EVALUATION OF LOCAL FEED RESOURCES, THEIR RESPONSE ON INTAKE, GROWTH, MILK YIELD AND COMPOSITION AND PRODUCT PROPERTIES OF NAMIBIAN INDIGENOUS GOATS

BY

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DECLARATION

This is to declare that this thesis has been composed by myself and has not been submitted in any previous application for a degree. All sources of information are shown in the text and listed in references and all help by others have been duly acknowledged.

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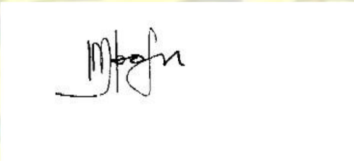

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ABSTRACT

The study evaluated alternative local feed resources as potential protein supplements for dairy goats. Four linked-experiments were carried out in this research. The first experiment, a survey was conducted to investigate farmer's indigenous knowledge on woody plants available in Omatako, Guinas, Tsandi, Daurês, Gibeon and Kongola constituencies of Namibia. Structured questionnaire was randomly administered through face to face interviews with farmers. Sixty (60) households were selected using purposive sampling strategy and GPS-point reading to evenly-space the points in the villages. Information on gender, age, level of education of farmers, type of livestock species reared and predominant woody plant species in the constituencies and their multiple uses were captured. The results from the survey revealed that farmers had profound knowledge on native woody plant species in their constituencies. Most households interviewed were male-headed (73 %), aged between 41- 60 years (43 %) and had at least primary (53.3 %), secondary (35.0 %), and very few with no education (3.3 %) background. The highest number of cattle (39 %) and goats (31 %) were recorded in Guinas, sheep (77.7 %) in Gibeon and chicken (34.1 %) in Kongola. *A. erioloba* and *C. apiculatum* were predominantly listed across all the constituencies, and *A. hereroensis*, *C. collinum* and *R. trichotomum* were the least common species listed as they were confined to certain constituencies. About 47 % of famers indicated to harvests pods and leaves for animal feeding, whereas 53.3 % do not harvest. *C. mopane*, *Z, mucronata*, *G. bicolor*, *A. erioloba* and *T. sericea* were used in the treatment diarrhoea in cattle and goats, whereas, *B. albitrunca* was used to improve fertility in breeding bulls.

The second experiment (Feed evaluation) determines the chemical composition and *in-vitro* gas production of 17 woody plant species collected during the survey from 6 constituencies. Woody plant pods (3) and leaves (16) were randomly collected by hand during wet {January}, early dry {May} and late dry {September} season. Chemical analysis of each sample was performed in duplicates and *in vitro* gas fermentation was replicated in 5 runs of 48 hours with 77 units in each run. Gas production readings were recorded at 3, 6, 9, 12, 24, 36 and 48 hours of incubation. Mean values for NDF were highest noted in *P. nelsii* leaves (499.9 g/kg DM) and lowest in *Z. mucronata* leaves (317.9 g/kg DM). ST concentrations were detected highest(15.5 g/100g DM) in *D. cinerea* pods and lowest in *A. karoo* leaves (1.9 g/100g DM).DM, OM, NDF and ST were significantly higher in dry season than in wet season (P>0.005) whereas, CP, Ash and ADF were not affected by season and location of study (P>0.05). Ca, P and Se concentrations were high in wet season than in dry season. P concentration differed by location with Kongola (3.6 g/kg) having highest value than others. There was a significant positive correlation between NDF and ADF (r=0.62), ST and ADF (r=0.46) but all these were negatively correlated to gas production parameters (P<0.05). CP had a weak relationship with cell-wall constituents and gas production parameters.

Among the 17 woody plant species, AE and DC pods were selected for further animal feeding based on chemical composition and *in vitro* gas production. An on-station feeding trial was conducted to determine the effect of AE and DC pod supplementation on intake, doe weight changes, growth of kids and estimate milk yield consumed by the kids on metabolic body weight basis. Forty eight (48) indigenous lactating does with average weight of 35 kg from parity 2 and 3 were allocated in a 2x3 factorial arrangement of treatments as a CRD with 6 does per treatment. The main factors were 2 pod types {AE; DC} at 3 different feeding levels {20; 40; 60 %}, benchmarked against positive {Commercial feed} and negative control {non-supplemented} resulting in 8 treatment diets. Phosphate-salt lick and water were available at *ad libutum.* The result showed that daily intake of does on Comm (430.9 gDM/day) were higher and lowest in AE (289.3 gDM/day) however, does on DC had the highest gain (38.9g) and lowest on Nosupp group (28.1 g), whereas does on AE had slightly higher final weight (35.6 kg). Kids from does on Comm had the highest ADG (114.4g) and lowest in AE (98.6g). When AE and DC were compared without the treatment controls, does on DC40 had highest intake (316.6 g DM/day), ADG (106.9 g) of kids and better weaning weights (15.6 kg). On average, milk consumption of kids per metabolic body weight was between 1.34 and 2.75 kg

DM/M$^{0.75}$/day. Does supplemented with AE60 and DC60 indicated reduced intake, growth and lower milk consumption of kids.

In the last experiment, milk obtained from the animal feeding trial was collected every second week to determine the effect of AE and DC pod supplementation on milk composition. Milk composition data was analysed in a 2x3 factorial arrangements of treatments as a CRD. In the 10th week of the feeding trial, 16 litres (2 litres per treatment) of milk was collected for the processing of fresh milk, fermented-sour milk and yoghurt for sensory evaluation. Sensory evaluation was assessed in a 3x8 factorial arrangements of treatments resulting in 24 products samples offered for testing by 20 panelists. Sensory evaluation using trained team was done to confirm the descriptive characteristics of the products mainly; the color, aroma, flavour, texture, consistency and overall productivity. A 5point Hedonic scale ranging from 1 to 5 was used to rate the products, where; 1= like very much, 3= neither like nor dislike and 5= dislike very much. The results indicated that AE and DC pod supplementation had no effect on total solids, fat, protein, solid-non-fat and ash; however, Ca and P concentrations in milk increased with DC rate and declined with AE rate. Fermented-sour milk and yoghurt were significantly rated highest for colour, aroma and overall palatability ($P<0.05$), whereas fresh milk mean scores were not significantly different ($P>0.05$).Panellist did not detect any unpleasant odours or off-flavours in the dairy products. The study concluded that supplementation with AE and DC pods improved performance (intake, growth, milk yield) in goats. Supplementing with 40 % DC was recorded to be superior in improving milk in lactating does and growth of kids.

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ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
ADF	Acid Detergent Fibre
ADG	Average Daily Gain
AE	*Acacia erioloba*
AOAC	Association of Official Analytical Chemists
Ca	Calcium
CO_2	Carbon Dioxide

CP	Crude Protein
CRD	Completely Randomised Design
DAPEES	Directorate of Agricultural Production, Extension and Engineering Services
DC	*Dichrostachys cinerea*
DM	Dry Matter
DVS	Director-ate of Veterinary Services
FAO	Food and Agricultural Organization
FAOSta	Food and Agricultural Organization Statistics
GDP	Gross Domestic Product
GLM	General Linear Model
GPS	Global Positioning System
IAEA	International Atomic Energy Agency
KNUST	Kwame Nkrumah University of Science and Technology
MAWF	Ministry of Agriculture Water and Forestry
N	Nitrogen
NDF	Neutral Detergent Fibre
NDP_4	Fourth National Development Plan
OM	Organic Matter
P	Phosphorus
PEG	Polyethelene glycol
SAS	Statistical Analytical Software
SD	Standard Deviation
Se	Selenium

SE	Standard Error
SPSS	Statistical Program for Social Sciences
ST	Soluble Tannins
UDS	University of Developmental Studies
UNAM	University of Namibia

CHAPTER ONE

1. GENERAL INTRODUCTION AND OUTLINE OF THE STUDY

In Southern African countries, livestock production systems are characterized by defined wet and dry seasons. Namibia is rated to have the driest climate in Southern Africa with a wide regional variation in annual rainfall, from less than 20 mm in the western Namib Desert and coastal zone to more than 700 mm at the north-eastern end strip of the Zambezi region (Mendelsohn, 2006). Regardless of the high temperature and low rainfall, which in most cases is accompanied by frequent years of drought, livestock production contribute the most to the Gross Domestic Product (GDP) from agriculture sector (NDP_4, 2012). The country has about 2.2 million cattle, 1.8 million goats, 2.5 million sheep and few pigs, altogether contributing about 76 % to the overall agriculture output (NLCR, 2010; NDP_4, 2012). About 80 % of beef and mutton production is exported annually to the Republic of South Africa and the European Union, which on average contributes between 10-15 % to national income (Kruger and Lammerts-Imbuwa, 2008; NMBAR, 2011) depending on the rainfall amount in a particular year.

Even though, livestock is the leading sector within agriculture, the dairy industry has not been well developed as compared to the beef industry. As a result, the country has been faced with heavy milk and dairy products imports over decades. Government through the Ministry of Agriculture, Water and Forestry (MAWF) recently encouraged local production and marketing to reduce dependency on imported dairy products (NDP_4, 2012). Based on the need during the preparation of the 2011/2012 Strategic Plan (MAWF, Namibia), a feasibility study was carried out on dairy production and marketing titled "Dairy Market Study with the view of implementing Milk Collection Centres in the communal farming areas. The main conclusion emanating from the Dairy Market Study and baseline study by Marius *et al.* (2012) was that, during the wet season (January to June); there was substantial amount of milk production in the communal farming areas. However, milk production declines as the long dry season approaches from July to December, and as natural grazing pastures becomes poor. As a result, farmers could not milk their animals throughout the year; hence implementing Milk Collection Centres may not be sustainable due to feed shortage and insufficient milk production. Namibia is a dry country, and therefore promotion of milk production should be done in tandem with the issue of animal feeding. This is why this study aimed to investigate alternative feed resources for ruminants that can be used as protein supplements in the dry season. The selection of the study locations focused on constituencies where informal practices of dairy and marketing existed and were ear-marked for Milk Collection Centres.

1.1 Outline of the study

Inadequate feeding in the dry season is a major cause of low livestock productivity (Aganga and Tshwenyane, 2003; Smith *et al*., 2005a; Mlambo *et al*., 2008) particularly in communal farming areas of Namibia. Animals depend on natural grazing lands and crop residues after harvest. Communal farmers rarely have the resources to purchase commercial feed supplements (Marius *et al.*, 2012). Most communal farmers have about 2-4 hectares of land, which is not enough to grow food crops and fodder. In the dry season, when animals are on the verge of starvation, woody plant pods can be used as feed (Rothauge, 2006). Although there is now a considerable body of published research on tree leaves and pods in Southern Africa, the technology has not been conveyed effectively to communal farmers as they barely incorporate tree leaves and pods in their feeding systems.

In resolving the challenges of feed availability and utilization of woody plant materials, the study considered the following experiments:

To identify local alternative feed resources, a survey was conducted through farmer's interviews to understand indigenous knowledge on use of woody plants. A structured questionnaire was used to obtain common woody plant species that were utilized by ruminants in Omatako, Guinas, Tsandi, Daures, Gibeon and Kongola constituencies located in communal farming areas of Namibia. Indigenous knowledge on the use of trees and shrubs in animal feeding is very important. Communal farmers and herders are acquainted with woody species that are nutritious and are utilized by ruminants (Thapa *et al*, 1997; Kindness *et al*., 1999; Chepape *et al*, 2011). This exercise was important to the author to aid in the identification and collection of most listed trees and shrubs in each study location.

Seventeen (17) most listed woody plants species were considered and their edible parts of leaves and pods or fruits were collected for chemical composition and *in vitro* gas production. Chemical composition was performed as described in AOAC (2007). *In vitro* gas production technique was carried-out as described by Menke *et al*. (1979) and Theodorou *et al*. (1994). Screening of woody plant browse enables the establishment of inventory of potential local tree and shrub leaves and pods. Such inventory would enable communities know the browses in their area and which pod or leaves to include in the formulation of feeds (rations) for supplementing dairy animals during lactation and in the dry season.

Based on literature, survey and availability of browse during 2013 to 2014, the study considered assessing only *A. erioloba and D. cinerea* pods. Dairy goat supplements were developed to evaluate animal responses on milk yield and growth. The study used lactating Namibian indigenous goats of Caprivi and Ovambo ecotypes. This experiment was designed to identify potential pod type with optimum feeding level that resulted in better milk yield and growth of does and kids.

The milk samples from Animal experiment were further evaluated for total solids, fat, protein, solidnon-fat, ash, calcium and phosphorus. Three dairy products were produced in order to assess their sensory (organoleptic) properties. The study assessed the effect of *A. erioloba and D. cinerea* pod supplementation on colour, aroma, flavour, texture and consistency of fresh milk, yoghurt and fermented sour-milk.

Indigenous goats were used in the study as this was the breed that was mostly kept in communal farming of Namibia. These breeds are genetically resistant to drought and diseases, and highly fertile enabling the multiplication of flocks quickly as compared to large stock (Greyling *et al*., 2004). It is known that many of the rural communities milk these goats for household consumption even though these animals were not bred for this purpose (Greyling *et al*., 2004).

