appropriate for specific production periods and animals to sustain their businesses. Composition of nutrients displayed on concentrate containers is however inadequate for in-depth assessment of products. This study determined nutrient composition, rumen dry matter disappearance and microbial colonization on residual substrate on commercial concentrate feeds and simulated total mixed rations for dairy calves, heifers, lactating and dry cows based on common feeding guidelines. Equivalent feeds for each herd group were obtained from three suppliers in the formal markets in Gauteng province of South Africa, making a total of twelve. An analysis of the data on container labels for the herd groups displayed similar feed values, as also reflected on the recommendation Tables of Act 36: Feeds and Fertilizer bill 1947 of South Africa.
Keywords: dairy cattle, fibre, rumen fermentation, nutrient density, diet simulation, microbial synthesis

CHAPTER ONE

1.1 INTRODUCTION AND BACKGROUND OF THE STUDY

The dairy production systems have evolved greatly due to advancements in technology, milking systems, feeding, housing, and biotechnology (Fulkerson et al. 2008). In South Africa, commercial dairying is advanced although most farms are challenged with low viability as evidenced by large decline in producers (ICAR, 2007). Huge costs of feed inputs, mainly concentrates for sustaining lactating herds are the major cause. There are wide spectrum of locally produced good and poor quality concentrates feed producers supplying concentrates for calf, heifer, lactating and dry dairy cows on the South Africa feed market while some are imported. Dairy farmers need to have good judgment in selecting concentrates appropriate for specific production conditions. Feed quality control is regulated under the Feed and Fertilizer bill 1947 ACT 36 of South Africa.

Most farmers rely on forages as sources of nutrients for their cattle, which are less costly (Peyraud and Delaby, 2001; Hassan, et al., 2011). However, concentrate supplementation remains crucial due to limitations in forage availability and quality (Virkaja¨rvi et al., 2002). Carbohydrates comprise 60-70% of the total diet are important in supplying energy (NRC, 2001). The rumen is one of the most important organs in the ruminant digestive system and maximizing the beneficial aspects of rumen while minimizing fermentation losses in diet formulation would be cost effective (Russell et. at., 1992). Tropical libraries are limited and marketed feeds are scantly labelled affecting accuracy of nutrient supply predictions.

1.2 PROBLEM STATEMENT

Sustainability of intensive ruminant production systems is highly variable (FAO, 2012). Costs of concentrate feeds affect intensive beef and dairy systems, reduce off-takes-growth, gain, reproduction and producers have limited scope for selecting the best concentrates for their animals. Also marketed feeds have limitations such as scant information on labels to indicate fiber, Protein, Ash and minerals, ranges are mainly provided to meet the minimum requirements of the Feeds and Fertilizer Act (1947). Rapid procedures such as simulations and in vitro are needed to generate data on nutrient availability and ascertain feed value. The limitations or lack of in depth nutrient assessment makes the procurement of concentrates by dairy milk producers

very subjective. Feed quality is the most critical component that influences productivity and profitability of dairy businesses and therefore warrants assessment.

1.3 JUSTIFICATION

The quality of feed ingredients, animal and environments plays a vital role in sustaining intensive ruminant production systems (FAO, 2012). This study notes that commercial feeds on the South Africa markets have limitations such as unavailability of quality information required for predicting nutrient availability from concentrate feeds produced for dairy herd groups and assumed to have equivalent nutrient value.

1.4 AIMS OF THE STUDY

The aim of this study were to assess nutritional profiles and evaluate rumen dry matter degradation and microbial protein synthesis of concentrate feeds for dairy herd groups -weaned calves, heifers, and lactating and dry dairy cattle

RESEARCH OBJECTIVES

To evaluate nutrient profiles of various commercial concentrates

To evaluate the variability in dry matter degradation using *In Sacco* procedures

To determine effects total bacterial populations on rumen residual fibre to estimate metabolizable energy and protein balance expected from concentrate feeds and total mixed rations formulated with each concentrate feed.

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CHAPTER TWO

Review of dairy farming and regulation in South Africa

2.1 Dairy cattle farming

There are six major dairy breeds in South Africa namely Holstein-Friesland, Jersey, Guernsey, Ayrshire, Brown Swiss, and Dairy Shorthorn (Gertenbach, 2014). There is a high demand for these animals to meet milk and meat demand of the ever increasing human population. Production systems for ruminant animals to meet this demand are strained. Good managerial decisions on nutritional needs at various stages of the dairy cow's life are very important for successful dairy farming. Dairy cattle have complex stomachs, which help them utilize complex feed material that are not readily digested by monogastric animals. (McDonald et.al. 2002).

2.2 The ruminant digestion system

Dairy cattle have foregut digestion chambers – the reticulum, rumen, omasum, and abomasum – where soluble nutrients and structural carbohydrates are digested (McDonald et al., 2002). This is a three stage process;

Fermentation in the foregut

Mono-gastric phase (Stomach and intestinal digestion)

Hindgut fermentation (Colon and caecum)

Degradation of feed in the ruminant starts when ingested feed mixes with saliva in the mouth and passes through the esophagus to the stomach. The structure of the ruminant stomach is shown below in Figure 2.1.

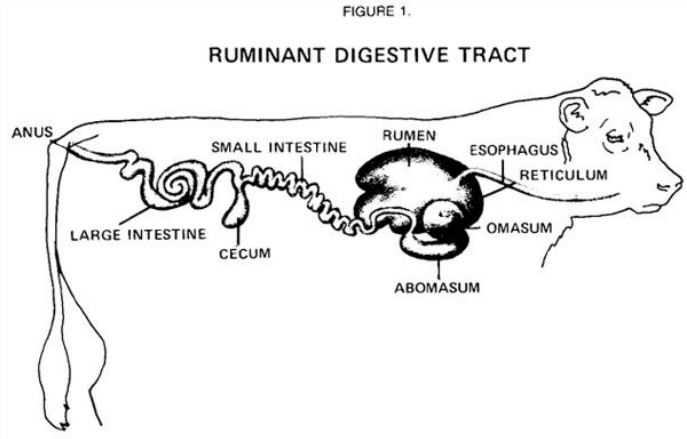

Figure 2.1 Ruminant digestive systems. Source: www.animal sci-old.tamu.edu

The reticulum is the first organ of the digestive system. It has a flash-shaped compartment and looks like a honey comb. It helps in the movement of ingesta to the rumen and omasum through its two passages, the reticulo-rumen and the reticulo-omasal. This organ also helps during the rumination of ingesta, so that complex feed can be digested properly. The rumen is the largest organ in the viscera. It is the part of the foregut where fermentation and absorption of microbial by-products takes place. The omasum is the third compartment of the ruminant stomach. It is unique, with flattened membranes that look like the pages of a book. It functions in grinding and squeezing water out of ingesta as it moves it to the abomasums. The abomasum is the true stomach, secretes the gastric juice which helps during digestion. The pH in the abomasums range between 2.5 and 6.7. This aids in the breakdown of protein and also kills microbes that escape from the rumen. Figure 2.2 shows the picture of ruminant fore-stomachs namely reticulum, rumen, Omasum and abomasums in their respective order.

Figure 2.2 The ruminant fore-stomach. Source: www.animal sci-old.tamu.edu

2.3 Rumen Microorganisms

Rumen microbes helps with fermentation of ingesta but the rate and extent of fermentation depends on the type of feed consumed which dictate the type of rumen microbes (Hungate, 1966). Bacteria, protozoa and fungi are main groups of rumen microbes that have been identified and differ in their function (Weimer, 2007). Digestion of sugars, starch, fiber, and protein is achieved by bacteria. The digestion of sugar which is a carbohydrate fraction produces gas such as carbon-dioxide (CO_2), methane (CH_4) and volatile fatty acids (VFAs) in the rumen. Production of short chain VFA (acetate and butyrate) is good indicators of fermentation pattern in the rumen. Increased concentrate diet tends to increase protozoa but lower rumen pH (Moir and Somers, 1956). Protozoa impede fermentation as they engulf bacteria. Fungi are small portion of the total rumen microbial population, but become visible in unlocking plant fibers for easy digestion by bacteria according to Weimer (2007). Fungi use up simple sugar during of digestion of starch, glycogen and cell wall polysaccharides (Gordon and Phillips, 1998). The absence of fungi results in reduced degradation and feed intake particularly poor quality forage.

2.4 Sources of Nutrients

Carbohydrate are key supplier of energy in ruminant feeding, from plant, crop and crop residue and consist of cellulose, hemicelluloses, starch and water soluble carbohydrate (McDonald, et.al., 2002). The knowledge of digestion dynamics in ruminant animals help in the prediction and formulation of diets (NRC, 2001). Degradation is influenced by characteristics of the diet, amount of potentially degradable nutrients, the feed intake level, the feed residence time in rumen, food exposure to the rumen microorganisms and environmental conditions in the rumen (pH and NH3 concentration) and source of nutrient according to Bannink et.al, (2006). All these parameters listed above depend on the action and survival of rumen microorganism during digestion of feed (Ørskov, 1988).

2.4.1 Nutrients from pasture

Pasture are cheapest source of nutrient for ruminant animals but their nutrient utilization varies with the harvesting stage of the plant (Dalley et al., 1999 and Scholtz, 2009) and cows potential production melt not be reach without energy supplementation but when pasture are well managed they can be used to maintain cow nutrient requirement but with levels of

supplementation (Woods et.al., 2005) because forage species, cultivar, growth stage (Tremblay et al., 2003), soil type (Aumont and Salas 1996), climate conditions (e.g., rainfall, temperature) (Mathison et al., 1996) and growing conditions (Cox et al., 1994) affects nutritive value of the pasture. Pastures supply fibre for an increase in rumen degradation and they are included in the diet as dry matter (DM) to promote the feed intake level as stated by Martinez, et al. (2009).

2.4.2 Nutrients from concentrate

Nutrient from concentrates feed are highly digestible ingredient added to the basal diet to improve the feed quality and efficiency. Concentrate are produced to meet a particular nutrient requirement which determines it name such as energy concentrate, protein concentrate, mineral concentrate, vitamin concentrate as well as feed additives. Energy concentrate are highly fermentable carbohydrate to supply readily digested nutrients and speed up feed metabolism (McDonalds et al., 2002). They are derived made from mostly cereals or cereal by-products, roots and tuber, liquid feeds like molasses, fats and oils etc. Carbohydrates are divided into s*tructural carbohydrate (SC) and non structural carbohydrate (NSC). These carbohydrate fractions determine the rate and extent of digestion of feed ingredients. However, these energy sources also contain small quantities of other nutrients—proteins, minerals and vitamins. The rumen degradation of carbohydrate fractions is shown in Figure 2.3 below.

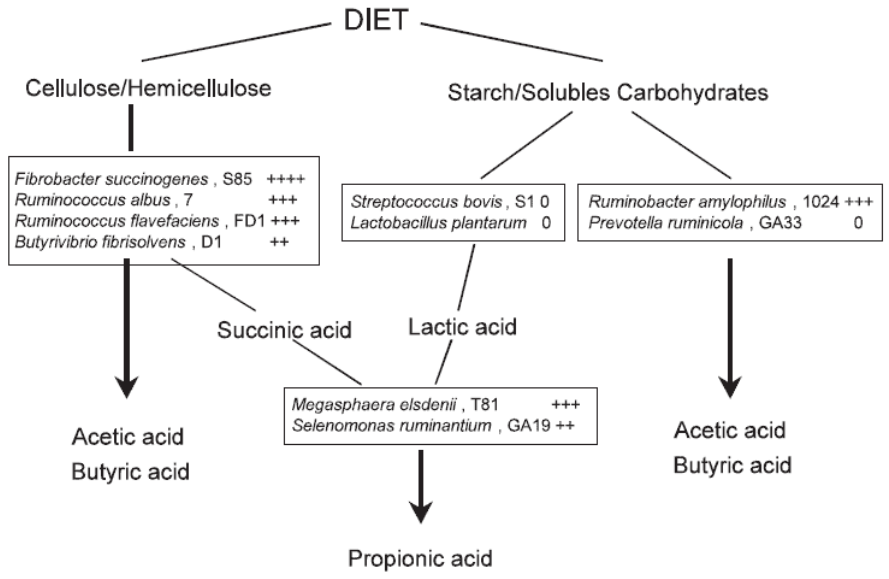

Figure 2.3 Rumen degradation of carbohydrate http:www.en.engormix.com

Protein concentrate are feedstuffs that contain more than 20% crude protein on the basis of dry matter. They are derived from either plant or animal origin. Plant protein sources are mainly oilseed meal or leguminous forages and animal protein sources are blood meal, bone mean, /feather meal, poultry manure, fishmeal, meat meal and carcass meal.

Digestible crude protein is divided into rumen degradable protein (RDP) and rumen undegradable protein (RUP). The RUP is absorbed as amino acids in the small intestine while the RDP is used up by the rumen microbes for microbial protein synthesis. Rumen microbes account for 50 to 80% of total absorbable protein supplied to the small intestine of ruminant as microbial protein (Stern, *et al.*, 2006) and in the degradation of amino acids (Robinson *et al.*, 2005, 2006). The Figure 2.4 below show the degradation pathway of protein.

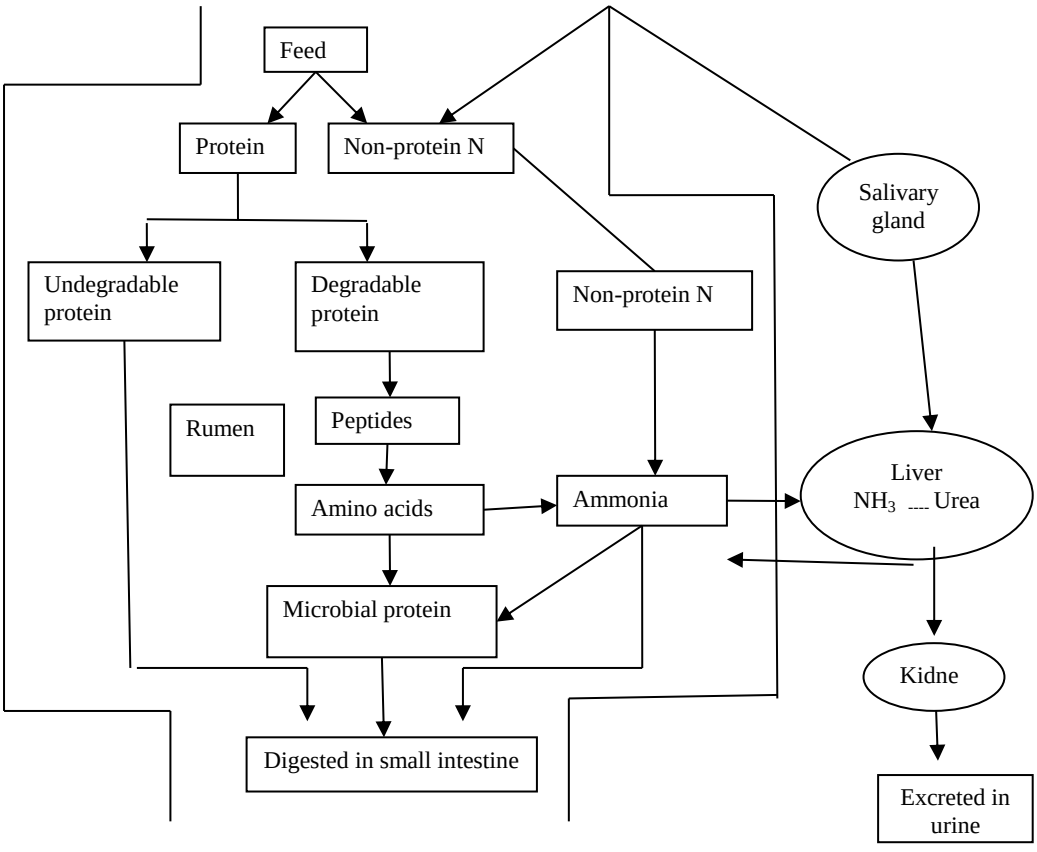

Figure 2.4 Degradation pathway of protein (McDonald, *et.al.*, 1995)

Minerals are found in most feed ingredient but inadequate for high-producing dairy cows. The mineral content of plant material as feed ingredient depends on the soil quality. Examples of mineral concentrate are bone meal, dicalcium-phosphate, limestone flour, magnesium oxide, mineral premix, monocalcium phosphate. Calcium (Ca) and phosphorus (P) are most limiting mineral in dairy cow and their ratio is important in formulating feed because it can affect the skeletal structure and bone of the animal. For normal nerve membrane and muscle plasma Ca concentration must be maintained at 1.25nm and if there is no balance to entry and loss of Ca it can result in milk fever (NRC, 2001). Phosphorus is the most biologically involved mineral and NRC (2001) recommend blood plasma concentration of 6 to 8 mg/dl and 4 to 6 mg/dl for growing and adult animals respectively.

Another means of improving feed efficiency dairy farming is through the use of feed additive. Additives are non-nutrient compounds or microbes added to the diet to modify metabolism and improve production, diet utilization or health. They causes desired animal response in a non-nutrient role by shift in pH thereby enhancing the level and efficiency of performance, improves digestion and reduces negative impacts of diet on health performance and environment (Hutjens, 1991). Example of feed additives used in dairy nutrition system are Anionic Salts and Product, Aspergillus oryzae, biotin, β-carotene, calcium propionate, protected choline, enzymes, magnesium oxide, methionine hydryoxy analog, methionine hydryoxy, monensin, niacin (B3, nicotinic acid, and nicotinamide), yeast culture and yeast, zinc methionine, probiotics (bacterial direct-fed microbes), propylene glycol, silage bacterial inoculants etc.

2.5 Dairy Cattle Diet requirements

Dairy cattle diet composition is a function of its ingredients which are water, carbohydrates, fats, proteins, amino acids, minerals and vitamins source. These ingredients supply the needed nutrient by the animal. Nutrient available is influence by different factors such as processing methods, feed particle size, anti-nutritional, animal health, stage of growth and production etc. The nutrient requirements for different class of dairy (calf, heifer, lactating and dry cow) are clearly stated by NRC, (2001).

