EFFECT OF SPINELESS CACTUS (*OPUNTIA FICUS-INDICA)* MEAL INCLUSION LEVEL ON VOLUNTARY FEED INTAKE AND MILK PRODUCTION OF HOLSTEIN COWS

MOELELWA ROSEMARY SERAKWANE

[redacted]

A RESEARH MINI-DISSERTATION

Submitted in fulfilment of the requirements for the degree of MASTER OF SCIENCE IN AGRICULTURE (ANIMAL PRODUCTION)

in the

FACULTY OF SCIENCE AND AGRICULTURE

(School of Agriculture and Environmental Sciences)

at the UNIVERSITY OF LIMPOPO

SUPERVISOR : DR F.V. NHERERA-CHOKUDA (ARC)

CO-SUPERVISOR : PROF J.W. NG'AMBI (UL)

FEBRUARY, 2019

DECLARATION

I declare that the dissertation hereby submitted to the University of Limpopo for the degree of Master of Science in Agriculture has not previously been submitted by me for a degree at this or any other university, that it is my own work in design and in execution, and that all material contained herein has been duly acknowledged.

…………………………… ……………………..........

Serakwane MR Date

ACKNOWLEDGEMENTS

First and foremost, I want to thank Almighty God. Without Him none of this would be possible. I would like to sincerely thank Prof J.W. Ng'ambi and Dr F.V. Nherera-Chokuda for being my masters project/dissertation supervisors. I, also, thank them for taking time out of their busy schedules to guide me through the entire research period. It has been a pleasure getting to know them over the years and their assistance, constructive criticisms and guidance, in particular, have been invaluable.

I would, also, like to thank Dr F.V. Nherera-Chokuda who taught me many of the statistical procedures and laboratory processes I have used for my Master's dissertation and for her advice, support and encouragement on everything from the start of my research study up to the final production of this dissertation. My gratitude also goes to the Agricultural Research Council Dairy Section Manager, Mrs S. Erasmus, for allowing me to use the animals for my experiment.

My special thanks, also, go to Mr N.Y. Dzivhani for his assistance in managing the animals during the experimental trial, Mr F. Seolwana, Mr N. Ragolane, and Mr O. Chabalala for their assistance with data collection. In addition, I would like to thank Mrs A. Mabunda for accommodating me during the study. Finally, I would like to thank my parents for their moral support, prayers, motivation, understanding, courage, inspiration and patience over all these years. I thank my siblings for being supportive since I started studying at the University of Limpopo. Without their support and words of encouragement this work would not have been completed.

I would like to thank Thapelo Kekana for helping me with the *in sacco* procedure and also for helping with data recording sheets, nylon bags, laboratory manuals to perform laboratory experiments during my study.

I, gratefully acknowledge the Agricultural Research Council (ARC) for providing me with feeding materials, laboratory equipments and the experimental animals and National Research Foundation for providing financial support for this study (project number: (AREC/03/7:PG).

DEDICATIONS

This dissertation is dedicated to God for His guidance and blessings throughout the study period. Also, I dedicate this work to my fiancé, Mr T.P. Moshole, for support, understanding, courage, patience, helpful sacrifices and for being there for me throughout my studies.

To both my parents Mr N.A. Serakwane and Ms M.S. Seroba, my three sisters Serakwane M.C., Serakwane M.P. and Serakwane M.F. and my little brother Serakwane N.N. for their support, motivation, encouragement and having faith in me throughout my studies.

ABSTRACT

A lack of energy and water in livestock production limit the performance of the animal. Therefore, the objective of this study was to determine the effect of spineless cactus as a source of energy and water on feed intake, feed digestibility and milk production of Holstein cows. Cactus serves as fresh forage or stored as silage for later feeding in livestock. However, there is limited information about cactus nutrients, their proportions in different species and the variability of these proportions with season. A total of four multiparous lactating Holstein cows with an average of 650 ± 80kg live weight were used and assigned to four dietary treatments with four replicates. Each animal was used four times. A cross-over design was used. The four dietary treatments were 0%, 4%, 8% and 12% of spineless cactus meal inclusion levels. The study period was 21 days of adaptation period and 6 days of collection period. Higher digestibility and energy supply (*P<0.05*) were observed with spineless forage diets compared to the control diet. Inclusion of spineless in the diets improved (*P<0.05*) diet intake and milk production in Holstein cows. However, an improved performance in milk production was observed with spineless cactus meal inclusion levels of 4%, 8% and 12%.

Amongst the diets, 0% inclusion level had lower dry matter intake of 22.7kg (*P<0.05*) compared to those which had spineless cactus meal. High dry matter intake resulted in higher (*P<0.05*) milk production of 22.7, 24.7, 23.4 and 23.8 litres for 0, 4, 8 and 12% spineless cactus meal inclusion levels, respectively. However, cows on 4% inclusion level had higher milk yield than the other diets. Milk quality (butter fat, protein, lactose, somatic cell count and milk nitrogen urea) of Holstein cows was not (*P>0.05*) affected by the level of spineless cactus meal inclusion in the diet. Dry matter intake, neutral detergent fibre intake, acid detergent fibre intake and metabolisble energy intake of the cows were optimized at different spineless cactus meal inclusion levels of 19.427% (r^2 = 0.992), 16.375% (r^2 = 0.974), 14.0% (r^2 = 0.984) and 22.909% (r^2 = 0.994), respectively. Spineless cactus meal inclusion had no effect (*P>0.05*) on ADF intake and crude protein intake. Apparent digestibility values (0.73, 0.76 and 0.76) were not significantly different at 4%, 8% and 12% of spineless cactus meal inclusion levels, respectively.

It is concluded that spineless cactus meal inclusion level in the diet affected (*P*<*0.05*) diet intake and milk production of the Holstein cows. However, these variables were optimized at different spineless cactus meal inclusion levels. It could be recommended that spineless cactus can fit perfectly in livestock rations with attention given to their low crude protein content. These opuntia species can be fed to livestock mainly cattle and sheep during any season but are needed the most during drought as supplements when forages are scarce or expensive to feed. It is, therefore, concluded that 8% of spineless cactus inclusion level can be used to maintain productivity of the animals.

Keywords: Feed intake, Apparent diet digestibility, Body condition score, Live weight, Milk quality, Milk composition

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Seasonal variation of rainfall has a great impact on available quantity and quality of feeds for ruminants, especially dairy cattle in the tropics (Wanapat *et al.,* 2000). Dairy cattle in rural areas depend, mostly, on available low quality roughages during winter and dry seasons. These low quality roughages are limiting in a number of nutrients, for example energy, protein, vitamins, etc., thus, they are characterized by low intake and digestibility values when eaten alone by ruminant animals (Reyes *et al.,* 2006). However, dairy cattle are economically and nutritionally important to rural communities in South Africa. Poor nutrition remains one of the major constraints to milk production in rural areas of South Africa, particularly during the dry season (Munyai, 2012). There is, therefore, need to utilise other alternative cheap sources of energy to improve the productivity of these dairy cattle. Spineless cactus (*Opuntia ficus-indica)* is an alternative feed for drought resilience and it is a good source of energy and water. Supplementing poor roughages with spineless cactus increases intake, forage digestibility and improves microbial activities in cattle and sheep (Ben Salem *et al.,* 1996). Spineless forages have been looked at as possible alternative source of energy for livestock during winter and dry seasons. However, the use of spineless cactus as an energy supplement for dairy cattle has not been extensively studied.

1.2 Problem statement

Smallholder Holstein dairy farmers hold an important role in household nutrition in some rural areas of Limpopo province, South Africa (Coetzee *et al*., 2004). However, productivity of these animals is low, mainly due to poor animal nutrition. During the dry and winter seasons animals depend on poor quality roughages which don’t supply adequate energy. Usually, there is an acute shortage of feed supply during the dry season and the available feeds are of poor quality, because they are, mainly, low in energy and high in fibre contents (Manzana, 2008). Smallholder dairy farmers cannot afford to buy available expensive dairy meals (Mupangwa *et al*., 2002). Therefore, it is important to utilize “climate smart forages” that are adaptable to semi-arid rural environments. Spineless cactus forage is a suitable forage doing well under poor production conditions. It is highly adaptable and prolific in dry areas due to its growing habits and physiological adaptation (Potgieter, 1995). Effective utilization of climate smart forage resources for dairy production is critical to sustainability of milk and meat businesses in rural areas of sub-Saharan Africa (Potgieter, 1995).

1.3 Motivation

The study will generate knowledge on utilization of succulent plants as forage for ruminants. Smallholder dairy farmers will have opportunity to optimise their milk businesses by feeding good energy feeds and also minimise production losses associated with poor nutrition. Information on the nutrition value and utilization of spineless cactus meal as an alternative feed for dairy cows will be generated and small holder dairy farmers will be able to use the information to manage their herd during drought seasons because during this time feed resources are scarce and expensive to buy. Smallholder dairy farmers face immense challenges related to nutritional management of lactating cows. Prime forage that provides nutritional similar to good quality dairy feed is essential for development of dairy farms, particularly for smallholders and emerging farms in rural areas. Spineless cactus is highly palatable and it improves the intake of fibrous feed materials like forages in ruminant diets. Spineless cactus are drought resistant and can remain succulent throughout the year. The study will add knowledge to the understanding of the use of spineless cactus as a supplement for dairy cows fed low quality forages. The knowledge on nutritional value and feeding value of cactus will then be utilised by dairy farmers to improve productivity of their animals. This will, hopefully, improve the nutritional and economic status of the farmers, especially in rural areas.

1.4 Aim and objectives

The aim of this study was to determine the effect of spineless cactus meal inclusion level on voluntary feed intake, diet degradability and milk production of lactating Holstein cows.

The objectives of the study were:

i. To determine the effect of spineless cactus meal inclusion level on voluntary feed intake of lactating Holstein dairy cows.

ii. To determine the effect of spineless cactus meal inclusion level on *in sacco* degradability and diet digestibility of lactating Holstein dairy cows.

iii. To determine the effect of spineless cactus meal inclusion level on nutrient supply, milk yield and composition of lactating Holstein dairy cows.

1.5 Hypotheses

i. Spineless cactus inclusion level had no effect on voluntary feed intake of lactating Holstein dairy cows.
ii. Spineless cactus inclusion level had no effect on *in sacco* degradability and diet digestibility of lactating Holstein dairy cows.
iii. Spineless cactus inclusion level had no effect on nutrient supply, milk yield and composition of lactating Holstein dairy cows.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Dairy farming is an important income generating activity that provides regular cash income, especially to rural households (Staal and Mullins, 1996). Dairy cattle, also, provide milk and hence food security in rural communities. However, the animals are dependent on communal area natural pastures (Becholie *et al*., 2005). The natural rangelands are characterised by harsh conditions of low rainfall and poor pastures. Natural rangelands contribute more than 80% of ruminant feeds (Darrag, 1995; Minson, 1990), however nutrient supply from these rangelands is seasonal. Cattle starvation is, therefore, a persistent problem in communal areas of Sub-Saharan Africa, especially in the sub-tropical zone. Rainfall is low and seasonal and natural pastures are overgrazed, which reduce plant species diversity and forage availability.

This fluctuating pattern of animal feed supply results in a pattern of gain and loss in animal growth and performance. According to De Kock (1980) and Leng (1990), improvements in dairy productivity and efficiency of feed utilization from low quality pastures can be achieved by the addition of climate smart forages that provide limiting nutrients such as energy and protein. Potgieter (1995) reported that spineless *Opuntia* is an alternative feed for dairy cows and it is a good source of energy and water. Dubeux, (2011) also observed that spineless *Opuntia* is palatable and is regarded as a valuable forage in Africa. *Opuntia* is a succulent plant adaptable to harsh production environments. Effective utilization of such feed resources for dairy production is needed to sustain productivity of dairy cows in communal areas (Dubeux, 2011).

2.2 Palatability and dietary preferences of ruminant animals

Animal feed is the most important input in livestock production. Adequate supply of feeds to the animals in terms of quantity and quality throughout the year is essentially important in productivity of livestock (Provenza, 1995). Inadequate feeding during drought seasons hinder the productivity of livestock and this has been a problem in rural areas because of the high cost of feeds during this time (Hove *et al.,* 2001). In most rural areas, especially during the dry period, livestock are fed only on crop residues or the native pasture that cannot meet maintenance requirements and the animals lose body weight.

The chemical composition of forages has an impact on the palatability of the forage and that, also, results in the preferences of a particular forage than the other. However, interrelationship between taste of the feed and its post-ingestive feedback also plays an important role in animal preferences to a certain forage (Provenza, 1995). According to Arnold *et al.* (1980) the sense of smell is critically important in forage selection. Secondary metabolites such as tannins, alkaloids and glycocides influence the plants palatability. The presence of tannins in plant materials reduces the intake and this may also affect the productivity of the animals (Bryant *et al.,* 1991)

2.3 Nutritional requirements for dairy cows

According to Sahlu *et al*. (2004) the nutrients requirements of dairy animals depend on rate of growth, body size, and reproduction status, level of milk production, previous nutritional plane, acclimatization and environmental conditions. Nutrient requirement are based on maintenance of normal body functions over time and they are adjusted with changes in physiological status of an animal such as animal growth, pregnancy, lactation and work (Sahlu *et al.,* 2004). Temperature, humidity, sunshine and wind velocity may increase or decrease nutrient needs depending upon the region (NRC, 2001). Even livestock of the same breed, age and sex differ from one another in terms of their nutritional needs. The need of feed changes within a meal and across days depending on the animals preferences (Provenza, 1996; Provenza *et al.,* 2003) nutritional requirements of livestock is a guideline to help formulate the ration that will sustain the animals to attain their genetic potential and also to develop a supplementary feeding strategies for without compromising some of the essential nutrients needed by the animal. An optimum growth rate and feed utilization efficiency according to inherent genetic potentiality of a particular category of animals can be achieved only through accurate evaluation of their nutrient requirements (Mandal *et al.,* 2005).

The minimum nutrient requirements of dairy cattle at different lactation stages as suggested by NRC (2001) are presented in Table 1. The table summarizes the current knowledge about the requirements for lactation of dairy cows based on the total yield per day data derived since the NRC (1988) report. The energy and protein requirements are higher in early lactation than mid and late lactation stages NRC (2001).

Table 2.1 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
RUP (%CP)	35-40	30-35	25
Soluble protein (%CP)	25-33	25-36	25-40
NDF (%DM)	30-34	30-38	33-43
ADF (%DM)	19-21	19-23	22-26
NE (Mcal/kg)	1.64	1.57	1.5
NFC (%DM)	30-42	30-44	30-45
TDN (%DM)	72-74	69-71	66-68
Cal (%DM)	0.8-1.1	0.8-1.0	0.7-0.9
Phosphorus (%DM)	0.5-0.9	0.4-0.8	0.4-0.7
Vitamin A (1000IU/day)	100-200	100-200	100-200

Sources: NRC (1988) NRC (2001)

Table 2.2 Maintenance energy requirements for cows of various body weights

Body weight (kg)	Daily energy requirement (Mcal NE/day)
400	7.16
450	7.82
500	8.46
550	9.09
600	9.70
650	10.30
700	10.89
750	11.47
800	12.03

Source: NRC (1998)

2.4 Forage feeding for dairy cattle

Forages are defined as edible parts of the plants that provide nutrients for grazing animals or can be harvested for feeding the animals. Forages are the staple diets for livestock, especially ruminant animals and are essential to productivity and profitability of dairy production. There is wide variety of fresh and conserved forages that are available for ruminant feeding (Barnes *et al.,* 1996). Grasses are the major source of forage for ruminant animals. Livestock consume mainly leaves and there are the fibrous in nature. Ruminant animals such as cattle and sheep require this fibre in their diets for proper digestion and also to enhance diet intake. Forage crops can be grazed directly by animals as pasture or conserved as hay or silage for winter or drought feeding. Animals obtain nutrients such as energy, protein, minerals and vitamins from forages. However, those essential nutrients decline in their concentration as the forage crops mature and become more fibrous (Barnes *et al.,* 1995).