The outcome of the thesis hopefully will be useful to the communal goat farmers who cannot afford commercial feed supplements and have no access to conventional by-products.

1.2 Research objectives

The research study aimed to address constraint of feeds in livestock production by developing alternative local protein supplements that can be used to overcome feed shortage particularly in the dry season. To realize this goal, the following specific objectives were set in this study:

a) Describe indigenous knowledge and identify woody plants species and sample leaves, fruits or pods utilized by ruminants in Omatako, Guinas, Daures, Tsandi, Gibeon and Kongola constituencies of Namibia;

b) Determine the chemical composition and *in-vitro* gas production of edible parts of seventeen (17) woody plants;

c) Develop dairy goat supplements using *Acacia erioloba and Dichrostachys cinerea pods* and evaluate animals responses on intake, milk yield and growth of does and kids;

d) Determine milk composition and sensory evaluation of fresh milk, fermented-sour milk (*omaere*) and yoghurt made from milk produced by lactating goats fed with *Acacia erioloba and Dichrostachys cinerea.*

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Goat population in the world

Goats are small ruminants that belong to *Capra hircus* species, the first and most domesticated amongst livestock (Peacock, 1996). Table 2.1 shows that world goat population is estimated at about 915 M and most (89 %) are found in developing countries of Africa and Asia (FAO, 2011). The reasons for these concentrations are that they have ability to withstand high ambient temperatures, degraded rangelands and have high disease resistance (Steele, 1996). Despite the high concentration of goats, goat keepers are often characterized as resource-poor who are economically, politically marginalized and regularly associated with social, religious and cultural prejudices (Peacock, 1996). Even with these set-backs, goats have a potential to make a significant contribution to food security, poverty reduction and improved livelihoods of rural farmers in Africa and worldwide.

Table 2.1 Goat population in the world

	Goat population in millions	World proportion (%)
Africa	276	30.1
Asia	536	58.6
Oceania	49	5.3
Europe	17	1.9
America	37	4.1
Worldwide	915	100.0

Source: FAO (2011)

2.1.1 Goat population in Namibia

Small stocks are abundant in the southern part of Namibia, and the communal farming area of the country. The highest breed of goats in the communal farming is the local indigenous goats and some crosses. However, Boer goat serves as an established breed for meat production and Angora goats is specifically kept for production of mohair. The exotic dairy goats such as Saanen, Toggen-burg and Anglo-Nubian exist in small numbers in the commercial farming areas. Table 2.2 shows goat numbers in Namibia from 2010 to 2014. Goat numbers has been estimated to fluctuate between 1.6 to 1.9

million from 2010 to 2014 (MAWF, 2014). This could be attributed to variability of the rainfall received in each year and across the Regions of Namibia.

Table 2.2 Goat numbers in Namibia for the period of 2010 - 2014

Year	Goat numbers
2014	1,892 439
2013	1,693 145
2012	1,933 103
2011	1,736 565
2010	1,690 467

Source: MAWF (2014)

2.1.2 Importance of goat production in Namibia

Goats contribute substantially to the livelihood of rural communities and remain as source of protein through provision of milk and meat (Greyling *et al*., 2004). Boer goat breed has been leading in the formal market due to demand for large carcasses. Live goats are exported to South Africa together with mutton production (NMBAR, 2011). In contrast, indigenous goats are seldom entered in the formal marketing system. However, indigenous goats are sold at local auctions, butchery and many times, communal farmers only sell when cash is needed. Locally, goats are slaughtered at celebrations ceremonies, and also exchanged with other goods in the informal market.There are four indigenous goat ecotypes recognized which represent a unique genetic resource suitable to different environmental condition within Namibia, namely; Kavango, Kunene, Ovambo and Caprivi.

Plate 2.1 shows the Caprivi and Ovambo doe ecotype with twin kids which were used for feeding (refer to chapter 5). The Caprivi and Ovambo are small-framed (29-30 kg) whereas; Kavango and Kunene are large-framed (31-37 kg) ecotypes (Soyinka *et al.*, 1997). Twinning is common in the Ovambo type and Caprivi, and tends to have good mothering ability. The mean weight of a kid at birth ranges from 2.0 to 3 kg and average gain per day of age ranged between 100 – 130 g/day).The importance of woody plants as fodder for livestock is discussed in the next section.

Plate 2.1 Caprivi (a) and Ovambo (b) does with twin kids at John Pandeni Research Station (Photo by Theopholina Nujoma, MAWF)

2.2 Importance of woody plants as fodder for livestock

Woody plants (also known as indigenous trees and shrubs) form a major component of the diet of livestock in the arid, semi-arid zones in Africa, India, Australia and Southern America (Otsyina *et al.*, 2000; Salem and Smith, 2008). Browse refers to the edible part of woody plants such as leaves, twigs, flowers, fruits and pods rather than eating grass, which is called grazing. A tree is a woody plant with one stem or trunk, and usually branching well above the ground. Similarly, a shrub is a bush with a number of stems of more or less equal size arising from near the ground and often branching low down

(Mannheimer and Curtis, 2009). Browse plants provide protein, vitamins and relative amount of mineral elements, which are mostly lacking in grassland pasture.

As a result of poor rainfall and frequent droughts in arid and semi-arid zones, browse trees turn out to be an alternative feed resource in dry season supplementation (Salem and Smith, 2008). Woody plants especially those of genus Acacia, are adapted to the low moisture environment and widely spread in southern Africa especially Namibia, Botswana, South Africa and Zimbabwe. Acacia species and *Dichrostachys cinerea* for example have foliage that grows in the dry season and pods and fruits are formed which are consumed by ruminants (Mlambo and Mapiye, 2015). In Zimbabwe, the use of tree pods as dry season protein supplement has been evaluated by Sibanda and Ndlovu, 1993; Kindness *et al*., 1999; Sikosana *et al*., 2002b; Mlambo *et al*., 2004; Smith *et al*., 2005b). In South Africa, a study by Chepape *et al.* (2011) in Bushbuckridge area reported that *Dichrostachys cinerea* was the most preferred species by both cattle and goats. Sanon *et al*. (2007) study reported the importance of some Sahelian browse as feed for goats in Burkina Faso. Ansah and Nagbila (2011) reviewed the importance local trees and shrubs as feed for livestock and medicinal purposesin Talensi-Nabdam district of the upper east region of Ghana. Aganga and Tswenyane (2003) reviewed the nutritive value of various browse species in Botswana.

In the coastal lowlands of Kenya, forage productions systems were developed such as *Leucaena leucocephala* and *Gliricidia sepium* cultivation were promoted in smallholder dairy farms in the region (Njarui and Mureithi, 2004). These fodder trees can be grazed or cut and fed as supplement to natural pastures or poor quality roughage. However, fodder conservation or animal feeding either through “cut and carry” is not a common practice in communal areas of Namibia. Animals access the trees and shrubs *in situ* during grazing, which may not be utilised effectively. According to Sanon *et al*. (2007), the most important part of the edible biomass is not directly accessible to the animal due to the height of the trees.

2.3 Description of some woody plant species used in the study

Figure 2.1 shows the map of Namibia in red and Figure 2.2 indicates different vegetation types in Namibia. In Namibia, there is diverse vegetation of woody plants available. There are at least seven vegetation types classified by Giess (1998) namely; Mopane Savanna, Mountain Savanna and Thornveld, Thorn-bush Savanna, Highland Savanna, Camel-thorn Savanna, Forest Savanna and Woodland. The main woody species that occur includes *Acacia mellifera* subsp. *detinens, Dichrostachys cinerea*, *Terminalia sericea*, *Acacia reficiens*, *Colophospermum mopane*, *Rhigozum trichotomum* and *Prosopis* species (de Klerk, 2004; Mannheimer and Curtis, 2009). These species are invasive and densely populated causing bush encroachment problem that has escalated over the years in Namibia. Bush encroachment is defined as the invasion or thickening of woody species resulting in an imbalance between grass to bush ratio. Extensive bush encroachment inhibits grass growth under their canopy decreasing the carrying capacity in the livestock ranching areas.

A. erioloba is widely spread in the country and not regarded as invasive species due to low number of young plants in relation to the mature ones. *A. erioloba and D. cinerea* pods were selected for supplementary feeding in this study because of their pod size, crude protein content (90-190 g/kg) and were well cited in literature as highly preferred by domestic ruminants (Mlambo *et al*., 2004).

Among the woody leaves, *Combretum apiculatum*, *C. collinum*, *Colophospermum mapane*, *Terminalia sericea* and *Ziziphus mucronata* are some of the potential species but could not be picked for feeding due to insufficient foliage formation during data collection time. This situation is normally experienced when rainfall season is delayed or simply during period of low rainfall in

November/December. *A. erioloba* tree and *D. cinerea* shrub are further discussed in the following section.

Figure 2.1 Map of Africa showing Namibia in red (Wikimedia, 2015)

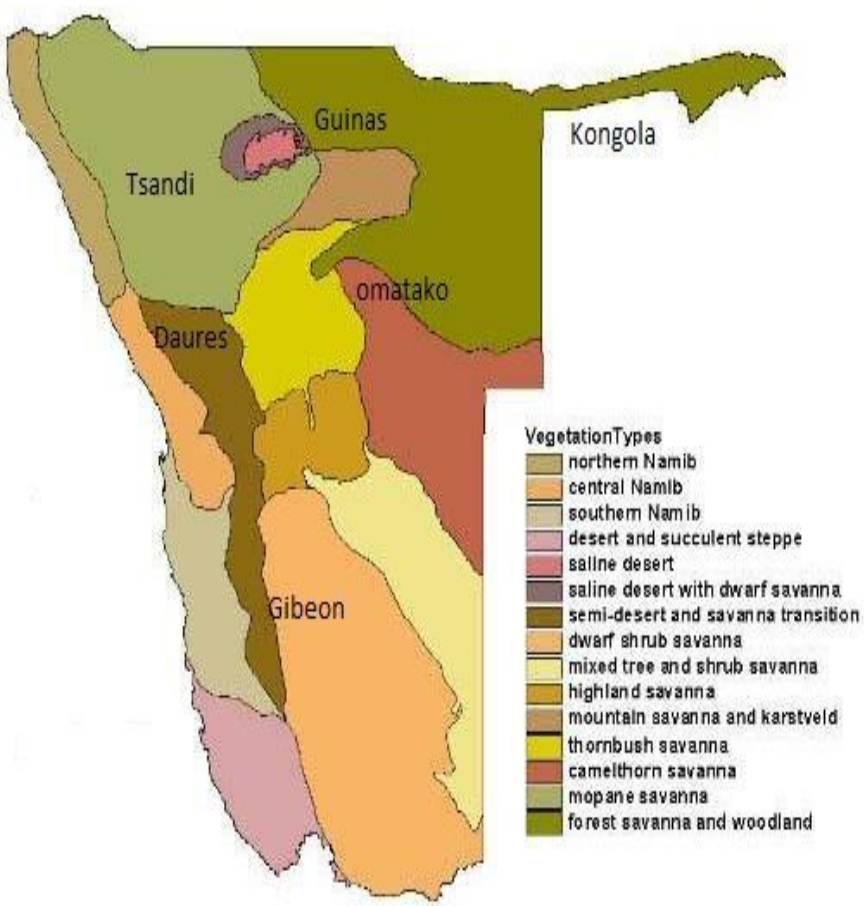

Figure 2.2 Map of Namibia showing vegetation types (Giess, 1998)

2.3.1 Acacia erioloba

Acacia erioloba common name Camel-thorn (Plate 2.2), is a southern African woody plant species that extends from Namibia to southern Angola, parts of Botswana, south-western Zimbabwe, the north-west of South Africa and into south west Mozambique (Barnes *et al.* 1997). *A. erioloba* tree is one of the most widespread species occurring in a range of vegetation types throughout Namibia. It is most found along dry river courses, plains, sand dunes, sometimes scattered within the thorn-bush and woodland savanna (Curtis and Mannheimer, 2005).

It is a semi-deciduous or deciduous tree with spreading canopy crown, up to 20 m high, dark grey to blackish, rough vertical fissures bark. The leaves have 2-5 bi-pinnately compound tips; young branchlets are red-brown and zig-zag; thorns are paired, straight, white often noticeably thickened at the base. The tree produces bright golden-yellow balls of flowers, singly or in pairs, appearing together with young leaves (Mannheimer and Curtis, 2009). Flowering usually begins in August, ending in November, with a sharp flowering peak in September (Barnes *et al.* 1997; Mannheimer and Curtis, 2009). Fruits are woody, grey velvety pods, often shaped like a human ear with about 825 seeds inside the pod (Plate 2.2). Seeds are only released as the pod decays on the ground, or is eaten by animals (Timberlake *et al.* 1999).