2.5.1 Calf requirements

Exclusive rearing programs for young calves begins with the cow because major growth of the calf is within the cow and supply all the nutrients needed for growth prior to calving (Donna et al., 2002). Colostrums is the first milk and feed the calf gets after birth, it is easily digested because it goes directly to the omasum and abomasum due to the under developed reticulum and rumen (McDonald et al, 1995). It helps the calf to build it immune system, prepare the stomach, bone structure as well as the growth and milk production potential (Faber et al., 2005). The reticulum and rumen only start functioning when the calf is introduced to solid feed with increase in life weight. Calves are the most efficient users of feed nutrient as compared to other groups. Highly degradable feed like concentrate pose the risk of bloating and this may have negative impact on animal health (Roth et al., 2009). Table 2.1 below shows the expected nutrient composition of calf starter.

Table 2.1: Nutrient composition for calf starter feeds

Nutrient	Amount
Crude Protein	16-20%
Calcium	0.70%
Phosphorus	0.45%
Potassium	0.65%
Copper	10ppm
Zinc	40ppm
Manganese	40ppm
Cobalt	0.10ppm
Selenium	0.30ppm
IU Vitamin A/lb dry matter	1818 IU
Vitamin D/lb dry matter	270 IU
Vitamin E/lb dry matter	12 IU

* Adapted from Nutrient Requirements for Dairy Cattle (2001)

2.5.2 Heifer requirements

Feeding the Young Heifer from 12 weeks to reach breeding weight by 12 months is essential as it affects first calving age and milk yield. The age of the heifer determines the amount of protein to be included in it diet moreover excess protein in diet does not automatically increase growth (Hoffman, 1999). When heifers are fed high concentrate diets the animal may have frothy bloat which is the only metabolic or ruminal malformation (Zanton and Heinrichs, 2008).

2.5.3 Early Lactating cattle requirements

The nutrient requirement of dairy cattle in milk production depends on stage and quality of milk produced (McDonald et al., 1995). A typical lactation curve (Figure 2.5) show trend of milk production weeks after parturition.

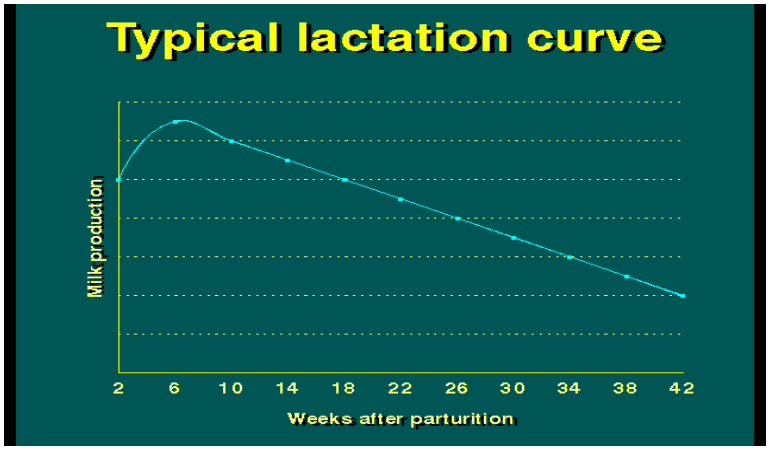

Figure 2.5 Typical lactation curve Source: http://www.dairygoodlife.com

The various stages of milk production are influenced by nutritional management. The early Lactating period starts at calving till 90 days in milk (DIM). Its characterised by peak milk production and negative energy equilibrium. These huge negative energy balance and insufficient dry matter intake (DMI), there is increased incidence of energy-related metabolic disorders; achieving maximum potential intake is difficult during this critical stage especially digesting fibre fractions and consequently increase energy and nutrient supply (Bagheri et al., 2009). To make up for this limited feed intake, the cow utilizes her body reserves as additional source of energy for milk production. Less body condition score during dry period could be a means of improving metabolic disorder in early lactation (Bjerre-Harpoth et al., 2014). It is critical to balance energy and protein to minimise loss in body condition and metabolic disorders such as milk fever, ketosis. Commercial energy concentrates with high nonstructural carbohydrate supply such as grain based concentrates; brewers grain, hominy chop, molasses etc would help to meet energy demand in early lactation. A crude protein content of 17-19% is recommended by NRC (2001). Protein requirement can also be met by the amount of amino acid that gets to the small intestine of lactating (Cyriac et al., 2008). Diet composition for lactating cows is shown in Table 2.2 below.

2.5.4 Mid-lactating cattle requirements

Mid Lactation stage is between 90-140 days post parturition and it is associated with peak dry matter intake (DMI) and lactation starts to decline (Erasmus et al., 2009). It is recommended that mid lactation cow should be fed 4% of the body weight and milk production can be maintained by the ration supplied to the cow (NRC, 2001). Effective fiber level should also be maintained similar to the early lactation stage. Crude protein (CP) should be lower as compared to early stage (15-17%). At the mid lactation stage the cow is also prepared for initiation of new pregnancy. Feeding CP higher than recommended leads to conversion of excess protein into energy, increasing N excretion and animal efficiency is decreased (Kalscheur et al., 2006). The Table 2.2 below shows recommended diet composition for lactating cow.

Table 2.2: Nutrient guidelines for lactating dairy cows

Stage of lactation	Early	Mid	Late
Average milk yield (kg/d)	40	30	20
Dry matter intake (kg/d)	24- 26	21-23	11-12
Crude protein (% DM)	17- 19	15-16	13-15
Ruminal undegraded protein (% CP)	35- 40	30-35	25
Soluble protein (% CP)	25- 33	25-36	25-40
Neutral detergent fiber (% DM)	30- 34	30-38	33-43
Acid detergent fiber (% DM)	19- 21	19-23	22-26
Effective fiber (% NDF)	25	25	25
Net energy for lactation (Mcal/kg)	1.64	1.57	1.5
Non-fiber carbohydrates (% DM)	30- 42	30-44	30-45
Total digestible nutrients (% DM)	72- 74	69-71	66-68
Fat (maximum in DM)	5- 6	4-6	3-5
Calcium (% DM)	0.8- 1.1	0.8-1.0	0.7-0.9
Phosphorous (% DM)	0.5- 0.9	0.4-0.8	0.4-0.7
Potassium (% DM)	0.9- 1.4	0.9-1.3	0.9-1.3
Sodium (% DM)	0.2- 0.45	0.2-0.45	0.18-0.45
Vitamin A (1000 IU/day)	100- 200	100-200	100-200

Source: Dairy Production342-450AFeeding during lactation

2.5.5 Late Lactating cattle requirements

Late lactation stage starts from 200-305 days after calving. At this stage milk production declines, the cow is pregnant, at least 5 months and nutrient intake exceeds it needs. The late lactation stage energy required to produce milk is less because milk production decreases whilst

pregnancy and the build-up of body score condition increases. Body condition improvement is best at this stage than dry period (John, 2009). As lactation diminishes body weight boost as fetus develops and replenishment of adipose tissue lost during early lactation. Energy and protein source are not critical at this stage, diet can be prepared with structural carbohydrate and non protein nitrogen source. Neutral detergent fibre (NDF) in diet formulated should be down to maintain adequate rumen pH (Mertens, 1997; Kolver and deVeth, 2002) as insufficient fibre reduces mastication time and expose the cows to unhealthy conditions such as acidosis (Mertens, 1997 and Bargo et al., 2003). The Table 2.2 above shows the nutrient requirement for late lactating cows.

2.5.6 Dry cattle requirements

Dry period starts from 60 to 14 days before parturition; at this stage there is fetal development, competition for abdominal space and as lactation continue until 8weeks to parturition doubles the task (Forbes, 1986). Nutrient supplies for non-lactating, pregnant cow is a little higher than maintenance. Good management and proper consideration should be given to the nutrition of the cow is important because dry cow nutrient requirements depends on physiological state and specific nutrient demands to prevent metabolic disorders (Boland et al., 2001, Overton and Waldron, 2004).

During late gestation, the fetal bone develops causing a deposition of calcium and phosphorus and accounts for an increase in their requirement. These minerals are intense in the fetal liver and used as a postnatal mineral reserve according to Van Saun et al. (2004) and Van Saun and Poppenga, (2007). The main purpose of feeding dry cows is to improve the metabolic status of early lactating and also increase DMI after calving to meet energy requirement, and production for next lactation (Dewhurst et al., 2000). Table 2.3 shows recommendation for mineral and vitamins in dry cow.

Table 2.3: Concentration of selected minerals and vitamins in the total diet recommended for a large Holstein dry cow from 240 to 280 days pregnant

Mineral/Vitamin	Dry matter basis
Calcium	0.44 - 0.48%
Phosphorus	0.22 - 0.26%
Magnesium	0.11 - 0.16%
Potassium	0.51 - 0.62%
Copper	12 -18 ppm
Zinc	21 - 30 ppm
Selenium	0.3 ppm
Vitamin E	1168 - 1211 ppm

*Assumes anionic salts are not being fed the last three weeks of gestation. Source: NRC (2001)

2.6 Degradation kinetics of dairy concentrate feed

This is a process of feed ingredient/nutrient disappearance or passage from the digestive system of animals. The information on concentrate feed bag label does not carry detained amount of nutrient availability and even little is known about their application in the feed evaluation system. Dairy concentrate are produced to meet different need of growing and production state to meet their nutrient requirement. Knowing the stage/status (wet, non-pregnant; wet, pregnant; dry, pregnant; dry, non-pregnant) of milking cows in tropical dairy farms is a useful tool to manage feeding and herd management. While sustainability of dairy farms is based on nutrient digested from the feed supplied and judged by performance, health, quality and quantity of produce of the animal (Habib, 2013). The generic composition of energy concentrates for calves is 18% CP, 0.70% Ca and 0.45% P. Heifer concentrates would have 12-15% CP, while lactating cow concentrates with 13-19% CP, 0.7-1.1% Ca and 0.4-0.9% P and dry cow with 13-15% CP 0.44-0.48% Ca and 0.22-0.26% P. Various techniques (in situ, in vitro and in vivo) have been used to measure the nutrient availability of different feedstuffs (Huntington and Givens, 1995; Vanzant et al. 1998; Broderick and Cochran, 2000)

2.7 Animal Performance

Feed efficiency is one important ways of measuring animal performance across species (Lascano and Heinrichs, 2009), which is a direct marker of the productivity of an animal. The ability of an

animal to convert unit weight of feed to unit weight means small amount of feed would be used to raise more livestock within a short period of time (Hoffman et al., 2007). Some factors affect feed efficiency such as age, sex, breed type, and feed composition, level of feeding, housing, disease, and managerial practices.

The marginal response (MR) of dairy cattle concentrate is dependent on herbage quality, allowance (HA, kg DM), inclusion level and type of concentrate, energy balance, stage of lactation and cow's genetic strain (Woods et al., 2003; Horan et al., 2005). If MR is positive and the cost of concentrate is less than milk yield then the use of concentrate justified economically.

2.8 Global marketing of concentrates

In South Africa more than 38 feed manufacturer and seven premix feed manufacturers are members of the Animal Feed Manufacturers Association (AFMA). Some producers prepare concentrates on farm which are utilized within the premises for cattle production. In most of Sub-Saharan Africa informal traders also market concentrates that have not gone through quality control systems. Feed producers in the formal economy use a variety of feed ingredient at their disposal which leads to large variety of ruminant feeds on the market and huge competition. Concentrate feed are very expensive, farmer select based on cost and to a less extent on nutrient availability.

Competition for cereal crops by human animal in developing countries account for a large share of expenditures of the low-income populations. There is a global decline in the prices of cereal due to the costs of grain production effects and it continue to push prices of industrial feeds as fuel, electricity and labour costs escalate. Moreover at the AFMA symposium (2014) it was reported that South Africa is neither importing nor exporting maize. The Figure 2.6 below shows the international grains council report from January 2000 to October 2014.

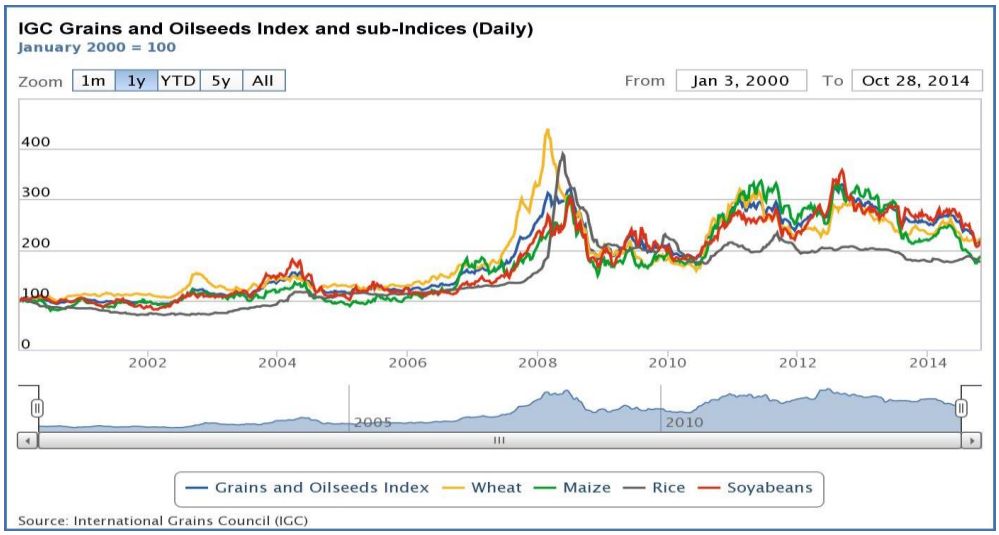

Figure 2.6 IGC grains and oilseed index (FAO, 2014)

Sustainability of intensive ruminant production systems is highly variable (FAO, 2012) because cost of concentrate feeds affect intensive beef and dairy systems. It reduces off-takes-growth, gain, reproduction. Farmer have limited scope for selecting the best concentrates for their animals because marketed feeds have limitations such as scant information on labels for fiber, protein, ash etc, no actual numbers but ranges (5-10%), no data on digestion, no terms and conditions on feed labels:, feed companies are non-committal on effects of feeds, scant information on feeding guidelines and feed quality is not monitored regularly.

2.9 Feed Formulation Strategy

High level of technical and scientific knowledge is required in manipulating rations for calf, heifers, lactating and dry cows to achieve optimal productivity in dairy farming. Diet formulation by a basic understanding of the changes in the animal, anticipated nutritional needs change of the cow, producers can plan their feeding programs and lower feed costs. In modern assessment, detailed information on fermentation and degradation kinetics of each feed component becomes essential (Yu et. al., 2004).

Moreover, the current animal feeding models, such as the beef NRC level 2 (2000), the dairy NRC (2001) and Cornell Net Carbohydrate and Protein System (CNCPS, Fox et al., 2004), requires parameters of ruminal kinetics for each carbohydrate fraction to estimate degradation of carbohydrate, microbial fermentation and energy utilization by the host animal, which are eventually used in predicting the animal performance in general.

2.10 Nutrient Modeling

Nutrients requirements are estimated using modelling techniques such as the large ruminant nutrition system (LRNS) the Cornell Net Carbohydrate and Protein System (CNCPS) (Fox et al., 2004) to facilitate formulation of generic diets and also diets for target levels of production these models include INRA etc. Modelling enables balancing of diets especially for the most limiting nutrients such as lysine and methionine that are deficient in feeds of plant origin

2.11 Regulation and registration of commercial stock feeds in South Africa

South African industrial feeds are regulated by ACT 36: Feeds and Fertilizer Bill 1947. The bill provides "licensing of facilities and rendering plants; to provide for the registration of feed additives, raw materials, animal by-products, imported fertilizers, feeds or pet foods, and home mixers; to provide for the appointment of a Registrar to administer the Act; to provide for the establishment of the Technical Standards Advisory Council; to provide for the designation of technical advisers, analysts and auditors; to provide for the regulation of the import, export, acquisition, disposal, sale or use of fertilizers and feeds; to repeal certain laws relating to fertilizers, feeds and sterilizing plants; and to provide for matters connected therewith". This Acts was created due to need to support "fertilizer, feed and rendering enterprises competing in the fast-moving consumer goods industry and for public policy objectives which promote compliance with issues in terms of animal, human and environmental health". The governing body helps in "disseminating an efficient and effective traceability system; ensure compliance with food safety requirements; improve food security through the availability of safe and efficacious fertilizers and feeds; protect the consumers and users of fertilizers and feeds; enhance product liability and consumer protection; and ensure compliance with matters that relate to animal, human and environmental health".

The regulation deals with an "environmentally friendly mechanism for handling environmental waste generated from the slaughter of animals through rendering plants in order for the waste to be used as fertilizers or feeding stuffs; a purely government led inspection to a system of government oversight that monitors controls; the introduction of a tariff system that will consider different classes of respective registration and license holders; the modernization of penalties in order to reflect modern-day economic realities and act as a deterrent to transgressors; strict

product liability in order to assign liability to the relevant person within the supply chain and support the objects of the Consumer Protection Act; the regulation of the evaluation, authorization, labeling, sale and use of fertilizers and feeds across the entire supply chain".

2.12 Summary

In view of the competitive global and local challenges in dairy milk business, management of feed costs remains the most critical facet of dairy farming. The downward trend in loss of family and large scale farms due to poor competitiveness is worrisome. Dairy cattle feeding strategies, formulation of rations and selection of concentrate brands are critical drivers of viability. Locally produced and also imported concentrates are on the South African market and are crucial in enhancing the expression of high genetic potential for milk in the dairy cows. Quality controls of these concentrate products although governed under ACT 36: Feeds and Fertilizer Bill 1947 and the industry should be enhanced by regular and independent monitoring in view of products adulteration cases affecting the feeds industry. Large volumes of expensive grain and by-products are imported into South Africa and in the past few years the melamine tainted products were noted worldwide. The rumen bacteria, which are the main target of ruminant nutrition and are sensitive to nutrient availability and hence quality variation in concentrates should be monitored frequently for all groups of dairy cattle, including neonates. In view of global competitiveness in the dairy industry, managing concentrate supply and quality plays a critical role in sustainability of businesses. European, Oceania and Western are highly industrialized with huge investment in feed quality monitoring. The South African industry is positioned for such growth but feed quality monitoring seems to be a weak link.