The highest level of efficiency of animal production can be achieved only by reaching the highest possible level of nutrient intake from forages (Blaxter, 1962). Forage intake by ruminants involves interactions between the forage itself, the microbes in the gastro-intestinal tract and the animal (McDonald *et al.,* 2002). Forage intake is a function of the forage rate of degradation by ruminal microbes, the rumen capacity, the forage digestibility and passage rate through the gut (McDonald *et al*., 2002). These factors are important when considering the forage feeding value. *In Sacco* digestibility and voluntary intake of a forage are consistently used to enable one to make an accurate and reliable assessment of forage feeding values in the majority of situations.

2.5 Composition of grasses verses spineless cactus

The nutrient composition of spineless Opuntia and grasses depends on various factors such as species, maturity, environment, fertilisation, soil fertility and harvesting conditions (Ball *et al.,* 2001). Quality of the forage has an influence on diet intake and diet digestibility and it can be defined as the extent to which the forage has the potential to produce a desired animal response. For example, the diet formulated for animal fattening should be able to meet that requirement at the end of the day (Ball *et al.,* 2001). Quality of forage of plant materials is determined by the maturity stage at which the plant material was harvested or grazed as pasture. This, also, has a great influence on forage consumption by animals. As the plant matures, essential nutrients and digestible dry matter levels in the animal diet decreases while fibre level increases. The fibre in the diet is determined by the crude fibre, NDF, ADF and ADL. As these nutrients increase the lignin content of the plant also increases drastically making other nutrients less available as lignin is highly indigestible. Spineless forage was found to have high nutritive value due to its good chemical composition. However, spineless forage is low in protein and fibre contents (De Kock, 1998).

Compared to grasses, spineless *Opuntia* forages have high energy content (14.3 MJ/kg). The energy in fresh spineless cactus cladodes is due to the high carbohydrates/starch content in the cladodes. Grasses have high fibre concentration than spineless at an optimal stage of growth. Collins (1988) found an optimal NDF concentration of 50 to 55% in grass forages except for alfalfa which is 40%.

Table 2.3 The nutritive aspects of grasses and spineless cactus

Nutritional aspects	Spineless cactus	Grass
Dry matter (%DM)	9.1	83.2
Gross energy (MJ/kg)	14.3	18.6
Crude protein (%DM)	6.9	8.4
NDF (%DM)	25.5	77.9
ADF (%DM)	14.5	42.6
Ash (%DM)	19.5	6.5
Non-fibrous carbohydrate (%DM)	51.4	-
Total Digestible Nutrients (%DM)	68.6	-

Sources: De Kock (1998); Pozy *et al*. (1996)

2.6 Dry matter intake and levels in dairy diets

Dry matter intake is the amount of feed a dairy cow consumes per day on a moisture-free basis. It is important in nutrition because it defines amount of nutrients available to an animal for health and production (NRC, 2001). There are three major factors that affect dry matter intake which are feed ration (quality and availability of forage and the amount and type of supplements), the environment and the animal itself (size, body condition, stage of life) and level of production. Dry matter is a factor that must be estimated before an animal diet can be properly calculated (NRC, 2001). Dry matter requirement in grass and concentrate for dairy cows is 8 to 10kg per day. During early lactation a dairy cow will require 16 to 18kg of dry matter per day to sustain milk production. Dairy cows consume 2 to 3 percent body weight of forage dry matter.

It was observed that the dry matter intake of lactating cows is affected by environmental conditions outside the thermal neutral zone which ranges from 5 to 20°C. Both Eastridge *et al*. (1998) and Holter *et al.* (1997) have shown dry matter intake decreases with ambient temperatures above 20°C. It is important to actually measure or accurately estimate dry matter intake so that diets can be properly formulated to prevent underfeeding or overfeeding of nutrients and to promote efficient use of nutrients (NRC, 2001). Estimating daily dry matter intake from pasture is a challenge since most ruminant animals eat to meet their energy requirements in response to energy expenditures such as in milk production.

2.7 Water requirements of dairy animals/lactating cows

Water is the most important nutrient for dairy cattle (NRC, 2001). The total body water content of dairy cattle is 56 to 81% of their body weight (Murphy, 1992). Physiological stage and body composition affect the body's water content. According to Andrew *et al*. (1995), cows in early lactation have more body weight in water (69.0%) than cows in late lactation (62.4%) with late-gestation dry cows intermediate in body water content (64.7%). Water is required for all life's processes. Water acts as a transport of nutrients and other compounds to and from cells. Water helps in digestion and metabolism of nutrients. Water acts as a medium that helps eliminate waste products such as urine, faeces and respiration from the body. Excessive heat from the body and maintenance of proper fluids such as blood and ion balance in the body are regulated by water. In pregnant animals water helps in the provision of a fluid environment for the developing foetus. Water also removes waste products from the foetus to the mother (Houpt, 1984; Murphy, 1992). A loss of 20% of the body water is fatal (Houpt, 1984). Spineless cactus has 90% water content. During dry season spineless cactus can provide dairy cows with adequate water.

Ruminants require large amounts of water every day (24-136 litres/day/cow) depending on the period of lactation (Murphy, 1992). Lactating cow require at least 60-70 litres of water per day for maintenance and an extra 4-5 litres for each and every litre of milk produced (Moran, 2005). However, a dry dairy cow requires around 15-6 litres of water per day (Holter and Urban, 1992). They meet this requirement via three sources: drinking, ingestion of water contained in feed, and water produced by the body's metabolism of nutrients (NRC, 2001). Loss of water from the body occurs through milk production, urine excretion, faecal excretion, sweat, and vapour loss from the lungs. Holter and Urban (1992) observed that water losses through milk of cows producing 33 litres/day were about 34% of total water intake (feed plus free water consumed) while 29 and 26% were observed by Dado and Allen (1994) and Dahlborn *et al*. (1998), respectively. Faecal water losses were similar to those of milk which is 30 to 35% of total water intake, and urine losses were about half of faecal losses (15 to 21%) in lactating cows. Factors that affect faecal water loss include dry matter intake, dry matter content of the diet fed to the animal, and digestibility of the diet (Murphy, 1992). Urinary water excretion is related positively to water availability, amount of water absorbed from the intestinal tract, urinary nitrogen, and urinary potassium excretion and negatively related to dietary dry matter (Murphy, 1992). Availability and quality of water are extremely important for animal health and productivity. Limiting water availability to cattle will depress production rapidly and severely (NRC, 2001; Holter and Urban, 1992)

2.8 Spineless cactus (*Opuntia ficus-indica)* as a livestock feed

Feed and water shortage is a major problem for the livestock sector in semi-arid and arid areas and utilisation of multipurpose trees and shrubs that can cope with low and erratic rain fall, high temperature, poor soils, and required low energy inputs can serve as an alternative strategy to reduce the chronic animal feed and water shortage (Teklehaimanot and Tritschler, 2011). Spineless cactus (*Opuntia ficus-indica*) possesses important characteristics for animal feed in drought-prone regions. This includes high dry matter yields, drought tolerance, good nutritive value and palatability for animals (Tegegne, 2001). It is a multipurpose crop and a valuable forage source of water and forage for livestock in dry areas, and this species is widely spread in semi-arid and arid regions of Africa (Ecoport, 2009). Spineless *Opuntia* forage is a source of energy and water in livestock diets (De Kock, 1980). Compared to grasses, spineless forages have a relatively higher concentration of gross energy exceeding 13.22 MJ/kg (De Kock, 1998)

Spineless cactus is a slow growing perennial shrub with cladodes very thick and succulent (Dubeux, 2011). Young cactus cladodes are used as vegetables and mature ones are for forage. Cactus remains succulent during the long dry season and can serve the animal as a source of feed and water during this period (Ecoport, 2009).

Furthermore, cactus is suitable as human food, as fuel, for medical uses, as forage, and in rangeland rehabilitation projects (Barbera *et al*., 1992). Cactus pear plays a key role as a lifesaving feed both for human and animals, especially in time of drought. In Africa the use of cactus for animal feed is currently limited to grazing during the dry season. Cut and carry of cactus is practised during drought periods, but it is not common (Dubeux, 2011). Although cactus cladodes have great potential in promoting a sustainable animal production system, knowledge is limited concerning its nutritive value, its utilisation as animal feed, and its role in animal performance. Farmers, usually, report that their animals get diarrhoea when fed high level of cactus during the dry season (De Kock, 1980).

2.8.1 The nutritional value of spineless cactus (*Opuntia ficus-indica)*

Spineless cactus plants have high water contents and energy. However, spineless cactus is low in crude protein as well as crude fibre (De Kock, 1998). The digestibility is moderate, ranging from 65 to 70% (Dubeux, 2011). Water content is 90%, and water soluble carbohydrates ranges from 45 to 55%. According to Marcelo *et al*. (2012) cactus exhibits low levels of dry matter (11.69%), crude protein (4.81%), NDF (26.79%) and ADF (18.85%). In contrast, cactus has high levels of total carbohydrates (81.12%), non-fibrous carbohydrates (58.55%), and mineral matter (12.04%). The crude protein in the spineless cactus varies depending on the species, the fertilization of the soil and the cultivation practices (De Kock, 1998). The chemical composition of spineless cactus is indicated in Table 2.4.

Regardless of genus or cultivar, spineless cactus exhibit low dry matter content. Studies reported by most researchers indicate that the DM content of cacti cladodes ranges from 8.5 to 14% (De Kock, 1980). Other authors reported the following dry matter contents Tegegne *et al.* (2007) 12.2%, Mciteka (2008) 9.13%, De Kock (1965) 11.0% and Nefzaoui et al. (1995) 10.0%. All these results were also in the agreement with results reported by Costa *et al.* (2009) 10 to 14% DM. The high moisture/water content of cactus cladodes helps mitigate the problem of watering animals in dry areas. Research shows that water intake is zero when cactus intake by sheep is about 300g of DM (Mciteka, 2008; Nefzaoui and Ben Salem, 2001). Gregory and Felker (1992) reported moisture content ranging from 84 to 94%. Tegegne (2001) reported moisture content of 92%. Batista *et al.* (2003) reported that the ash content of cactus variety ranges from 10.4 to 13.3%. This is lower than the values reported by Ben

Salem *et al*. (1996) and Ben Thlija (1987) which are 27.4 and 30%, respectively. The high ash content of cactus cladodes is mainly because of the high calcium content reported by other researchers (Shoop *et al.,* 1977).

Protein content of cactus cladodes is generally very low (De Kock, 1998; Ben Salem *et al.,* 1996). Average values of 3.8 and 5.8% (DM basis) have been reported by Ben Salem *et al.* (1994) and Ben Salem *et al.* (1996), respectively. It has been recommended by De Kock (1980) that any ration for no reproductive sheep and cattle should contain at least 8% of crude protein. Because rations or feeds with low protein content are poorly ingested by animals. Potgieter (1995) mentioned that other noticeable deficiencies of cactus pear are the low phosphorus and sodium contents, which can be supplemented with an inexpensive lick consisting of 60% bone meal and 40% salt. The positive characteristics of cactus pear as a feed source are its high calcium, carbohydrate (energy) and digestibility which are above 70%. In general *Opuntia* is considered to be, high in *in vitro* digestibility of 77.4% and low in crude protein content which is approximately 3.2% (Lopez-Garcia *et al*., 2001).

Table 2.4 Chemical composition of spineless cactus

Nutrients	Units	Amount
Dry matter	%DM	9.2
Crude protein	%DM	4.4
Ether extract	%DM	2.3
Total carbohydrate	%DM	82.9
Non-fibrous carbohydrate	%DM	51.4
NDF[2]	%DM	31.4
ADF[2]	%DM	15.5
Lignin	%DM	3.2
NDF[1]	%DM	26.7
ADF[1]	%DM	11.3
Ash	%DM	9.6
TDN	%DM	68.6
Gross energy	MJ/kg DM	13.22

Source: De Kock (1998)
NDF[1]: Neutral detergent Fibre; ADF1: Acid detergent Fibre

Table 2.5 Average chemical composition of cactus cladodes

	DM (%)	Chemical content (as % of DM)			
		Ash	CP	CF	NFE
Average	11.01	17.19	4.76	10.91	65.30
Minimum	4.74	8.18	2.50	7.82	56.70
Maximum	17.00	23.53	7.87	14.50	72.67
Standard deviation	3.87	4.61	1.90	2.24	5.25

Sources: De Kock (1980); Lozano (1958); Teles (1978); Theriez (1965).

Table 2.6 Chemical composition of cladodes of different ages

Month/years	Description	Protein (%DM)	Fat (%DM)	Ash (%DM)	Crude fibre (%DM)	Non nitrogen extract (%DM)
0.5	Young stem (nopalitos)	9.4	1	21	8	60.6
1	Freshly leaf (penca)	5.4	1.29	18.2	12	63.1
2	Freshly leaf (penca)	4.2	1.40	13.2	14.5	66.7
3	Freshly leaf (penca)	3.7	1.33	14.2	17	63.7
4	Lignified stem	2.5	1.67	14.4	17.5	63.9

Sources: López, Fuentes and Rodríguez (1997); cited in Pimienta-Barrios (1993).

Table 2.7 Chemical composition of fresh cladodes

Nutrients analysis	Unit	Average
Dry matter	% as fed	9.1
Gross energy	MJ/kg DM	14.3
Crude protein	%DM	6.9
Crude fibre	%DM	14.6
NDF	%DM	25.5
ADF	%DM	14.5
Lignin	%DM	2.6
Ether extract	%DM	1.9
Ash	%DM	19.5

Sources: Morrison (1956); Pozy *et al*. (1996); Tegegne *et al.* (2007).

2.8.2 Feeding value of spineless cactus (*Opuntia ficus-indica)*

Animal feed resources fluctuate seasonally and are often of limited availability. Finding alternative feed resources that can sustain animal production during the long dry season is an essential need. Cactus is a drought-tolerant and succulent feed resource available throughout the year and it is an alternative feed and water source for animals during dry seasons. The cladodes of the plant are harvested for forage while the pear (fruit part) is harvested for human consumption. Spineless are also total feeds, supplying almost all the biomass and other nutrients needed to support high levels of animal production (Barbera, 1995).