At about 10 years of age, A. *erioloba* tree can begin flowering, and by age 20, can produce regular large pod crops (Barnes *et al.* 1997) and they do not start to produce pods until over 3m in height (van Wyk *et al.*, 1985). Pods have been found to fall between July and August. Pod production is linearly related to tree size (Barnes *et al*. 1997), so as trees become older, they become more valuable as a source of forage, and pods for livestock. It provides large patches of shade for livestock and good source of fire wood.

(a) *Acacia erioloba* tree and pods

(b) *Dichrostachys cinera* shrub and pods

Plate 2.2 *Acacia erioloba* tree (a) *Dichrostachys cinerea* (b) shrub and pod types

2.3.2 Dichrostachys cinerea

Dichrostachys cinerea common name; Sickle-bush is a deciduous legume shrub in the Fabaceae family (Plate 2.2). It is widely spread in a variety of habitats in the central and northern parts of Namibia and very common in Southern Africa. It is among the serious invasive woody species, dominating large areas and forming thick bush on plains, along rivers courses and hill slopes in most places in Namibia.

The species has an open round crown, a deep tap root and many lateral roots that makes eradication difficult (de Klerk, 2004). The bark is yellowish to dark grey-brown to black, usually rough, occasionally grooved. The leaves are bi-pinnately compound, alternate or clustered with petiole 3-50 mm long. Flowers are of two types; the basal flower is pink, varying from white to purple with staminodes.

The fruit has a cluster of contorted pods which are dark brown and not splitting when matures (Curtis and Mannheimer, 2005). In Namibia, pods are normally available between May to September (dry season). The leaves and pods are browsed by livestock and game, especially giraffe and kudu. Pods are relatively high in crude protein (90-190 g/kg)) and highly preferred by domestic and wild animals during the period of food scarcity (Mlambo *et al*., 2004).In Botswana, DM content could be 43 % in the wet season (March to May) and increases up to 74 % in the dry season (July to September) (Aganga *et al*., 2005). The foliage of *D. cinerea* is rich in tannins and particularly in condensed tannins, which may be detrimental to digestibility, however, Matlebyane *et al*. (2009) considered that the total phenolic content was low enough to be nutritionally safe for ruminants. Thorns may injure animals and have been reported as a major problem in hooves of cattle and goats.

The wood of *D. cinerea* is hard, durable and resistant to termites, and is used to make walk stick (knob kieries), tool handles and pole fences. The tree is used to make firewood and form excellent charcoal industry in Namibia (Curtis and Mannheimer, 2005).

2.3.3 Farmer's knowledge in the utilization of woody plant species for livestock

Indigenous knowledge is society-based information that people use to differentiate local-level knowledge from the global knowledge that has generated over the past centuries. In agriculture, it provides the basis for decision making on feed management and their medicinal purpose particularly by resource poor farmers. Farmer's knowledge on native plants has been used by many researchers to support laboratory results on chemical composition of the feeds. Farmers' knowledge and utilisation of woody plants as feed for livestock has been assessed (Komwihangilo *et al*., 1995; Thapa *et al*., 1997; Thorne *et al*., 1999; Komwihangilo *et al*., 2001; Ansah and Nagbila, 2011**;** Chepape *et al*., 2011). Local people generally recognised woody plants which are well appreciated by animals, plant parts consumed and their nutritive importance. Some local woody plants have been used in medicinal and ethno-veterinary practices in ruminant livestock production (Matlebyane *et al*. 2010) and for fuel wood (Mannheimer and Curtis, 2009). In Zimbabwe, Kindness *et al*. (1999) reported farmers' views during informal meeting about the negative effect of anti-nutritional factors on goats consuming excessive amounts of *Acacia nilotica* fruits. Farmers in mid hills of Nepal ranked fodder trees in terms of two locally described attributes viz. *posilopan* and *obhanopan* which broadly translate to nutritional value and palatability respectively (Thapa *et al*., 1997).

In a recent survey conducted by Kasale (2013) in Sibbida constituency of Zambezi region of Namibia, farmer's group discussion aided in ranking *Acacia erioloba, Dichrostachys cinerea, Guibourlia coleosperm and Colophospermum mopane* woody species in order of their importance. *Dichrostachys cinerea* was reported by respondents as the most preferred woody plant species by both cattle and goats in Bushbuckridge region in South African (Chepape *et al*., 2011). Shenkute *et al*. (2012) used structured and semi-structured questionnaire to collect information from key informants on types of woody plant species available, their vernacular names, season favored, palatability, parts of plants eaten and relative attractiveness to animals or animal preferences.

2.3.2 Significance of woody plants in the nutrition of goats

Goats play an important role in the livelihood of communal farmers as a source of protein (milk and meat), fiber, hide and hooves as well as mohair. Goat milk is highly nutritious and has a higher nutritional profile than human milk (Peacock, 1996). The small size of fat globules, higher digestibility and less allergic perspective were the reasons of preferred goat milk feeding in infants over cow milk (Tripathi, 2015). Goats are highly prolific, producing twins or triplets especially the indigenous breeds, allowing owners to build flocks quickly. The goat is often used as a first step towards livestock ownership, as with a large flock part can be sold and replaced by sheep or cattle. Many other attributes of goats are reported in many literatures, including small size and low price, which is ideal for slaughter at any celebration. They are easy to manage by family labour and can survive in harsh conditions. Goats display certain qualities, such as hardiness, high tolerance to temperatures, drought and diseases and therefore are well adapted to the harsh climatic condition in communal farming areas of Namibia.

With regard to the feeding behaviour, the goat is a natural browser, feeding by preference on tree leaves, flowers, fruits, pods and even the woody stem of trees. Their small mouth and mobile upper lip and tongue enable them to pick small leaves between thorns, flowers, fruits and other plants parts, thus choosing only the most nutritious available feed. They are very active, moving quickly between and around trees, and can walk long distances in search of food to satisfy their nutrient requirements. Goats are shown to eat preferentially at heights between 20 and 120 cm above ground and can stand on their hind legs or even climb trees to reach the preferred forage. Goats are known to feed on a wide variety of forages, and the choice is influenced by the diversity of feeds available. This habit seems to be related to the need to maintain the rumen environment within a certain physiological and microbiological range (Morand-Fehr, 2005). However, goats seem not to thrive well when kept on a single type of feed for any length of time (Decandia *et al.*, 2008). The feeding strategies of goats, reported by Luginbuhl and Poore (1998) consist of selecting grasses when the protein content and the digestibility are high, but switching to browse when their nutritive value tended to be higher. However, where browse is not available, goats can feed on grasses and crop residues (Rothauge, 2006), but tend to prefer less coarse grasses (Luginbuhl and Poore, 1998). The preference of goats for consuming browse is useful in controlling bush encroachment and invasive species of woody plants in the veld of Southern Africa (de Klerk, 2004).

2.4 Evaluation of nutritive value of ruminant feedstuffs

Nutritive value describes the chemical composition of the feed to provide the nutrients required by an animal for normal body processes such as maintenance, growth, reproduction, lactation and health (NRC, 2001). Chemical composition and digestibility determines the feeding value as well as the amount and type of nutrients that the animal can derive from the feed. However, some plant species and environmental factors influence the nutritive value of browse. Feed intake is important as it establishes the amount of nutrients available to an animal. Feeds of high nutritive value promote high productivity. Feed intake in ruminants consuming fibrous forages is primarily determined by the level of rumen fill, which in turn, is directly related to the rate of digestion and passage of fibrous particles from the rumen. Owing to this, techniques of feed assessment such as chemical, biological and analytical have been evolved. This has made it possible for feed assessment and comparisons so that planning of feeding systems as well as formulation of feedstuff to meet animal requirements can be made with accuracy (NRC, 2001). Some of these techniques for assessing the nutritive value of feeds are discussed in the following sections.

2.4.1 Chemical composition of woody plant species

Chemical composition varies for different woody species in DM, Ash, CP, ADF, ADF and CT as summarised in Table 2.3. DM ranged between 881 g/kg DM in *Terminalia sericea* leaves (Ndlovu and Nherera, 1997) to 952 g/kg DM in *Acacia nilotica* leaves (Mokoboki *et al*., 2005). Ash represented the minerals was detected highest (102 g/kg) in *Ziziphus mucronata* leaves (Shenkute *et al*., 2012) and lowest (50 g/kg) in *Colophospermum mopane* leaves (Lukhele and Ryssen, 2003).

Protein content varies between woody plant species and the edible part of the same plant. Mlambo *et al.* (2004) reported Nitrogen (N) content of *Dichrostachys cinerea* pods of 37.4 g/kg (N x 6.25 factor) and CP content of 234 g/kg. Kamupingene and Abate (2004) found relative amount of CP in the leaves of *Acacia erioloba*, *Acacia mellifera* and *Grewia flavescent* as indicated in Table 2.3. However, Lukhele and Ryssen (2003) reportedslightly low CP concentrations of foliage in *Combretum* species including *C. mopane*. Larbi *et al*. (1998) detected higher levels of CP in fodder trees and shrubs in the humid tropics. This suggested that both leaves and pods of woody species have equally feeding values to livestock.

NDF, ADF and condensed tannin of woody species reported in different studies were highlighted in Table 2.3. The neutral detergent fraction (NDF) of the diet describes those forage component that are slowly degradable in neutral solvent such as cellulose, hemicellulose and lignin. NDF content was reported lowest (323 g/kg DM) in *Combretum apiculatum* (Lukhele and Ryssen, 2003) and higher in the leaves of *Terminalia sericea* (647 g/kg DM: Ndlovu and Nherera, 1997). Van Soest (1994) reported that NDF ranges from 540 to 770 g/kg DM for different forage species. The acid detergent fibre (ADF) fraction includes cellulose and lignin and therefore recoverable with ADF. The highest ADF was found in *Terminalia sericea* leaves (Ndlovu and Nherera, 1997) and lowest in *Acacia tortilis* pods (118 g/kg DM: Mokoboki *et al*., 2005).

Fibre has been recognised as a required dietary ingredient for many herbivorous animal species and is necessary for normal rumen function in ruminants (Van Soest *et al*., 1991). Increasing levels of NDF limits dry matter intake. Diet containing 21-25 % NDF from high quality forage will return more milk production. According to the studies illustrated in Table 2.3, CT was lower in *Acacia mellifera* leaves and higher in *Acacia nilotica* leaves (Aganga *et al.,* 2001; Mokoboki *et al.*, 2005). Reed (1995) emphasised that presence of certain phenolic in browse interfere with protein content and may be over or underestimated in feed analysis hence availability to the animal.

Table 2.3 Chemical composition of some woody plant species in different studies (g/kg DM)

Species	AE		DC		AK	AM	AN	AT		CM	CA	GB	GF	TS	ZM	Mean
Part	P	L	P	L	L	L	L	L	P	L	L	L	L	L	L	
DM	-	-	928	-	945	-	952	948	888	-	-	900	-	881	895	917.1
ASH	-	-	-	-	-	60	-	-	57	50	54	92	-	96	102	365.4
CP	133	142	234	418	108	100	152	150	125	141	122	157	177	163	161	165.5
NDF	415	452	334	418	505	520	572	622	330	380	323	547	512	647	370	463.1
ADF	298	337	249	350	407	430	472	545	188	307	247	419	277	496	269	352.7
CT	21	18	34	20	31	2	44	5	-	-	-	-	21	-	-	21.8
Source	1	2	3	4	5	6	5	5	7	8	8	9	2	10	9	

Legend: DM= dry matter; ASH=ash; CP= crude protein; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; CT= condensed tannins; AE= *Acacia erioloba;* DC= *Dichrostachys cinerea;* AK= *Acacia karoo;* AM= *Acacia mellifera;* AN= *Acacia nilotica;* AT= *Acacia tortilis;* CM= *Colophospermum mopane;* CA= *Combretum apiculatum;* GB= *Grewia bicolor; Grewia flavenscens;* TS= *Terminalia sericea;* ZM= *Ziziphus mucronata*. P= pods; L= leaves; Source: [1]Mlambo *et al*., 2008; [2]Kamupingene and Abate, 2004;[3]Mlambo *et al*., 2004; [4]Sebata *et al*, 2011; [5]Mokoboki *et al*., 2005; [6]Aganga *et al*., 2001; [7]Lengarite *et al*., 2014; [8]Lukhele and Ryssen, 2003; [9]Shenkute *et al*., 2012; [10]Ndlovu and Nherera, 1997

2.4.2 *In-Vitro* methods

The nutritional value of the fodder plants can be estimated with adequate precision from *in vivo* digestibility (Getachew *et al*., 1998). However, due to the expense and time required to conduct animal trials, alternative biological procedures (i.e. *in vitro* and *in situ* techniques to predict organic matter digestibility have been developed (Antwi, 2010). The *in vitro* gas production technique has been used to stimulate ruminal fermentation of feed and feed stuffs (Getachew *et al*., 2004) for decades. The *in vitro* method technique is a relative simple method for evaluating feeds as large numbers of samples can be incubated and analysed at the same time (Getachew *et al*., 1998). Besides, the methods have the advantages of being less costly, less time consuming, good reproducibility and also correlated well with values measured *in vivo* trials (Getachew *et al*., 2004). This method has been applied successfully in feed evaluation, including calculating organic matter digestibility, the metabolisable energy of feeds, plant cell wall (NDF, ADF, ADL) degradability and kinetics of their fermentation. The effect of secondary metabolites such as tannin or saponins on rumen fermentation can also be evaluated *in vitro* (Makkar, 2003).