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CHAPTER THREE

Nutrient value and rumen degradation of formally marketed commercial concentrate feeds for dairy cattle in South Africa

Abstract

There is a wide variety of concentrates for dairy cattle on the formal and informal markets and dairy farmers need to be astute in selecting feeds appropriate for specific production periods and animals to sustain their businesses. Composition of nutrients displayed on concentrate containers is however inadequate for in-depth assessment of products. This study determined nutrient composition, rumen dry matter disappearance and microbial colonization on residual substrate on commercial concentrate feeds and simulated total mixed rations for dairy calves, heifers, lactating and dry cows based on common feeding guidelines. Three suppliers that distribute on the formal market, dairy concentrates for each dairy herd group (calves, heifers, lactating and dry cows) that are assumed to be equivalent in nutritional value were selected. The suppliers were identified as Xi, Yi, and Zi each supplying feeds for the four dairy herd groups. Concentrates were analyzed for dry matter, organic matter, ether extract, calcium, phosphorus and gross energy and fiber fractions. Degradation was determined using *In Sacco* technique for 2, 4, 6, 8, 18, 24 and 48hrs. Calf and heifer feeds had 14-18% CP while lactating and dry cows ranged between 15-17%. All Zi feeds were high in fat (6%), whilst other sources ranged between 2- 3% consistent with minimum values on source labels. Supplier labels indicated a range of 7-10% for ether extracts, overestimating energy supply. Lignin was <2% and TDN were high. Calcium was < 1% for all feeds relative to values of 0.8-1.5% labelled across sources. There was scant data on phosphorus on supplier labels, analyses showed 0.4% indicating a Ca: P ration of 2:1. The Z-concentrates supplier had highest DMD; Z_{calf} concentrate had 87% DM digestibility (DMD) within 24hrs compared to 74 and 78% for X_{calf} and Y_{calf} respectively. Rate of degradation was very low for X_{calf} (0.04) compared to Z at 0.14. The Z_{dry} cow had over 77% and 98% DMD at 24 and 48hrs. No definite pattern on microbial count for all concentrate. Generally the Zi concentrate for all group showed better quality. Evidently variations exit in nutrient profile

among sources impacting degradability and microbial population feed residue of post *in Sacco* even though source labels indicate similarity in nutrient levels. The regulatory framework for dairy concentrates should check the regular assessment and reporting of concentrate quality on registered feeds as monitoring and evaluation process.

Keywords: fiber, *In Sacco* Degradability, protein, Simulation.

3.1 Introduction

There is substantive loss in numbers of dairy farms as result of changes in production costs and global competition, similar trends of declining numbers in the commercial sector are evident in the US and other developed nations, notably as costs of production on small scale are much higher compared to factory farms (Tauer and Mishra, 2003). The high costs of grain production continue to push prices of industrial feeds as fuel, electricity and labour costs escalate. Dairy cattle nutrition systems have to be dynamic to maintain economic viability in a globally competitive environment. Industrial concentrate supplements are therefore critical in furnishing nutrient requirements of energy, protein, vitamins and minerals for target production whilst optimizing production costs and minimizing loss of nutrient. Forages complement industrial feeds and they include grasses, legumes and industrial co-products are consumed by dairy cattle as source of nutrients and animal performance or production depends on the feed quality (nutrient). Forages are high in fibre content and increase bulkiness stimulating rumen movement and mixing of ingested materials.

South African industrial feeds are regulated by ACT 36: Feeds and Fertilizer Bill 1947. The Act defines ranges of various nutrients (crude protein, fat, vitamins, minerals, fiber) expected for feeds in different categories such as beef, sheep, goats, dairy, cats and dogs. All commercialized feeds have to be registered and composition of basic nutrients displayed clearly on bags. The data on feed labels is scanty and not adequate for estimating feed value as defined by Fox et al. (2004) and Dairy NRC (2001). Regular independent monitoring is an essential tool that would prevent flooding of poor quality concentrate on the feed market, as informal production and trading of concentrates is also a threat.

The objectives were to (a) evaluate the nutrient profile of various commercial concentrate feed marketed for dairy calves, heifer, lactating and dry cow and (b) assess rumen dry matter

degradability (DMD) variability and (c) to determine effects of total bacterial populations on rumen residual fiber.

3.2 Materials and Methods

The experiment was conducted at the Dairy cattle Unit of the Agricultural Research Council Animal Production Institute (ARC-API) in Irene South Africa (Longitude 28^0 13' S: latitude 25^0 55' E, altitude 1524m) about 15 kilometers South of Pretoria.

3.2.1 Concentrate feed selection

Three suppliers that distribute on the formal market, dairy concentrates for each dairy herd group (calves, heifers, lactating and dry cows) that are assumed to be equivalent in nutritional value were selected. The suppliers were identified as Xi,Yi, and Zi, each supplying feeds for the four dairy herd groups. Feed were purchased during mid-summer 2013.

3.2.2 Sample size

Three types of calf feeds, three Heifer feeds, three Lactating cow feeds and three dry cow feeds were selected as shown in Table 3.1 and tested in a complete randomized design (CRD) per dairy herd group. Feed source was the treatment factor.

Table 3.1: Source identification and products

Dairy herd group	Feed source		
	Supplier X	Supplier Y	Supplier Z
Calf	X_{calf}	Y_{calf}	Z_{calf}
Heifer	X_{heifer}	Y_{heifer}	Z_{heifer}
Lactating Cow	$X_{lactating\ cow}$	$Y_{lactating\ cow}$	$Z_{lactating\ cow}$
Dry Cow	$X_{dry\ cow}$	$Y_{dry\ cow}$	$Z_{dry\ cow}$

3.2.3 Animal and feeding

The experimental animals were treated according to guidelines approved by the South African National Ethics Committee for the Use of Animals in Biomedical Experiments. Two Holstein cows fitted with a 10 cm cannula were used for *in Sacco* experiments.

3.3 Experimental Procedure

3.3.1 Data collection

Different concentrate feed labels from the feed bags of selected suppliers were collected and basic nutrient profiles recorded as shown in Table 3.2 below.

Table 3. 2: Nutrient profile of commercial concentrates feeds for dairy cattle on feed labels

Source ID		Protein	M	Fiber		Fat		Calcium		Phosphorus		NPN	Urea
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Max	Max
Calf	X_{calf}	18	12	10	15	2.5	7.0	-	0.8	0.4	-	-	-
	Y_{calf}	18	12	-	15	2.5	7.0	0.6	0.8	0.4	-	-	0.9
	Z_{calf}	18	12	10	15	2.5	7.0	-	0.8	-	0.4	-	-
Heifer	X_{heifer}	17	12	-	9	2.5	8.5	-	1.3	0.6	-	1.7	
	Y_{heifer}	17	12	-	10	2.5	9.0	-	1.3	0.6	-	1.0	-
	Z_{heifer}	18	12	-	13	2.5	10	0.8	1.5	0.5	-	-	1.5
Lactating	$X_{lactating\ cow}$	17	12	-	9	2.5	8.5	-	1.5	0.6	-	-	1.7
	$Y_{lactating\ cow}$	17	12	-	12	2.5	10	0.8	1.5	0.5	-	-	1.5
	$Z_{lactating\ cow}$	16	12	12	-	5.0	10	0.6	1.5	0.8	-	1.2	3.8
Dry	X_{drycow}	18	12	-	9	2.5	8.5	-	1.3	0.5	-	-	1.7
	Y_{drycow}	12	12	12	-	2.5	10	0.8	1.2	0.5	-	-	-
	Z_{drycow}	17	12	-	12	2.5	10	0.8	1.5	0.5	-	1.5	1.2

M= moisture, NPN= non protein nitrogen

3.3.2 Feed sample preparation

Samples of 12 commercial concentrate that were in pellets form and other samples Eragrostis (*Eragrostis curvula*) grass (EG) and Lucerne (*Medicago sativa*) hay (LH), were milled (to pass a 32 mm sieve). Samples were thoroughly mixed and transferred to an airtight container and label immediately.

3.4 Chemical analyses

Dry matter (DM) of concentrate feed was determined by drying the samples in the oven at 100° C overnight and organic matter (OM) was estimated by placing 5g of sample in a weighed crucible and then put into muffle furnace at 550^0C for eight hours method 967.03), the ash were

cooled in a desicator before taking final weight according to AOAC (1999) (OM= DM-ash). Ether extracts (EE) were determined according to the method described by AOAC (2005) procedure 2003.05. Crude protein (CP) was determined by measuring nitrogen content using the Kjedahl procedure (AOAC, 2000) procedure 968.06. Gross energy (GE) of the feed samples was determined by combustion in an adiabatic bomb calorimeter (PARR model 2081). Calcium (Ca) were determined according to Giron (1973) using a Perkin Elmer atomic spectrophotometer. Phosphorus (P) by a procedure of AOAC (2000) method 965.17. Fibre extractions (NDF, ADF, and ADL) were done according to reagents described by Van Soest et al. (1991). Acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN) were according to Licitra et al. (1996) by measuring the CP content of the ADF and NDF residue by Kjeldhal analysis and contents were expressed as a percentage of total nitrogen (Van Soest et al., 1991). All samples were analysed in triplicates.

Calculations

NFC (non fiber carbohydrates) =100 – (CP + EE + ash + NDF), Mertens, (1992).

TDN % = 0.98*(100-NDFIN-CP-ASH-EE+ IADICP) + (KDCP*CP) + 2.70* (EE-1) + 0.75*(NDFIN-Lig) * (1 – (Lig/NDFIN) $^{2/3}$) – 7 (Weiss et al., 1992)

Where

NDICP: neutral detergent insoluble N (expressed as N*6.25).

ADICP: acid detergent insoluble N (expressed as N*6.25).

Lig is Lignin (% of DM) calculated as (ADL/100)*NDF

3.5 *In Sacco* degradability studies

The rumen dry matter degradability of carbohydrate fractions of commercial concentrates was determined by the polyester bag technique in agreement with the description by Michalet-Doreau et al. (1987) as well as McDonald et al. (1995). Feed sample weighing 5 g are placed into a permeable synthetic fabric nylon bags which was then inserted into the rumen through the cannula and incubated for 0, 2, 4, 6, 18, 24 and 48 hours. At termination samples were immersed in water, washed with a vacuum machine for 20 min and dried in the oven at 40^0C for 48 hours to determine the quantity of feed DM remaining as undigested material. Degradation at zero time was estimated by weighing 5 g of each sample inside the nylon bag. Sample without rumen incubation was washed with water in the vacuum machine for 20 min and dried in the oven at

40^0C for 48 hours to determine the quantity of feed dry matter remaining as unwashed material. Figure 3.1 below shows pooled out sample from canulated cow. Units are expressed in percentage dry matter (%DM).

Figure 3.1 Pooled out bag sample from cannulated animal

In Sacco dry matter degradation kinetics

Non-linear procedures (Proc NLIN) in SAS (2010) were used to estimate *in Sacco* dry matter degradation kinetics in the rumen. Data were fitted into exponential model without lag time (Orskov and McDonald, 1979) to determine the rate constant (c) and potential degradation (b).

Degradation kinetics calculations

The fermentation characteristics were calculated according to this model:

Equation 1: $P = a+b\ (1-e-ct)$ Ørskov and McDonald (1979)

Effective degradability (ED; %DM) was calculated from the aforementioned parameters assuming a passage rate (kp) of 8%/h, McDonald (1981) model:

Equation 2: $ED = a + \frac{(b*C)}{(c+kp)}$

Where a= is the soluble fraction, b= insoluble but potentially degradable fraction, c= rate of degradation, and kp= rate of passage. The coefficients a, b, and c were acquire from the exponential equations of the NLIN procedure of SAS (SAS 2010, Inst., Inc., Cary, NC), while kp was assumed to be 8% for concentrate feeds.

3.6 Microbial Analyses Procedures

Undigested feed materials from rumen dry matter degradability (DMD) were further analyzed for microbial population attached to fiber. Samples from each time intervals *in Sacco* DMD residues were washed in the water vacuum and dried at room temperature. The residues were dissolved in 10% formalin solution in normal saline (0.9% NaCl) for direct total count of bacteria. Procedures for the anaerobic technique, preparation of medium and dilution of the rumen contents was carried out as described by Hungate, (1950); Bryant and Burkey (1953a) and Dehority (1969). After the post *in Sacoo* residue samples have been diluted with the media in an anaerobic chamber these samples in agar plate were put in the incubator for 24hours at room temperature. The samples were transferred from the camber to the incubator through a desiccator. When incubation time was completed agar plate were removed from the incubator put under microscopic light to count the colonies formed on each plate by the microbes and readings were recorded.

3.7. Statistical Analysis

Data for nutrient profile, microbial count and *in Sacco* dry matter digestibility was analyzed separately for each dairy herd group in a CRD. Data were checked for normality and homogeneity of variance using statistical package in MINITAB 17 (Minitab, 2010) see appendix. Analysis of variance (ANOVA) procedures in MINITAB 17 Statistical Software, version 17 (Minitab, 2010) were used. Treatments means were compared using Tukey's test**.**

The model used for analysis was:

$Yi = \mu + \tau i + \varepsilon i$

Where: Yi is an observation of the dependent variable,

μi is the population mean for the variable,

τi is the random effect of the treatment (Xi, Yi, Zi)

εi is the random error associated with the observation i

Significance was declared at $p < 0.05$.

3.8 Results

3.8.1 Nutrient profile of calf concentrates feed

The nutrient profile of dairy calf concentrate feeds from three major suppliers is shown in Table 3.3. The calf concentrate feeds were 17-18% similar to feed label data indicated as 18% (Table 3.1). The Z_{calf} concentrate was least in neutral detergent fibre (NDF), hence had the highest content of non-fiber carbohydrates (NFC), and total digestible nutrient (TDN). The X_{calf} was low in soluble components (NPE) 46% and NFC = 27% DM. Ether extract (EE) was within the range indicated on feed source labels (2-7% DM).

Table 3.3: Nutrient profiles for three calf commercial concentrates feeds (units are expressed in %DM except energy Mcal/kg)

	X	Y	Z	
Parameter		Lsmeans		SEM
Dry matter	92.4	92.3	92.0	0.068
Organic matter	92.7	92.6	93.5	0.188
Gross energy	3.8	3.9	3.9	0.155
Ether extract	3.9[b]	2.3[c]	5.8[a]	0.002
Crude protein	17.4	16.7	17.7	0.233
Neutral detergent fibre	46.2[a]	39.5[b]	35.1[c]	0.004
Acid detergent fibre	14.1[a]	10.5[b]	10.2[b]	0.001
Acid detergent lignin	2.8	2.4	2.4	0.146
Non polar extract	46.2	48.2	56.9	3.702
Neutral detergent insoluble crude protein (NDICP)	1.4[a]	1.4[a]	1.0[b]	0.004
Acid detergent insoluble crude protein (ADICP)	0.1	0.1	0.2	0.041
Non fibre carbohydrate	32.3[b]	41.1[a]	41.2[a]	0.002
Total digestible nutrient	97.1[b]	92.8[c]	99.7[a]	0.387
Calcium	0.9[b]	1.1[a]	1.1[a]	0.004
Phosphorus	0.5	0.5	0.4	0.022

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

3.8.2 Degradation kinetics of calf concentrates feed dry matter

The *in Sacco* dry matter degradation kinetics of dairy calf concentrate feeds are shown in Table 3.4 and Figure 3.2 below (refer to Appendix J for DMD table). There was no significant

difference within 4 hours. All concentrates were highly degradable 67% within 18 hours. Z_{calf} was rapidly degraded and with ED of 88%.

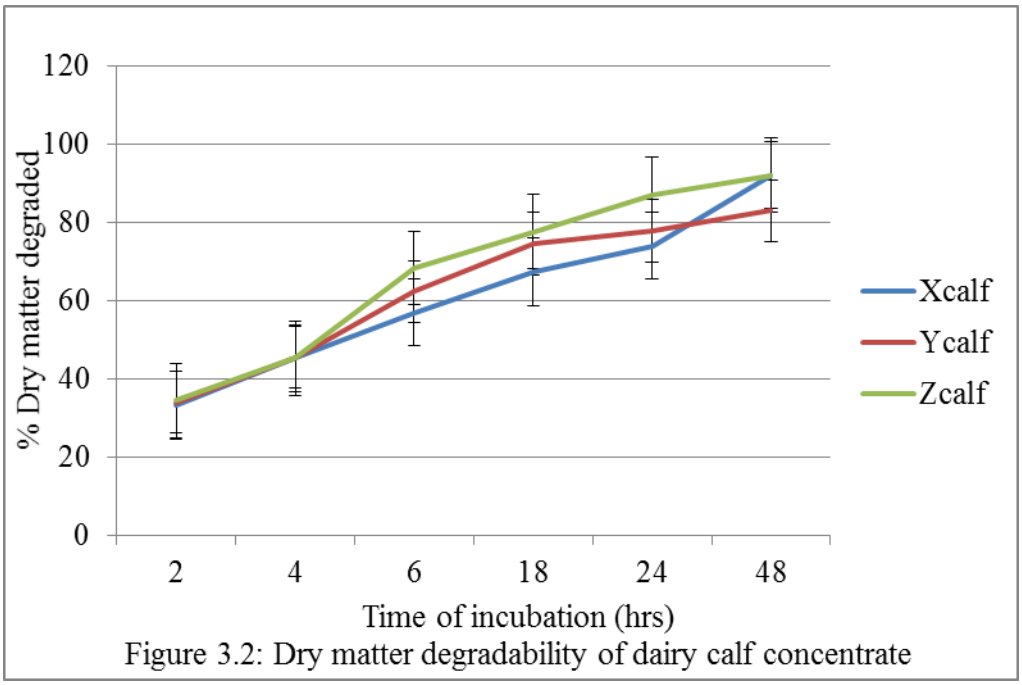

Figure 3.2: Dry matter degradability of dairy calf concentrate

Table: 3.4: *In Sacco* dry matter degradation kinetics of three calf concentrates feeds (%DM)

	X	Y	Z	SEM
a	66.1[a]	66.8[a]	73.8[a]	0.063
b	99.8[a]	81.8[c]	90.9[b]	0.001
c	0.04[b]	0.17[a]	0.14[a]	0.002
ED	86.1[a]	82.7[b]	88.8 [a]	0.017

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05). a: fraction that is soluble or immediately degraded, b: potentially degraded but insoluble fraction, c: rate of degradation. ED= Effective degradation, a= is the soluble fraction, b= insoluble but potentially degradable fraction, c= rate of degradation.