For cattle, to provide the daily energy requirements for the survival of a 400kg animal, 2850g of TDN are required per day. Such animal will require approximately 4385g of dry cactus to meet its requirements (De Kock, 2001). It means a daily intake of 44 to 45kg of fresh cladodes will be required to meet this requirement. However, an animal can only consume an average of 40kg of cactus per day due to high moisture content in the cladodes. The energy requirement for the survival of a 35kg sheep is approximately 350g of TDN per day. A total ingestion of 538g of dry cactus will be sufficient to provide the required energy. This means that 5 to 6kg of fresh cactus must be ingested daily (De Kock, 2001). However, a sheep eats an average of 4kg a day. This means that small ruminant can have an inclusion level of 7kg/day for optimal response. Large ruminant animals such as dairy cattle can have the inclusion level of

21kg in the diet to maintain its energy level. Cactus cladodes are highly palatable, with average daily consumptions of 6 to 9kg for sheep and 50 to 80kg for cattle (Nefzaoui and Ben Salem, 2001). Cactus cladodes have a very low gut fill value, because their intake does not reduce fibrous feed intake and the improved rumen conditions enhance the fibrous feed intake (De Kock, 1998). Feeding cactus helps to solve the problem of animal watering. Sheep fed for a long period (400 to 500 successive days) with large amounts of cactus stopped drinking water (Rossouw, 1961; Harvard-Duclos, 1969). Woodward *et al*. (1915) with Holstein cows reported similar results. However, Cottier (1934) suggested that it is not possible to suppress water in cattle fed on cactus.

The high water content of cactus pads could help solve the problem of watering animals in dry areas. Research results show that water intake is suppressed when cactus intake by sheep is about 300g of dry matter (Nefzaoui and Ben Salem, 2001; Ben Salem *et al.,* 1996). Terblanche *et al*. (1971) reported similar findings. The volume of water consumed by animals decreased from 2.4 litres for the control diet to 0.1 litre when the level of spineless cactus consumption exceeded 300g DM (Nefzaoui and Ben Salem, 2001). Ben Salem *et al*. (1996) noted that intake of grass hay increased significantly with an increase of the cactus in the diets. The author also noted that spineless cactus is a good supplement to ammonia or urea-treated straw, since it provides the soluble carbohydrates necessary for the efficient use of the non-protein nitrogen by microbes in the rumen (Nefzaoui *et al*., 1993). Cactus pear can play a stabilizing role in agriculture as it can prevent stock losses during droughts, save natural grazing from over-grazing, increase farm income and alleviate poverty in rural areas (Potgieter, 1993). Santana *et al*. (1972) reported that Holstein cow fed with maize silage and spineless cactus had no different in milk production and fat content.

2.9 *Eragrostis curvula* grass (Weeping love grass) as livestock feed

Eragrostis curvula is commonly known as weeping love grass. It is generally considered to be poor forage for grazing livestock and its main advantage is its high productivity and drought tolerance (Torell *et al*., 2000). *Eragrostis curvula* grass is important to livestock in South Africa. It is used for grazing pasture or hay. The foliage is nutritious and palatable when green but its nutritional quality does decline greatly with age. The energy content is low during dry seasons and its digestibility declines quickly with age (Torell *et al.,* 2000). Weeping love grass has quickly gained acceptance by farmers for its persistence carrying capacity and drought resistance but there is controversy about its nutritive value and its place in animal feeding is not well defined (Vera *et al*., 1973). Dry matter digestibility of fresh or dry *Eragrostis curvula* forage is relatively low and varies between 43 and 60% (Synman, 1991). *In situ* dry matter degradability of *Eragrostis curvula* grass is low (Vieyra *et al*., 1995). Weeping love grass is not a very palatable species though it may be more palatable to sheep than to cattle (Mills, 1977). *Eragrostis curvula* grass is a perennial summer growing grass that produces good quality hay. Its other use is for pasture and erosion control. *Eragrostis curvula* is a more productive forage than native grassland, making this species a good alternative for the livestock industry (Esqueda *et al*., 2001).

2.9.1 Feeding value

Feeding value is defined as the amount of feed ingested and the efficiency with which nutrients are extracted from a given feed (Norton and Poppi, 1995). The feeding value of forage is mainly determined by voluntary intake, crude protein and structural carbohydrates. The intake of forage is influenced mainly by digestible dry matter, crude protein content and the extent of degradation (Minson, 1990). Crude protein levels and *in vitro* dry matter digestibility vary largely with age of material and nitrogen fertility of the soil. *In vitro* dry matter digestibility values of 65 and 18% CP have been measured in young growing material compared with 50 and 6% in older material. Dry matter digestibility of fresh and dry *Eragrostis curvula* forage is relatively low and varies between 48 and 60% (Castro *et al.,* 1984; Synman, 1991)

Table 2.8 Chemical composition, nutrient composition, digestibility and ME values of fresh *Eragrostis curvula*

Nutrient	Unit	Average	SD	Min	Max.
Dry matter	% as fed	38.2	7.0	28.1	48.3
Crude protein	%DM	9.0	1.9	5.6	13.1
Crude fibre	%DM	38.3	2.7	30.7	42.1
NDF	%DM	73.3	-	-	-
ADF	%DM	44.5	-	-	-
Lignin	%DM	6.4	-	-	-
Ether extract	%DM	1.9	0.4	1.1	2.7
Ash	%DM	4.6	1.0	3.6	7.1
Gross energy	MJ/kg DM	19.1	-	-	-
Ruminant digestibility & ME values	Unit	Average	SD	Min.	Max.
OM digestibility	%	53.3	-	-	-
Energy digestibility	%	49.4	-	-	-
DE	MJ/kg DM	9.4	-	-	-
ME	MJ/kg DM	7.6	-	-	-

Sources: Alibes *et al*. (1990); Erasmus *et al*. (1994); Berhane *et al*. (2006); Pozy *et al*. (1996).

OM: Organic matter; DE: Digestible energy; ME: Metabolisable energy; SD: Standard deviation

Table 2.9 Chemical composition, nutrient composition, digestibility and ME values of *Eragrostis curvula* hay

Nutrient	Unit	Average	SD	Min	Max
Dry matter	% as fed	83.2	14.9	66.0	93.0
Crude protein	%DM	8.4	2.2	5.7	13.0
Crude fibre	%DM	34.8	5.5	29.5	40.5
NDF	%DM	77.9	4.3	72.6	82.7
ADF	%DM	42.6	4.0	38.2	47.3
Lignin	%DM	6.1	3.4	1.9	9.7
Ether extract	%DM	2.0	0.6	1.3	2.4
Ash	%DM	6.5	2.1	4.7	9.2
Gross energy	MJ/kg DM	18.6	-	-	-
Ruminant digestibility & ME values	Unit	Average	SD	Min	Max
OM digestibility	%	55.1	-	-	-
Energy digestibility	%	51.3	-	-	-
DE	MJ/kg DM	9.5	-	-	-
ME	MJ/kg DM	7.7	-	-	-
ME	%	51.4	-	-	-

Sources: Berhane *et al*. (2006); Erasmus *et al*. (1994); Synman (1991).

2.10 Conclusion

The tropical areas cover 37% of land. Ruminants live in this environment and their principal sources of feed are low quality pastures and forages with little or no supplementation. Dairy cows in rural areas depend on low quality roughages which are limiting in energy and protein. The result is poor productivity, particularly during winter and dry seasons. There is some evidence that supplementation of these low quality roughages with spineless forages can improve productivity of the animals. *Opuntia* forages used for animal feeding are abundant, easy and cheap to grow, palatable and drought tolerant. Such characteristics make them a potentially important feed supplement for livestock, particularly during periods of drought and low feed availability. A large portion of opuntia plant biomass is vegetative material rather than fruits, and it can be fed to livestock as fresh forage or stored as silage for later feeding.

However, data on the utilization of different spineless cultivars grown in South Africa is not available. This study determined the effects of spineless forage supplementation on voluntary diet intake, digestibility, milk production and body change of Holstein cows.

CHAPTER 3

METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Study site

The study was conducted at the Animal Production Institute, Agricultural Research Council (ARC-API) in Pretoria, South Africa. The GPS coordinates are latitude 25º 53′ 63″ S and longitude 28º 10′ 90″ E, altitude 1480 m. The ambient temperature around the study area ranged from 6.5 to 25ºC. The relative humidity was 79% with mean annual rainfall of 823mm (SA Weather Station, Irene, 2007).

3.2 Experimental procedures, dietary treatments and design

Two experiments were conducted. The feeding experiment determined the effects of inclusion of spineless cactus on milk production and *in sacco* digestibility. Four dietary treatments were applied in a cross-over design (SAS, 2008). The experiment was conducted to determine the effects of spineless forage inclusion level on voluntary feed intake, digestibility and body condition score of Friesian dairy cows.

3.2.1 Experiment one (feeding trial)

Four multiparous mid-lactating Friesian dairy cows, weighing 650 ± 80kg live weight were used. The animals were allocated to four dietary treatments with varying inclusion levels of spineless cactus (*Opuntia ficus-indica)* of 0, 4, 8 and 12% on DM basis (Table 3.2). Supply of semi-complete concentrate was maintained at 2.5% BW. For each cross-over of experimental animals 21 days of adaptation period and 6 days of collection period were applied. The animals were kept in an Experimental Animal Unit with partial roof and concrete floor. The animals had access to a resting area with gravel floor of about $60m^2$. Animals were fed individually and clean water was provided *ad libitum*. Spineless Opuntia leaves were harvested at vegetative stage. The leaves were chopped to 20 to 30mm pieces. Daily feed intake was measured by the difference in weight of the feed offered and the refusals. The refusals was collected and measured daily at 08h00 in the morning before feeding.

3.2.2 Experiment two (in sacco degradability trial)

An *in sacco* degradability experiment was done using spineless cactus harvested at vegetative stage, *Eragrostis curvula* hay, semi-complete concentrate and the three experimental diets with different levels of spineless inclusion*. Eragrostis curvula* hay and semi-complete concentrate were dried and milled. The spineless cactus was cut into small pieces and incubated inside a rumen of a cannulated animal to determine the degradability of the feed materials. Each feed material was assigned as a treatment, with two replications, in a completely randomized design. One mature Friesian-Holstein multiparous cow weighing 650 ± 80kg live weight, fitted with a rubber rumen cannula was used to determine the degradability profile of the feed material using the Nylon Bag Technique (Mehrez and Ørskov, 1977; Bhargava and Ørskov, 1987). The animal was kept in the experimental unit and fed *ad libitum* a diet of spineless cactus, *Eragrostis curvula* hay and semi-complete concentrate. The cow was fed for 21 days prior to the ruminal incubation of the nylon bags, to allow animal's adaptation. Fresh drinking water was also provided *ad libitum* throughout the experiment. The chemical composition of diet ingredients and experimental diets are indicated in Table 3.1 and Table 3.2, respectively.

3.2.2.1 Determination of *in sacco* degradability of the diets

In sacco degradability was determined using the method of Mehrez and Ørskov (1977) and Bhargava and Ørskov (1987) for dietary treatments having different levels of spineless. For individual feed material, fresh cactus was cut into pieces of 1.0 cm while semi-complete and *Eragrostis curvula* hay were dried and milled. Five grams of each individual sample were weighed in duplicate into nylon bags and incubated in the ventral sac of the animal fitted with ruminal cannulas for 0, 4, 8, 18, 24, 36, 48, 60, and 72 hours. Following ruminal incubations, bags were washed in tap water until the run-off water was clear and then dried in a forced-air oven at 60^{o}C for 48 hours. Zero hour disappearance was estimated by washing bags of each treatment in tap water for 5 minutes. The dried residues were analysed for dry matter, and ash. Disappearances of DM at each incubation time were calculated from the concentrations of the nutrients in the original samples, and the residues were used to estimate ruminal kinetic parameters according to the equation of Ørskov and McDonalds (1979). The effective ruminal degradability of DM was estimated using the equation of Ørskov and McDonalds (1979), which assumes a ruminal outflow rate of 5% per hour)

Table 3.1 Dry matter and chemical composition of diet ingredients

Feed	DM (%)	Ash (%)	OM (%)	CP (%)	ME (MJ/kg)	EE (%)	NDF (%)	ADF (%)	ADL (%)	NFC (%)
Spineless	12.6	21	79	2.2	2.4	1.7	20	8.0	1.4	42.3
Eragrostis	92	6	94	3.2	1.5	1.3	70	56	12.3	19.5
Semi-complete concentrate	95	9	91	16	2.6	1.9	52	23	6.1	35.5

Semi-complete concentrate composition: Urea = 6.5/1000; CP from NPN=13.3 g/kgDM

Table 3.2 Composition of feed materials in the experimental diets

Feed	Diet 1	Diet 2	Diet 3	Diet 4
Spineless Opuntia	0%	4%	8%	12%
Eragrostis curvula hay	66%	62%	58%	54%
Semi-complete concentrate	34%	34%	34%	34%

Table 3.3 Dry matter (DM) and composition (%) of experimental diets

Parameter	Diet 1 (Control diet)	Diet 2	Diet 3	Diet 4
Dry matter (%DM)	92	42.5	41.5	39.9
Crude protein (%DM)	13.1	12.9	12.7	12.4
Ether extract (%DM)	7.9	8.0	7.5	7.4
Non-fibrous carbohydrates (%DM)	22.9	24.7	26.1	28.1
Neutral detergent fibre (%DM)	27.6	26.1	25.7	24.4
Total carbohydrates (%DM)	46.3	47.8	49.4	49.8
Metabolisable energy (MJ/kg)	1.97	2.02	2.03	2.10

3.3 Voluntary feed intake and body condition score (BSC) of animals

Daily feed intake was determined by difference in weight of feed offered and the feed refusals. Weighing of animals was done in the morning before offering feeds to the animals (Sarwatt *et al.,* 2003). Body condition scoring of the animals was done using a five-point scale to check the difference in performance of the animal (Table 13) at the inception and termination of the experiment (Wildman *et al.,* 1982). Change in body weight and nutrient outflow were estimated using AMTS model equations (Fox *et al*., 2004). Daily milk yield and milk quality of individual animals were determined. Milk was analysed for lactose, crude protein, milk urea nitrogen, butter fat and somatic cell count at Lacto lab (Irene) using a MilkoScan Analyser (Foss manufacture).

Table 3.4 Body condition scoring of dairy cows using a five-point scale

Score	Condition	Description
1	Very thin	Animal appears emaciated. Severe depression below tail head and between pin bones. No body fat and the stomach is sunk in.
2	Thin	Areas between tail head and between pin bones are somewhat depressed. No subcutaneous body fat and has a V-shaped waistline
3	Ideal/ average	Areas between pin bones and around tail head appear smooth without signs of fat deposit. There is slightly amount of subcutaneous body fat.
4	Fat	Area of tail head and pin bones is rounded with evidence of fat deposits. Shoulders and hip bones are covered by a moderate fat layer.
5	Excessively fat	Tail head appears to be buried in fatty tissue. Shoulders and bones are covered by a thick fat layer. Fat deposit can be seen in the limbs.

Sources: Heinrichs and Ishler (2011); Wildman *et al*. (1982).

3.4 Faecal collection

Faeces were collected by hand at 08h00 in the morning before feeding for six consecutive days for each animal. Faeces were collected and weighed every morning before feed was offered. At the end of the collection period, the faeces was thoroughly mixed and put in a sealed polythene bag for each animal. Faeces samples were then weighed, and dried in an oven at 60°C for 4 days to determine apparent digestibility. Apparent digestibility was determined using the total amount of faecal output of each experimental animal per day and the dried samples extracted from the total faecal output.

Apparent digestibility equation

$$Apparent\ digestibility = \frac{dry\ faecal\ sample - wet\ faecal\ sample}{dry\ faecal\ sample}\ x\ 100$$

3.5 Chemical analysis

Feeds, feed refusals, faeces and *in sacco* residues were analysed for dry matter (DM), ash and ether extract (EE) according to AOAC (2002) procedures (methods 934.01, 942.05 and 920.37, respectively). Ash corrected neutral detergent fibre (aNDF, AOAC method 2002.04), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to the method of Van Soest *et al.* (1991). Cellulose and hemicellulose were estimated using equations of Van Soest *et al*. (1991). Crude protein (CP) was determined using Kjeldahl method (AOAC 2002, procedure 954.01). Non-fibre carbohydrates were calculated as NFC = [100-(NDF + % CP + % Fat + Ash)]. Energy contents were determined using the bomb calorimeter (AOAC, 2002).