The two-stage *in vitro* method was first reported by Tilley and Terry (1963) stimulates the activities in the rumen and lower digestive tract. The forage of substrate is anaerobically fermented in a buffered rumen fluid for 48h in the first stage. This is followed by 48h of acidpepsin digestion to digest un-degraded plant cell and microbial protein. The Tilley and Terry (1963) technique has the advantages of examining many samples at one time with the use of apparatus and gives highly reproducible results. The analysis provides an estimate of *in vitro* digestibility from which *in vivo* digestibility can be predicted. However, with this method, data regarding degradation kinetics is not provided.

2.4.3 Gas production technique

The Menke *in vitro* gas-production technique is commonly used to determine the amount of gas produced over a 24-hours incubation period (Osuji *et al*., 1993). The amount of gas released when a feed is incubated *in vitro* with rumen fluid is closely related to the digestibility of the feed (Menke *et al*., 1979). This has made it crucial to determine the energy value of feed to ruminants. By knowing the *in-vitro* dry matter digestibility of feedstuffs, it is easier to make decisions on the amount of feed to be supplemented. Ørskov and McDonald (1979) among many authors clearly describe the differences of the rate of degradation among feedstuffs and if two feedstuffs reach the same level of digestibility they may not have the same pattern of fermentation. The fermentation rate can be different. Practical feeding experiments with two such feeds show that the one with the highest rate of fermentation allows for higher levels of production.

2.4.4 Carbon dioxide and methane production

When a feedstuff is incubated with buffered rumen fluid *in vitro*, the carbohydrates are fermented to short chain fatty acids (SCFA), gases mainly of carbon dioxide (CO_2) and Methane (CH_4) and microbial cells (Getachew *et al*., 1998). CO_2 and $CH_4$are produced in the rumen of cattle, sheep and goats, absorbed into the bloodstream and released in the lungs, then lost through the mouth during breathing or eructation (belching). Gas production is basically the result of fermentation of carbohydrates to acetate, propionate and butyrate. Gas production from protein fermentation is relatively small as compared to carbohydrate fermentation. The contribution of fat to gas production is negligible. When 200 mg of coconut oil, palm kernel oil and/or soybean oil were incubated, only 2.0 to 2.8 ml of gas were produced while a similar amount of case in and cellulose produced about 23.4 ml and 80 ml gas (Menke and Steingass, 1988; Getachew *et al*., 1998). Methane production results from the incomplete use of the energy in feed. Higher methane losses from the rumen means that the ruminant animals are using feed less efficiently to produce meat or milk. Many factors which affect methane emissions from ruminants are most likely to be through feeding and management changes. Most research on methane production has been on confined beef or dairy animals fed conserved and processed forage. However, extensive grazing animals may produce different level of methane compared to confined animals because the forage type and amount consumed is different (Getachew *et al*., 2004). In various studies, foliage as well as fruits and seeds of fodder shrubs and trees have been reported to suppress ruminal protozoa population (Dube *et al*., 2001). This natural defaunating, i.e. protozoa eliminating, activity of some multi-purpose trees and shrubs-derived feeds was shown to be the result of their plant secondary metabolites. Reducing methane production can be of direct economic benefit because it coincides with greater energy use efficiency of the feed by the animal (Salem*et al.*, 2010). Basha *et al.* (2012) reported a gas production in *Dichrostachys cinerea*, similar in the dry and early wet seasons but higher in the late wet season.

2.5 Factors affecting the nutritional value of woody plant browses

2.5.1 Plant type

Woody plants have moderate amount of crude protein and minerals that can maintain sufficient nutritional levels during critical period of the year such as in summer, when grasses have been depleted (Luginbuhl and Poore, 1998). Studies confirmed that woody plants generally have high protein content, high lignin and tannin content when compared to grasses and legumes (IAEA, 2006). However, the amounts vary greatly from one species to another and phenological stage of the plant. Protein content is higher in young leaves and stems than in other parts of the plant (Topps, 1992). A plant may have satisfactory dry amounts of inorganic and organic nutrients as forage for livestock but is of little value if it lacks palatability. Furthermore, the palatability and abundance of the various species determine the botanical composition of the grazing animal's diet (Rothauge, 2006).

2.5.2 Stage of plant maturity and season

The stage of growth seems to be the most important factor affecting the chemical composition and digestibility of range forage. Plant cell wall analysis, based on detergent extraction, is a good indicator for predicting nutritional value of fibrous feeds, because, voluntary dry matter intake and dry matter digestibility are dependent on cell wall constituents, especially NDF and lignin (IAEA, 2006). In general, all forages are highly succulent in early growth, which markedly enhances their palatability. Most plants decline in nutrient composition with advanced maturity (Topps, 1992). Ndlovu *et al*. (1995) reported a decline in crude protein and IVDMD while NDF and ADF increased with leaf maturity of browse. The protein content of forage legumes is generally related to stage of maturity. Protein content decreases with age while yield increases with age. As the season advances and plant mature, the protein content decreases hence tannin level increases (IAEA, 2006). Variation in chemical composition could also be due to differences in time of samples of collection of trees leaves or pods. Different season showed significant effects on the chemical composition of the trees as leaves became more fibrous and lignified during winter months (IAEA, 2006).

2.5.3 Climate

Climatic factors include; temperature, humidity, precipitation, light intensity and altitude influence the nutritive value of woody plants. Although plants are dependent upon the soil for their mineral nutrients, climatic factors affect respiration, assimilation, photosynthesis and metabolism to the extent that the mineral and organic matter content of plants may be strongly modified by climatic factors even though grown on the same soil. Precipitation may have direct and indirect influences upon the quality of browse. Rainfall, in general, tends to increase nitrogen; phosphorus and ether extract (the soluble fat constituent). Even if browse species are less affected by summer droughts than grasses and forbs because of their deeper root systems, they are able to thrive and remain the option during the dry period (Aganga *et al*., 1998).

2.5.4 Anti-nutritive factors

Woody plants have developed survival strategies either as a way of soring nutrients or as a means of defending their structure and reproductive elements from herbivores or in some instance to make use of the animals to spread their seeds. Tannins are chemical or secondary compounds found in plants not directly involved in the process of plant growth but act as deterrents to insects and fungal attack or being eaten by animals (Hagerman, 1987). During some plant growth stage, the animals are discouraged from eating the plants while during other stages the consumption of such plants is encouraged. Some herbivores have also developed survival strategies e.g. the ability to select certain parts of the plants or to develop microbial populations capable of minimizing anti-nutritive factors such as the destruction of limousine and some tannin from tanniferous plants. Anti-nutritive factors are often associated with woody plants rather than grasses. Many woody plant leaves contain various levels of anti-nutritional factors that have an affinity for carbohydrates, amino acids and minerals rendering them unavailable for rumen micro-flora and the animal (Silanikove *et al*., 2001; Makkar, 2003). Tannin could exhibit both negative and positive effects on nutritive value depending on the amount in the browse (Scalbert, 1991).

2.6 Effect of tanniferous woody plants on animal performance

Tannins are defined as water soluble phenolic compounds of plants with molecular weight between 500 and 3000 Daltons. They are distinguished from other polyphenolic compounds by their ability to precipitate gelatine and other proteins from aqueous solution (Silanikove *et al*., 2001). They have negative effect on protein metabolism and decrease palatability of feeds at high levels (Barry and Manley, 1986; Bryant *et al*., 1992) but at very low levels, most are beneficial (Foo *et al*., 1996). High levels of tannins are common in some woody plants such as Acacia and *Dichrostachys* species (Mlambo and Mapiye, 2015). Condensed tannins and hydrolysable tannins are the two major classes of tannins. Condensed tannins are made up of flavan-3-ols linked via carbon-carbon bonds. They are also called proanthocyanidins as treatment with acidic alcohol produces coloured anthocyanidin. Hydrolysable tannins are polyesters of phenolic acids (gallic acids, hexahydroxydiphonic acid and their derivatives) and d-glucose or quinic acid. Proanthocyanidins are the most common type of tannin found in forage legumes (Reed, 1995). Polyethylene glycol (PEG) is a tannin-inactivating agent that promotes effective utilization of tanniferous woody plant browse (Mlambo *et al*., 2008).

Woody plants often have thorns, fibrous foliage and growth habits which protect the crown of the tree from defoliation. Plants synthesize tannins in order to defend themselves against insect, fungal and herbivores, also known as 'defence' theory. The proposed mechanism of defence is their astringent taste and their ability to interfere with digestive enzymes of predators (Mueller-Harvey and McAllan, 1992). Tannin synthesis depends on plant cell vacuole differentiation and exogenous factors. Seasonal effects, light intensity, temperature and soil fertility has all been implicated in tannin synthesis (Mueller-Harvey and McAllan, 1992). Anti-nutritional factors act within the animal's digestive system by binding to substrate which can be protein, carbohydrates, lipids, minerals and vitamins (Haslam, 1993 and Norton, 1994). Anti-nutrients can also inhibit digestive enzymes or can be antimicrobial (Scalbert, 1991, Asfari *et al.*, 1993). Goats are capable of selecting low tannin containing older growth on browse and leave out current's season growth which has higher tannin content (Mueller-Harvey and McAllan, 1992). Sikosana *et al.* (2002b) reported high levels of tannins in *Acacia nilotica* reduced growth rates of animals due to lower feed intake and protein digestibility. The effect of tanniferous feeds on milk fat and protein composition varies markedly depending on the concentration of tannins present in the feeds (Vasta *et al*., 2008; Mlambo and Mapiye, 2015).

2.7 Factors that affects dry matter intake (DMI)

Dry mater intake is important as it establishes the amount of nutrients available to an animal for health and production (NRC, 2001). Several factors are related to nature in which feed is presented to the animal such as moisture content, physical form, chemical composition and fibre content (Attoh-Kotoku, 2011). These factors influence the chewing activity and salivary production, rumen microbial activity and digestibility and rumen feed passage rate through the gastro-intestinal tract; hence milk production and fat percentage in milk. The length and diameter of the particles size plays a role in rumination and feed intake. Too long feed parts do not pass effectively from the rumen and reduced intake. By contrast, chopped or grounded feed increases intake compared to that offered whole or ungrounded form (Lengarite *et al*., 2014). When diet is lower than 12 % CP, it decreases intake. Mineral deficiencies decrease intake such as phosphorus, sulphur and sodium. Fibre is the slowly digestible or indigestible component of feed that occupies space in the gastro-intestinal tract of animals which includes cell wall components such as lignin (indigestible) cellulose and hemicellulose (rumen degradable components). Ruminants require fibre in the diet to maximize production and maintain health by sustaining optimal and stable nutrient environment. An adequate intake of NDF and ADF is necessary for maintaining optimal ruminal pH. Feed with more than 25 % NDF affect rumen fill and limit DMI as they are slowly cleared in the rumen hence slow passage rate through the gastro-intestinal tract. A positive correlation between milk fat concentration and diet Neutral-Detergent fibre (NDF) has been reported. Santini *et al.* (1992) found a significant increase in milk fat concentration, from 2.48 to 3.32 %, as acid-detergent fibre (ADF) increases from 14 to 26 % (on a DM basis) in high-producing goats in early lactation. Presence of ligneous fractions, tannins and other secondary compounds reduces intake as they interfere with protein digestion (Waghorn, 2008).

2.8 Effect of woody plant browse on animal performance

Different studies have supplemented goats with browse pods as shown in Table 2.4. Supplementation of *Dichrostachys cinerea* fruits at different levels of 0.5 %, 1.0 % and 1.5 % to growing Abergelle goats browsing in the lowlands of Ethiopia. The highest DM intake of 84.6 g/day$^{-0.75}$ BW and gain of 21.7g/day was recorded for the group that received 1.5 % D. cinerea fruits than in other groups (Yayneshet *et al*., 2008).

Sikosana *et al*. (2002a) fed various browse fruits that includes *Acacia erioloba Acacia erubescens, Dichrostachys cinerea, Acacia nilotica and Acacia tortilis* fruits to indigenous castrated males. Animals were restricted to receive a maximum of 200 g pods per day per goat to determine their growth performance and carcass characteristics. Goats offered *A. nilotica* and *D. cinerea* pods had higher growth rate of 13.3 and 4.8 g/day respectively than in other treatments. Goats offered with A. *nilotica* (-27 g/day), A. *erioloba* (-3.3g/day) and A.

erubescens (-1.9g/day) had significantly lower weights. The reason for lower growth in *A. nilotica* group was due to high amount of anti-nutritional factors in the fruits. In a second experiment by Sikosana *et al*. (2002a) similar browse fruits were offered to determine the intake of indigenous castrated Matebele goats. Goats which received *D. cinerea* had higher intake of 844 g/day and *A. nilotica* with lowest of 491g/day than in other groups.