3.8.3 Microbial colony count of particulate matter post incubation dairy calf concentrate

Microbial colony count of dairy calf concentrate feed at each sampling time of post *in Sacco* is shown in the Table 3.5 below. There was no clear pattern in microbial populations post incubation. Microbial count tended to be high 6 hours post incubations but the pattern varied.

Table: 3.5: Microbial colony counts of dairy calf concentrate particulate matter post incubation

	X		Y		Z		
Time	Lsmeans	StDev	Lsmeans	StDev	Lsmeans	StDev	P value
2 hours	105.5	24.75	259.0	57.98	182.0	106.07	0.246
4 hours	37.0^{ab}	38.18	3.0^{ab}	0.01	104.5^{a}	57.28	0.001
6 hours	172.5	180.3	244.5	78.50	188.0	142.80	0.870
18 hours	201.5	139.3	176.0	175.40	93.5	6.40	0.712
24 hours	22.0^{ab}	31.11	77.0^{b}	2.83	128.5^{a}	6.36	0.004
48 hours	163.0^{a}	24.04	37.0^{c}	8.49	80.0^{b}	9.90	0.009

^{a,b,c,} Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

3.8.4 Nutrient profiles of heifer concentrate feeds

Dairy heifer concentrate feed were iso-energetic across sample. Significant difference was observed for DM, CP and EE across the three sources but Z_{heifer} had higher ether extract (6.7%) although within the range listed on the feed bags between 2.5 to 10%. Table 3.6 below shows Observed heifer concentrate nutrient profile.

Table 3.6: Nutrient profiles for three heifer commercial concentrates feeds (units are expressed in %DM except energy Mcal/kg)

Parameter	X	Y	Z	SEM
		Lsmeans		
Dry matter	93.3	93.7	91.6	0.181
Organic matter	90.7	89.8	90.1	0.113
Gross energy	3.7	3.7	3.8	0.116
Ether extract	2.4[b]	3.1[b]	6.1[a]	0.002
Crude protein	17.4[a]	15.4[b]	14.0[c]	0.002
Neutral detergent fibre	75.8	74.1	72.0[a]	0.452
Acid detergent fibre	31.8	28.7	30.1	0.507
Acid detergent lignin	6.0	6.8	9.3	0.361
Non polar extract	17.6	19.6	19.6	0.220
Neutral detergent insoluble crude protein (NDICP)	2.3[a]	1.7[b]	1.4[c]	0.003
Acid detergent insoluble crude protein (ADICP)	0.1[c]	0.3[a]	0.2[b]	0.004
Non fibre carbohydrate	4.3[b]	7.3[a]	7.8[a]	0.003
Total digestible nutrient	92.4[b]	93.0[b]	99.9[a]	0.002
Calcium	0.9[b]	0.9[b]	1.2[a]	0.004
Phosphorus	0.5	0.5	0.6	0.119

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

3.8.5 Degradation kinetics of heifer concentrates feed dry matter

The *in Sacco* kinetic dry matter degradation (DMD) dairy heifer concentrate feed are shown in Table 3.7 (refer to Appendix K for DMD table) and Figure 3.3 below. There was significant difference for DMD across heifer concentrate within each sampling time. At 24 hours over 65% was digested while Z_{heifer} had higher value of 72%. The rates of degradation were very low (0.02 to 0.06). The fraction of slowly degradable fibre was highest in Z_{heifer}.

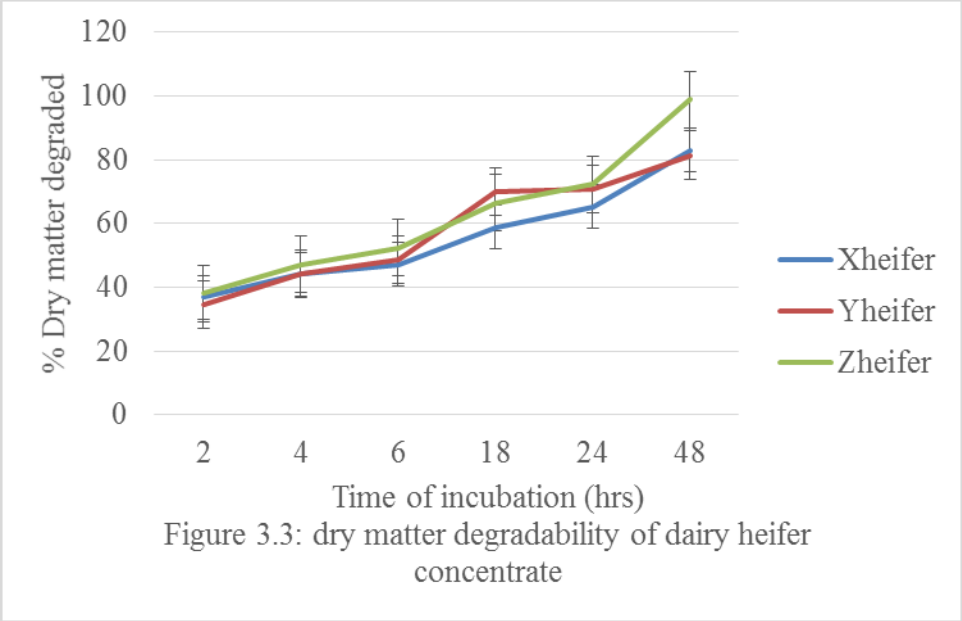

Figure 3.3: dry matter degradability of dairy heifer concentrate

Table 3.7: *In Sacco* dry matter degradation kinetics of three heifer concentrates feeds (%DM)

	X	Y	Z	SEM
A	55.1[ab]	52.9[b]	65.2[a]	24.15
B	84.2[ab]	83.5[b]	96.8[a]	25.44
C	0.02[b]	0.06[a]	0.02 [b]	0.010
ED	70.1	88.7	84.6	23.60

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05). a: fraction that is soluble or immediately degraded, b: potentially degraded but insoluble fraction, c: rate of degradation. ED= Effective degradation, a= is the soluble fraction, b= insoluble but potentially degradable fraction, c= rate of degradation.

3.8.6 Microbial colony count of particulate matter of post incubation dairy heifer concentrate

Microbial colony count of dairy heifer concentrate feed at each sampling time of post *in Sacco* is shown in the Table 3.8 below. No clear pattern was observed in microbial populations post incubation. Microbial count tended to be high 18 hours post incubations but the pattern varied.

Table 3.8: Microbial colony counts of dairy heifer concentrate particulate matter post incubation

	X		Y		Z		
Time	Lsmeans	StDev	Lsmeans	StDev	Lsmeans	StDev	P value
2 hours	113.50[a]	53.03	77.0[a]	56.57	174.4[a]	115.97	0.004
4 hours	58.50[b]	75.66	16.0[c]	21.21	257.5[a]	60.10	0.003
6 hours	165.0[ab]	190.90	243.5[a]	79.90	34.5[ab]	60.10	0.003
18 hours	159.0[a]	199.40	224.0[a]	107.50	143.0[a]	159.80	0.002
24 hours	20.5[ab]	6.40	117.0[ab]	162.60	128.5[a]	103.90	0.002
48 hours	24.0[b]	16.97	3.00[b]	4.24	261.5[a]	7.78	0.001

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

3.8.7 Nutrient profiles of lactating cow concentrate feeds

Nutrient profile observed for three source of commercial concentrate for lactating cow is shown in the Table 3.9 below. Crude protein ranged between 15-17% and source label indicate minimum levels between 16-17%. The $X_{\text{lactating cow}}$ had least value for NDF, ADF and ADL but showed highest values for NPE and ADICP across source. Neutral detergent fibre was above 38% in all the three concentrates and gross energy (energy density) seemed to be low for this group of cattle. Phosphorus and Ca were also very low.

Table 3.9: Nutrient profiles for three lactating cow commercial concentrates feeds (unit expressed in %DM except for energy Mcal/kg)

Parameter	X	Y	Z	SEM
		Lsmeans		
Dry matter	91.4	90.4	91.9	0.024
Organic matter	93.3[b]	94.5[a]	94.7[a]	0.004
Gross energy	3.5	3.7	3.9	0.479
Ether extract	2.8[b]	2.7[b]	5.4[a]	0.004
Crude protein	14.8[b]	17.3[a]	14.9[b]	0.003
Neutral detergent fibre	39.3[c]	43.3[b]	45.8[a]	0.004
Acid detergent fibre	7.5	8.4	9.6	1.534
Acid detergent lignin	1.3	1.6	1.5	0.082
Non polar extract	52.1[a]	47.1[b]	46.1[b]	0.004
Neutral detergent insoluble crude protein (NDICP)	1.3[a]	1.3[a]	1.1[b]	0.002
Acid detergent insoluble crude protein (ADICP)	0.18[a]	0.14[b]	0.07[c]	0.001
Non fibre carbohydrate	42.8[a]	36.5 [b]	33.8[b]	0.001
Total digestible nutrient	93.0	93.4	98.2	0.174
Calcium	1.4 [a]	0.8 [b]	0.8[b]	0.001
Phosphorus	0.3[c]	0.6[a]	0.5[b]	0.003

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

3.8.8 Degradation kinetics of lactating cow concentrates feed dry matter

The *in Sacco* dry matter degradation (DMD) dairy lactating concentrate feed are shown in Table 3.10 refer to Appendix L for DMD table and Figure 3.4 below. There was significant difference for DMD across lactating concentrate feed within each sampling time. At 6 hours over 42% was degraded in all feeds while at 18 hours degradation was 55, 57 and 67% for $X_{\text{lactating cow}}$, $Y_{\text{lactating cow}}$ and $Z_{\text{lactating cow,}}$ respectively. Rate of degradation for lactating concentrate was low for all concentrates.

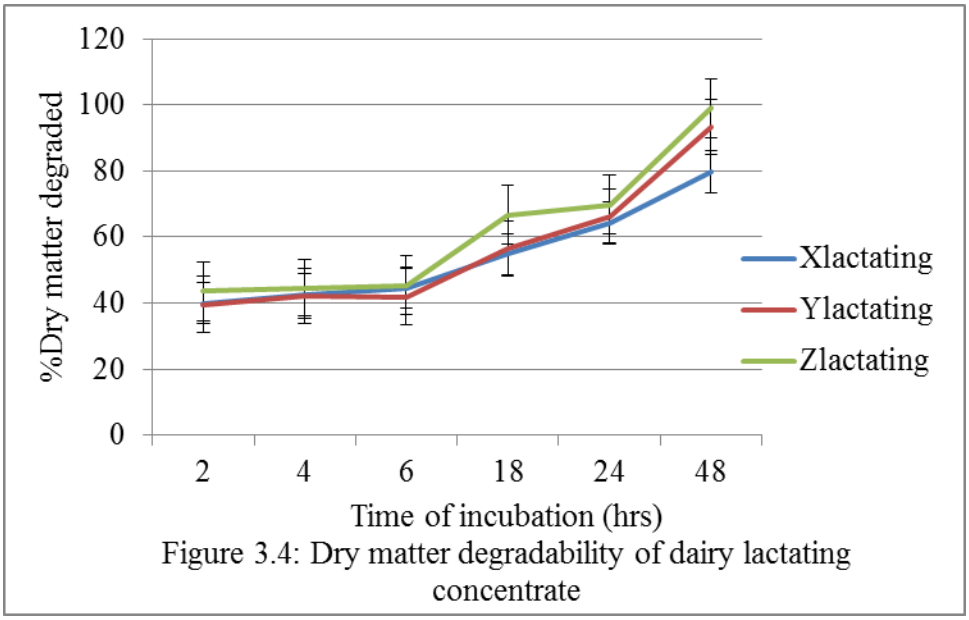

Figure 3.4: Dry matter degradability of dairy lactating concentrate

Table 3.10: *In Sacco* dry matter degradation kinetics of three lactating concentrates feeds (%DM)

	X	Y	Z	SEM
B	85.2[b]	94.5[a]	97.3[a]	1.65
C	0.02[a]	0.01[b]	0.01[b]	0.01

a,b,c,

Lsmeans within each row with similar letter(s) are not significantly different (P>0.05). a: fraction that is soluble or immediately degraded, b: potentially degraded but insoluble fraction, c: rate of degradation. ED= Effective degradation, ED and a fractions not computed due to lack of fit, b= insoluble but potentially degradable fraction, c= rate of degradation.

3.8.9 Microbial colony count of particulate matter post incubation dairy lactating concentrate

Microbial colony count of dairy lactating cow concentrate feed at each sampling time is shown in the Table 3.11 below. There was no obvious pattern in microbial populations post *in Sacco* incubations count. Microbial count tended to be lower 24 hours post incubations.

Table 3.11: Microbial colony counts of dairy lactating concentrate particulate matter post incubation

	X		Y		Z		
Time	Lsmeans	StDev	Lsmeans	StDev	Lsmeans	StDev	P value
2 hours	65.5	19.09	72.5	60.10	78.5	111.02	0.985
4 hours	152.0	209.30	83.5	118.10	243.5	13.40	0.578
6 hours	161.0^{ab}	196.60	97.5^{ab}	74.20	224.5^{a}	13.40	0.0.03
18 hours	300.0^{a}	0.01	98.0^{b}	15.56	204.5^{ab}	72.83	0.004
24 hours	41.5	58.69	86.0	73.54	91.0	1.41	0.648
48 hours	17.50^{c}	24.75	212.0^{a}	62.23	157.5^{b}	26.16	0.003

^{a,b,c,} Lsmeans within each row with similar letter(s) are not significantly different (P>0.05)

3.8.10 Nutrient profiles of dry cow concentrate feeds

Crude protein for dry cow concentrate is between 13 - 16.5% with $Z_{dry\ cow}$ having highest CP content, feed labels also indicated $Z_{dry\ cow}$ as 21%; 5 units over the observed value. Fibre bound nitrogen was low and there were no difference in ADICP content. The ether extract was within the range on the feed bags across source; $Z_{dry\ cow}$ however had twice the EE of $X_{dry\ cow}$. Gross energy density was similar. Significant difference was observed for NDF, with 47% NDF DM in $Y_{dry\ cow}$ and 32% NDF DM for the $Z_{dry\ cow}$ concentrate. Minerals content of all dry cow concentrates were less than 1.5 % DM in X and Y but Ca was high in $Z_{dry\ cow}$. Table 3.12 shows the nutrient profiles of the dry cow concentrates.

Table 3.12: Nutrient profile for three dry cow commercial concentrates feeds (units are expressed as %DM except energy Mcal/kg)

	X	Y	Z	
Parameter		Lsmeans		SEM
Dry matter	92.4	91.4	91.1	0.118
Organic matter	92.9[b]	94.5[a]	94.7[a]	0.003
Gross energy	3.9	3.7	3.7	0.159
Ether extract	2.4[b]	3.2[b]	5.1[a]	0.002
Crude protein	15.1[ab]	13.1[b]	16.5[a]	0.004
Neutral detergent fibre	41.0[b]	47.0[a]	32.0[c]	0.002
Acid detergent fibre	9.4	7.5	7.5	1.367
Acid detergent lignin	1.7	1.7	1.5	0.132
Non polar extract	51.4[b]	44.4[c]	57.3[a]	0.002
Neutral detergent insoluble crude protein (NDICP)	1.3[a]	1.3a[a]	1.1[b]	0.002
Acid detergent insoluble crude protein (ADICP)	0.3	0.4	0.2	0.201
Non fibre carbohydrate	41.3[ab]	36.5[b]	46.3 [a]	0.002
Total digestible nutrient	92.4[b]	97.7[a]	97.6[a]	0.003
Calcium	1.0[b]	0.9[b]	2.5[a]	0.004
Phosphorus	0.5[b]	0.4[c]	0.8[a]	0.003

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

3.8.11 Degradation kinetics of dry cow concentrates feed

The *in Sacco* dry matter degradation (DMD) dairy dry concentrate feed are shown in Table 3.13 refer to Appendix M for DMD table and Figure 3.5 below. Difference in DMD were observed within 6 hours; $Z_{dry\ cow}$ had highest DMD from onset and was completely degraded within 48 hours, 19 and 14 % units above X and Y. There was an inverse relationship with rate of degradation which was lowest for Z dry.

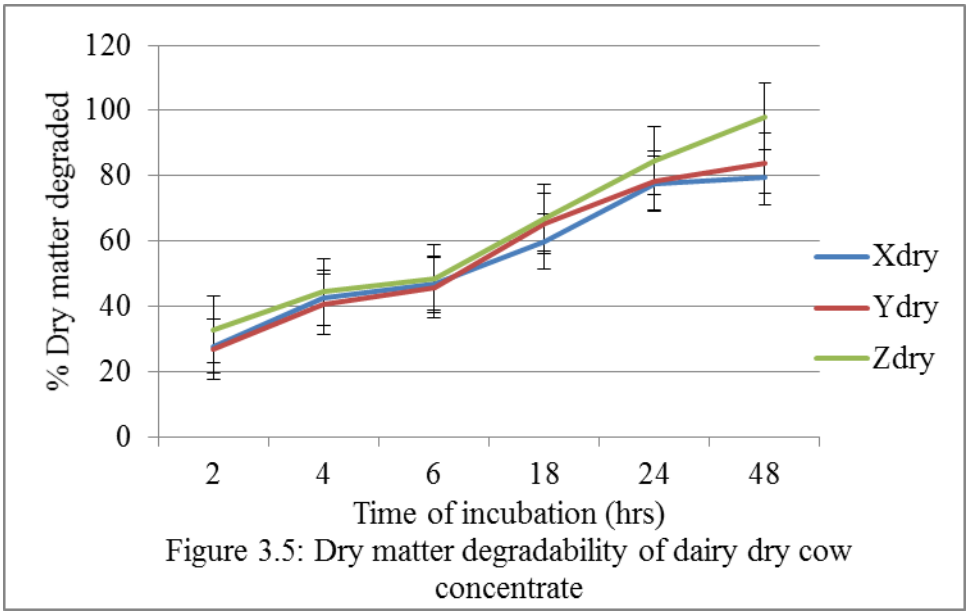

Figure 3.5: Dry matter degradability of dairy dry cow concentrate

Table 3.13: *In Sacco* dry matter degradation kinetics of three dry cow concentrates feeds (%DM)

	X	Y	Z	SEM
A	57.9[b]	65.5[b]	77.9[a]	3.75
b	80.6[b]	85.4[b]	96.5[a]	3.04
c	0.08[a]	0.07[a]	0.04[b]	0.01
ED	98.2	105.2	110.0	5.53

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05). a: fraction that is soluble or immediately degraded, b: potentially degraded but insoluble fraction, c: rate of degradation. ED= Effective degradation, a= is the soluble fraction, b= insoluble but potentially degradable fraction, c= rate of degradation.