3.6 Statistical analysis

All data on voluntary feed intake, diet digestibility, milk production, milk composition and in sacco degradability were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 2008). Treatment Means were separated using the Duncan multiple range test and significance declared at ($P<0.05$). The responses in optimum intake, digestibility and milk production to level of spineless inclusion were modeled using the following quadratic equation:

$Y=a + b_1x + b_2x^2$

Where Y= optimum intake, digestibility, and milk production; a = intercept; b = coefficients of the quadratic equation; x = dietary level and $-b_1/2b_2$ = x value for optimum response. The quadratic model was fitted to the experimental data by means of the NLIN procedure of SAS (SAS, 2008).

CHAPTER 4

RESULTS

4.1 Effect of spineless cactus meal inclusion on voluntary feed intake and body condition score of the cows

The results for dietary intake of Holstein cows on *Eragrostis curvula* hay supplemented with different levels of spineless forage meal are presented in Table 4.1. Spineless cactus meal inclusion level did not affect ($P>0.05$) diet dry matter intake as a percentage of body weight and crude protein intake by Friesian cows. However, cows on spineless cactus meal inclusion levels of 8 or 12% had higher ($P<0.05$) dry matter intakes than those on 0% inclusion level. Friesian cows on spineless cactus meal inclusion levels of 4, 8 or 12% had similar ($P>0.05$) dry matter intakes. Similarly, cows on 0 or 4% spineless cactus meal inclusion levels had the same ($P>0.05$) dry matter intakes. Friesian cows on 8% spineless cactus meal inclusion level had higher ($P<0.05$) NDF intake than those on 0 or 4% inclusion levels. Similarly, cows on 4 or 12% spineless cactus meal inclusion levels had higher ($P<0.05$) NDF intakes than those on 0% inclusion level. However, cows on spineless cactus meal inclusion levels of 8 or 12% had similar ($P>0.05$) NDF intakes. Similarly, cows on spineless cactus meal inclusion levels of 4 or 12% had the same ($P>0.05$) NDF intakes. Friesian cows on spineless cactus meal inclusion levels of 4, 8 or 12% had higher ($P<0.05$) ADF intakes than those on inclusion level of 0%. However, cows on 4, 8 or 12% spineless cactus meal inclusion levels had similar ($P>0.05$) ADF intakes. Friesian cows on spineless cactus meal inclusion levels of 8 or 12% had higher ($P<0.05$) ME intakes than those on inclusion levels of 0 or 4%. Similarly, cows on spineless cactus meal inclusion level of 4% had better ($P<0.05$) ME intake than those on 0% inclusion level. However, cows on inclusion levels of 8 or 12% spineless cactus meal had similar ($P>0.05$) ME intakes.

Diet DM, NDF, ADF and ME intakes by Holstein cows were optimized at different spineless cactus meal inclusion levels of 19.4 (r^2 = 0.992), 16.4 (r^2 = 0.974), 14.0 (r^2 = 0.984) and 22.9 (r^2 = 0.994) %, respectively (Figures 4.1, 4.2, 4.3 and 4.4, respectively and Table 4.3).

Table 4.1 Diet dry matter, fibre, crude protein and metabolisable energy intakes by Holstein cows*

Treatment (Cactus inclusion level)	DMI (kg)	DMI as % of BW	NDFI (kg)	ADFI (kg)	CPI (kg)	MEI (Mcal/d)
0%	22.7±2.38[b]	3.3±0.18[a]	13.0±1.66[c]	6.7±1.09[b]	2.8±0.08[a]	55.1±3.56[c]
4%	24.1±2.53[ab]	3.5±0.31[a]	13.6±1.78[b]	7.1±1.71[a]	2.8±0.08[a]	57.8±3.78[b]
8%	25.3±2.33[a]	3.6±0.32[a]	14.1±1.63[a]	7.4±1.07[a]	2.9±0.07[a]	60.2±3.49[a]
12%	25.4±1.95[a]	3.7±0.23[a]	13.9±1.41[ab]	7.3±0.93[a]	2.9±0.06[a]	60.8±2.89[a]

* : Values presented as means ± standard error (SE)

[a, b, c] : Means in the same column not sharing a common superscript are significantly different (*P<0.05*).

DMI : Dry matter intake, NDFI: Neutral detergent fibre intake, ADFI: Acid detergent fibre intake, CPI: crude protein intake, MEI: Metabolisable energy intake.

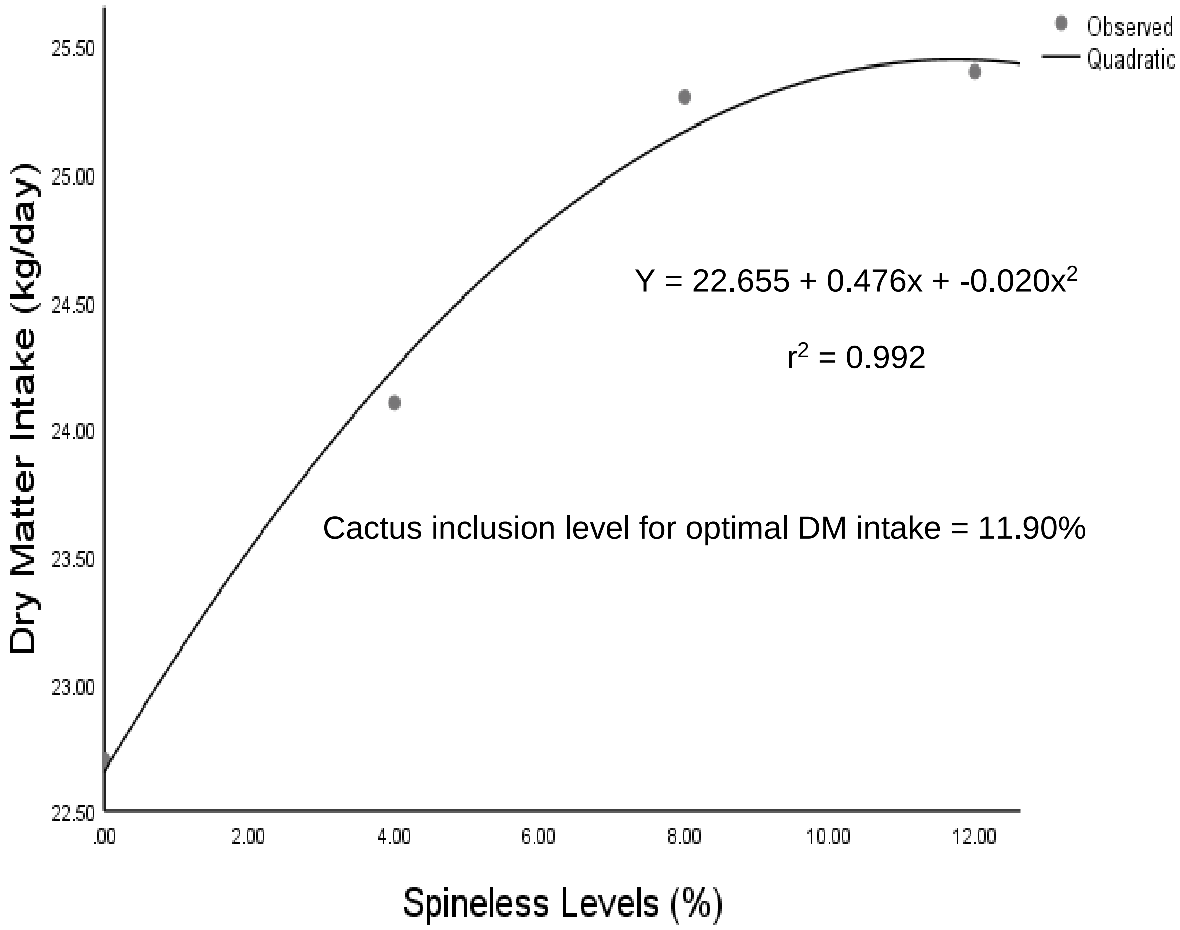


Figure 4.1 Effect of spineless cactus meal inclusion level on DM intake of lactating Holstein cows

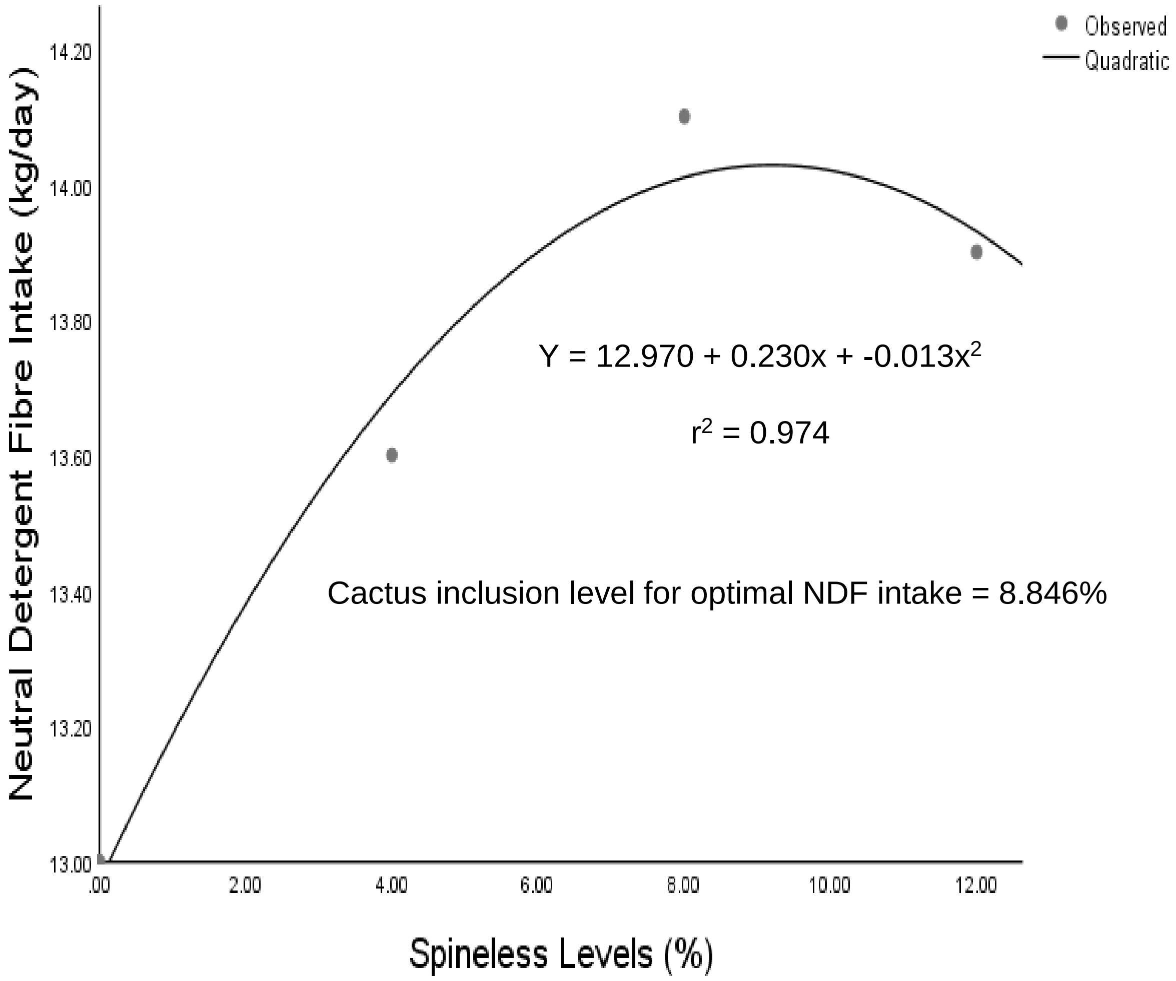


Figure 4.2 Effect of spineless cactus meal inclusion level on NDF intake of lactating Holstein cows

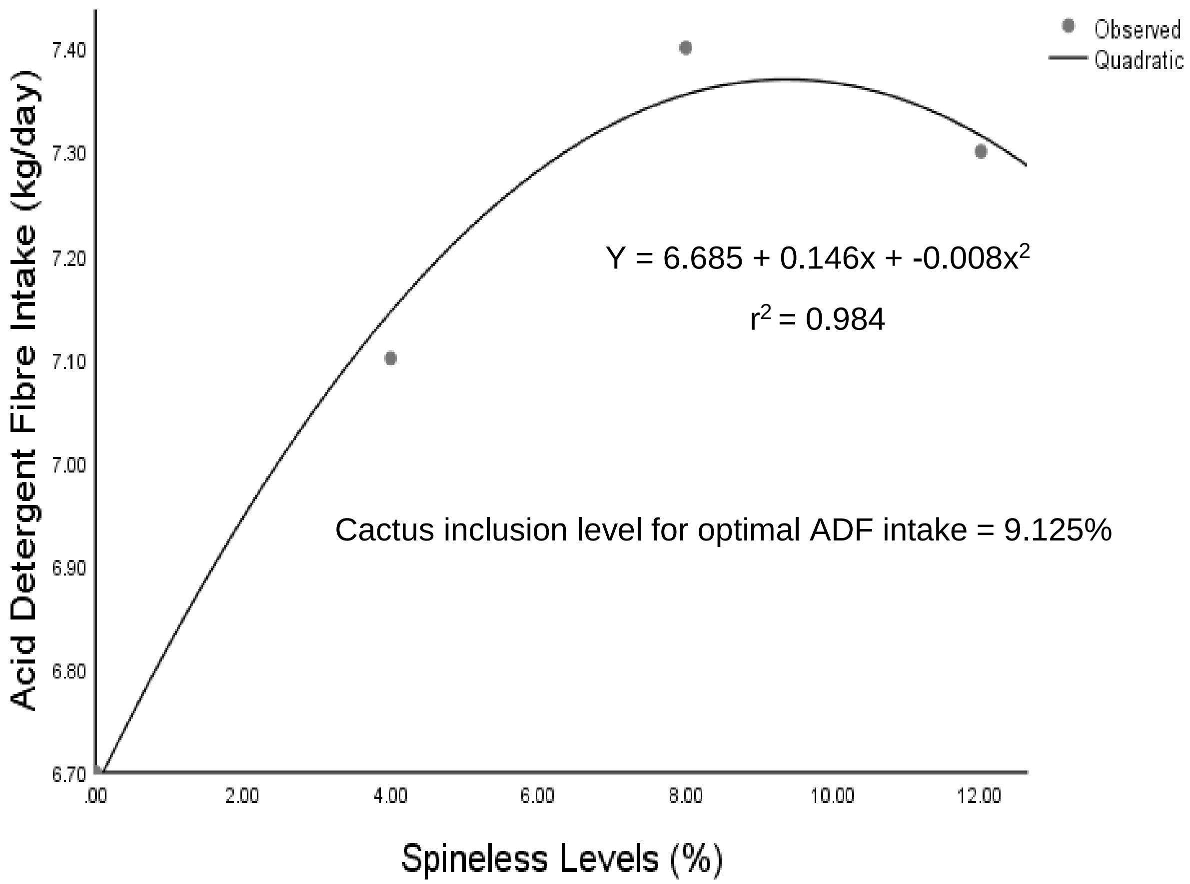


Figure 4.3 Effect of spineless cactus meal inclusion level on ADF intake of lactating Holstein cows