In a study by Maphosa *et al*. (2009), lactating Matebele does were supplemented with *Dichrostachys cinerea* pods containing 19 % CP. The result indicated that kids from supplemented and not milked (SNM) group had higher ADG (103 g/day) than kids from not supplemented and milked (NSM) (85 g/day) and supplemented and milked (SM) (74 g/day) groups. Weaning weight of kids from SNM was higher (12.8 kg) than NSM (11.2 kg) and SM (10.2 kg) group.

In contrast, does from SM group produced more milk yield of 308 ml/day than SNM (273 ml/day) group. In another study in Kenya by Lengarite *et al*. (2014) whole and milled *Acacia tortilis* pods were fed to lactating goats. The authors reported intake of 186 and 413 g/day and milk yield of 300 g/day and 349 g/day respectively.

Table 2.4 Example of intake, growth and milk yield of goats supplemented with browse in different studies

Goat type	Browse species	Plant part & Amount offered	Intake (g DM/day)	Gain (g/day)	Milk yield (ml/day)	Author
Abergelle growing males	*D.cinerea*	Pods at 0.5%	84.6/ $BW^{0.75}$	10.0	Not applicable	Yayneshet *et al.*, 2008
	D.cinerea	Pods at 0.1%	83.8 $BW^{0.75}$	15.8		
	D.cinerea	Pods at 1.5%	94.3 $BW^{0.75}$	21.7		
Indigenous castrated Matabele goats		All pods 200g/day	Exp.1	Exp.2	Not applicable	Sikosana *et al.*, 2002a
	A.erioloba		731	-3.3		
	A.erubescens		669	-1.9		
	D.cinerea		844	4.8		
	A.nilotica		491	-27		
	A.tortilis		-	13.3		
Matebele Lactating does and kids	*D.cinerea*	Pods 200g/day	SM	74	308	Maphosa *et al.*, 2009
			SNM	103	-	
			NSM	85	273	
Small East Africa goats	*A.tortilis*	Pods 200 g/day	882 - 95	82 - 87	300-349	Lengarite *et al.*, 2014
Xhosa Lop-eared goats	*A. karoo*	Fresh leaves 200g/day	Not determined	105 versus 43	Not applicable	Ngambu *et al.*, 2013

Legend: SM= supplemented and milked; SNM= supplemented and not milked; NSM= not supplemented and milked

In a study by Ngambu *et al*. (2013) supplementation *Acacia karoo* fresh leaves on growth, ultimate pH, colour and cooking losses of meat from indigenous Xhosa lop-eared goats. Supplemented castrated kids had higher growth rate of 105 versus 43 g/day and meat quality than the non-supplemented goats.

2.9 Factors affecting milk yield and composition

Different breeds have different yield potential which is classified as dairy or non-dairy. Saanen, Alpine, Toggenberg, Anglo-Nubian are all examples of dairy breeds. Breed type and genetic factor is the most important factor affecting milk yield in goats (Akinsoyinu *et al.*, 1977; Steele, 1996). The exotic dairy goat such as Saanen, genetically, has potential to produce over 5 litres of milk per day. Indigenous goats such as those found in communal areas of southern Africa, do produce only 0.25 litres (Kindness *et al*., 1999; Sikosana, 2002b; Greyling *et al*., 2004). Indigenous goats are not generally used for dairy purposes, and their milk production has not been accurately estimated (Greyling *et al*., 2004). Indigenous goats have strong genetic maternal instinct resulting in unwillingness to let-down the milk, and instead holding it back for the kid. In goats, the number of kids at parturition has been found to be a relevant factor for variation of milk yield. Carnicella *et al. (*2008) reported that goats kidded twins yielded more milk than those with single kids. Studies have observed an increase in early stage of lactation and gradually decline with advance in lactation. Also, milk production increases with advancement in the age of the animal. The effect of parity on milk yield has been reported (Carnicella *et al.*, 2008). Goats in their third and fourth lactation yielded 302 kg compared with 257.8 kg and 276.4 kg in goats in their first and second parity respectively. Kidding season affects milk yield due to changes in temperature. Hot or humid months of the year affect the intake patterns on the animal, which tended to be lower in summer months, and increase in cooler months of winter.

According to FAO (2002), goat milk comprises a concentration of water (87 %), fat (3.5 %), protein (4.6 %), lactose (4.5 %), solid non-fat (14 %) and minerals (0.7-0.85 %). A major factor which influences milk fat and protein concentration is milk yield. Genetic and phenotypic correlations between milk yield and fat and protein concentrations are negative (Pulina *et al*., 2008). However, other non-genetic factors such as feeding determines the amount of fat and protein in milk, and hence the yield of cheese (Fekadu *et al*., 2005). Fat content is the most sensitive to nutritional changes of the animals as compared to other milk components. Fat and protein content are less affected by parity, however, high amount of both parameters in milk is found during early lactation just after calving. According to the results obtained from a study conducted in South Africa at Medunsa, the milk content of indigenous goats showed higher percentage of fat (9.33), protein (5.04) and lactose (5.21) than the exotic Saanen and crossbreed goats (Donkin, 1997). The age of the animal also influence the fat and protein concentration, both declines as the animal become older. As the animal ages, fat drop with 0.2 % in each year of lactation and protein decreases from 0.02 to 0.05 % (Pulina *et al.*, 2008). Mastitis infections reduce fat and casein but increase blood protein content and somatic cell count in milk. However, the infection is not common in indigenous lactating goats as they are not heavy milkers as compared to dairy breeds.

2.9.1 Milk mineral content

Forages generally do not contain sufficient minerals to meet dietary requirements, so supplements are usually required (Pulina *et al*., 2008). Mineral mixes of salt with calcium, phosphorus, and trace minerals are typically used. Calcium (Ca) and Phosphorus (P) are very important in milk production of goats. In goats, Ca and P requirement are high and substantial for growing kids than in adult animals. The concentration of Ca (1.3g/L) and P (0.9g/L) are similar to those of cow's milk (Pulina *et al*., 2008) however; the concentration differs with stage of lactation.

2.10 Estimation of milk yield in goats

Methods to estimate milk yield includes the voluntary feed intake weigh-suckle-weigh technique, hand milking and the use of oxytocin to stimulate milk-let-down (. In extensive farming system of browsing goats, milk of the first month of lactation is usually suckled by the kid. Milk from early lactation is measured by partial milking thus after the kid has suckled and in many instance quantities of milk data from this phase is scarce. This situation lead to unexpected out comes such as the estimation of curves without lactation peak. Milk yield can be estimated from the average daily gain of the kid or direct method of feed intake directly through live weight differences (Wahome *et al*., 1994). The accuracy of measure is strongly dependent on the precision of the scale and of the weight loss related to the faeces and urine excretion during the period of measure

2.11 Dairy products from goat milk

Fermented dairy products have been used for many years and have played an important part in human diet. Yogurt is one of the popular fermented milk products having different names and forms (Tamime and Robinson, 2007). It is manufactured with starter culture of lactic acid-producing bacteria, *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. Different sources of milk differ in composition, which after fermentation provide different types of yogurt with different consistencies (Routray and Mishra, 2011).

Sheep and goat milk have been used to prepare yogurt during different studies. Pure goat milk was found to be unsuitable for the production of yogurt as this milk is low in solids and the yogurt produced had "the lowest firmness and significantly inferior organoleptic characteristics" compared to others (Routray and Mishra, 2011).

2.11.1 Effect of diet on sensory characteristics of dairy products

Goat milk is sought for its perceived number of health benefit and unique taste. However, a number of health claims have no scientific evidence (Tripathi, 2015). A study by Tripathi (2015) indicated that goat diet improves the quality of milk through increased anti-oxidant activity with potential therapeutic benefits of anti-carcinogenic and anti-viral properties. Increased demand of goat milk consumption was driven by the small size fat globules in comparison to those in cow milk. In both species, fat globules ranges from 1 to 10µm. Goat milk is less allergic, highly digestible and has more CLAs, ratio of Omega 3 and 6 fatty acids that prevent cardio vascular diseases in human (Tripathi, 2015).

Milk colour is attributed to a combination of many compounds such as casein, carotenoids and fat globules. The concentration of these compounds in milk is related to breed, parity, physiological stage and many more. However, nutrition also plays a very important part, especially for milk fat content and the carotenoids, which can affect the colour. Casein and fat are regarded as giving a white colour to milk, while carotenoids give a yellowish shade. Donkin (1997) indicated that carotenoid pigment are lacking (goat milk is white), as is the agglutinating agent that causes the cream line in standing cow milk.

Flavour is the sensory impression (smell and taste combined) that can be attributed to all substances present in food and feed of plants (herbs, forage, grains) or animal origin (milk) and that can be pleasant or unpleasant to the consumer (Fedele *et al.*, 2005). Studies had shown that, what was perceived by the senses, by smelling or tasting milk, was direct or indirectly linked to what the animal ate (Fedele *et al*., 2005). This is true in cow milk which may taste "garlicky" after eating certain grasses (Silanikove *et al.*, 2010). However, cows are usually under strict management as to what and when they eat. Goats survive predominantly on woody plants where some plants predominate over the others, depending on the environment, season and geographical location (*Fedele et al*., 2007). Woody plants contain aromatic substances such as ketones, alcohols and terpenes (Pulina *et al*., 2008). When these compounds volatilize and through breath-in air, or are freed after a partial digestion of the feed and through belched gases, they reach the lungs where they are absorbed into the blood, and then transferred to the milk. The conversion of these compounds from feed to milk is fast and their effects on flavour is more pronounced on browsing goats than goats feeding on commercial feed (Silanikove *et al*., 2010). The higher content of chloride than is common in cow milk can result in goat milk having a slightly salty flavour. Usually this is not a problem and consumers may find it preferable (Haenlein, 2004).

Woody plants form a major source of goat diet in semi-arid and arid condition and they contain high amount of secondary compounds such as tannins. Indigenous goats in rural areas are able to consume as much as 10g/day of hydrolysable tannins and 100-150g/day of condensed without any indication of toxicity (Silanikove *et al*., 1996). Unlike sheep and cattle which are known as grazers, goats have adapted in their feeding behaviour allowing them to consume plants containing aromatic or flavour compounds (thyme and mint) that can impart the smell or flavour to the milk or milk products (Silanikove *et al*., 2010). However, all plants contain aromatic substances, even though only some of them supply flavours that can be easily perceived by human senses. A study by Silanikove *et al.* (2010) indicated that the physical, chemical and organoleptic features of milk and other dairy products were most affected by goat's diet. Compounds that are known to accumulate in milk content were monoterpenes and identified to affect aroma of milk. In another study, milk terpenes were used as biochemical indicator of the composition of forage consumed by animal hence farm origin of the dairy product (Pulina *et al*., 2008). Sesquiterpene have also been detected in the milk cheese (Fedele *et al.*, 2005). An old study by Henke (1958) reported that limitation of feeding *Leucaena* to dairy cows is that it has been reported to produce a taint in milk (which is not removed by pasteurisation) (Stobbs and Fraser, 1971), but contrasted the finding of

Hamilton *et al.* (1969) who found that the taint could be removed by pasteurisation**.** However, this study did not intend to detect terpenes in milk and this concept will not be referred to again in any other section.

2.12 Inference from literature

Woody plant species cited in the literature are important fodder for livestock, but if densely populated tended to cause bush encroachment problems in Namibia. This includes; *Acacia mellifera, Dichrostachys cinerea, Terminalia sericea, Terminalia sericea, Colophospermum mopane* and *Rhigozum trichotomum* in the southern part of the country. Woody plant species contribute substantially to the nutrition of livestock, even though increasing number of bush densities resulted in loss of land productivity and reduced carrying capacity. However, animals heavily depend on these browses as source of fodder especially during the dry season; therefore, complete removal should not be considered. Past and current studies provided a lot of evidence on woody browse as an alternative feed resource for livestock, locally available and inexpensive and good source of protein that do not compete with human food.

Nutritional value of woody species have been estimated from one browse to another, their leaves, fruits or pods using different method including *in vivo* and *in vitro*. However, due to the high cost and time involved in conducting *in vivo* trials, *in vitro* studies have been adopted in the feed evaluation of nutritive values especially when dealing with large numbers of feedstuff. Studies have indicated positive relationship between indigenous knowledge information, chemical composition and gas production and can thus predict accurately the feeding value of browse.

Nutritive value of woody plants depends on several factors viz. type of browse, chemical content, stage of maturity or season, climatic condition and nutrients in the soil. Crude protein content in fruits and pods tended to be high than other part of the plant, however feeding value are low when the fibre and lignin content are high Tannin content also tended to be high in unripe fruits and young leaves. Certain woody browses maintain sufficient nutritional level during critical times of the year, and pods are formed and mostly available in dry season. Soil nutrient influence the chemical content of the browse indirectly especially in minerals thus mineral supplementation is required on browsing animals.