3.8.12 Microbial colony count of particulate matter post incubation dairy dry cow concentrate

Microbial colony count of dairy dry cow concentrate feed at each sampling time is shown in the Table 3.14 below. There was no distinct pattern in microbial populations post *in Sacco* incubation count.

Table 3.14: Microbial colony count of dairy dry cow concentrate particulate matter post incubation

	X		Y		Z		
Time	Lsmeans	StDev	Lsmeans	StDev	Lsmeans	StDev	P value
2 hours	118.5[ab]	21.92	226.5[a]	41.72	167.0[ab]	94.75	0.004
4 hours	234.0[a]	93.34	44.0[ab]	62.23	61.0[ab]	36.77	0.001
6 hours	106.5	27.60	178.0	172.50	150.5	23.30	0.793
18 hours	132.0[ab]	110.31	300.0[a]	0.01	70.5[ab]	51.62	0.004
24 hours	89.5[b]	78.49	266.0[a]	48.08	242.0[a]	63.64	0.002
48 hours	121.0	24.04	225.0	106.07	28.00	39.60	0.130

[a,b,c,] means within each row with similar letter(s) are not significantly different (P>0.05).

3.9 Discussion

3.9.1 Variations in quality of calf commercial concentrate feed

Feed Digestibility is affected by nutrient availability in the rumen and the balance of energy and protein supply for microbial growth which is influenced by the feed quality and form (Porter et al. (2007)). Since ingredients were not defined it was difficult to determine proportions of rumen degradable protein and carbohydrate fractions. It seems however that Z concentrate had a better balance of the various nutrient fractions and hence the consistently higher DMD of concentrates feed. The NFC% in our findings was lower to Hoover et al. (1991) and Aldrich et al. (1993) report of 36% NFC DM that increases bacterial nitrogen flow to the small intestines providing adequate energy for microbial growth. Highly degradable feed like Z_{calf} concentrate pose the risk of bloating and this may have negative impact on animal health (Roth *et al.,* 2009) and it is uneconomical therefore good quality forage would be suitable as complimentary feeds with Z_{calf}, as the forage would boost NDF % in diet and slow down protein degradation in the rumen, as rapid degradation leads to Nitrogen (N) loss as ammonia. Our result corresponds with the finding of Porter et al. (2007) that digestible nutrient in calf feed are higher with low fibre content. Feeding recommendation of up to 3kg/calf/day concentrates feeds, mixed with good quality forage would optimize rumen function. Yang and Beauchemin, (2002) and Tafaj et al. (2005)

reported that 20-50% concentrate level in addition to good quality hay would enhance rumen degradability and rumen development. Feed dry matter degradation of 60-80% would achieve high daily growth rates in calves. All three concentrates would therefore be considered as good quality for dairy calves.

3.9.2 Heifer commercial concentrate feed

The concentration of crude protein (CP) in the heifer concentrates in our findings was within values proposed by Zanton and Heinrich (2008) and maximum protein efficiency has been demonstrated when heifers are fed diets containing 14 to 14.5% CP (Zanton and Heinrichs, 2008) as observed in this study. Although X_{heifer} had higher value and supplier data for CP was between 17-18%. The heifer concentrate NDF was higher than recommended range. The indefinite pattern observed in our finding on microbial colonization is in line with observation by Arroyo and Gonzalez (2013). Feeding heifers high concentrate diets may results in metabolic and ruminal abnormality (Zanton and Heinrichs 2008). Lucerne hay would be a possible substitute for heifer concentrates as it had a high DMD. Moody et al., (2007) indicated that concentrate or highly digested forage can be used as substitutes in heifer diet. Slow degraded concentrate feed (X_{heifer}) would be a better option complemented with high quality forage when raising heifers. Cursory attention is usually given to heifer nutrition as most producers feed their heifers with residues from lactating or calf concentrate or total mixed ration to minimize feed costs. The practice is acceptable as cow or calf concentrates are more nutrient dense. The differences observed in dry matter degradation (DMD) may be traced to the source of feed ingredient and different processing method used by supplier in formulating their feed. The dairy business would not be sustainable as age at first calving is delayed and first lactation milk would be reduced. The Z_{heifer} seemed to be the best in this category.

3.9.3 Lactating cow commercial concentrate feed

Crude protein in our finding was low compared to 18% recommended by Caraviello *et al.*, (2006) for early lactation dairy cows. Feeding high CP results in loss of energy as excess N is converted to urea and excreted consequently reduced DMI and reduced animal efficiency (Allen, 2000; Kalscheur *et al.,* 2006) due to poor digestion processes. The indefinite pattern observed in microbial colonization is in line with observation by Arroyo and Gonzalez (2013). The NDF was

39% in our findings and it is within recommendation(Meissner and Paulsmeier, 1995) because NDF affect dry matter intake and milk production (Staples, et al. 1992 and Meissner and Paulsmeier, 1995). The concentrates had low energy density, CP and minerals and would not support very high levels of milk production. The risk of metabolic disorders would be high (Mertens, 1997; Kolver and deVeth, 2002) unless the diets are supported with additives, energy boosters, and mineral concentrates. However, additional nutrients would increase the cost of producing milk in early lactation. As such, concentrates from X, Y and Z would be suitable for low-medium milk producing cows.

3.9.4 Dry cow commercial concentrate feed

Variations in sources of ingredients and processing affected nutrient availability in the rumen for supporting microbial growth. The NRC (2001) recommended feeding concentrates to dairy dry cows from 60 to 100% to prepare for early lactation, since the level of feeding during dry period tend to affect the production during early lactation. The $Y_{dry\ cow}$ had high NDF implying that the fractions of readily available nutrients were low. The recommended TDN for dry cow is 75% (Boyazoglu, 1999) and all three concentrate in our findings were above recommendation. The low cp, energy, mineral concentration and very high NDF would preclude the assessed concentrates in our finding as nutrient sources for close up cows. The fore-stomachs have reduced space due to pregnancy therefore the feeds should be nutrient dense.

3.10 Conclusion and Recommendations

Evidently variations occur in nutrients across sources even though source labels indicate similarity in nutrient. Generally the compositions of concentrates were within the range stipulated by the Regulator although key components of CP and fat tended to be different from what the supplier indicated. The Z supplier seemed to have higher quality of concentrates. Suppliers source different ingredients and process them using different methods which affects nutrient availability. Change in seasons, variations in soils, storage and processing of ingredients play a huge role in determining nutrient quality of concentrates. It is therefore premature to conclude that a particular brand is superior due to the myriad of components that fluctuate and affect ingredient quality. It is recommended that suppliers display energy, protein, fat, minerals and vitamin supply as also mandated on human feeds, to enable clients to make better judgment

when selecting concentrates and also rapid assessment using nutrition tools. Farmers should select feeds based on nutritional needs of different groups of animals and quality of forage available to maximize their production potential. Regular monitoring and evaluation of feeds on the dairy markets is an essential component for quality control as dairy businesses are sensitive to fluctuations in the economy.

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CHAPTER FOUR

Rumen degradability of dairy cattle rations

Abstract

Variations in composition and disappearance of nutrients in dairy cattle concentrates occur across source type as dictated by ingredients and availability of nutrient pools This study determined rumen dry matter degradation (DMD) and levels microbial colonization on rumen residual fiber of dairy concentrate diets with Lucerne/Eragrostis diets. For each dairy herd group three total mixed rations were formulated based on commonly recommended proportions for the various groups and identified based on dairy herd group: Rations simulated for calves were Xcalf (Xc), Ycalf (Yc) and Zcalf (Z_C); heifers, Xheifer (X_H), Yheifer (Y_H) and Zheifer (Z_H); early lactating cows, Xearly lactation (X_{EL}), Yearly lactation (Y_{EL}) and Zearly lactation (Z_{EL}); late lactating cow Xlate lactation (X_{LL}), Ylate lactation (Y_{LL}) and Zlate lactation (Z_{LL}) and far dry cows Xfar dry (X_{FD}), Yfar dry (Y_{FD}) and Zfar dry (Z_{FD}). The concentrates, forages and diets were analyzed for DM, OM, EE, GE, P, Ca, and NDF. *In Sacco* DMD for 4, 8, 18, 24, 30 and 48hrs incubation time using two lactating dairy cows and 24hrs post *in Sacco* residue for microbial count. Prediction of nutrient supply and balances were done using level 1 of the AMTS mechanistic model based on requirements for calf, early and late lactation dairy cows. The X_C was least in CP and Ca but was high in EE. The Zc had consistently high OMD and rumen microbial count in rumen fibre residue while predict calf TMR showed sufficient protein supply. The heifer TMR differed in EE, Ca and P . At 24 hours only 43% OMD was observed for X_H and low microbial count. Also differences were observed $P<0.05$ for EE, GE, Ca and P in the TMR of early lactation. The Z_{EL} TMR exhibiting the highest OMD of 82% at 48hrs and predicted body weight loss in early lactation was low. The late lactation diets were iso-nitrogenous but differences observed in Ca and P but predicted supply of energy and protein were sufficient as indicated by the positive balances and efficiency of N and P use averaged 25g/d. The dry cow TMR differed in CP, Ca and P. At 24 hour OMD with X_{FD} highest in OMD while Z_{FD} was highest in bacterial count The rations formulated using concentrates from Z were had better nutrient profiles and outperformed other rations of assumed equivalent nutrient value

Keywords: dairy cattle, rumen fermentation, nutrient density, diet simulation, microbial synthesis

4.1. Introduction

Dairy meal is a lay term commonly used to define concentrate feeds for lactating cow groups, calf meal, heifers and dry cows, respectively. The generic composition of energy concentrates for calves is 18% CP, 0.70% Ca and 0.45% P. Heifer concentrates would have 12-15% CP, while lactating cow concentrates with 13-19% CP, with % 0.7-1.1% Ca and 0.4-0.9% P and dry cow with 13-15% CP 0.44-0.48% Ca and 0.22-0.26% P. Several feed manufacturers distribute products that reflect the exact values and ranges in nutrients as stipulated by the Registrar (Feeds and Fertilizer Act, 1947) to align with the composition of the registered product. Monitoring and evaluation of feed products essential in quality control of commercially marketed concentrates and protecting client rights. A myriad of factors influence the quality of the final product including conditions in storage. Hence the probability of maintaining quality of the end product from manufacturing to that on dispensary is low.

Feeds high in CP may be low in nitrogen availability due to Maillard products, or excessive rumen degradable protein that may cause ammonia poisoning or interactions with trypsin inhibitors. High energy density may indicate feeds high in soluble carbohydrates that cause acidosis or high fat content which may inhibit rumen bacteria. The South African utilizes nutrition models, such as the dairy NRC (2001) and Cornell Net Carbohydrate and Protein System (CNCPS, Fox et al., 2004) in animal requirements and formulation of recipes for target production and ensure quality of products. Nutrient modelling is a rapid assessment method based on precise characterization of feed chemistry, potential degradation and rates of passage of the various protein, carbohydrate fractions, metabolizable energy and protein synthesis. Given the wide spectrum of dairy concentrates marketed in South Africa, external quality control is critical to manage entry of poor quality concentrates on both formal and informal markets.

The objective of the study were (a) to assess nutrient composition of simulated diet, (b) evaluate rumen organic matter degradation, (c) effect of bacterial populations on rumen residue fibre and (d) to estimate metabolizable energy and protein balance expected from concentrate feeds and total mixed rations formulated with each concentrate feed marketed in South Africa for dairy herd groups

4.2 Material and Methods

4.2.1 Site of experiment

The experiment was conducted at the Dairy cattle Unit of the Agricultural Research Council Animal Production Institute (ARC-API) in Irene South Africa (Longitude 28^0 13' S: latitude 25^0 55' E, altitude 1524m) about 15 kilometers South of Pretoria.

4.2.2 Sample selection

Three suppliers that distribute on the formal market, dairy concentrates for each dairy herd group (calves, heifers, lactating and dry cows) that are assumed to be equivalent in nutritional value were selected. The suppliers were identified as Xi, Yi, and Zi, each supplying feeds for the four dairy herd groups as shown in Table 4.1 below. Feed were purchased during mid-summer 2013. The trial had three feed sources and four dairy groups-total of 12 concentrate types. Three TMR diets were formulated based on commonly recommended dairy rations to meet nutritional requirement of listed animal. All analyses were based on dairy animal group and feed source was fixed.

Feed samples in pellet form and complementary forage samples Eragrostis (*Eragrostis curvula*) grass (EG), Lucerne (*Medicago sativa*) hay (LH), and lucerne leaves (LL) (for calf) were ground (to pass a 2 mm sieve). Samples were thoroughly mixed and transferred to an airtight container and label immediately.

Table 4.1: Source identification and animal group

	Feed source		
	X	Y	Z
Calf (C)	X_C	Y_C	Z_C
Heifer (H)	X_H	Y_H	Z_H
Early lactating (EL)	X_{EL}	Y_{EL}	Z_{EL}
Late Lactating (LL)	X_{LL}	Y_{LL}	Z_{LL}
Far dry (FD)	X_{FD}	Y_{FD}	Z_{FD}

4.2.3 Diet formulation

Total mixed ration were formulated as shown in Table 4.2 based on common feeding guidelines for dairy herds farmers in Gauteng. Calf ration was based on new industry recommendations to increase forage in diets of calves. High forage rations are recommended for heifers, High concentrate diets in early lactation

Table 4.2: Proportions of Simulated rations of Concentrate and forage feed

Concentrate type	Eragrostis	Lucerne	Concentrate
$X_{C,}$ $Y_{C,}$ Z_C	-	30%	70%
$X_{H,}$ Yh, Z_H	55%	-	45%
$X_{EL,}$ $Y_{EL,}$ Z_{EL}	15%	5%	80%
$X_{LL,}$ $Y_{LL,}$ Z_{LL}	18%	12%	70%
$X_{FD,}$ $Y_{FD,}$ Z_{FD}	58%	-	42%

X, Y, and Z= Sources of Dairy concentrates

4.3. Chemical analysis

Dry matter (DM) of concentrate feed was determined by drying in the oven at 100° C overnight and organic matter (OM) was estimated by placing sample in muffle furnace at 550^0C for eight hours method 967.03) AOAC (1999) (OM= DM-ash). Ether extracts (EE) were determined according to the method described by AOAC (2005) procedure 2003.05. Crude protein (CP) was determined by measuring nitrogen content using the Kjedahl procedure (AOAC, 2000) procedure 968.06. Gross energy (GE) of the feed samples was determined by combustion in an adiabatic bomb calorimeter (PARR model 2081). Calcium (Ca) was determined according to Giron (1973) using a Perkin Elmer atomic spectrophotometer. Phosphorus (P) by a procedure of AOAC (2000) method 965.17. Fibre extractions (NDF, ADF, and ADL) were done according to reagents described by Van Soest et al. (1991). All samples were analysed in triplicates.

4.4 *In Sacco* degradability studies

The rumen degradability of carbohydrate fractions of simulated diets consisting of commercial concentrates mixed with either lucerne or grass or both depending on the animal requirement was determined by a method to facilitate the retrieval of polyester bag technique by Cruywagen (2006). The simulated diets weighing 5 g are placed into a permeable synthetic fabric nylon bags which was then inserted into the rumen through the cannula and incubated for 0, 4, 8, 18, 24, 30 and 48 hours. At termination samples were immersed in water, washed with a vacuum

machine for 20 min and dried in the oven at 40^0C for 48 hours to determine the quantity of feed DM remaining as undigested material. Degradation at zero time was estimated by weighing 5 g of each sample inside the nylon bag. Sample without rumen incubation was washed with water in the vacuum machine for 20 min and dried in the oven at 40^0C for 48 hours to determine the quantity of feed dry matter remaining as unwashed material. Units are expressed in percentage organic matter (%OM).

4.5 Ration evaluation

The stimulated diets of the three sources of calf, early and late lactation cow nutrient profile were inputted into the large ruminant nutrition system level 1 of the AMTS model (Tylutki et al., 2014). Feed libraries were updated using composition of ingredients used in the study. Animal descriptions, production status and management factors were loaded into the model as well as environmental temperature of 20^oC, humidity 40%, wind speed 1.6 (Km/h) used. Predictions were only done for transition groups (calf; early and pregnant late lactation cow). Calf model inputs; nutrient requirement for 90 day old calf, 67 kg body weight, and receiving 3.7 kg feed as feed basis. The early lactating cow model inputs included 20 kg DM/d TMR, cows weighing 550 kg and producing 30 litres of milk in a zero grazing system. The late lactating cow model had inputs of 20 kg DM/d TMR, cows weighing 600 kg, producing 20 litres of milk and five (5) month pregnant.

4.6 Microbial Analyses on residual fibre

Undigested feed materials from 24bhours rumen dry matter degradability (DMD) were further analyzed for microbial population attached to fiber. Samples from each time intervals *in Sacco* DMD residues were washed in the water vacuum and dried at room temperature. The residue were dissolved in 10% formalin solution in normal saline (0.9% NaCl) for direct total count of bacteria. Procedures for the anaerobic technique, preparation of medium and dilution of the rumen contents was carried out as described by Hungate, (1950); Bryant and Burkey (1953a) and Dehority (1969). After the post *in Sacoo* residue samples have been diluted with the media in an anaerobic chamber these samples in agar plate were put in the incubator for 24hours at room temperature. The samples were transferred from the camber to the incubator through a desiccator. When incubation time was completed agar plate were removed from the incubator put

under microscopic light to count the colonies formed on each plate by the microbes and readings were recorded.