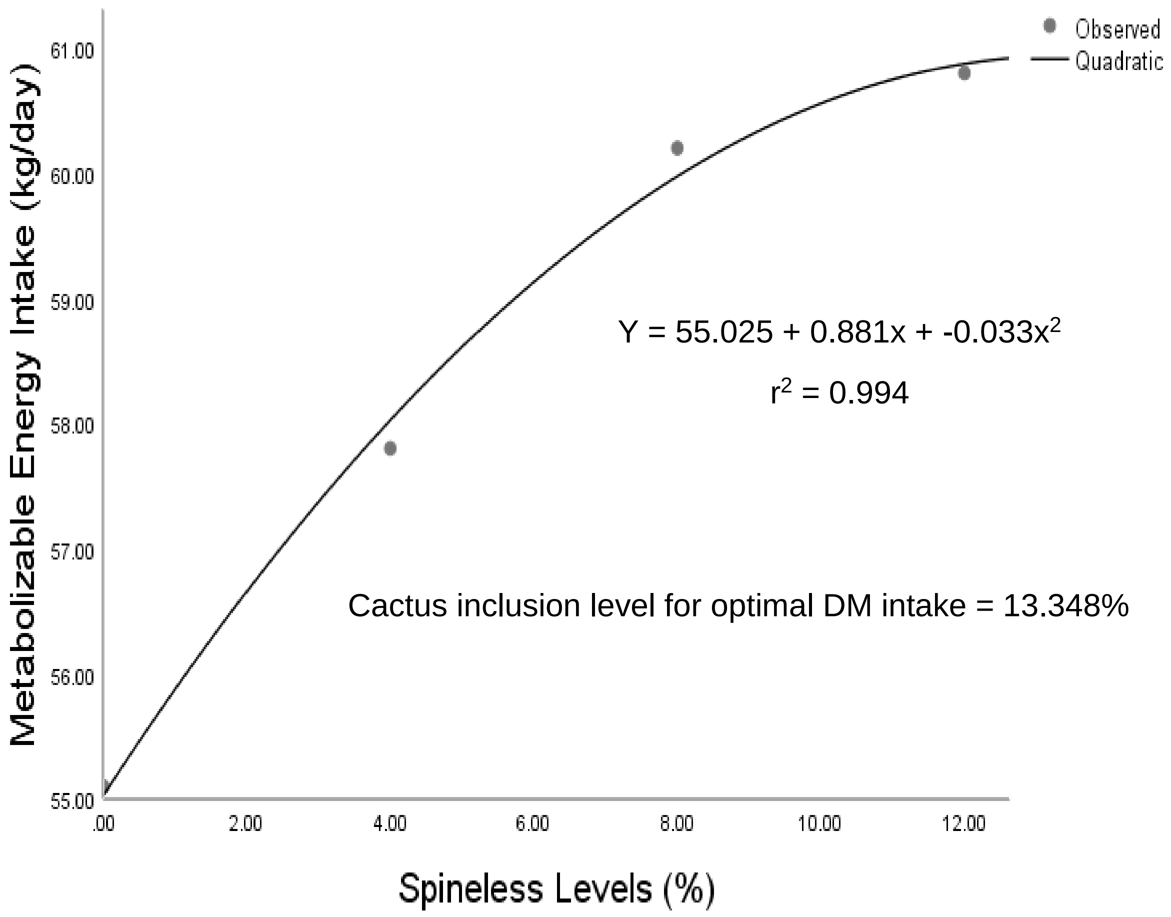


Figure 4.4 Effect of spineless cactus meal inclusion level on ME intake of lactating Holstein cows

Table 4.2 Spineless cactus meal inclusion levels for optimal DM intake, NDF intake, ADF intake and ME intake in Holstein cows on a basal diet of *Eragrostis* hay

Factor	Formula	r^2	Optimal Y-level	Cactus level (%)
DM intake	$Y = 22.655 + 0.476x + -0.020x^2$	0.992	25.87 kg/cow/day	11.90
NDF intake	$Y = 12.970 + 0.230x + -0.013x^2$	0.974	13.987 kg/cow/day	8.846
ADF intake	$Y = 6.685 + 0.146x + -0.008x^2$	0.984	7.35 kg/cow/day	9.125
ME intake	$Y = 55.025 + 0.881x + -0.033x^2$	0.994	60.905 MJ/d	13.348

r^2: Co-efficient of determination
x: Spineless cactus meal inclusion level for optimal intake

4.2 Effect of spineless cactus meal inclusion on diet nutrient balance and nutrient requirements of Holstein cows

The results for nutrient balance and nutrient requirements of the experimental diets are presented in Table 4.3. Metabolisable energy intake for maintenance was adequate although lower (*P<0.05*) for 0, 4 or 8% inclusion levels. However, cows on spineless cactus meal inclusion level of 12% had higher (*P<0.05*) metabolisable energy intake for maintenance than those on 0, 4 or 8% inclusion levels. Friesian cows on spineless cactus inclusion levels of 0, 4 or 8% had similar (*P>0.05*) metabolisable energy intake for maintenance. Friesian cows on 0 or 8% spineless cactus meal inclusion levels had higher (*P<0.05*) metabolisable energy intake for lactation than those on 4% inclusion level. However, cows on spineless cactus meal inclusion levels of 0, 8 or 12% had similar (*P>0.05*) metabolisable energy intake for lactation. Similarly, cows on spineless cactus meal inclusion levels of 4 or 12% had the same (*P>0.05*) Metabolisable energy intake for lactation. Friesian cows on 8 or 12% spineless cactus meal inclusion levels had higher (*P<0.05*) metabolisable energy for total supply than those on 0 or 4% inclusion levels. However, cows on 8 or 12% spineless cactus meal inclusion levels had similar (*P>0.05*) metabolisable energy intake for total supply. Similarly, cows on 0 or 4% spineless cactus meal inclusion levels had similar (*P>0.05*) metabolisable energy intake for total supply. Friesian cows on spineless cactus meal inclusion level of 0% had higher (*P<0.05*) metabolisable energy intake for balance than those on 4, 8 or 12% inclusion levels. Similarly, cows on 8% spineless cactus meal inclusion level had higher (*P<0.05*) metabolisable energy intake for balance than those on 4 or 12% inclusion levels. However, cows on spineless cactus meal inclusion levels of 4 or 12% had similar (*P>0.05*) metabolisable energy intake for balance. Friesian cows on spineless cactus meal inclusion level of 12% had higher (*P<0.05*) metabolisable energy intake for % required than those on 0 or 4% inclusion levels. Similarly, cows on 8% spineless cactus meal inclusion level had higher (*P<0.05*) metabolisable energy intake for % required than those on 0 or 4% inclusion levels. However, cows on spineless inclusion levels of 8 or 12% had similar (*P>0.05*) metabolisable energy intake for % required. Similarly, cows on 0 or 4% spineless cactus inclusion levels had the same (*P>0.05*) metabolisable energy for % required.

Spineless cactus meal inclusion level did not affect (*P>0.05*) metabolisable protein intake for maintenance, lactation, total supply and % required. Cows on spineless cactus inclusion level of 12% had higher (*P<0.05*) metabolisable protein balance than those on 0, 4 or 8% inclusion levels. Similarly, cows on spineless cactus meal inclusion level had higher (*P<0.05*) metabolisable protein balance than those on 0 or 4% inclusion levels. Friesian cows on 4% spineless cactus meal inclusion level had better (*P<0.05*) metabolisable protein balance than those on 0% inclusion level.

Table 4.3 Nutrient requirements and balances for the Holstein cows*

		Maintenance	Lactation	Total supply	Balance	% Required
ME (Mcal)	0%	18.2 ± 2.34^{b}	27.8± 4.12^{a}	46.4 ± 4.21^{b}	6.0 ± 1.19^{a}	96 ± 13^{c}
	4%	17.9 ± 2.73^{b}	25.5 ± 3.82^{b}	46.1 ± 4.10^{b}	2.6 ± 0.59^{c}	96 ± 15^{c}
	8%	17.9± 2.63^{b}	27.8 ± 3.72^{a}	50.2 ± 3.91^{a}	4.6 ± 1.17^{b}	104 ± 19^{ab}
	12%	19.0 ± 3.70^{a}	26.4 ± 2.93^{ab}	48.5 ± 3.43^{a}	3.1 ± 1.27^{c}	107 ± 21^{a}
MP (%DM)	0%	1111 ± 203^{a}	1157 ± 191^{a}	2342 ± 189^{a}	5.6 ± 2.25^{d}	100 ± 13^{a}
	4%	980 ± 391^{a}	1064 ± 231^{a}	2200 ± 267^{a}	71 ± 13^{c}	104 ± 12^{a}
	8%	1131 ± 197^{a}	1156 ± 187^{a}	2507 ± 153^{a}	129 ± 15^{b}	105 ± 16^{a}
	12%	1009 ± 215^{a}	1101 ± 167^{a}	2336 ± 197^{a}	196 ± 18^{a}	109 ± 10^{a}

* : Values presented as means ± standard error (SE)

a, b, c, d : Means in the same column not sharing a common superscript are significantly different (*P<0.05*).

ME : Metabolisble energy

MP : Metabolisble protein

4.3 Effect of spineless cactus meal inclusion level on diet dry matter digestibility

The results of the effect of spineless cactus meal inclusion level on apparent dry matter digestibility of the diets by Holstein cows are presented in Table 4.4. Spineless cactus meal inclusion levels of 4, 8 or 12% had higher (*P<0.05*) dry matter digestibility values than those having 0% inclusion level. However, diets having spineless cactus meal inclusion levels of 4, 8 or 12% had similar (*P>0.05*) dry matter digestibility values.

Table 4.4 Apparent diet dry matter digestibility by Holstein cows*

Treatment (cactus inclusion level)	Apparent digestibility (decimal)
0%	0.67 ± 0.07^{b}
4%	0.73 ± 0.05^{a}
8%	0.76 ± 0.06^{a}
12%	0.76 ± 0.06^{a}

* : Values presented as means ± standard error (SE)

a, b : Means in the same column not sharing a common superscript are significantly different (*P<0.05*).

4.4 Effect of spineless cactus meal inclusion level on Holstein cow milk yield and composition

The results of the effect of spineless cactus meal inclusion level on Holstein cow milk and composition are presented in Table 4.5. Spineless cactus meal inclusion level had no effect (*P>0.05*) on Holstein cow milk fat protein, lactose, somatic cell count and milk nitrogen urea. However, milk yield was affected (*P<0.05*) by spineless cactus meal inclusion level. Holstein cows on spineless cactus meal inclusion level of 4% had higher (*P<0.05*) milk yield than those on inclusion levels of 0, 8 or 12%. Similarly, cows on an inclusion level of 12% produced more milk (*P<0.05*) than those on 0% inclusion level. However, cows on spineless cactus meal inclusion levels of 8 and 12% had similar (*P>0.05*) milk yields. Similarly, cows on inclusion levels of 0 and 8% had same (*P>0.05*) milk yields.

Table 4.5 Effect of spineless cactus meal inclusion level on Holstein cow milk yield and composition*****

Treatment (cactus inclusion level)	Milk yield (litres)	Fat (%)	Protein (%)	Lactose (%)	Somatic Cell Count (ml)	Milk nitrogen urea (Mg/dl)
0%	22.7±4.21[c]	2.4±0.56[a]	3.0±0.20[a]	4.6±0.19[a]	788±1160[a]	8.6±2.25[a]
4%	24.7±3.82[a]	2.3±1.03[a]	3.0±0.26[a]	4.8±0.22[a]	528±808[a]	12.6±6.60[a]
8%	23.4±3.92[bc]	2.2±1.22[a]	3.0±0.23[a]	4.7±0.25[a]	445±406[a]	12.0±7.75[a]
12%	23.8±3.70[b]	2.0±1.27[a]	2.6±1.23[a]	3.9±1.82[a]	625±1016[a]	8.6±5.59[a]

* : Values presented as means ± standard error (SE)

a, b, c : Means in the same column not sharing a common superscript are significantly different (*P<0.05*).

4.5 Body condition score of Holstein cows fed different inclusion levels of spineless cactus

The results of the effect of spineless cactus meal inclusion level on body condition score of Holstein cows are presented in Table 4.5. Spineless cactus meal inclusion level did not affect (*P>0.05*) body condition score values of Friesian cows. Friesian cows on spineless cactus meal inclusion levels of 4, 8 or 12% had similar (*P>0.05*) body condition score values as those on 0% inclusion level

Table 4.6 Body condition score of Holstein cows*

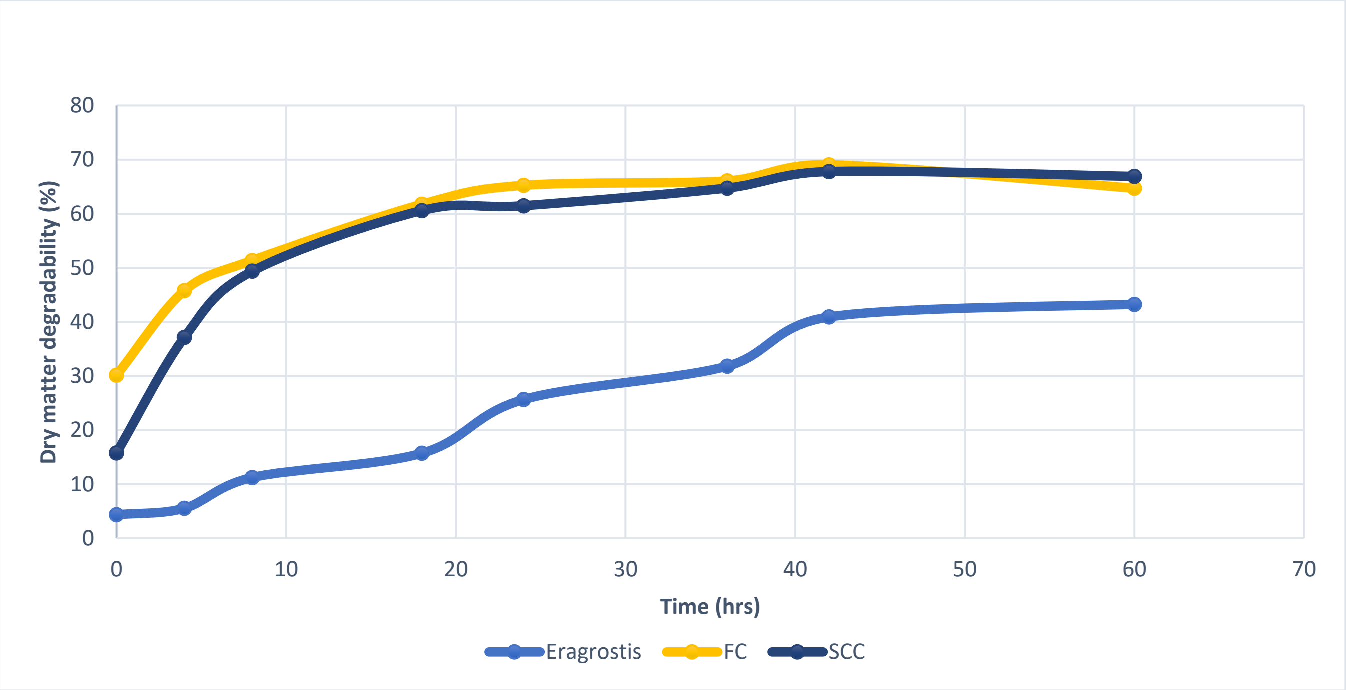
Treatment (cactus inclusion level)	Body condition score (decimal)
0%	2.88 ± 0.14[a]
4%	2.81 ± 0.13[a]
8%	2.75 ± 0.01[a]
12%	2.94 ± 0.13[a]

* : Values presented as means ± standard error (SE)

a : Means in the same column sharing a common superscript are not significantly different (*P<0.05*).