Studies which had embarked on browse as feed supplements reported beneficial nutritional effects including increased growth in young animals, improved milk production and meat quality and fatty acid composition, improved fibre and wool quality, minimized internal parasitic load in small ruminants and reduced methane and ammonia emissions. However, woody browse tended to contain varying amount of anti-nutritive factors, such that if animals consume large quantities of tannin rich feeds may cause toxicity. Browse processing techniques such as sun-drying, soaking in aqueous solution of wood ash and the use of tannin-binding agents such as polyethylene glycol have been shown to be effective, however, their adoption in subsistence farming could be constrained with availability and affordability. Therefore, appropriate feeding strategies have to be designed based on the nutritional evaluation of the woody browse.

Positive responses have been reported in some meat quality attributes such as colour, tenderness and juiciness. However, little work devoted to the effect of browse pods on milkoff flavour, and odours by trial participants or consumers has not been sufficiently documented.

CHAPTER THREE: EXPERIMENT 1

3. Indigenous knowledge and identification of alternative local feed resources as potential feeds for goats in the communal farming areas of Namibia

3.1 INTRODUCTION

Namibia has a diverse vegetation of woody plants and shrubs which form part of the diet of grazing livestock on natural rangelands. The study focused on communal area of Namibia, which is dominated by subsistence mixed crop-livestock farming system (Marius *et al*, 2012). Livestock rearing is considered as a major source of income for the majority of resource-poor farmers in the area. In most developing countries in Africa, research has shown that, sustainable production of livestock usually involves efficient utilization of locally available resources, predominantly feed and medicines (Chepape *et al*., 2011). Similarly, most people living in the rural areas, especially the low income groups, rear livestock on diets consisting of high quantities of indigenous plants. Communal farmers rely on their visual observations and experiences in feeding and health management of livestock (Kavana and Msangi, 2005) and ethnobotany or traditional healers (Cheikhyoussef *et al*., 2011) in the use of indigenous plants. However, the low quality and quantity of available forages during the dry season are major constraints for improved livestock production in these areas. Like in many rural areas of Namibia, the available grazing is not generally sufficient to meet the maintenance requirements of grazing animals (Katjiua and Ward, 2006) during the dry season.

Woody plant species form a major source of animal feeds in Africa, and are highly valued by rural and peri-urban communities. These woody plants have multiple roles in helping the people to meet their basic needs such as feed, fire wood, timber and building materials, wood carving and as human and veterinary medicines (Mannheimer and Curtis, 2009).

Woody plants contain appreciable amounts of nutrients that are deficient in other feed resources such as grasses during dry period of the year. Fodder trees and shrubs have deep root systems enabling the extraction of water and nutrients from deep down in the soil profile. Most browse plants have high crude protein, ranging from 10 to more than 25 % on a dry matter basis (Moleele, 1998; Aganga and Mesho, 2008). The reliable amount of protein in the browse resource can be used to develop a sustainable feeding system and increase livestock productivity.

Different communities have their own knowledge about plants and their uses. Farmers have an impressive knowledge of browse species **(**Komwihangilo *et al*., 2001). Involving farmers in the process of data collection is important because as potential users of new technologies to be developed, their knowledge and preferences are critical (Haugerud and Collinson, 1990). However, some of the knowledge is likely to be distorted or lost completely if transfer is not done continuously from one generation to another. The study was conducted to describe indigenous knowledge and identify feed resource available in six constituencies of Namibia. Furthermore, the study assessed gender, age, the level of education of farmers, utilization of the woody species as animal feeds, ethno-veterinary knowledge and number of livestock species available.

3.2 MATERIALS AND METHOD: EXPERIMENT 1

3.2.1 Location of the study area

Namibia structure is made up of 14 regions, district, town, and constituency under which is cascaded many villages and settlements. A settlement is a place occupied by people, which may further develop into a small town. A constituency consists of different villages, which are further subdivided into many households, each representing a family unit. There are currently 121 constituencies in Namibia, the number and size of each constituency varies with the size and population of each area. This study focused only on six constituencies mainly; Omatako, Guinas, Daurês, Tsandi, Gibeon and Kongola situated in communal farming areas of Namibia. In Gibeon and Kongola, the constituency structure is defined into households and no distinct villages per se.

Table 3.1 shows the description of the study constituencies. There is diversity of farming systems in Namibia, due to different amount of rainfall received and hence vegetation type in each Region. The mean temperature ranged between 3 – 36 ºC. Otjozondjupa Region is characterized by Thorn bush savanna with mean rainfall that ranged between 266- 505 mm and therefore limited to livestock farming. Oshikoto Region, the mean rainfall is slightly higher (550-660 mm) defined with mixed trees and shrubs suitable for mixed crop and livestock farming. Hardap Region in the southern part of the country is dominated by Dwarf shrub savanna, suitable for sheep and goats farming. Zambezi region tended to have the highest rainfall in the country, and is described by Forest savanna and woodland with mixed crop-livestock farming system (Mendelson, 2006; Sweet and Burke, 2006; Jürgens *et al*., 2010; Marius *et al*., 2012).

Table 3.1 The description of the study locations

Region	Constituency	Settlement/Village	Geographical coordinates	Mean annual rainfall	Mean temperature	Vegetation type	Main agricultural activity
Otjozondjupa	Omatako	Ovitoto	21.97733S 17.21905 E	266-505mm	3°-36° C	Thorn bush savanna	Livestock farming only
Oshikoto	Guinas	Oshivelo	18.57014 S 17.20885 E	550-660mm	3°-40° C	Woody plants and shrubs	Mixed crop and livestock farming
Omusati	Tsandi	Omakange	18.14556 S 14.29066 E	270-300mm	10°-30° C or above	Mopane savanna	Livestock and limited crop production
Erongo	Dâures	Omatjette	21.05431 S 15.50664 E	100-350mm	3°-36° C	Semi-desert and savanna horizon	Livestock farming only
Hardap	Gibeon	Gibeon	25.12689 S 17.77933 E	100-300mm	1°-36° C	Dwarf shrub savanna	Livestock (Small-stock) farming
Zambezi	Kongola	Kongola	17.82136 S 23.39718 E	500-900mm	10°-36° C or above	Forest savanna and woodland	Mixed crop and livestock farming

Source: Mendelson, 2006; Sweet and Burke, 2006; Jürgens *et al.*, 2010; Marius *et al.*, 2012

3.2.2 Survey sampling strategy

The target population of the study was defined as consisting primarily of livestock keepers in Omatako, Guinas, Tsandi, Daurês, Gibeon and Kongola constituencies. Households were randomly selected using purposive sampling strategy. Figure 3.1 shows Map of Africa showing Namibia in red and Figure 3.2, the Map of Namibia showing the survey way-points in each constituency. Geographical point system (GPS) point-reading was used to identify and mark the centre and evenly spaced the points in the village at distance of5-15 Kilometres apart. Households without livestock species were not interviewed.

3.2.3 Source of plant samples and questionnaire administration

A structured questionnaire (AP1 Questionnaire used for survey) was used to interview face to face with farmers in the local language spoken in each of the study locations (Plate 3.1b). A sample of sixty households (10 per location) was obtained for the identification of local feed resources. Plant samples were collected from Omatako, Guinas, Tsandi, Daures, Gibeon and Kongola constituencies.

Samples of leaves and pods or fruits were collected in January, May and September 2014.

3.2.4 Statistical analysis

Data analysis was performed using Statistical Package for Social Sciences (SPSS, 2013) Version 21 software and descriptive statistics (percentage or proportions and frequencies) were presented.

Figure 3.1Map of Africa showing Namibia in red (Wikimedia, 2015)

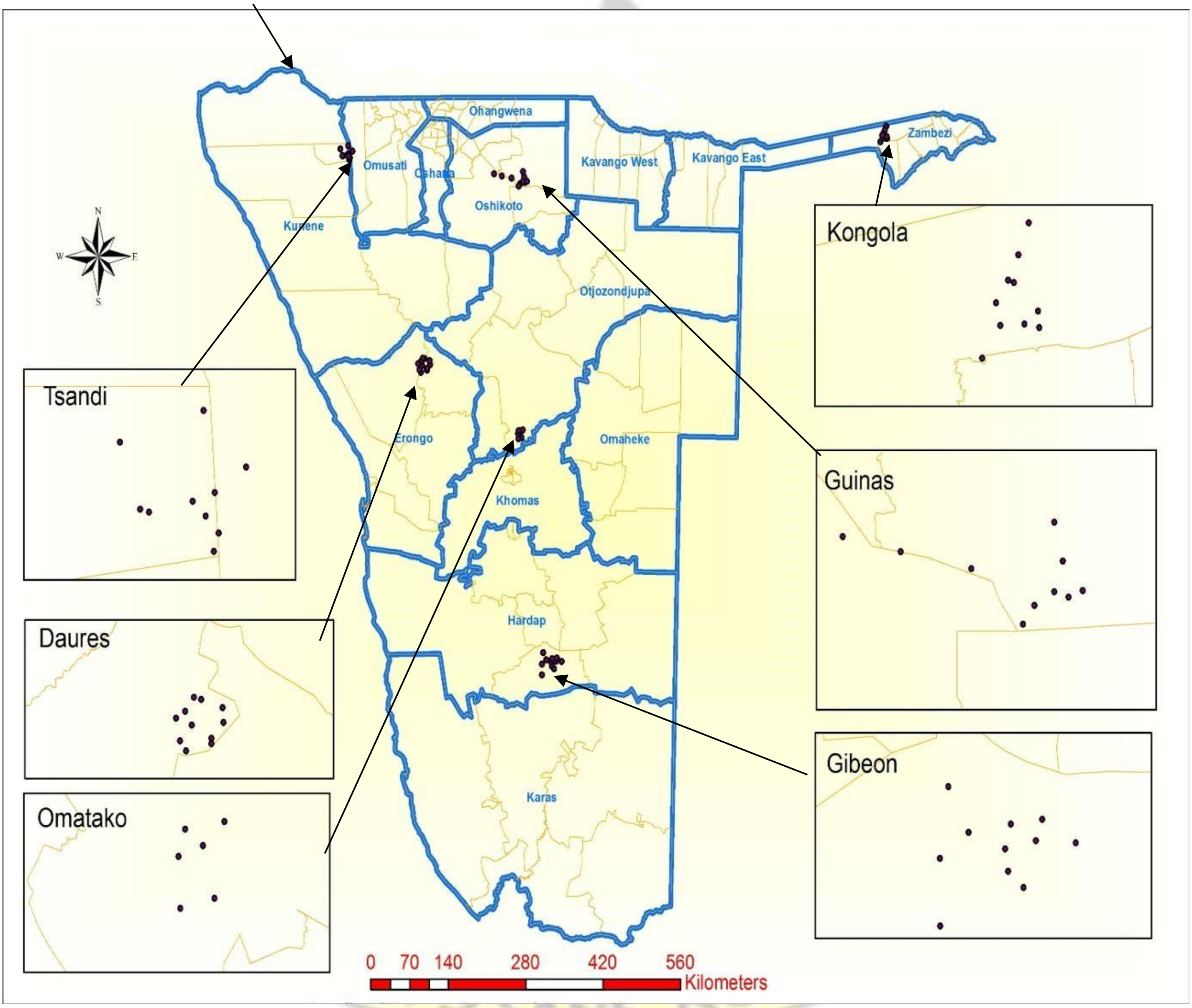

Figure 3.2 Map of Namibia showing constituencies and distribution of the survey way-points around each location on a radius of 5 to 15 kilometres distance apart

Plate 3.1 Researchers collecting plant samples in Daures and Kongola constituencies (a), conducting an interview with a farmer in Gibeon (b), and a farmer assisting in shrub identification in Guinas (c)

3.3 RESULTS: EXPERIMENT 1

3.3.1 Overview

There was no difficulty encountered during survey, An Agricultural Extension Officer in each constituency introduced the researcher to the farmers. The questionnaire was administered in six constituencies in January 2014.

3.3.2 Socio-demographic description of the respondents

Table 3.2 shows gender, age and level of education of the respondents per study location. A total of 60 livestock keepers and herders with profound knowledge on plant species browsed were interviewed, of which 73 % were males and 27 % females.