Animal management and data collection: The experimental animals were treated according to guidelines approved by the South African National Ethics Committee for the Use of Animals in Biomedical Experiments.

LIMITATIONS

Concentrate material of Y heifer was contaminated during the experiment and most data was excluded from the analyses.

4.7 Statistical Analysis

Data for nutrient profile, microbial count and *in Sacco* organic matter digestibility was analyzed separately for each dairy herd group in a complete randomize design (CRD). Data were checked for normality and homogeneity of variance using statistical package in MINITAB 17 (Minitab, 2010) see appendix. Analysis of variance (ANOVA) procedures in MINITAB 17 Statistical Software, version 17 (Minitab, 2010) were used. Treatments means were compared using Tukey's test**.**

The model used for analysis was:

$Yi = \mu + \tau i + \varepsilon i$

Where: Yi is an observation of the dependent variable,

μi is the population mean for the variable,

τi is the fixed effect of the ith treatment, where i = X_C, Y_C, Z_C OR X_H, Y_H, Z_H OR X_{EL}, Y_{EL}, Z_{EL} or X_{LL}, Y_{LL}, Z_{LL} OR X_{FD}, Y_{FD}, $Z_{FD.}$

εi is the random error associated with the observation i

Significance was declared at $p < 0.05$.

4.8 Results

4.8.1 Nutrient profile of the simulated calf diets

Table 4.3 shows the nutrient profile of calf diets. Dairy calf stimulated diets were iso-energetic but difference were observed in crude protein (CP), ether extract (EE), calcium (Ca) and phosphorus (P). The X_C diet was least in CP and Ca but was high in EE. The calcium phosphorus ration varied in all diets.

Table 4.3: Nutrient composition of simulated calf diets (units express as %DM except for energy in Mcal/kg)

	X	Y	Z	
Parameter		Lsmean		SEM
Dry matter (DM)	93.3	93.2	93.3	0.105
Organic matter	94.2	94.3	94.5	0.110
Crude protein	14.5[c]	15.7 [b]	17.1[a]	0.220
Ether extract	2.6[a]	2.5[ab]	2.3[b]	0.037
Gross energy	3.9	3.8	3.9	0.115
Neutral detergent fibre	42.3[a]	39.1[b]	37.0[b]	0.210
Calcium	1.0[b]	1.1 [a]	1.1[a]	0.010
Phosphorus	0.36[c]	0.42[a]	0.39 [b]	0.006

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05).

4.8.2 *In Sacco* degradation of simulated calf diets on organic matter and bacteria count

The *in Sacco* organic matter degradation (OMD) for dairy calf simulated diets is shown Figure 4.1(refer to Appendix N for OMD table). Organic matter degradability differed across diets. The Z_C had consistently high OMD while X_C ration was least. At 24 hours only 42% OMD was observed for X_C. The difference between Z_C and X_C diets ranged between 10 to 19% which was significant. None of the diets were degraded beyond 75% at 48 hours. The microbial counts on residue at 24 hours are also shown in the Table 4.4. Microbial mass on residue differed. The Z_C has the highest count of rumen micro-organisms attached to fibre while XC was least.

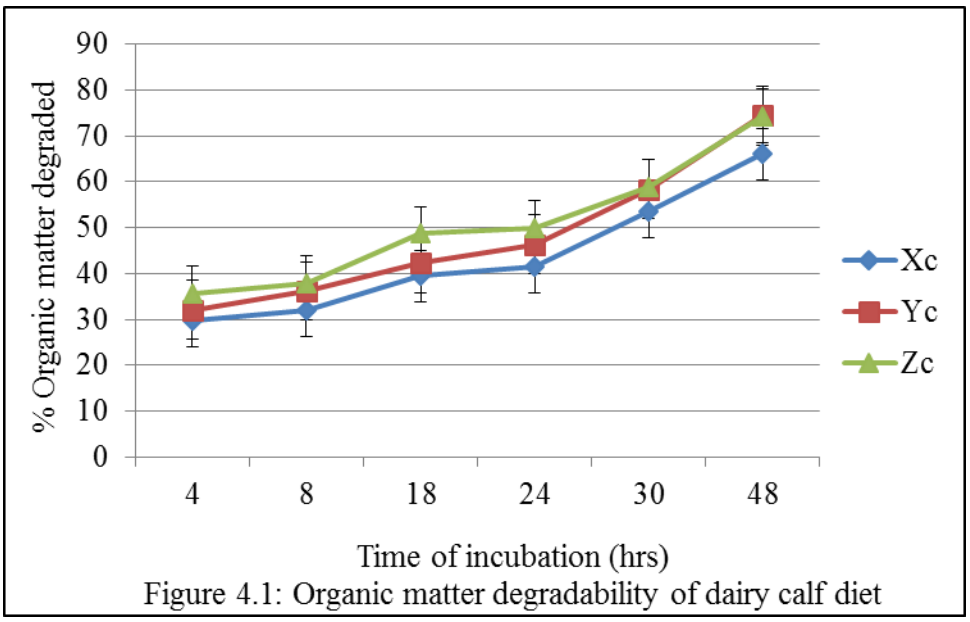

Figure 4.1: Organic matter degradability of dairy calf diet

Table 4.4: Microbial colony count on particulate matter post incubation of simulated calf diets

	X	Y	Z
24 hours	1.2×10^6	2.4×10^7	3.0×10^7

The predicted nutrient compositions of calf simulated diets are shown in Table 4.5-4.7. Differences were observed in the predicted nutrient requirement, diet concentrate, animal performance and rumen environment. Total ration forage was within acceptable range. About 3 kg of simulated diet would be required to meet metabolizable energy requirements. Model predictions show that the calves would not be in negative energy balance and there was sufficient protein supply.

Table 4.5: Predicted calf diet concentration (%DM)

	X	Y	Z
Total forage in ration	32	34	35
Total non-fibre carbohydrate	33	29	27
Apparent total digestible nutrients	57	59	62
Metabolizable energy (Mcal/kg)	2.05	2.12	2.25
Net energy for maintenance (Mcal/kg)	1.20	1.26	1.39

Predicted calf growth requirements were ME= 6.8 Mcal/d, MP= 253g/d, Ca= 3 g/d and P= 4g/d

Table 4.6: Predicted Nutrient balances in calves

Source	X		Y		Z	
	ME	MP	ME	MP	ME	MP
Requirements	Mcal/d	g/d	Mcal/d	g/d	Mcal/d	g/d
Total Supplied	6.83	303	7.03	315	7.50	318
Balance	0.00	50	0.2	62	0.6	65

Table 4.7: The rumen environment of calf

Rumen Values	units	X	Y	Z
% Ruminal Nitrogen Balance	%	166	149	154
Predicted Ruminal pH	required	6.11	6.10	6.09

4.8.3 Nutrient profile of the simulated heifer diets

The dairy heifer simulated diets were different in Ca and P concentrations (Table 4.8). The X_H diet was least in Ca and P. Protein content was low in all simulated diets, relative to requirements for growing dairy calves. The simulated diet NDF was also very high.

Table 4.8: Nutrient profile of simulated dairy heifer diets (units express as %DM except for energy in Mcal/kg)

	X	Z	
Parameter	Lsmean		SEM
Dry matter	93.5	93.0	0.105
Organic matter	94.3	94.4	0.108
Crude protein	11.2	10.1	0.130
Ether extract	1.9	2.1	0.146
Gross energy	3.9	4.1	0.116
Neutral detergent fibre	66.7	62.8	2.311
Calcium	0.5^{b}	0.7^{a}	0.007
Phosphorus	0.3^{b}	0.4^{a}	0.007

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05)

4.8.4 *In Sacco* degradation of simulated heifer diets on organic matter and bacteria count

The *in Sacco* organic matter degradation (OMD) is shown in Figure 4.2 (refer to Appendix O for OMD table). Differences were observed in OMD at 8 and 24 hours. None of the diets were degraded beyond 65% at 48 hours. The microbial counts on residue at 24 hours are also shown in the Table 4.9. Microbial mass on residue differed- X_H had a higher count of rumen micro-organisms attached to fibre while Z_H was least.

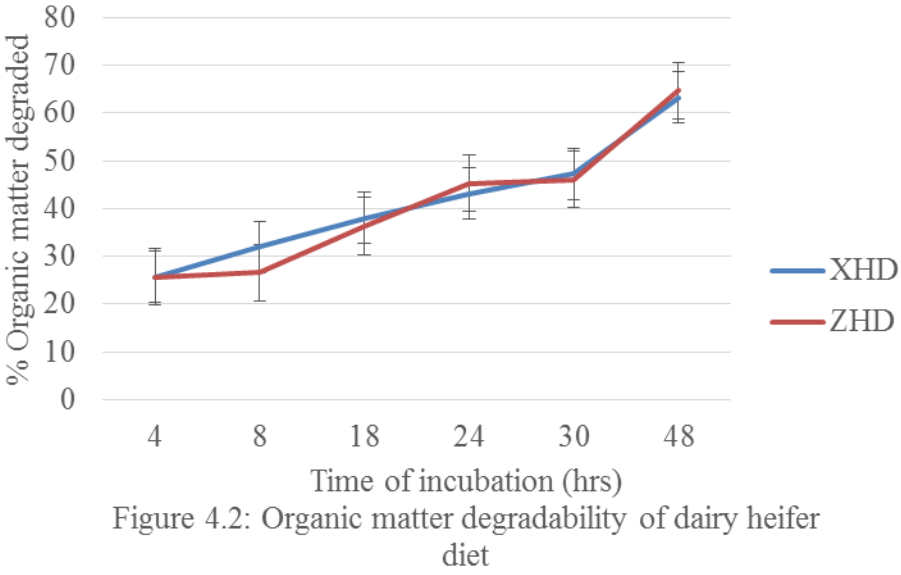

Figure 4.2: Organic matter degradability of dairy heifer diet

Table 4.9: Microbial colony count on particulate matter post incubation of simulated heifer diets

	X	Z
24 hours	1.82×10^7	9.3×10^6

4.8.5 Nutrient profile of the simulated early lactation cow diets

Table 4.10 shows the nutrient profile of early lactating diets. Dairy early lactating cow diets were close in crude protein concentration but difference was observed in EE, GE, Ca and P. The Y_{EL} diet was high in EE and P but was least in Ca. The NDF was very high, > 40% DM and mineral supply very low.

Table 4.10: Nutrient composition of simulated early lactation diets (units express as %DM except for energy in Mcal/kg)

	X	Y	Z	
Parameter		Lsmean		SEM
Dry matter	93.0	92.7	93.3	0.259
Organic matter	92.3	91.3	92.7	0.262
Crude protein	14.8	15.4	14.7	0.267
Ether extract	2.0^{b}	2.3^{a}	2.1^{b}	0.018
Gross energy	4.5^{a}	3.9^{ab}	3.8^{b}	0.577
Neutral detergent fibre	44.0^{b}	46.4^{ab}	47.9^{a}	0.234
Calcium	1.4^{a}	0.5^{c}	0.9^{b}	0.035
Phosphorus	0.31^{c}	0.47^{a}	0.45^{b}	0.004

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05)

4.8.6 *In Sacco* degradation of simulated early lactation diets on organic matter

The *in Sacco* organic matter degradation (OMD) for dairy early lactation cow diet are shown in Figure 4.3 (refer to Appendix P for OMD table). Differences were observed OMD but Z_{EL} had consistently high OMD compared to X_{EL} and $Y_{EL.}$ None of the diets were degraded beyond 82% at 48 hours. The microbial counts on residue at 24 hours are also shown in the Table 4.12. Differences were observed in microbial mass on residue. The Y_{EL} has lower count of rumen micro-organisms attached to fibre.

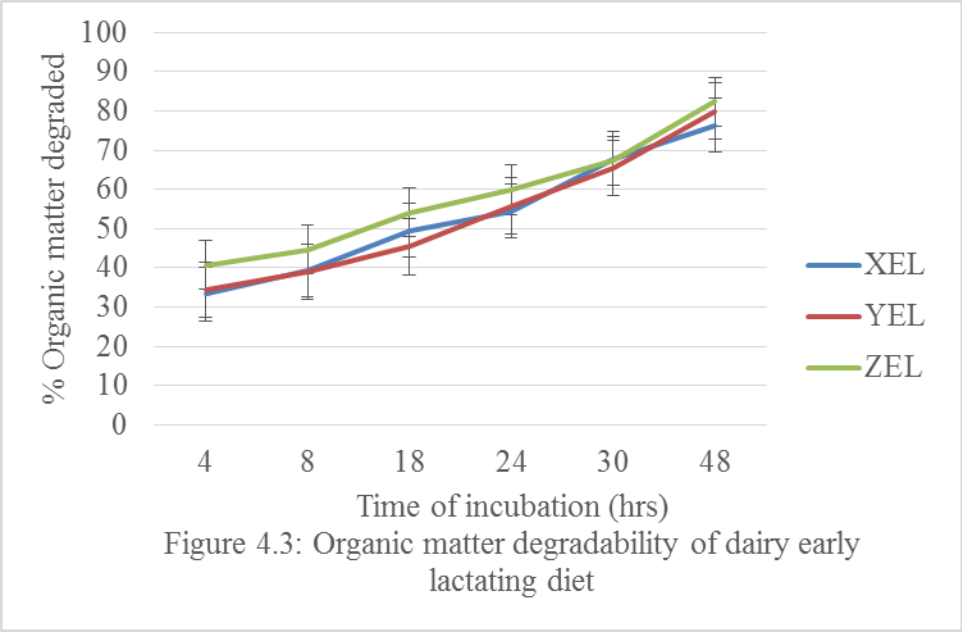

Figure 4.3: Organic matter degradability of dairy early lactating diet

Table 4.11: Microbial colony count on particulate matter post incubation of simulated early lactation diets

	X	Y	Z
24 hours	3.0×10^7	1.4×10^6	3.0×10^7

The predicted nutrient compositions of early lactation simulated diets are shown in Table 4.12-4.14. Differences were observed in the predicted nutrient requirement, diet concentrate, animal performance and rumen environment. Diets were high in TDN (71%). Predicted body weight loss in early lactation was low, it would take at least 10 days to lose 1 kg for cows on ZEL and 3 days for cows on YLL. Protein supply (MP) was adequate on ZLL, although rumen nitrogen balance indicated excesses in all diets. The ME (Mcal/Kg) was low as also indicated by the low non-fibre carbohydrate content.

Table 4.12: Predicted early lactation diet concentration (%DM)

Diet Concentration	X	Y	Z
Total forage in ration	34	34	34
Total non-fibre carbohydrate	33	29	27
Apparent total digestible nutrient	71	70	71
Metabolizable energy (Mcal/kg)	2.70	2.67	2.73
Net energy for maintenance (Mcal/kg)	1.74	1.72	1.76

Maintenance requirements were predicted as ME= 49.9Mcal/d, MP= 2111g/d, Ca= 57g/d and P= 52g/d

Table 4.13: Predicted Nutrient balances and changes in body weight for early lactation cow

Source	X		Y		Z	
	ME	MP	ME	MP	ME	MP
Requirements	Mcal/d	g/d	Mcal/d	g/d	Mcal/d	g/d
Total Supplied	48.9	2027	48.3	2085	49.4	2046
Balance	-1.1	-84	-1.7	-26	-0.50	65
Weight Change due to Reserves (kg/d)	-0.2		-0.3		-0.1	

Table 4.14: The rumen environment of early lactation cow

Rumen Values	X	Y	Z
% Ruminal N Balance (% required)	139	153	138
Predicted Ruminal pH	6.36	6.38	6.39

4.8.7 Nutrient profile of the simulated pregnant late lactation cow diets

The dairy pregnant late lactation diets were iso-nitrogenous and iso-energetic but difference were observed in Ca and P. The X_{LL} had higher Ca and lowest P (Table 4.15).

Table 4.15: Nutrient composition of simulated pregnant late lactation diets (units are expressed in %DM except for energy Mcal/kg)

	X	Y	Z	
Parameter		Lsmean		SEM
Dry matter	93.0	92.7	93.1	0.026
Organic matter	92.3	91.3	92.7	0.222
Crude protein	13.7	14.1	13.9	0.311
Ether extract	1.8	2.5	2.4	0.287
Gross energy	3.8	3.9	4.0	1.094
Neutral detergent fibre	40.1	41.3	42.3	0.258
Calcium	0.9^{a}	0.7^{c}	0.8^{b}	0.018
Phosphorus	0.3^{c}	0.5^{a}	0.4^{b}	0.006

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05)

4.8.8 *In Sacco* degradation of simulated pregnant late lactation diets on organic matter and bacterial count

The *in Sacco* organic matter degradation (OMD) for dairy late lactating cow diet is shown in Figure 4.4 (refer to Appendix Q for OMD table). Differences were observed in OMD but Z_{LL} were consistently higher while Y_{LL} was least. None of the diets were degraded beyond 82% at 48 hours. Microbial mass on residue differed (Table 4.16). The Y_{LL} has the lowest count of rumen micro-organisms attached to fibre while Z_{FD} was highest.