Spineless cactus meal and concentrates had similar (*P>0.05*) dry matter degradabilities of 62, 65 and 69% at incubation periods of 18, 36 and 42 hours, respectively (Figure 4.5). However, dry matter degradabilities for grass hay were lower (*P<0.05*) at all incubation periods than those for spineless cactus meal and concentrates.

The diet having no spineless cactus meal inclusion had lower (*P<0.05*) degradability values at 36, 42 and 60 hours of incubation than those of diets having 4, 8 or 12% spineless cactus meal inclusion levels (Figure 4.6). However, diets having 4, 8 or 12% spineless cactus meal inclusion levels had similar (*P>0.05*) dry matter degradabilities at 18, 36, 42 and 60 hours of incubation.



Key: FC = Fresh cactus; SCC = Semi-complete concentrate

Figure 4.5 Dry matter degradability of individual feeds

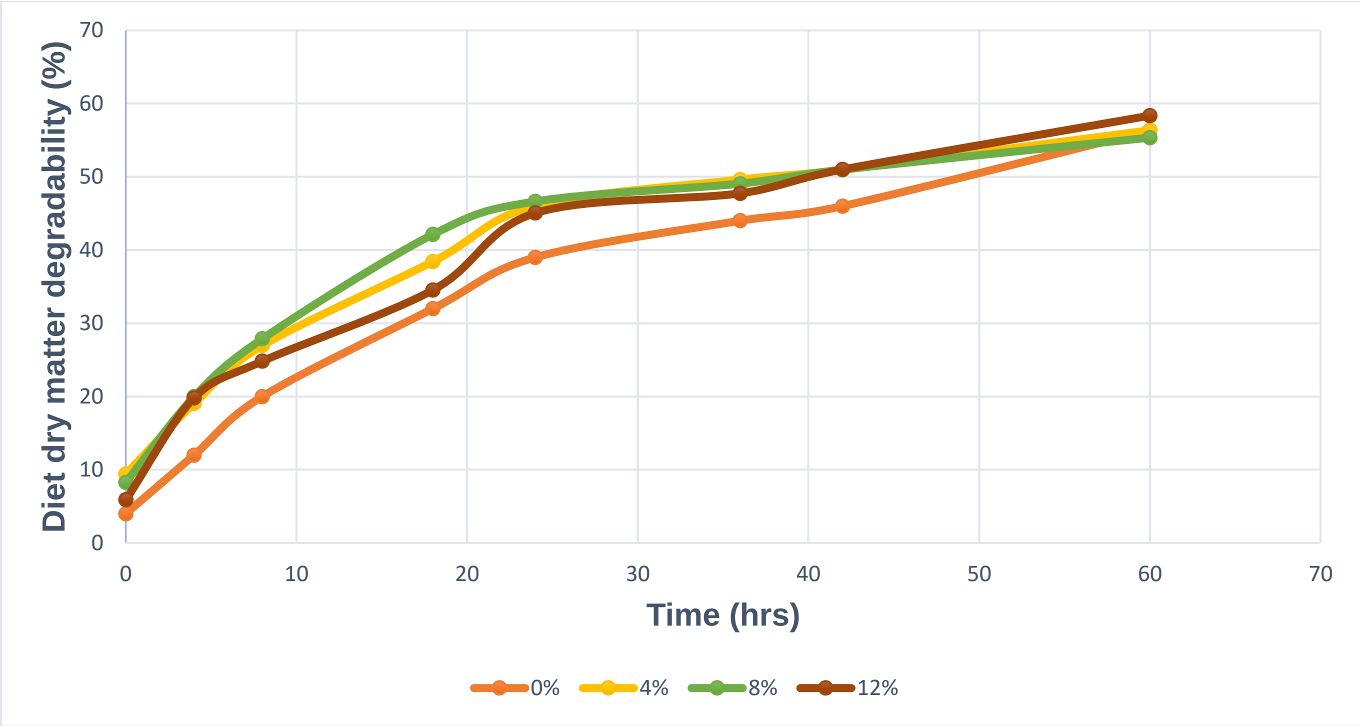


Figure 4.6 Dry matter degradability of experimental diets

CHAPTER 5

DISCUSSION

5.1 Voluntary feed intake of Holstein cows fed different inclusion levels of spineless cactus

Dry matter intake as percentage of body weight ranged from 3.3 to 3.7%. Dry matter intake increased as the level of cactus inclusion increased because spineless cactus is highly digestible with low fibre and high sugar content (De Kock, 1998). The DM intake values usually range between 3.5 and 4% of body weight although intake of up to 5% BW has been reported for Holsteins (Heins *et al*., 2008; NRC, 2001). The 3.3% intake was likely limited by the high fibre content of *Eragrostis* due to physical fill effect (Allen, 1996; Mertens, 1994). The high soluble carbohydrate content of spineless cactus in the diets improved energy supply to rumen microbes. Cows consumed forage fibre (NDF) at 2% BW (Table 4.1), which was higher than limits expected for lactating Holstein cows. The fibre was sufficient as noted by John (2016) who indicated that forage fibre (NDF) intake for dairy cows should be limited to 1.1 to 1.2% of their body weight in the diet. Fibre is one of the more important nutrients in a dairy cow diet because of its role in maintaining rumen function. Neutral detergent fibre is a measure of the total insoluble fibre and it includes cellulose, lignin and hemicellulose. NRC (2001) recommended that a diet should have 30% NDF with a minimum of 21% coming from forage sources only. Acid detergent fibre is a measure of the fibre concentration in animal feeds and it is used to calculate the net energy for lactation in dairy diets. As acid detergent fibre in the diet increases, digestibility and nutrient availability decrease. Low ADF in the diet means higher energy value and digestibility. Thus, inclusion of spineless cactus on low quality roughages improved digestibility of the diets.

NRC (2001) and John (2005) reported that a diet for dairy cows should have a minimum of 19% ADF. The cows on cactus had higher ADF intake of 29%. Acid detergent fibre in forages is least digestible by livestock which includes cellulose and lignin and this means that there is intake of indigestible nutrients from the diets. Lignin is indigestible. At 0% spineless cactus inclusion level ADF intake was 30.5%. Mature grasses have fibre contents that are of poor degradability, which fill the rumen and hence reduce ability to take more feed (Mertens, 2004). Low physical fill effect of cactus promotes higher forage intake. Cactus pear is high in non-fibre carbohydrates, compared to concentrate and hay. Robertson and Van Soest (1981) and Russell *et al*. (1992) noted that degradable carbohydrates are sources of energy for anaerobic fermenters and stimulate their growth. Aldrich *et al*. (1993) reported that 36% NFC increased rumen bacterial nitrogen outflow. The NFC of diets ranged between 22.9 and 28.1% which shows that all diets had adequate fibre content to maintain the animals.

The crude protein intake for maintaining a lactating dairy cow is 16% (NRC, 2001). The CP intake in the present study was sufficient for maintenance and milk production. Milk production averaged 23kg per day and 16.4% CP is needed to support that level of milk production (NRC, 2001). The 16% in this study was sufficient to support milk production at this observed level. Addition of cactus did not improve protein intake. Low crude protein intake could have caused rumen degradable protein deficiency and impacted negatively on rumen fermentation and microbial synthesis, which subsequently reduced metabolizable energy and protein availability for dairy cows (Imaizumi *et al.,* 2010; NRC, 1989; NRC, 2001). Reduced fermentation due to rumen degradable protein deficiency may decrease dry matter intake, however, there was no conclusive report found. NRC (2001) reported that there was no correlation between dry matter intake and dietary crude protein content. The current study also found that there is no correlation between dry matter intake and crude protein content. The intake was correlated to the inclusion levels of spineless cactus in the diets of the cows.

The cows on cactus had higher ME intake. The ME Intake increased as the level of cactus inclusion in the diets increased. One litre of milk requires 1.1Mcal, which means that 24Mcal was needed to support 20 litres of milk (NRC, 2001). The average weight of the animals was 650kg, the maintenance energy required was 11Mcal (NRC, 2001). This means that the cows had enough energy for milk production. NRC (1989) reported that a minimum of 0.31Mcal NE_L is required to produce 0.45kg of milk containing 3.5% fat. Milk fat inversion was noted and that condition is associated with low forage intake (Linn, 1988; NRC, 1988). This condition of milk fat inversion results in reduction in milk fat and change in milk fat composition (Banks *et al*., 1983). Holstein cows consumed 2% of the forage as percentage body weight, however, poor degradability of the forage could have resulted in poor VFA production and hence, the condition of milk fat inversion was noted. Cows on 8 and 12% cactus inclusion level had sufficient ME intakes than the ones on the other diets. Cows on 8 and 12% had enough energy for maintenance and milk production. Causes of milk fat inversion include both an alteration in rumen fermentation and availability of endogenous fatty acid sources in the diets which result in low production of acetic and butyric acids needed for milk fat (Christie, 1979).

5.2 Nutrient requirements and balance of different spineless cactus diets for Holstein dairy cows

Dietary CP was not limiting, rather energy was lower in the present study. The high energy content at 12% inclusion level is attributed to the high sugar content of the cactus. Energy is essential for milk synthesis, especially milk lactose. Glucose synthesized from VFA is utilized by the mammary gland to make lactose. Milk quality at 12% was unusually low in lactose content, yet cows had the highest MEI. Metabolisable protein is essential for synthesis of milk protein. Metabolisable protein is the true protein that is digested postruminally and the component amino acids absorbed by the intestines (Janos and Eszter, 2011). For cows producing 30kg of milk 9.6% MP is required to maintain this level of milk (NRC, 2001). Metabolisable protein was not limiting. The high total carbohydrates in the diets make the diets to be degradable and release more of nutrients to the animal. The high moisture content of spineless cactus makes it a good water source that can be used to alleviate the problem of animal watering, especially during prolonged droughts.

5.3 Apparent diet digestibility of different inclusion levels of spineless cactus

The low digestibility at 0% cactus inclusion level could be related to the high NDF intake. The fibre was contributed mostly from hay, and *Eragrostis curvula* hay is of low forage quality (Torell *et al*., 2000). As cactus level increased, the NFC and mostly sugars increased, resulting in increased source of readily available energy in the rumen and hence higher values for 4, 8 and diet 12% inclusion levels. Rumen microbes that use sugars produce more volatile fatty acids and these acids can provide up to 80% of the energy needs of the animal (Moran, 2005; Annison and Bryden, 1998). This explains the high value of apparent digestibility for Holstein cows on 4, 8 and 12% inclusion levels. Since intake was improved by the cactus inclusion it means more feed materials were consumed hence the high apparent diet digestibility. Spineless *Opuntia* in the diets had a positive effect on apparent digestibility.

Concentrate in the diet is essential for protein supply. Concentrates are low in fibre and contain high levels of proteins and other essential nutrients (Alibes and Tisserand, 1990). Hay in the diets provides rumen microbes with sufficient fibre for digestion, resulting in more chewing and more saliva flow into rumen and turning of rumen contents. Saliva is rich in mineral ions which serve as buffering agents in the digestive system (Bailey and Balch, 1961). Saliva, also, neutralises the acids produced during fermentation and helps to maintain an ideal environment for bacteria growth. The sugar or starch content of the cactus is the major NFC fraction in the diets, therefore, more nutrients are absorbed by the animal and dry matter intake was improved in diets high in NFC content. Sugar content improves glucose level in the diet and the ruminal digestion of diets increases (Oba, 2011; Martin *et al.,* 2001).

5.4 Milk yield and composition of Holstein dairy cows fed different inclusion levels of spineless cactus

Milk fat was significantly low, especially for cows on 12% that had the highest cactus intake. Fibre degradation results in high acetate production which promotes fat synthesis. Cactus contains sugars and promotes synthesis of propionate, a precursor for glucose and milk sugar synthesis (Kleiber *et al.,* 1953). The 2.0% fat content at 12% inclusion level is an indicator of serious metabolic disorders (Haq *et al.,* 2016). All diets resulted in significantly low milk fat. Milk fat was less than protein content, resulting in possible milk fat inversion. Milk fat of Holstein cows averaged 3%. This was unexpected as animals consumed at least 2% BW as NDF. The milk sampling process could have compromised the results. There were no indicators of metabolic disorders during the experimental period. Although it was reported that there are several factors affecting milk composition such as breed, genetic variation within breed, health, environment, management practices and diet (Linn, 1988). The inclusion of spineless cactus in this study didn’t affect milk composition of the experimental animals.

The level of lactose is expected to be 4.7% in Holstein cow’s milk (Young *et al*., 1986). The lactose contents for all the diets were sufficient although Diet 4 had lower lactose content. Somatic cell count (SCC) is used as an indicator of the milk quality. Subclinical mastitis was noted in the present study, this could be related to environment and management factors. Dohoo and Meek (1982) reported that subclinical mastitis reduces milk quality and decreases milk yield. Somatic cells contain lipolytic and proteolytic enzymes which degrade fats and proteins in milk. An increase in somatic cell count causes mastitis and increases the amount of destructive enzymes present in milk which increases the rate of deterioration of milk fat and protein (Kehrli and Shuster, 1994). Mastitis is the inflammation of the udder caused by a microbiological infection. Mastitis, generally, causes decline in milk fat and change in milk composition (Kitchen, 1981). The general effect of mastitis is to impair milk synthesis and loosen the connections between cells and increase permeability of blood constituents (Jenness, 1985). Milk urea nitrogen is the function of milk protein that is derived from blood urea nitrogen. Milk urea nitrogen in the present study ranged between 8.6 and 12.6mg/dl. Milk urea nitrogen expected levels for Holstein cows range between 8 and 16mg/dl (Dohoo and Meek, 1982), the MUN was within the range reported by other studies. Low MUN values reduce the rumen bacteria resulting in limited milk protein. High MUN values make feed protein to be wasted along with excreting excess nitrogen into the environment (Jenness, 1985).

5.5 In sacco degradability

Eragrostis curvula hay had lower *in sacco* dry matter disappearance than spineless and semi-complete concentrate due to the low fibre and high soluble carbohydrate contents (Batista *et al*., 2003). Shoop *et al*. (1977) reported that 80% of the total digestibility of cactus occurs during the first 16 hours of a 48 hour incubation period whereas only 73% and 71% of total digestion of pellets (concentrates) and hay, respectively, occurred during the initial 16 hours. The main difference between cactus and other forage crops is nutrient degradability in the rumen. Forage crop degradability in the rumen is often reached after 48 hours while cactus nutrients are rapidly degraded in between 6 and 12 hours (Ben Thlija, 1987). The optimal inclusion level was at 8% because the feed materials disappeared within 24 hours due to the low fibre and high carbohydrate content in the diet. At 0% inclusion level the disappearance of the feed materials was low and the diet disappeared after 48 hours due to high fibre content from the grass hay.