Table 3.2 Gender, age and level of education of the respondents per study location

	Location(Constituency)						
	Omatako	Guinas	Tsandi	Daurês	Gibeon	Kongola	Total
Respondent	10	10	10	10	10	10	60
Gender							
Female	4(40)	2(20)	4(40)	2(20)	2(20)	2(20)	16(27)
Male	6(60)	8(80)	6(60)	8(80)	8(80)	8(20)	44(73)
Age							
21-40	1(10)	3(30)	5(50)	1(10)	1(10)	2(20)	13(22)
41-60	5(50)	5(50)	5(50)	4(40)	4(40)	3(30)	26(43)
>60	4(40)	2(20)	0(0)	5(50)	5(50)	5(50)	21(20)
Level of education							
Primary	6(60)	6(60)	3(30)	7(70)	4(40)	6(60)	32(53.3)
Secondary	3(30)	2(20)	7(70)	2(20)	5(50)	2(20)	21(35.0)
Tertiary	1(10)	2(20)	0(0)	0(0)	0(0)	2(20)	5(8.3)
No education	0(0)	0(0)	0(0)	1(10)	1(10)	0(0)	2(3.3)

Figures in parenthesis ( ) are in percentage

The largest group consisted of individuals between 41-60 years in all the locations. The majority of the respondents had at least primary education (53.3 %) followed by those with secondary level (35.0 %), tertiary education (8.3 %) and very few with no education (3.3 %).

Table 3.3 below indicates livestock species in the study locations. Livestock provides a livelihood to the majority of the people in communal areas in the study. Among livestock species, cattle, goats and chicken were commonly kept in the study locations. The highest number of cattle (39 %) and goats (31 %) were recorded in Guinas, sheep (77.7 %) in Gibeon, chicken (34.1 %) in Kongola and donkeys (36.7 %) in Daurês. There were no sheep, pigs and donkeys recorded in Kongola, and pigs were not kept in Omatako and Daurês constituencies.

Table 3.3 Livestock species in the study locations

	Location (Constituency)						
	Omatako	Guinas	Tsandi	Daurês	Gibeon	Kongola	Total
Resp.	10	10	10	10	10	10	60
Cattle	303(11)	1033(39)	311(12)	525(20)	118(5)	330(13)	2620
Goats	244(8)	926(31)	590(20)	475(16)	706(24)	9(0.3)	2950
Sheep	126(18.4)	2(0.3)	19(2.8)	5(0.7)	531(77.7)	0	683
Pigs	0	12(75)	1(6.3)	0	3(18.8)	0	16
Chicken	86(13.1)	153(23.3)	70(10.7)	67(10.2)	56(8.5)	224(34.1)	656
Donkeys	7(5.5)	16(12.5)	28(21.9)	47(36.7)	30(23.4)	0	128

Keynote: Figures in parenthesis are in percentage; zero (0) means the species was not listed; Resp = respondent

3.3.3 Utilization, availability and accessibility of local woody plant species

Respondents indicated common or dominant woody species in their locations as shown in Table 3.4. In Omatako constituency, *Combretum apiculatum, Ziziphus mucronata and* fewer *Acacia mellifera and A. erioloba* species were listed by 80, 70, 50 and 30 % respondents respectively. The abundant trees and shrubs indicated by the respondents in Guinas Constituency were namely; *Terminalia sericea* by 90 %. The least was *Terminalia prunioides and Bauhinia petersiana* (10 %). In Tsandi constituency, *Combretum apiculatum* (70 %), *Colophospermum mopane* (50 %), *Catophractes alexandri*, and *Terminalia prunioides* (60 %) were the abundant browse species mentioned by respondents in the study. In Daures constituency, *Acacia karoo* (90 %) and *Catophractes alexandri* (60 %) were the most abundant browse specie in the area mostly browsed by goats. In the southern part of the country (Gibeon), *Acacia mellifera* (50 %), *Rhigozum trichotomum* (90 %) *and Catophractes alexandri* (60 %) were the most dominant browse species, and formed a large part of the small-stock diet. *Baphia massaiensis, Combretum collinum* and *Terminalia sericea* were the abundant trees and shrubs mentioned by the respondents in Kongola constituency.

Table 3.5 shows the responses of respondents with regards, to woody plants available and whether it is a tree or shrub. Respondents also indicated the edible parts of the plants, and the animal species mostly consuming the part. Respondents showed that leaves were the most consumed but pods of some woody species were also consumed. The local name used in the description is related to the language spoken in each constituency were the tree or shrub was found.

Table 3.4 Number of farmers identified woody plants species in the study locations

	Location (Constituency)						
Woody species	Omatako	Guinas	Tsandi	Daurês	Gibeon	Kongola	Total
Respondent	10	10	10	10	10	10	60
Acacia erioloba	3(30)	6(60)	2(20)	4(40)	1(10)	2(20)	18
Acacia hereroensis	-	-	-	1(10)	-	-	1
Acacia karoo	-	-	-	9(90)	3(30)	-	12
Acacia mellifera	5(50)	4(40)	2(20)	4(40)	5(50)	-	20
Baphia massaiensis	-	3(30)	-	-	-	7(70)	10
Bauhinia petersiana	-	1(10)	1(10)	-	-	-	2
Catophractes alexandri	2(20)	-	5(50)	6(60)	6(60)	-	19
Colophospermum mopane	-	-	5(50)	2(20)	-	-	7
Combretum apiculatum	8(80)	2(20)	7(70)	3(30)	1(10)	3(30)	24
Combretum collinum	-	-	-	-	-	8(80)	8
Dichrostachys cinerea	2(20)	5(50)	1(10)	1(10)	-	-	9
Grewia bicolor	-	6(60)	1(10)	-	-	-	7
Philenoptera nelsii	-	6(60)	3(30)	-	-	3(30)	12
Rhigozum trichotomum	-	-	-	-	9(90)	-	9
Terminalia prunioides	1(10)	1(10)	6(60)	3(30)	-	-	11
Terminalia sericea	-	9(90)	2(20)	-	-	5(50)	16
Ziziphus mucronata	7(70)	-	-	5(50)	1(10)	-	13
Total	28	43	35	38	26	28	

Keynote: Values based on multiple responses; figures in parenthesis () are in percentage; dash (-) means the species was not listed.

Table 3.5 Woody plants, their edible parts and animal species identified by farmers in the study locations

Local Name	Common Name	Botanical name	Edible part	Habitat	Animal species
Omwoonde (Osh), muhoto (Loz)	Camel-thorn	*Acacia erioloba*	Pods	Tree	Cattle
Oroo (Otj)	Mountain-thorn	*Acacia hereroensis*	Leaves	Tree	Goats
Orusu (Otj)	Sweet karoo	*Acacia karoo*	Leaves & Pods	Tree	Goats
Okadhilankono (Osh), omusaona (Otj)	Black-thorn acacia	*Acacia mellifera*	Leaves & Pods	Tree/shrub	Goats
Ofufe (Osh), isunde (Loz)	Sand camwood	*Baphia massaiensis*	Early leaves	Shrub	Cattle, goats
Ofufe (Osh),	White bauhinia	*Bauhinia petersiana*	Early leaves	Shrub	Cattle, goats
Okalyadi (Osh), omukaravize (Otj)	Trumpet-thorn	*Catophractes alexandri*	Leaves	Shrub	Goats
Omusati (Osh),	Mopane	*Colophospermum mopane*	Early leaves	Tree/shrub	Cattle, goats
Omumbuti (Otj)	Kudu bush	*Combretum apiculatum*	Leaves	Tree	Cattle, goats
Mutobo (Loz)	Variable combretun	*Combretum collinum*	Leaves	Tree	Cattle, goats
Ongete (Osh), muselesele (Loz)	Sickle bush	*Dichrostachys cinerea*	Leaves & Pods	Tree/shrub	Goats
Omushe (Osh)	Two-coloured raisin-bush	*Grewia bicolor*	Leaves & fruits	Shrub	Goats
Omupanda (Osh), mukololo (Loz)	Kalahari apple-leaf	*Philenoptera nelsii*	Leaves	Tree	Cattle, goats
Driedoring (Afr),	Three-thorn rihigozum	*Rhigozum trichotomum*	Leaves	Dwarf shrub	Goats
Omuhama (Otj)	Purple-pod terminalia	*Terminalia prunioides*	Leaves	Tree/shrub	Cattle, goats
Omugolo (Osh), muhonono (Loz)	Silver terminalia	*Terminalia sericea*	Leaves	Tree/shrub	Cattle
Omukaru (Otj)	Buffalo-thorn	*Ziziphus mucronata*	Leaves & fruits	Tree/shrub	Cattle, goats

Local languages which were used in the study were; Afrikaans (Afr), Otjiherero (Otj), Oshiwambo (Osh) and Lozi (Loz)

With regards to accessibility of leaves and pods, out of 60 respondents from study locations, 47 % indicated that they collected pods to feed their animals during the dry period. Whilst, 53 % respondents indicated that they do not collect pods or cut tree leaves for the purpose of feeding animals.

Farmers assigned various reasons as to why they do not harvest woody plant pods as indicated in Figure 3.3.The respondents were asked to state if they collect pods for animal feeding purpose. Of the 53 % who stated that they do not practice pod collection, 33.3 % of the respondents indicated that they just allow animals to find pods and leaves on their own during grazing. Others (8.3 %) mentioned that it was rather a difficult task to harvest or collect pods, and some do not fall from the tree (6.7 %). The least number of respondent indicated that woody species with pods were scarce around their farming areas (5 %).

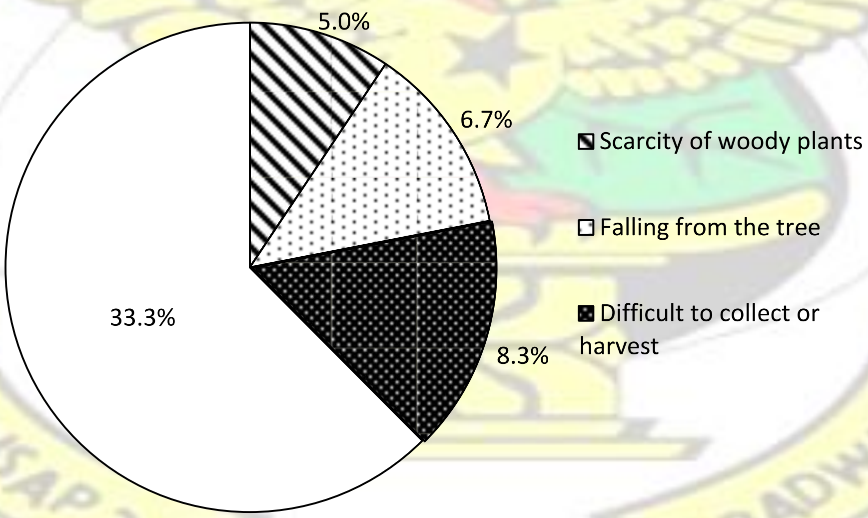

Figure 3.3 Problems indicated by farmers in accessing the woody plant browses

3.3.4 Ethnoveterinary knowledge

Farmers' indigenous knowledge of medicinal properties of woody plant species as outlined in Table 3.6.*Colophospermummopane*, *Ziziphus mucronata*, *Grewia bicolor*, *Acacia erioloba* and *Terminalia sericea* were used to treat the condition of diarrhoea in cattle and goats. *Boscia albitrunca* leaves were used to improve fertility in breeding bulls. Tree or shrub roots were the common plant part used in the treatment of animal diseases.

Table 3.6 Farmers indigenous knowledge of medicinal properties of woody plant species

Item	*Colophospermum* *sericea*	*Ziziphus* *albitrunca*	*Grewia* species and *Acacia mopane* *erioloba*	*Terminalia* *mucronata*	*Boscia*
Part used	Leaves	Leaves and early stems	Roots	Roots	Leaves
Animal Species	Cattle	Adult cattle and calves	Goats and cattle	Cattle	Cattle
Usage form	Leaves are grounded, mixed with water and given to the animal orally	Leaves and stems are grounded, added to boiling water, cooled, before it is given to the animal orally.	Grounded roots are soaked in warm water, cooled and given to the animal orally.	Roots are boiled and give the animal in 1 litre or ½ to young ones.	Roots are grounded, mixed with water and given to the animal orally
Nature of disease/ condition	Diarrhoea	Diarrhoea and retained placenta in cows	Diarrhoea	Diarrhoea	Boost libido in bulls

3.4 DISCUSSION: EXPERIMENT 1

Experiment 1 was designed to describe indigenous knowledge on woody plants species to support identification of local browse utilized by communal ruminants.

3.4.1 Socio-demographic description of the respondents

There were more male respondents than females interviewed. This could be attributed to the fact that more households were headed by males and in their absence; the respondents were predominantly male herders. The majority of the respondents were aged between 41 and 60. Komwihangilo *et al.* (2001) and Chepape *et al*. (2011) reported similar gender, age group, and that pensioners (older people) were readily available and had profound knowledge on plant species browsed by animals. Most respondents in this study had at least primary and secondary education, in contrast of Chepape *et al*. (2011) who reported more illiterate respondents. This observation implies that educated individuals are more likely to adopt the new feeding strategy generated by the study.