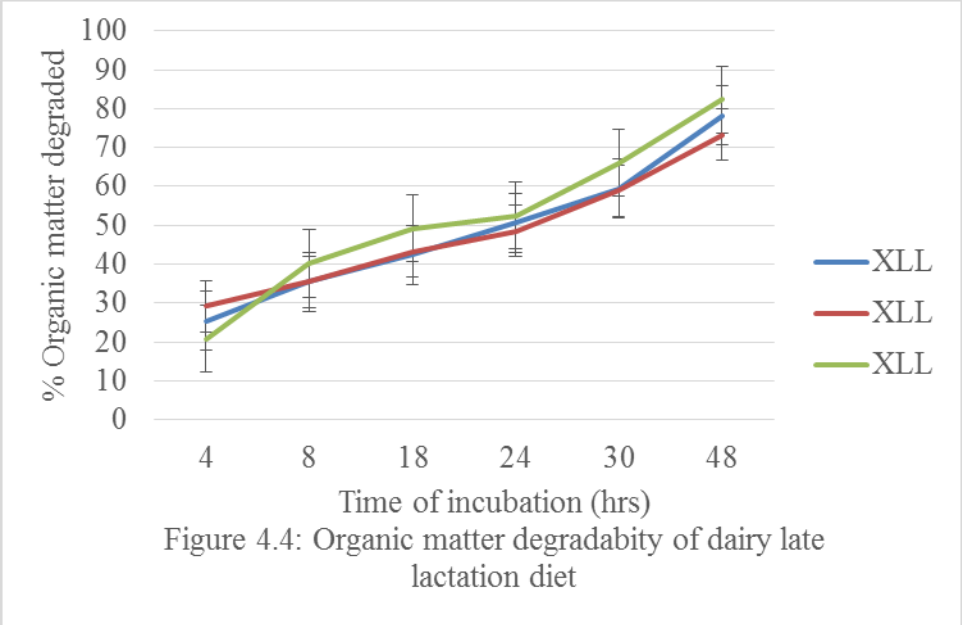

Figure 4.4: Organic matter degradabity of dairy late lactation diet

Table 4.16: Microbial colony count on particulate matter post incubation of simulated late lactation diets

	X	Y	Z
24 hours	2.93×10^7	2.4×10^6	8.8×10^6

The predicted nutrient compositions of late lactation total mixed ration (TMR) are shown in Table 4.17-4.18. No differences were observed in the predicted nutrient requirement, diet concentrate and animal performance. Supply of energy and protein were sufficient as indicated by the positive balances, as expected in late lactation. Predicted efficiency of N and P use averaged 25g/d.

Table 4.17: Predicted pregnant late lactation cow diet concentration (%DM)

	X	Y	Z
Total non-fibre carbohydrate	34.8	34.8	34.8
Metabolizable energy (Mcal/kg)	2.5	2.5	2.6
Net energy for maintenance (Mcal/kg)	1.6	1.6	1.7

Predicted maintenance requirements for ME= 42.5Mcal/d and MP= 1828.6g/d

Table 4.18: Predicted Nutrient balances in pregnant late lactation cow

Source	X		Y		Z	
	ME	MP	ME	MP	ME	MP
Requirements	Mcal/d	g/d	Mcal/d	g/d	Mcal/d	g/d
Total Supplied	43.3	2181	44.2	2302	44.7	2211
Balance	0.9	352.2	1.7	490.2	2.4	390.2

4.8.9 Nutrient profile of the simulated far dry and pregnant diets

The dairy pregnant far dry simulated diets were iso-energetic but differences were observed in CP, Ca and P. The Y_{FD} TMR was least in Ca and P. The Table 4.19 shows the nutrient profile of far dry simulated ration.

Table 4.19: Nutrient composition of simulated far dry and pregnant cow diets (units are expressed in %DM except for energy Mcal/kg)

	X	Y	Z	
Parameter		Lsmean		SEM
Dry matter	93.3	92.5	92.5	0.213
Organic matter	94.1	95.0	92.5	0.245
Crude protein	11.5[a]	8.2[c]	10.9[b]	0.003
Ether extract	1.6	1.7	2.4	0.256
Neutral detergent fibre	46.6	45.1	48.5	0.845
Gross energy	3.8	3.9	3.7	0.602
Calcium	0.5[b]	0.6[b]	1.0[a]	0.001
Phosphorus	0.3[b]	0.3[b]	0.4[a]	0.001

[a,b,c,] Lsmeans within each row with similar letter(s) are not significantly different (P>0.05)

4.8.10 *In Sacco* degradation of simulated far dry diets on organic matter and bacteria count

The *in Sacco* organic matter degradation (OMD) for dairy pregnant far dry simulated diets is shown in Figure 4.5 (refer to Appendix R for OMD table). Differences were observed across

source, X_{FD} and Z_{FD} were consistently higher than Y_{FD} OMD. None of the diets were degraded beyond 68% at 48 hours. The microbial mass attached to fibre also differed (Table 4.20). The Y_{FD} has the least count of rumen micro-organisms attached to fibre while Z_{FD} was highest.

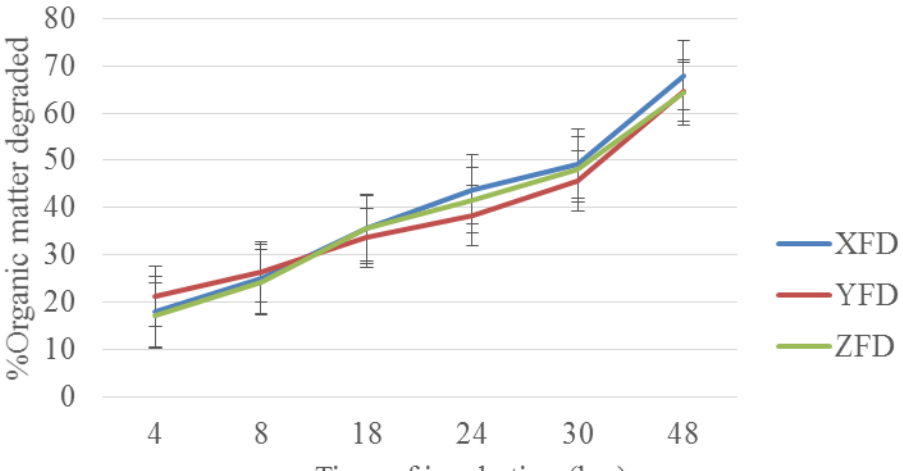

Figure 4.5: Organic matter degradability of dairy far dry diet

Table 4.20: Microbial colony count on particulate matter post incubation of simulated far dry diets

	X	Y	Z
24 hours	1.37×10^7	5.4×10^6	1.18×10^7

4. 9 Discussion

4.9.1 Evaluation of simulated dairy calf diets

Rumen degradability and metabolism of calf simulated diets is affected by the type of diet which is a major factor in calf rumen development as well as the fibre content. All three calf simulated diets had high OMD which means better degradation of structural and non-structural carbohydrate in the simulated diets according to (Offner *et al.,* 2003) but not in line with Bannink et al. (2006) report that highly digestible carbohydrate diet alter the young calve stomach development. The X_C crude protein was less than recommended. The minimum requirement for NDF in calf diets is 27% and the three simulated diets in our findings are above

the recommendation. Fibre content and quality plays a major role in rumen epithelium, microbes, rumination, and size of the rumen, papilli, muscular development and also help to prevent metabolic disorder such as bloat and parakeratosis (porter et al 2007) of calves. This is a good indication that the TMR in our findings would influence intake, growth rate, rumen development and fermentation according to Suarez, et al. 2006). At three months of age the rumen is fully developed. Calcium was within recommendation but phosphorus was less with X_C with the lowest supply. The Y and Z diets would support better growth performance in calves.

4.9.2 Evaluation of simulated dairy heifer diets

The balance of energy and protein supplied by feed ingredient in the rumen for microbial growth results in microbial protein for the animal use. The simulated dairy heifer diets supplied nutrients required for growth, although NDF content was high, possibly due to high intake of Lucerne and Eragrostis hay. The NDF content was also high in the concentrates. The diet based on concentrate Z_H had high degradability and promoted growth of fibre degrading bacteria as shown by the high microbial population on residual fibre. The diets seemed to have good balance of degradable carbohydrates and protein to enable both non-fibre and structural bacterial to grow. The crude protein content was however relatively low and would limit growth delaying onset of puberty, breeding and age at first calving. It is critical therefore to review the quality of the concentrate and proposed diets. The two concentrates did not have a high nutrient density as also indicated by very low Ca and P levels. Concentrates for dairy heifers vary in CP and energy density. NRC, (2001) reported 15% CP and 2.5 Mcal/kg and ranges from 2.5-3.2 Mcal/kg for heifer growing at 800g/day. Feed higher amounts of the concentrate is recommended due to the low protein content when forages where added to the diet. However Rotger, et al. (2005) reported that high concentrate diet for heifers decrease ratio of acetate-to-propionate with age thereby increasing the total ruminal VFA concentration.

4.9.3 Evaluation of simulated dairy early lactating cow diet

The diets NDF was within the minimum of 39% set by Mertens, (1997) and Bargo et al. (2003). Low NDF exposes the cows to health problems example acidosis, laminitis and decreases time of mastication whilst higher NDF levels limits nutrients supply especially if quality of fibre is low. The crude protein content was adequate for the set production level in early lactation. Although

ruminal N balance was over 130%, indicating excess N in diet, it is possible that the poor utilization of N was due to low supply of degradable carbohydrate and the inability of rumen microorganisms to degrade amino acids from diet (Robinson *et al.,* 2005, 2006). Bacterial growth is limited by uncoupled energy and protein supply resulting in loss of N as ammonia and also energy as methane resulting in environmental pollution. Although research as shown that ruminant can be productive on a lower N input that the recommended value (Christensen et al. 1993; Christensen et al. 1994). The diet with Z_{EL} ranked higher than X and Y and this could be ascribed to the balance of nutrients in the concentrate and forage.

4.9.4 Evaluation of total mixed ration of late lactating cow diet

The simulated late lactation diets were very low in crude protein, supplying just above the minimum required for maintenance. The energy require at this stage of lactation is usually lower than early lactation due to the decline in milk production although needed for pregnancy, reserved for early lactation and building body score (John, 2009). The diets net energy for maintenance is above the predicted supply with Z_{LL} having highest supply of energy. There was adequate supply of energy to support late lactation and to gain body conditions. Low protein would limit fetal growth as much of embryonic growth is proteineous.

The predicted rumen digestible protein (RDP) recommended for dairy cows ranges from 9.5 to 10.5% dietary DM depending. The diets in this analyses had less RDP % DM and Inadequate supply of RDP causes decrease in ammonia concentration, microbial population and fibre digestion in the rumen (Firkins et al., 1986) as well as dry matter intake (Allen, 2000). The supply of microbial and undegraded protein amino acids reaching the small intestine can be used for meeting MP requirements (Cyriac et al., 2008). Although Christensen et al. (1993) and Christensen et al. (1994) reported that a much lower N input than recommendation can still maintain ruminant productivity. Our simulated late lactation diets NDF range was within recommendation of Mertens, (1997); Bargo et al. (2003). All three simulated diets provide adequate nutrient support during late lactation.

4.9.5 Evaluation of the dairy far dry cow diet

The simulated diets were above the threshold calcium (Ca) and phosphorus (P) but the dietary crude protein was low. The main purpose of feeding dry cows is to improve the metabolic status

of early lactating and also increase DMI after calving to meet energy requirement, and production for next lactation (Dewhurst et al., 2000). Due to the low crude protein in the simulated diet it is important to supply a more nutrient dense concentrate at this stage to meet the fetal and cow nutrient requirement. The metabolic status of far dry pregnant cow is affected by the diet composition and energy content of the total mixed ration (TMR) (Douglass et al. (2006); Janovick, et al. (2011) and Damgaard et al. (2013). Another important nutrient at this stage is Ca and P which are needed during bone development of the fetal and are concentrated in the fetal liver to serve as post postnatal reserve according to Van Saun, et al. (2004) and Van Saun and Poppenga (2007). The simulated diets were low in energy and protein and should be fed together with additives, protein and energy boosters.

4.10 Conclusion and Recommendations

Balancing the need for rumen available protein and carbohydrate that will optimize microbial growth, metabolism in the rumen, reduce health stress and nutrient loss to the environment through excretion via urine or faeces optimizes dairy production. Even though concentrates seemed to be of equivalent value, based on label data, their behavior in Sacco was different. Monitoring and evaluation of registered feed products is key in quality control to minimize the risk of producers purchasing adulterated or pseudo products at exorbitant prices. The Feeds and Fertilizer Act does not have requirements for producers to show or prove nutrient availability. Dairy cattle producers therefore need to invest more in checking the quality of products through accredited research and laboratory facilities as that would provide more precise data on product quality. It is premature to conclude if either X, Y or Z sourced concentrates were superior, further analyses of amino acid profiles, mineral availability and feeding tests are recommended on all registered products. This additional information would increase competitiveness of the various suppliers and also improve accounting for nutrient imports and movement within a farm system.

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Chapter Five

Conclusion and Recommendation

There were variation in the nutrient quality of the various commercial concentrate for different animal group used on dairy farms in South Africa as supplement to forage. These various affect the dry matter degradation of feed and microbial population count. Suppliers source and process their feed ingredient differently and seasonal variation affects nutrient availability. South Africa produces grain crops such as maize, wheat, barley, seed oils such as sunflowers, cotton and soybean but also imports significant amounts of these raw materials for feed manufacturing. Maize, soybean and cottonseed are main components of stock feeds. The price of maize increased drastically over the past two years causing surges in concentrate prices. Feed quality and nutrient density are therefore a buffer against such global pressures. Poor quality concentrates impact herd productivity and animal wellness.

Optimal utilization of the unique feature of the ruminant animal (rumen) which enables them to utilise forages. Coupling of energy and protein is essential for balancing the ruminal need that would optimize microbial growth and metabolism in the rumen is key to successful dairy cattle feeding program. Highly fermentable carbohydrate feeds should be fed together with high available proteineous feeds otherwise an imbalance on either side would cause loss of nutrients to the environment either nitrogen or energy (methane) or health stress to the animal. The ratio and production of short chain volatile fatty acids such as acetate, propionate (C3) and butyrate is good pointer of good or poor fermentation patterns in the rumen. The concentrate derived from grains tends to promote synthesis of C3 while grasses produce more C2. An essential glucose precursor in energy metabolism and milk synthesis is propionate.

Regular monitoring and evaluation of commercial feeds is an essential component in feed quality control. The recurring fluctuations in climate and global markets affect viability of dairy businesses as these are highly dependent on grains (insert references here).

The Z_{calf} pure concentrate, Y and Z simulated diets shows better balance of carbohydrate and protein evident in the nutrient profile and degradation kinetics of the feed stuff. The heifer concentrates showed huge competiveness within the various source but the simulated diets was low in protein which is essential for the animal target growth in view of this pure concentrate is recommended and forage supplementation. The early lactation pure concentrate crude protein was low while neutral detergent fibre was within recommendation while diet Z_{EL} ranked higher

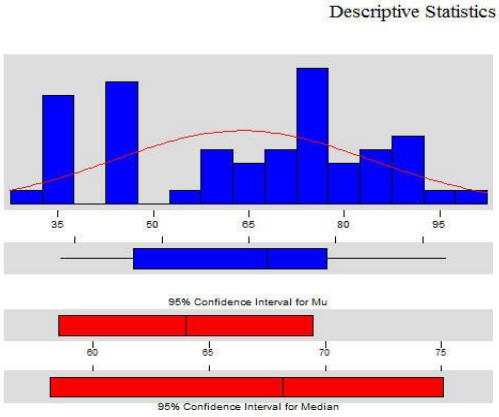
than X and Y due to the balance of nutrients in the concentrate and forage. The diets had negative energy balance and less nutrient loss to the environment from the LRNS. All three pregnant late lactation cow simulated diets provided adequate nutrient support during late lactation for both the cow and fetus. While the far dry simulated diets showed imbalance in energy and protein and should be fed together with additives, protein and energy boosters.

Farmers should select feeds based on the needs of the different animal groups to maximize their genetic and production potential and well as the processing method used for their feed for a sustainable dairy farm.

Further research is required to assess effects of nutritional limitations on reproductive physiology and actual productivity in dairy cattle. Regular monitoring of commercial concentrates should be mandated in the revised Feeds and Fertilizer Bill.

Appendixes

Calf concentrate feed descriptive statistic



Variable: % DM DEGRADE

Anderson-Darling Normality Test

A-Squared:	1.196
P-Value:	0.004
Mean	63.9981
StDev	19.9980
Variance	399.918
Skewness	-1.8E-01
Kurtosis	-1.22708
N	54
Minimum	32.3485
1st Quartile	45.0681
Median	68.1967
3rd Quartile	78.5943
Maximum	99.1756

95% Confidence Interval for Mu

58.5397	69.4565

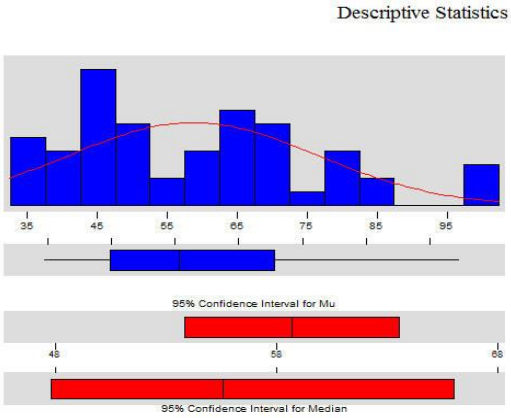
95% Confidence Interval for Sigma

16.8108	24.6878

95% Confidence Interval for Median

58.1332	75.1170

Heifer concentrate feed descriptive statistic



Variable: % DM DEGRADE

Anderson-Darling Normality Test

A-Squared:	0.969
P-Value:	0.014
Mean	58.6930
StDev	17.7406
Variance	314.730
Skewness	0.567735
Kurtosis	-4.8E-01
N	54
Minimum	34.2431
1st Quartile	44.7764
Median	55.5783
3rd Quartile	70.6106
Maximum	99.8268

95% Confidence Interval for Mu

53.8507	63.5353

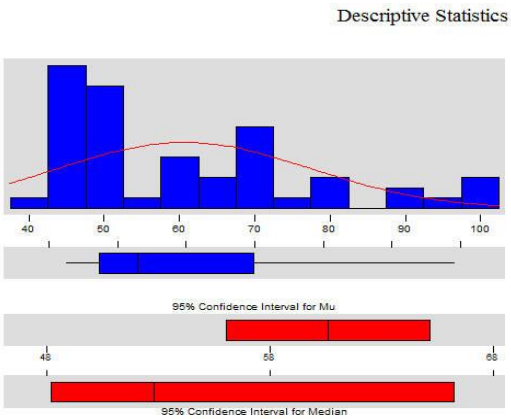
95% Confidence Interval for Sigma

14.9132	21.9011

95% Confidence Interval for Median

47.7777	66.0436

Lactating concentrate feed stastistic



Variable: % DM DEGRADE

Anderson-Darling Normality Test

A-Squared:	3.169
P-Value:	0.000
Mean	60.6125
StDev	16.6757
Variance	278.078
Skewness	0.997803
Kurtosis	-2.2E-02
N	54
Minimum	42.2534
1st Quartile	47.1676
Median	52.8087
3rd Quartile	69.7759
Maximum	99.4142