Shoop *et al*. (1977) compared ruminal disappearance of cactus with that of early bloom alfalfa hay. The authors found that DM disappearances following 16 and 48 hours of ruminal incubation were higher for cactus (52.9% and 66.4%, respectively) than for early bloom alfalfa hay (44.5% and 62.9%, respectively). The higher ruminal disappearance of cactus is attributed to its low fibre and high soluble carbohydrate contents. It is evident from the present study and those of Batista *et al*. (2003) and

Shoop *et al*. (1977) that cactus is highly degradable in the rumen. This is also confirmed by the findings of other studies, which showed high *in vitro* and *in vivo* digestibility for spineless cactus in relation to other fodder and shrub species (Ben Salem *et al*., 1994, 1996).

5.6 Body condition score of Holstein cows fed different inclusion levels of spineless cactus

Body condition score (BCS) values ranged between 2.75 to 2.94. The body condition values was at a normal range. Butler and Smith (1989) reported that a score of 3 is acceptable as it is an average body score. They further indicated that a score of 1 denotes a very thin cow, while 5 denotes an excessively fat cow. Body condition scoring is a method of evaluating fatness or thinness in cows according to a five-point scale and using the score to fine-tune dairy herd nutrition and health (NRC, 2001). Body condition influences productivity, reproduction, health, and longevity of dairy cattle. Generally BCS is negatively related to dry matter intake and this also has an effect on milk production and can contribute to ketosis, a displaced abomasum, or other metabolic and production consequences of nutritional stress (Butler and smith, 1989). Montiel and Ahuja (2005) indicated that the nutritional status and balance of an animal is evaluated through BCS, as it reflects the body energy available for metabolism, growth, lactation and other activities. Cows carrying excess condition before calving have a greater risk for low feed intake in the critical transition period around the time of calving and reduced feed intake influences milk production. Body condition score below 3 (thinness) can frequently lower production and milkfat levels because of insufficient energy and protein reserves to maintain production whereas fatness can results in difficulties in breeding especially in heifer feeding management (Butler and Smith, 1989 and NRC, 2001)

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Spineless cactus contained more than 12% gross energy. Therefore, spineless cactus can be used as energy supplements for dairy cows on low quality forages. Energy is the most limiting nutrients in dairy diets. Although spineless cactus is not a balanced feed, it is considered as a cheap source of energy and is highly digestible. Spineless has a low gut fill because its intake does not reduce fibrous feed intake and the improved rumen conditions enhance the fibrous feed intake. Forages are high in lignin and this lignin inhibits intake because it is indigestible. Supplementation of poor quality forges with spineless will enhance intake and rumen fermentation resulting in high diet intake. Energy is the most limiting nutrient in dairy diets and seasonal inadequate of feed hinders the performance of livestock, especially in rural areas. Spineless cactus exhibits high NFC and can be used as an alternative energy supplement for ruminants on low quality roughages. Although it is low in crude protein and fibre, it is a good source of energy which is essential in livestock production and for maintaining livestock performance. Voluntary feed intake was improved in diets containing spineless cactus. The high water content in spineless cactus did not exert negative effects on its intake and digestibility. Spineless cactus in the diet improves fermentation in the rumen and, hence, high diet intake.

Dairy cows require diets with high energy, protein and water contents. Energy and water are essential for milk production. A lactating dairy cow requires 4 to 5 litres of water to produce a litre of milk and also it requires a diet containing 16.1 Mcal to produce 23 litres of milk. Diets supplemented with spineless had higher milk yield. It is, therefore, concluded that spineless inclusion in dairy diets can improve the performance of the animal and spineless can be an excellent replacement for a portion of poor fodder. The high moisture content in cactus cladodes could serve as an important water source for animals during periods of drought. Diet intake, digestibility and milk production were optimized at different spineless inclusion levels. Several studies reported that cactus based diets increase not only milk production but also improve quality of butter fat and storage life. Milk production increased as the level of cactus inclusion level increased in the diet. This study is useful to the arid and semi-arid regions dairy farmers in Sub-Saharan Africa, which suffer from shortage of feed sources for animals, especially during dry seasons. Spineless cactus has approximately 90% moisture (water) content. The high water content in spineless cactus cladodes contribute significantly to the total water required by lactating cows per day, especially during drought. Lack of water intake can lead to reduced dry matter intake, lower milk yield and a loss in body condition.

Degradability of the diets was high in diets containing spineless cactus. Spineless cactus disappear faster than forages in the rumen due to its low fibre and high soluble carbohydrate content. The carbohydrate content of spineless cactus degrade faster in the rumen and enhance the production of volatile fatty acids which are essential for milk production.

6.2 Recommendations

Spineless cactus can be used in livestock rations with attention given to their low crude protein content. Although it can be fed to animals in any season, it is needed the most during drought as a supplement when forages are scarce or expensive. The optimal inclusion level of spineless cactus in dairy diets can be recommended to be 8% because this enhanced diet intake and milk production of the experimental animals. Feeding of climate smart forages such as cactus to dairy cattle increases milk production and also improves the household income of dairy farmers in rural areas. Reliance on industrial feeds will be reduced and farmers will be able to sustain their livestock during drought seasons without compromising the productivity and profitability of the farm. Further research is envisaged on the effects of spineless inclusion levels on nutrient metabolism in lactating dairy cattle.

CHAPTER 7

REFERENCES

Aldrich, J.M., Muller, L.D., Varga, G.A. and Griel, L.C. Jr. (1993). Non-structural carbohydrate and protein effects on rumen fermentation, nutrients flow and performance of dairy cows. *Journal of Dairy Science* 79: 1091-1105.

Alibes, X. and Tisserand, J.L. (1990). Tables of the nutritive value for ruminants of Mediterranean forages and by-products. CIHEAM 152p

Allen, M.S. (1996). Physical constrains on voluntary intake of forage by ruminants. *Journal of Animal Science* 74: 3064-3075

Andrew, S.M., Erdman, R.A. and Waldo, D.R. (1995). Prediction of body composition of dairy cows at three physiological stages from deuterium oxide and urea dilution. *Journal of Dairy Science* 78: 1083-1095.

AOAC. (2002). Association of Analytical Chemists, Official Methods of Analysis, (7th edition), AOAC, Washington, D.C.

Arnold, G.W., De Boer, E.S. and Bondy, C.A.P. (1980). The influence of odour and taste on the food preferences and food intake of sheep. *Australian Journal of Agricultural Research* 31: 571-587.

Bailey, C.B. and Balch, C.C. (1961). Saliva secretion and its relation to feeding in cattle. The composition and rate of secretion of mixed saliva in the cow during rest. *British Journal of Nutrition* 15: 383-402.

Ball, D.M., Collins, M., Lacefield, G.D., Martin, N.P., Mertens, D.A., Olson, K.E., Putnam, D.H., Undersander, D.J. and Wolf, M.W. (2001). Understanding forage quality. American Farm Bureau Federation Publications. Auburn University.

Banks, W., Clapperton, J.L. and Steele, W. (1983). Dietary manipulation of the content and fatty acid composition of milk fat. *Proceedings of Nutritional Society* 42: 399-406

Barbera, G. (1995). History, economic and agro-ecological importance. Page 1-11, *in:* Barbera, G. Inglese, P. and Pimienta-Barrios, E (Eds) Agro-ecology, cultivation and uses of cactus pear. FAO Plant Production and Protection Paper, 132 pp1-12.

Barbera, G., Carimi, F. and Inglese, P. (1992). Past and present role of the Indian-fig prickly pear (*Opuntia ficus-indica* (L.) Miller, Cactaceae) in the agriculture of Sicily. *Economic Botany* 46: 10-22.

Barnes, R.D., Filter, D.L. and Milton, S.J. (1996) *Acacia Karroo*. Tropical forestry papers 32. Oxford Forestry Institute. Oxford University.

Barnes, R.F., Miller, D.A. and Nelson, C.J. (1995). Forage Volume 1. An Introduction to Grassland Agriculture Vol. 2: The Science of Grassland Agriculture, 5th edition. Iowa State University Press.

Batista, A.M.V., Mustafa, A.F., Santos, G.R.A., de Carvalho, F.F.R., Dubeux Jr, J.C.B., Lira, M.A. and Barbosa, S.B.P. (2003). Chemical composition and ruminal dry matter and crude protein degradability of spineless cactus. *Journal of Agronomy and Crop Science* 189: 123-126.

Becholie, D., Tamir, B., Terrill. T.H., Singh B.P. and Kassa, H. (2005). Suitability of tagasaste (*Chamaecytisus palmensis* L.) as a source of protein supplement to a tropical grass hay fed to lambs. *Small Ruminant Research* 56: 55-64.

Ben Salem, H., Nefzaoui, A. and Abdouli, H. (1994). Palatability of shrubs and fodder trees measured on sheep and dromedaries: Methodological approach. *Animal Feed Science and Technology 46*: 143-153.

Ben Salem, H., Nefzaoui, A., Abdouli, H. and Ørskov, E.R. (1996). Effect of increasing level of spineless cactus (Opuntia ficus-indica var. inermis) on intake and digestion by sheep given straw-based diets. *Journal of Animal Sciences* 62: 293-299.

Ben Thlija, A. (1987). Nutritional Value of Several *Opuntia* species. MSc thesis. pp84. Oregon State University.

Berhane, G., Eik, L.O. and Tolera, A. (2006). Chemical composition and *in vitro* gas production of vetch (*Vicia sativa*) and some browse and grass species in northern Ethiopia. *African Journal of Range and Forage Science* 23: 69-75.

Bhargava, P.R. and Ørskov, E.R. (1987). (Eds). Manual for the Use of the Nylon Bag Technique in the Evaluation of Feedstuffs. The Rowett Research Institute, Aberdeen, UK: pp 1-20.

Blaxter, K.L. (1962). The Energy Metabolism of Ruminants. Academic Press. London, UK.

Bryant, P., Provenza, F.D., Paul, J.P., Reichardt, B., Clausen, T.P. and Du Toit, J.T. (1991). Interactions between woody plants and browsing mammals mediated by secondary metabolites. *Annual Review of Ecology and Systematics* 22: 431-446.

Butler, W.R. and Smith, R.D. (1989). Interrelationships between energy balance and postpartum reproductive function in dairy cattle. *Journal of Dairy Science* 72: 767-783

Castro, H.C. and Gallardo, M.R.A. (1984). Evaluation of the nutritive value of four cultivars of weeping love grass [*Eragrostis curvula (Schrad) Nees*] in the winter. *Production Animal* 4: 1015-1018.

Christie, W.W. (1979). The effects of diet and other factors on the lipids composition of ruminant tissues and milk. *Progress in Lipids Research* 17: 245-277

Coetzee, L., Montshwe, B.D. and Jooste, A. (2006). The marketing of livestock on communal lands in the Eastern Cape Province: Constrains, challenges and implications for the extension services. *South African Journal of Agricultural Extension* 34: 81-103.

Collins, M. (1998) Composition and fibre digestion in morphological components of alfalfa-timothy sward*. Animal Feed Dictionary Technology* 19: 135-143.

Costa, R.G., Beltrao Filho, E.M., Medeiros, A.N., Givisiez, P.E.N., Queiroga, C.R. and Melo, A.A.S. (2009). Effects of increasing levels of cactus pear (*Opuntia ficus-indica L. Miller)* in the diet of dairy goats and its contribution as a source of water. *Small Ruminant Research* 82: 62-65.

Cottier H. (1934). Quelques aliments de disette, leur valeur et leur emploi. *La Tunisie Agricole* 37: 127-141.

Dado, R.G. and Allen, M.S. (1994). Variation in and relationships among feeding, chewing, and drinking variables for lactating cows. *Journal of Dairy Science* 77: 132-144.

Dahlborn, K., Akerlind, M, and Gustafson, G. (1998). Water intake by dairy cows selected for high or low milk-fat percentage when fed two forage to concentrate ratios with hay or silage. Swedish *Journal of Agricultural Research* 28: 167-176.

Darrag, A. (1995). Range and feeding balance in livestock. Paper presented in the workshop on pastoralism and pasture resource development sector in Kosti, Sudan (in Arabic).

De Kock, G.C. (1965). The management and utilisation of spineless cactus (Opuntia spp) In: Vol.2. International Grassland Congress for Africa. pp 1471-1474. Sao Paolo, Brazil.

De Kock, G.C. (1980). Drought resistant fodder shrub crops in South Africa. In: H.N. Le Houerou, Ed. Browse in Africa: The Current State of Knowledge. Papers presented at the International Symposium on Browse in Africa, Addis Ababa 8-12 April. Addis Ababa: International Livestock Centre for Africa. pp 399-408.

De Kock, G.C. (1998). The use of cactus pear (*Opuntia spp.*) as a fodder source in the arid areas in Southern Africa. Proc. International Symposium on Cactus Pear and Nopalitos Processing and Uses. Universidad de Chile, Santiago, and FAO International Cooperation Network on Cactus Pear p.83-95.

De Kock, G.C. (2001). The use of *Opuntia* as a fodder source in arid areas of Southern Africa. In: Cactus (Opuntia spp.) as Forage. Mondragon-Jacobo and Perez-Gonzalez Ed., FAO Plant Production and Protection Papers: pp 161.

Dohoo, I.R. and Meek, A.H. (1982). Somatic cell count in bovine milk. The *Canadian Veterinary Journal* 23: 119-125.

Dubeux, J.C. (2011). Use of cactus for livestock feeding. Universidade Federal Rural de Pernambuco (UFRPE).

Eastridge, M.L., Bucholtz, H.F., Slater, A.L. and Hall, C.S. (1998). Nutrient requirements for dairy cattle of the national research council versus some commonly used software. *Journal of Dairy Science* 81: 3049-3062.

Ecoport, (2009). Ecoport database. Ecoport, FAO.

Erasmus, L.J., Botha, P.M., Cruywagen, C.W. and Meissner, H.H. (1994). Amino acid profile and intestinal digestibility in dairy cows or rumen-undegradable protein from various feedstuffs. *Journal of Dairy Science* 77: 541-551.

Esqueda, C.M.H. and Carrillo, R.R.L. (2001). Forage and beef production with introduced grasses in Chihuahua Mexico. *Tecnica Pecuaria en Mexico* 39: 139-152.

Fox, D.G., Tedeschi, L.O., Tylutki, T.P., Russell, J.B., VanAmburgh, M.E., Chase, L.E., Pell, A.N. and Overton, T.R. (2004). The Cornell Net Carbohydrate and Protein System Model for Evaluating Herd Nutrition. Cornell University, USA.

González C.F., Llamas, L.G. and Bonilla, A.J. (1998). Utilización del nopal como sustituto parcial de alfalfa en dietas para vacas lecheras. *Tec. Pecuario en México* 36: 73-81.

Gregory, R.A. and Felker, R.P. (1992). Crude protein and phosphorus contents of eight contrasting *Opuntia* forage clones. *Journal of Arid Environments* 22: 323-331.

Harvard-Duclos, B. (1969). Las plantas forrajeras tropicales. Barcelona: Blume. p380.

Haq, Z., Rastogi, A., Sharma, R.K., Amrutkar, S., Gupta, M., Manzoor, N and Mudasir, M. (2016). Nutrition and metabolic diseases in dairy cattle. A review. *International Journal of Agricultural Sciences* 8: 1154 - 1159

Heinrichs, A.J. and Ishler, V.A. (2011). Body Condition Scoring as a Tool for Dairy Herd Management. Department of Dairy and Animal Science. The Pennsylvania State University. Extension circular 363. pp 3.