95% Confidence Interval for Mu

56.0609	65.1641

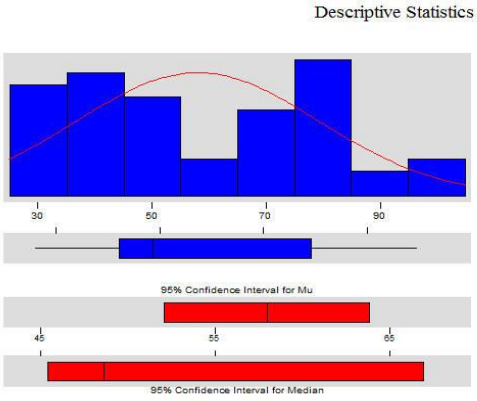
95% Confidence Interval for Sigma

14.0180	20.5864

95% Confidence Interval for Median

48.1753	66.2845

Dry cow concentrate feed statistic



Variable: % DM DEGRADE

Anderson-Darling Normality Test

A-Squared:	1.144
P-Value:	0.005
Mean	57.9791
StDev	21.3067
Variance	453.977
Skewness	0.228278
Kurtosis	-1.13456
N	53
Minimum	25.7826
1st Quartile	42.1577
Median	48.6301
3rd Quartile	79.1647
Maximum	99.7772

95% Confidence Interval for Mu

52.1063	63.8520

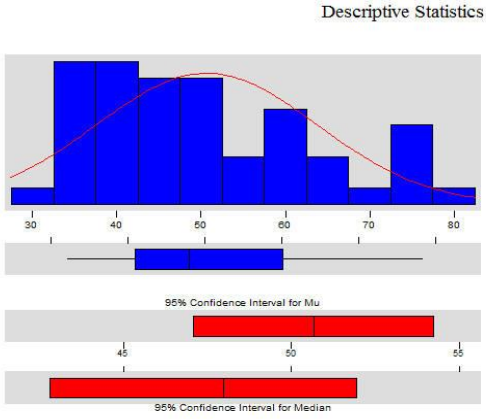
95% Confidence Interval for Sigma

17.8839	26.3623

95% Confidence Interval for Median

45.4040	66.9763

Calf simulated diets statistics



Variable: % DM DEGRADE

Anderson-Darling Normality Test

A-Squared:	1.196
P-Value:	0.004
Mean	50.6663
StDev	13.0706
Variance	170.840
Skewness	0.655107
Kurtosis	-6.0E-01
N	54
Minimum	31.9585
1st Quartile	40.8251
Median	47.9892
3rd Quartile	60.1058
Maximum	78.4276

95% Confidence Interval for Mu

47.0987	54.2339

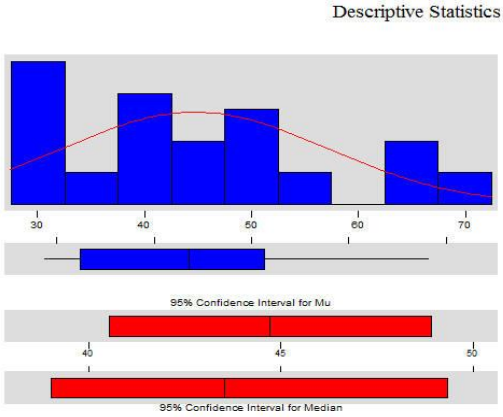
95% Confidence Interval for Sigma

10.9875	16.1358

95% Confidence Interval for Median

42.7926	51.9530

Heifer simulated diets statistic



Variable: % DM DEGRADE

Anderson-Darling Normality Test

A-Squared:	0.783
P-Value:	0.038
Mean	44.7200
StDev	12.3914
Variance	153.548
Skewness	0.463987
Kurtosis	-7.5E-01
N	36
Minimum	28.5543
1st Quartile	32.3689
Median	43.5509
3rd Quartile	51.2773
Maximum	68.3337

95% Confidence Interval for Mu

40.5273	48.9127

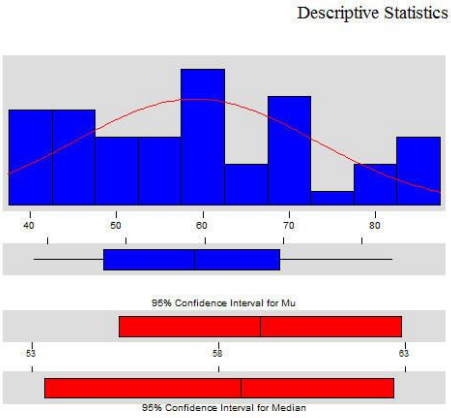
95% Confidence Interval for Sigma

10.0505	16.1639

95% Confidence Interval for Median

39.0102	49.3651

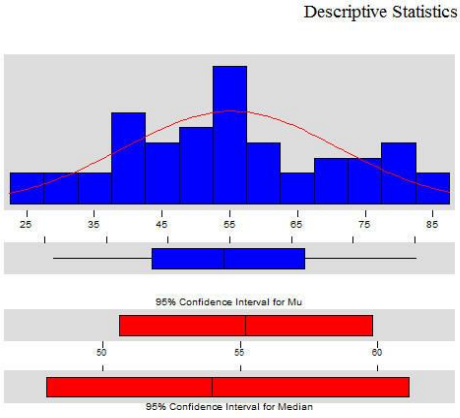
Early lactation simulated diets



Variable: % DM DEGRADE

Anderson-Darling Normality Test	
A-Squared:	0.588
P-Value:	0.119
Mean	59.1277
StDev	13.8319
Variance	191.323
Skewness	0.244178
Kurtosis	-9.6E-01
N	54
Minimum	38.1403
1st Quartile	47.0674
Median	58.6197
3rd Quartile	69.4996
Maximum	83.9941
95% Confidence Interval for Mu	
55.3623	62.9031
95% Confidence Interval for Sigma	
11.6275	17.0757
95% Confidence Interval for Median	
53.3331	62.7076

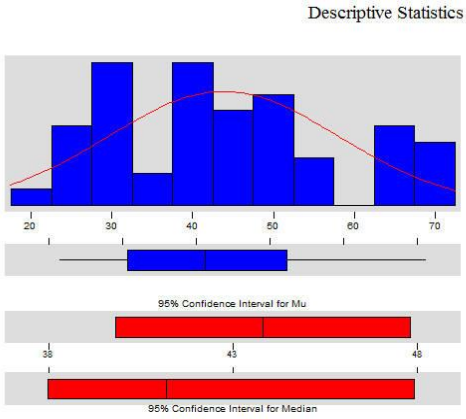
Late lactation simulated diets statistics



Variable: % DM DEGRADE

Anderson-Darling Normality Test	
A-Squared:	0.381
P-Value:	0.389
Mean	55.1977
StDev	15.8216
Variance	250.324
Skewness	0.209413
Kurtosis	-7.5E-01
N	48
Minimum	26.2150
1st Quartile	42.3977
Median	53.9944
3rd Quartile	67.1744
Maximum	85.5393
95% Confidence Interval for Mu	
50.6036	59.7918
95% Confidence Interval for Sigma	
13.1710	19.8179
95% Confidence Interval for Median	
47.9494	61.1641

Pregnant far dry simulated diets statistics



Variable: % DM DEGRADE

Anderson-Darling Normality Test	
A-Squared:	0.895
P-Value:	0.021
Mean	43.8080
StDev	14.2127
Variance	202.000
Skewness	0.402787
Kurtosis	-7.5E-01
N	51
Minimum	21.2020
1st Quartile	30.6011
Median	41.1874
3rd Quartile	52.3698
Maximum	71.2588
95% Confidence Interval for Mu	
39.8106	47.8054
95% Confidence Interval for Sigma	
11.8919	17.6675
95% Confidence Interval for Median	
37.9703	47.9408

J. *In Sacco* dry matter degradability of three calf concentrates feeds units are expressed %DM

	X	Y	Z	
Time		Lsmeans		SEM
2 hours	33.2	34.0	34.4	1.224
4 hours	45.2	45.4	45.2	0.651
6 hours	56.9^{c}	62.2^{b}	68.3^{a}	0.004
18 hours	67.3^{b}	74.4^{a}	77.5^{a}	0.003
24 hours	73.9^{c}	77.7^{b}	87.0^{a}	0.002
48 hours	92.0^{a}	82.9^{b}	94.0^{a}	0.003

K. *In Sacco* dry matter degradability of three heifer concentrates feeds units are expressed in %DM

	X	Y	Z	
Time		Lsmeans		SEM
2 hours	36.8^{b}	34.6^{c}	38.1^{a}	0.004
4 hours	44.0^{b}	44.3^{b}	47.1^{a}	0.001
6 hours	47.2^{b}	48.8^{b}	52.4^{a}	0.004
18 hours	58.8^{c}	69.9^{a}	66.4^{b}	0.003
24 hours	65.2^{c}	70.7^{b}	72.3^{a}	0.002
48 hours	83.9^{b}	81.4^{b}	98.8^{a}	0.004

L. *In Sacco* dry matter degradability of three lactating cow concentrates feeds units are expressed in %DM

	X	Y	Z	
Time		Lsmeans		SEM
2 hours	39.9^{b}	39.5^{b}	43.6^{a}	0.003
4 hours	42.6^{b}	42.1^{b}	44.3^{a}	0.004
6 hours	44.6^{a}	41.9^{b}	45.4^{a}	0.003
18 hours	54.8^{b}	56.5^{b}	66.6^{a}	0.003
24 hours	64.4^{b}	66.2^{ab}	69.8^{a}	0.003
48 hours	79.8^{c}	93.3^{b}	99.0^{a}	0.002

M. *In Sacco* dry matter degradability of three dry cow concentrates feeds units expressed in %DM

	X	Y	Z	
Parameter		Lsmeans		SEM
2 hours	27.8[b]	26.9[b]	32.9[a]	0.004
4 hours	42.5[b]	40.5[c]	44.4[a]	0.002
6 hours	47.1[ab]	45.9[b]	48.4[a]	0.004
18 hours	59.9[c]	65.4[b]	67.1[a]	0.003
24 hours	77.7[b]	78.2[b]	84.7[a]	0.002
48 hours	79.5[b]	83.9[b]	98.2[a]	0.002

N. Organic matter degradation of simulated calf diets and bacterial counts on residues

	X	Y	Z	
Time		Lsmeans		SEM
4 hours	29.7[b]	32.1[ab]	35.7[a]	0.003
8 hours	32.0	36.2	38.0	0.004
18 hours	39.5[b]	42.3[ab]	48.7[a]	0.001
24 hours	41.5[c]	46.4[b]	50.0[a]	0.001
30 hours	53.6[b]	58.4[a]	59.0[a]	0.003
48 hours	66.1[b]	74.5[a]	74.4[a]	0.003

O. Organic matter degradation of simulated dairy heifer diets and bacterial counts on residues

	X	Z	
Time	Lsmean		SEM
4 hours	25.7	25.7	1.258
8 hours	30.3[a]	26.6[b]	0.004
18 hours	38.0	36.4	1.260
24 hours	43.1[b]	45.3[a]	0.004
30 hours	47.3	46.1	2.104
48 hours	63.2	64.7	2.301

P. Organic matter degradation of simulated early lactation diets and bacterial counts on residues

	X	Y	Z	
Time		Lsmean		SEM
4 hours	33.3[b]	34.4[b]	40.7[a]	0.002
8 hours	39.2[b]	38.9[b]	44.7[a]	0.004
18 hours	49.6[b]	45.4[c]	54.1[a]	0.003
24 hours	54.5[b]	55.8[b]	59.9[a]	0.002
30 hours	67.9	65.5	67.3	1.368
48 hours	76.4[b]	80.0[a]	82.3[a]	0.003

Q. Organic matter degradation of simulated pregnant late lactation diets and bacterial counts on residues

	X	Y	Z	
Time		Lsmean		SEM
4 hours	25.4[b]	29.2[a]	20.8[c]	0.003
8 hours	35.5[b]	35.5[b]	40.2[a]	0.002
18 hours	42.4[b]	43.3[b]	49.2[a]	0.003
24 hours	50.7[ab]	48.6[b]	52.5[a]	0.003
30 hours	59.4[b]	58.9[b]	66.0[a]	0.001
48 hours	78.2[ab]	73.3[b]	82.3[a]	0.002

R. Organic matter degradation of simulated far dry pregnant diets and bacterial counts on residues

	X	Y	Z	
Time		Lsmean		SEM
4 hours	18.6[b]	21.3[a]	17.2[c]	0.002
8 hours	25.0	26.4	24.3	0.969
18 hours	35.6	33.6	35.7	1.039
24 hours	43.8[a]	38.3[b]	41.5[a]	0.003
30 hours	49.2[a]	45.6[b]	48.0[a]	0.002
48 hours	68.0[a]	64.5[b]	64.4[b]	0.004

S. Nutrient variability and rumen degradation of commercial concentrate feeds for dairy cattle in South Africa

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Abstract

Commercial concentrate feeds for dairy cattle in South Africa were assessed for variability in nutrient profiles and rumen degradation. Three feed sources (Xi, Yi, Zi) were randomly selected and feeds for calf, heifer, lactating and dry cow collected. Concentrates and complementary forages (Lucerne and Eragrostis hay) were analysed for nutrient supply. Degradation was determined using *In Sacco* technique for 2, 4, 6, 8, 18, 24 and 48hrs. Calf and heifer feeds had 14-18% CP while lactating and dry cows ranged between 15-17%. All Zi feeds were high in fat (6%), whilst other sources ranged between 2- 3% consistent with minimum values on source labels. Supplier labels indicated a range of 7- 10% for ether extracts, overestimating energy supply. Lignin was <2% and TDN were high. Calcium was < 1% for all feeds relative to values of 0.8-1.5% labelled across sources. There was scant data on phosphorus on supplier labels, analyses showed 0.4% indicating a Ca: P ration of 2:1. The Z-concentrates supplier had highest DMD; Z_{calf} degraded 87% by 24hrs. When rations of concentrates (60%) with the standard forages (40%) were simulated as diets for early lactating cows, $Z_{early\ lactating\ diet}$ had best results which degraded 84% within 48 hrs compared to Xi (78%). Evidently variations in nutrient among sources impacted degradability even though source labels indicate similarity in nutrient levels. It is critical to assess feed batches to increase precision in ration formulation when using mechanistic models.

Keywords: fibre, formulation, In Sacco Degradability, protein, Simulation.

T. Metabolizable energy and protein adequacy for microbial synthesis and growth in commercial concentrates for Holstein dairy calves

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Abstract

Dairy neonates are reared mostly on milk, incremental amounts of concentrate feeds added milk as the rumen develops. Concentrates constitutes complete diets post-weaning as forage is gradually introduced. Several brands of dairy concentrate are marketed in South Africa. Investing in appropriate feed is a profound business function as early nutrition influences future productivity. Three premium calf concentrates (X, Y, and Z) were randomly selected among marketed feeds and purchased during mid-summer. Concentrates were analyzed for composition, *In Sacco* fermentability and prediction of metabolizable energy and protein (MP and ME), microbial protein yield was done using level 1 of the AMTS mechanistic model (Tylutki *et al.*, 2014) based on requirements of post-weaned Holstein calves supplied sole concentrate diets. Crude protein were 17.4, 16.7, 17.7%DM, NDF 46.2, 39.5, 35.1% DM, NDICP 1.4, 1.4, 1.0%DM, and ether extracts were different (4, 2 & 6% DM) for X, Y and Z respectively. Bag label EE were similar (2.5 to 7%). Non-fibre carbohydrates ranged from 28 to 34% DM and ME were 2.85; 2.9 and 3.1 Mcal/kg DM for X,Y and Z. Concentrate Z had better fermentation with c = 0.10 and effective degradability (87.8%DM). Predicted ME and MP supply were lower in X (97% and 94% of required for target growth) affecting microbial protein yield. Although X, Y and Z were marketed as prime calf concentrates, large variations in metabolism were evident with Z showing better nutrient balance for growth. Simulations of marketed concentrates are critical for feed quality control.

Keyword: dairy calves, rumen fermentation, nutrient density, diet simulation

U. Disappearance of standard forage diets supplemented with various lactating dairy concentrates and microbial colonization of rumen fiber

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Abstract

Variations in composition and disappearance of nutrients in lactating dairy cattle concentrates are dictated by ingredients, methods of processing, storage and target production levels subsequently. This study determined rumen dry matter disappearance (DMD) and levels microbial colonization on fiber in Lucerne/Eragrostis diets supplemented with lactating dairy concentrates. Dairy concentrates were sourced from three suppliers (X, Y, Z) in Gauteng province of South Africa during mid-summer. Three TMR diets were formulated to meet nutritional requirement of a mature Holstein cow at 30 days in milk averaging 35kg milk/day and three TMR diets for late lactation cows as recommended by concentrate suppliers. The concentrates, forages and diets were analyzed for nutrient composition and *in Sacco* DMD for 4, 8, 18, 24, 30 and 48hrs using two lactating dairy cows. Concentrate crude protein contents were 16, 19 & 16% DM, gross energy was 15, 16 &15 MJ/Kg and fat was 3, 3 & 6% DM for X, Y and Z respectively. Significant differences were observed in nutrient composition among sample in CP, EE, E Ca and P. Concentrate for the early lactating group supplied by Y had highest content of CP (17%), EE (2.5%) and P (0.5%) but was least in Ca (0.5%). Significant differences was also observed for in DMD of early lactating cow diets with Z supplement exhibiting the highest DMD at 60% and 82% at 24 and 48hrs whilst X and Y supplemented diets averaged 55% and 78%. The Y early lactating cow diet had the least count of total bacteria on fiber at 24hrs indicating low microbial colonization of dietary fibre. There were no significant variations in TMR for late lactation cows but X supplemented had least value for EE and P. Highest levels of DMD also occurred with TMR supplanted with Z sources concentrate. While total bacteria count was significantly higher for X late lactation diet (2.93×10^7) at 24 hrs post incubation. The variation in degradation and microbial count are determined by ingredient and different processing methods used by the manufacturers to formulate these concentrate. Nutrient

availability for rumen microbial growth is highly variable and regular quality control tests including diet simulations are essential to monitor and make appropriate recommendations of rations for specified production levels.

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