Heins, B.J., Hansen, L.B., Seykora, A.J., Hazel, A.R., Johnson, D.G. and Linn, J.G. (2008). Crossbreds of Jersey x Holstein compared with pure Holsteins for body weight, body condition score, dry matter intake and feed efficiency during the first one hundred fifty days of first lactation. *Journal of Dairy Sciences* 91: 3716-22.

Holter, J.B. and W.E. Urban, W.E Jr. (1992). Water partitioning and intake in dry and lactating Holstein cows. *Journal of Dairy Science* 75: 1472-1479.

Holter, J.B., West, J.W. and McGillard, M.L. (1997). Predicting ad libitum dry matter intake and yield of Holstein cows. *Journal of Dairy Science* 80: 2188-2199.

Houpt, T.R. (1984). Water balance and excretion. In: Duke’s Physiology of Domestic Animals. 10th Edition. M.J. Swenson, Ed. Comstock Publishing Co. New York.

Hove, l., Topps, J.H., Sibanda, S. and Ndlovu, L.R. (2001). Nutrient intake and utilisation by goats fed dried leaves of shrub legumes *Acacia angustissima Calliandra* *calothyrsus* and *Leucaena leucocephala* as supplements to native pasture hay. *Journal of Animal Feed Science* 91: 95-106.

Imaizumi, H., Santos, F.A.P., Bittar, C.M.M., Correia, P.S. and Martinez, J.C. (2010). Diet crude protein content and sources for lactating dairy cattle. *Journal of Science Agriculture (Piracicaba, Braz)* 67: 16-22

Janos, S. and Eszter, Z. (2011). Nutrition of Ruminants. The protein value of feeds in ruminant's nutrition. Animal husbandry and breeding. University of West-Hungary.

Jenness, R. (1985). Biochemical and nutritional aspects of milk and colostrum. Chapter 5 in Lactation B.L Larson, Editors ed. Ames: Iowa State University Press.

John, H. (2016). Feeding forage in Dairy Diets. Hay and forage grower pp 18-19.

John, M. (2005). Tropical dairy feeding: In Feeding Management for Small Holder Dairy Farmers in the Humid tropics. Landlinks Press, pp 312.

Kehrli, M.E. and Shuster, D.E. (1994) Factors affecting milk somatic cell and their role in health of the bovine mammary gland. *Journal of Dairy Science* 77: 619-627.

Kitchen, B.J. (1981). Bovine mastitis: milk compositional changes and related diagnostic tests. *Journal of Diary Research* 48: 167-188

Kleiber, M., Black, A.L., Brown, M.A. and Tolbert. B.M. (1953). Propionate as a precursor of milk constituents in the intact dairy cow. *Journal of Biological Chemistry* 203: 339-346.

Leng, R.A. (1990). Factors affecting the utilisation of poor quality forage by ruminants particularly under tropical conditions. *Nutritional Research Reviews* 3: 277-303.

Linn, J.G. (1988). Factors affecting the composition of milk from dairy cows. pp 224-241 in Designing Foods Animal Products Options in the Market Place. Washington DC. National Academy Press.

López, J.J., Fuentes, J. and Rodríguez, A. (1997). Industrializacion de la tuna cardona (Opuntia streptacantha*).* Prickly pear fruit industrialisation. *Journal of Professional Association of Cactus Development* 2: 169-175.

Lopez-Garcia, J.J., Fuentes-Rodriguez, J.M. and Rodriguez, R.A. (2001). Production and use of *Opuntia* as forage in Northern Mexico. In: Cactus (Opuntia spp.) as Forage, Mondragon-Jacobo and Perez-Gonzalez Ed., FAO Plant production and protection papers N°169: 161p, FAO, Rome.

Lozano, G.M. (1958). Contribución al estudio e industrialización Del nopal (*Opuntia spp*.). BSc Diss., Esc. Sup. De Agric. "Antonio Narro". Saltillo, México

Mandal, A.B., Paul, S.S., Mandal, G.P., Kannan, A and Pathak, N.N (2005). Deriving nutrient requirements of growing Indian goats under tropical conditions. *Small Ruminants Research* 58: 201-217.

Manzana, N.P. (2008). Optimal feeding systems for small scale dairy herds in the North-West Province of South Africa. MSc Dissertation. University of Pretoria.

Marcelo de, Andrade Ferreira[1], Safira Valença Bispo[2], Rubem Ramos Rocha Filho[1], Stela Antas Urbano[1] and Cleber Thiago Ferreira Costa[1] (2012). The Use of Cactus as Forage for Dairy Cows in Semi-Arid Regions of Brazil. Brazil. Chapter 8 pp 169-189.

Martin, S.A., Sullivan, H.M. and Evans, J.D. (2001). Effect of sugar and malate on ruminal microorganisms. *Journal of Dairy Science* 83: 2574-2579.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. and Morgan, C.A. (2002). Animal Nutrition. Six edition. Pearson Education Ltd Edinburgh, Gate. Harlow. Essex. pp153.

Mciteka, H. (2008). Fermentation Characteristics and Nutritional Value of *Opuntia ficus-indica var.fisicaulis* Cladodes Silage. MSc Thesis. University of Free State.

Mehrez, A.Z. and Ørskov, E.R. (1977). A study of the artificial fibre bag technique for determining the degradability of feeds in the rumen. *Journal of Agricultural Science* (Cambridge) 88: 645-650.

Mertens, D.R. (1994). Regulation of forage intake In: Forage Quality, Evaluation and Utilisation G.C Fahey (Ed) Animal Society Agronomy. Madison pp 450-493

Mills, P.F.L. (1977). A comparison of the preferences of cattle and sheep for different grasses. *Rhodesia Agricultural Journal* 74: 41-43.

Minson, D.J. (1990). Forage in Ruminant Nutrition. Academic Press, San Diego. pp. 483.

Montiel, F. and Ahuja, C. (2005). Body condition and suckling as factors influencing the duration of postpartum anestrus in cattle: a review. *Journal of Animal Production* Science 85: 1-26

Moran, J.B. (2005). Tropical dairy farming feeding management for small holder dairy farmers in the humid tropics. Melbourne. CSIRON Publications. 290 pp.

Morrison, F.B. (1956). Compendio de la alimentación del ganado. México: UTEHA p 721.

Munyai, F.R. (2012). An Evaluation of Socio-economic and Biophysical Aspects of Small-scale Livestock Systems Based on a Case Study from Limpopo Province: Muduluni Village. PhD thesis. University of the Free State, Bloemfontein.

Mupangwa, J.F., Ngongoni, N.T., Daka, D.E. and Hamudikuwanda, H. (2002). The effect of supplementing a basal diet of veld grass hay with increasing levels of velvet bean hay (Mucuna pruriens) on nutrient parameters in sheep. *Livestock Research for Rural Development* 14: 101-124.

Murphy, M.R. (1992). Water metabolism of dairy cattle. *Journal of Dairy Science* 75: 326-333.

Nefzaoui, A. and Ben Salem, H. (2001).*Opuntia* spp.: a strategic fodder and efficient tool to combat desertification in the WANA region. In: Mondragón-Jacobo, C.; Pérez González, S. (Eds.). Cactus *(Opuntia* spp.) as forage. Rome: Food and Agriculture Organization of the United Nations, pp 73-90.

Nefzaoui, A., Ben Salem, H and Ben Salem, L. (1995). Ewe-lambs feeding with cactus-based diets. Effect of the type of nitrogen supplement. IV International Symposium on the Nutrition of Herbivores - Satellite “Ruminant use of fodder resources in warm climate countries.” Montpellier, France.

Nefzaoui, A., Chermiti, A. and Ben Salem, H. (1993). Spineless cactus (*Opuntia ficus-indica var. inermis*) as a supplement for treated straw. 7th Meeting of the FAO Sub-Network on Mediterranean Pastures and Fodder Crops. April, 21-23, Chania (Greece): pp 130-133.

Norton, B.W. and Poppi, D.P. (1995). Composition and nutritional attributes of pasture legumes. In: D'Mello, J.P.F., Devendra, C. (Eds.), Tropical Legumes in Animal Nutrition. CAB International, Wallingford, UK, pp 23-46.

NRC. (1988). Nutrient Requirements of Dairy Cattle. Sixth revised Edition. Washington D.C National Academy Press. 157p.

NRC. (1989). Nutrient Requirements of Dairy Cattle (6th Rev. Ed.) Washington, D.C.: National Academy Press.

NRC. (2001). Nutrient Requirements of the Dairy Cattle.7th edition. Washington DC. National Academy Press. 381p.

Oba, M. (2011). Effects of feeding sugars on productivity of lactating dairy cows, Canada. *Journal of Animal Science* 91: 37-46

Ørskov, E.R. and McDonald, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighed according to rate of passage. *Journal of Agricultural Science* 92: 499-503.

Pimienta-Barrios, E., Barbera, G. and Inglese, P. (1993). Cactus pear (*Opuntia spp., Cactaceae)* International Network: An effort for productivity and environmental conservation for arid and semi-arid lands. *Cactus and Succulent Journal* 65: 225-229.

Potgieter, J.P. (1993). The spineless prickly pear, salt bush and American aloe as drought-tolerant crops for the drier Northern Transvaal area. Pietersburg: Department of Agriculture. Northern Transvaal.

Potgieter, J.P. (1995). The cactus pear (*Opuntia Ficus-indica*) in South Africa: Cultivation and research in the Northern Province (Review paper). 6th National and 3rd International Cactus pear congress, Guadalajara, Mexico. pp 352-362.

Pozy, P., Dehareng, D. (1996). Composition et valeur nutritive des aliments pour animaux au Burundi. Institut des Sciences Agronomiques, Atelier du Burundi/ Université Catholique de Louvain / Université du Burundi - Publication Agricole.

Provenza, F.D. (1995). Post-ingestive feedback as an elementary determinant of food preference and intake in ruminants. *Journal of Range Management* 48: 2-17.

Provenza, F.D. (1996). Acquired aversions as the basis for varied diets of ruminants foraging on rangelands. *Journal of Animal Science* 74: 2010-2020.

Provenza, F.D., Villalba, J.J., Dziba, L.E., Atwood, S.B. and Banner, R.E. (2003). Linking herbivore experience, varied diets, and plant biochemical diversity. *Small Ruminant Research* 49: 257-274.

Reyes, J., Senra, A., Vidal, I., Gonzalez, M.R., Gonzalez, R.M. and Fonte, D. (2006). Effect of the grazing intensity on the system soil-plant-animal in low input conditions. Performance of grazing Holstein cows. Cuban *Journal of Animal Science* 39:147-150.

Robertson, D.R. and Van Soest, P.J. (1981). The detergent system of analysis In: James W.P.T., Theander, O (Eds). The Analysis of Dietary Fibre in Food. Marcel Dekker. NY. Chapter 9 pp 123-158.

Rossouw, C.W. (1961). The prickly pear - nature's fodder bank and silo. *Farming in South Africa* 37: 23-26.

Russell, J.B., O'onnor, J.D., Fox, D.G., Van Soest, P.J. and Sniffen, C.J. (1992). A net carbohydrates and protein system for evaluating cattle diets. Ruminal fermentation. *Journal of Animal Science* 70: 3551-3561.

SA Weather Station, Irene (2007). http://www.tutiempo.net/en/Climate/Pretoria Irene/04-2007/682630.htm.

Sahlu, T., Goetsch, A.L., Luo, J., Nsahlai, I.V., Moore, J.E., Galyean, M.L., Owens, F.N., Ferrell C.L. and Johnson, Z.B. (2004). Nutrient requirements of goats: Developed equations, other considerations, and future research to improve them. *Small Ruminant Research* 53: 191-219.

Santana, O.P., Estirna, A.L. and Farias, I. (1972). Palma versus silagem na alimentação de vacas leiteiras. *Rev. Soc. Bras. Zoot* 1: 31-40.

Sarwatt, S.V., Laswai, G.H. and Ubwe, R. (2003). Evaluation of the potential of *Trichanthera gigantea* as a source of nutrients for rabbit diets under small-holder production system in Tanzania. *Livestock Research for Rural Development* 15: 24-34

SAS. (2008). Statistical Analysis System. Statistics Software. Release 9.1, SAS

Shoop, M.C., Alford, E.J. and Mayland H.F. (1977). Plains Prickly pear is a good Forage for Cattle. *Journal of Range Management* 30: 12-16.

Snyman, L.D. (1991). Nutritive value of maize residues in comparison with Eragrostis curvula hay as feed for sheep. *Animal Feed Science Technology* 34: 213-227.

Staal, S.J. and Mullins, G.R. (1996). Dairy consumption and its determinants in costal Kenya. Kenya Agricultural Research Institutes (KARI). International Livestock Research Institutes (ILRI). Collaborative Research Project. Nairobi, Kenya. pp 32-47.

Tegegne, F. (2001). Nutritional value of *Opuntia ficus-indica* as a ruminant feed in Ethopia. In: C. Mondragon and S. Gonzalez (Eds), cactus (*Opuntia spp*) as forage. FAO *Plant Production and Protection Paper* 169:91-99

Tegegne, F., Kijora, C. and Peters, K.J. (2007). Study on the optimal level of cactus pear (*Opuntia ficus-indica*) supplementation to sheep and its contribution as source of water. *Small Ruminant Research* 72: 157-164.

Teklehaimanot, H.S. and Tritschler, J.P. (2011). Evaluation of Spineless Cactus (*Opuntia ficus-indicus*) as an Alternative Feed and Water Source for Animals during dry season in Eritrea. In book: Sustainable Agricultural Development. pp 245-252.

Teles, F.F.F. (1978). Nutrient Analysis of Prickly Pear (*Opuntia ficus-indica*). PhD Thesis. Ann Arbor, Michigan.

Terblanche, I. L., Mulder, A.M. and Rossouw, J.W. (1971). The influence of moisture content on the dry matter intake and digestibility of spineless cactus. *Agro-Animalia* 3: 73-77.

Theriez, M. (1965). Recherches sur la digestibilité de *Opuntia ficus-indica* var. inermis en Tunisie. Inst. Nat. Rech. Agr.

Torell, L.A., Kirksey, R.E., Donart, G.B. and Libbin, J. D. (2000). Economics of grazing weeping love grass with stockers in the Southern Great Plains. *Journal of Range Management* 53: 268-276.

Van Soest, P.J., Robertson, J.B. and Lewis, B.A. (1991). Methods of dietary fibre, neutral detergent fibre and non-starch monosaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Vera, R.R., Irazoqui, H. and Menvielle, E.E. (1973). The nutritive value of weeping love grass during the spring season. *Journal of the British Grassland society* 28: 149-152.

Vieyra, C.A., Coraglio, J.C., Bollati, G.P., Bulaschevich, M.C., Nienstedt, E.F. and Valdez, H.A. (1995). In situ dry matter disappearance in several tropical forage species at the regrowth stage. *AgriScientia* 12: 11-18.

Wanapat, W., Puramonkon, T.J. and Sipkuak, W. (2000). Feeding cassava hay for lactating cows. *Asia-Australia Journal of Animal Sciences* 13: 478-482.

Wildman, E.E., Jones, G.M., Wagner, P.E. and Bowman, R.L. (1982). A dairy cow body condition scoring system and its relationship to selected production characteristics. *Journal of Dairy Science* 65: 495-501.

Woodward, T. E., Turner, W. F. and Griffith, D. (1915). Prickly pear feed for dairy cows. *International Agricultural. Research* 4: 405-449.

Young, C.W., Killer, J.K. and Freeman, A.E. (1986). Production, consumption and pricing of milk and its components. *Journal of Dairy Science* 69: 272-281