3.4.2 Utilization of woody plant species

Respondents identified the trees and shrubs they have listed and the researcher's opinion was very important as some local browse names were based on genus only and not specific to the species name. As per information obtained in the survey, several species were limited to certain constituencies. *Combretum apiculatum, Ziziphus mucronata and Acacia erioloba* and fewer *Acacia mellifera* species were indicated in Omatako. The abundant trees and shrubs indicated by the respondents in Guinas Constituency were namely; *Philenoptera nelsii*, *Acacia erioloba, Dichrostachys cinerea*, *Grewia bicolor* and *Terminalia sericea*. In Daures constituency, *Acacia karoo* and *Catophractes alexandri* were the most abundant browse specie in the area mostly browsed by goats. In the southern part of the country (Gibeon), *Acacia mellifera,* *Rhigozum trichotomum and Catophractes alexandri* were the most dominant browse species and formed a large part of the small-stock diet. The woody species found in Daures and Gibeon was in agreement with the information published by Mendelsohn (2006). In Tsandi constituency, *Colophospermum mopane, Catophractes alexandri*, *Combretum apiculatum* and *Terminalia prunioides* were the predominant woody species mentioned by the respondents in the study. *Baphia massaiensis*, *Combretum collinum* and *Terminalia sericea* were the abundant trees and shrubs mentioned by the respondents in Kongola.

3.4.3 Livestock species reported by respondents

The predominant livestock species reported in the study was cattle and goats with the highest number in Guinas. The reason could be that, cattle and goats were mostly found in Guinas. Guinas constituency is located in Oshikoto Region where cattle and goat numbers were higher than in other northern Regions namely; Oshana, Omusati and Ohangwena (MAWF, 2014). The average annual rainfall varies from 550-660 mm and the area is characterized by bush shrubs suitable for goat farming (Table 3.1), however, very few sheep were listed as these were mostly found in the southern part of the country. The largest number of sheep was reported in Gibeon under Hardap Regions. This is the southern part of the country, dominated by dwarf shrubs savanna that is associated with low rainfall, however, suitable for both goat and sheep farming. Sheep, donkeys and pigs are not kept in Kongola and pigs were also not cited in Daurês and Omatako constituency. The result is in agreement with those reported by Mendelsohn (2006) who did not found similar livestock species in Kongola. The reason for this could be attributed to the culture, tradition and religious of the farmers in each study constituency.

3.4.4 Availability and accessibility of trees and shrubs

The proportion of respondents (47 %) indicated to harvest pods and leaves for animal feeding was lower compared to those who do not practice it at all. The results were in agreement with those reported by Komwihangilo *et al.* (1995) in Central Tanzania, where farmers harvested pods and stored them in homes for the purpose of feeding calves and sick animals which could not walk long distances in search of water and feed during the dry season. The same results were also found by Kindness *et al*. (1999) who indicated that livestock owners harvested and stored pods for dry season feeding.

Figure 3.3 show the farmers problems in accessing the woody plant pods. In this survey, more respondents (53 %) did not harvest pods even if available, but could be useful feed resources for their livestock. Respondents assigned various reasons as to why they do not harvest woody plant pods. Some indicated that, woody pods do not easily dropped-off from the tree and difficult to harvest. Animals were allowed to find woody plant pods on their own during grazing/browsing, regardless whether they were accessible or not. In South Africa, Chepape *et al*. (2011) reported farmers that complained that browse harvest was somehow time consuming and laborious. Some respondents indicated that woody plant with pods were rather scarce in their farming surroundings. The author agreed that this situation could be true in Gibeon constituency, as it is dominated by dwarf shrubs mainl*y* of *R. trichotomum* though highly favoured by goats, it does not bear fruit or pods. The small stocks browse substantially on shrubs and can thrive in areas where cattle could only be farmed at very low stocking rates (Mendelsohn, 2006).

3.4.5 Ethnoveterinary knowledge

The result indicated that farmers used woody species to remedy different animal diseases and disorders. Tree leaves and roots of *Colophospermum mopane, Ziziphus mucronata, Grewia bicolor*, *Acacia erioloba* and *Terminalia sericea* were dried, grounded in to powder, mixed with water and the solution was offered to the sick animal. In addition, farmers in all constituencies indicated the value of *Aloe* plants as it was used to treat all general livestock diseases. However, the *Aloe* plant was not included in the list of woody species because is a herb and not consumed by animals. The observation is in agreement with Mannheimer and Curtis(2009); Matlebyane *et al*. (2010); Chepape *et al*. (2011) who reported various multiple roles of woody plants including for veterinary medicines. More research is required to investigate the ethnoveterinary knowledge of the woody plants.

3.5 CONCLUSIONS

Respondents were knowledgeable of most common woody plant utilized by livestock and that this could add value to feeding practices during dry period. It is important for researchers to include indigenous knowledge on plant species studies for easier identification of woody plants that existed in the constituencies, the type of livestock utilizing the plant and their various uses on medicinal purposes. However, it might be useful to verify these claims about the veterinary medical potential of woody plants and herbs. Furthermore, there is the need to integrate chemical and nutritive value of the pods as discussed in the following chapter (Experiment 2).

CHAPTER FOUR: EXPERIMENT 2

4. Chemical composition and *in-vitro* gas production characteristics of woody plant leaves and pods of Namibia during wet and dry seasons

4.1 INTRODUCTION

Samples of woody plant leaves and pods were collected during the survey (Chapter 3), their chemical composition and *in vitro* gas production is discussed in this chapter.

Woody plant browse is an important feed resource during the dry season in Southern Africa, when grass biomass and quality is low (Ndlovu and Nherera, 1997). There has been limited animal feeding trials conducted with woody plant browse in Southern Africa (Smith *et al*., 2005b), because of the efforts, cost involved and the difficulty in collecting sufficient quantities of potential browse species. Many studies on nutritive value of woody species have been limited to chemical composition regardless of past recommendations (Le Houerou, 1980) that priority research should be given to intake and digestibility studies.

Several browse species have been evaluated as alternative feed resources as protein supplement during dry season (Ndlovu and Nherera, 1997; Tefera *et al*., 2008; Sebata *et al*., 2011). Tree and shrub species that produce both leaves and pods thus contribute substantially to the diets of livestock (Sikosana *et al*., 2002b). Woody plant browse are reported to be of good nutritive value ranging between 100- 280 g/kg of CP and low to medium content of NDF from 110- 646 g/kg contents (Sibanda and Ndlovu, 1993). While these woody plants provide feed for the livestock, they are reputed to contain anti-nutritional factors which have varied animal response when ingested (Mueller-Harvey, 2006). Larbi *et al. (*1998) reported data on nutritive value and the seasonal variation in quality in West Africa.

The *in-vitro* gas production (Menke and Steingass, 1988) method has been used to evaluate forages because the fermentation kinetics allow for an evaluation of distinct phases of gas production and soluble and insoluble fractions of the forage can be evaluated separately (Makkar, 2003). The *in vitro* gas production technique is a relatively simple method for evaluating feeds, and was developed to predict fermentation of ruminant feedstuffs (Getachew *et al*., 2004). The method is quick and less expensive means of determining the nutritive value of feeds for ruminants (Babayemi *et al*., 2009).

This study set to evaluate the chemical composition mainly; DM, CP, NDF, ADF, water soluble tannins and *in vitro* gas production on 17 indigenous woody species as affected by location and season. The 17 woody species has been identified in the survey (Chapter 3) and needed further assessment as to their potential as feed supplements for livestock during the dry period in Namibia. In addition, the study determined the relationships between chemical composition and gas production characteristics of the woody leaves and pods.

4.2 MATERIALS AND METHOD: EXPERIMENT 2

4.2.1 Location of the experiment

Chemical composition was conducted at the Directorate of Agricultural Research and Development Laboratory, Ministry of Agriculture, Water and Forestry (MAWF), Windhoek, Namibia.

The *in vitro* gas production was conducted at Department of Animal Science Forage Laboratory, University for Development Studies, Nyankpala Campus, Tamale, Ghana.

4.2.2 Source of forages samples

All forages were harvested from Daurês, Gibeon, Guinas, Kongola, Omatako and Tsandi constituencies of Namibia. These constituencies have been identified in Chapter 3. The constituencies are located at different altitudes above sea level since they are spread throughout the country. The annual rainfall ranges from 100 mm in the south and west part to 900 mm north-eastern part of the country. The average temperature ranges from 3 °C in winter to 36 °C or above in hot summer (Table 3.1). Forages were harvested in three phases, following the seasonal vegetation changes; January (wet season), May (early dry season) and September (late dry season), when ruminants were assumed to browse them.

Woody plant leaves and pods collected for chemical and *in-vitro* gas production were used in this study mainly; *Acacia erioloba, Acacia mellifera, Acacia karoo, Acacia hereroensis, Dichrostachys cinerea, Grewia bicolor, Combretum apiculatum, Combretum collinum, Philenoptera nelsii, Terminalia prunioides, Terminalia sericea, Colophospermum mopane, Baphia massaiensis, Bauhinia petersiana, Catophractes alexandri, Rhigozum trichotomum, and Ziziphus mucronata.*

4.2.3 Sample collection and preparation

Leaves or pods of the same species were collected from different trees and shrubs by hand, mixed in one khaki paper bag and a sample was then drawn from it. Samples were allowed to dry under a well ventilated room and further oven-dried at 60-70 °C for 12 hours. Individual samples were grounded to pass through 1mm sieve. About 500 g sample weight of each was stored in air-tight plastic container for subsequent analyses.

4.2.4 Experimental design

Chemical analysis and *in vitro gas* production was performed on 77 plant samples obtained from 6 study locations over three seasons. The main factors were woody species (17); month (January, May and September); plant part (pods and leaves) and study locations (6). There were 5 runs of 48 hours of fermentation with 77 units in each.

4.2.5 Chemical analysis of the feed

Individual leave and pods samples were collected and prepared as outlined in section 4.2.3.

Dry matter (DM) content of the browse was determined by placing the sample in the oven at 105° C for 5 hours (AOAC, 2007). Total ash was obtained by igniting the samples in a muffle furnace at 550° C for 4 hours and the remaining residue was ash. Organic Matter (OM) was calculated by the difference of DM and Ash values. Total Nitrogen (N) was determined by Kjeldahl method and crude protein was obtained by calculating N x factor 6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) was determined as described by van Soest *et al*. (1991). Water soluble tannins was extracted from fat free samples in 70 % aqueous acetone extraction followed by colorimetric determination using Folin and Ciocalteau phenol reagent method. Calcium (Ca), Phosphorus (P) and Selenium (Se) was detected using flame emission spectrophotometry (AOAC, 2007).

4.2.6 In vitro gas production

4.2.6.1 Source of inoculum

Rumen digesta was obtained from the two male West African Shorthorn cattle from the slaughter house abattoir in Tamale, Ghana. The rumen digesta was collected early morning after the animal was starved for 12 hours before slaughter. During carcass opening, the digesta was immediately collected into a flask and transported to the laboratory at distance of 20 Kilometres.

4.2.6.2 In vitro incubation in digestive bottles and gas measurements

Samples were incubated *in vitro* with rumen fluid in calibrated glass syringes following the procedure of Menke and Steingass (1988) and Theodorou *et al*. (1994). Rumen digesta was squeezed into a beaker through 1mm four layer of cheese cloth, homogenized and kept at 39 ºC in the water bath under continues flushing with CO_2 before use. This was diluted with four litres of buffer solution containing reagent (macro, micro minerals, and buffer and reduction solution). Amount of 0.2g of feed sample in each culture bottle (Plate 4.1c), each mixed with 30ml of solution and placed into a 39 ºC water bath (Plate 4.1d). Gas production data was recorded after 3, 6, 9, 12, 24, 36 and 48 hours of incubation. The culture bottles were gently shaken every 3 hours interval after reading and corrected of blank culture bottle in each run (Plate 4.1a). The digital Manometer Device (Product: HT-1895, China) was used to measure the gas pressure in pounds per square inch (psi) (Plate 4.1b).

Gas volume was estimated by applying Boyle's law (Lopez *et al*., 2007) using the expression:

y (ml) = $V_h/P_a \times P_t$, Where:

y = the volume of gas production recorded in the culture bottle,

V_h = the headspace volume, P_a =

the atmospheric pressure and P_t

= pressure measured at time t.

A compatible spreadsheet program (SigmaPlot, Version 10.0) was used to fit the curves to experimentally derived cumulative gas profiles using the model of France *et al*. (1993). The mean gas volume readings were fitted to the exponential equation suggested by Ørskov and McDonald (1979).

$$y = b\,(1 - e^{-ct})$$

Where; *y*= gas produced at time *t*, *b* = the potential gas production, and *c*= the rate of gas production.

4.2.7 Statistical analysis

Data for DM, OM, Ash, CP, NDF, ADF and Soluble Tannins were analysed to obtain Least Square Means by woody species, season and location using PROC GLM of SAS (1999).

In vitro constants were determined by a curve fitting procedure using Sigma-Plot software Version 10.0. The data obtained from the gas production were subjected PROC mixed procedure of SAS (1999) to calculate Least Square Means estimates and were compared where differences occurred in the analysis. Unless otherwise indicated, significance was declared at ($P < 0.05$).

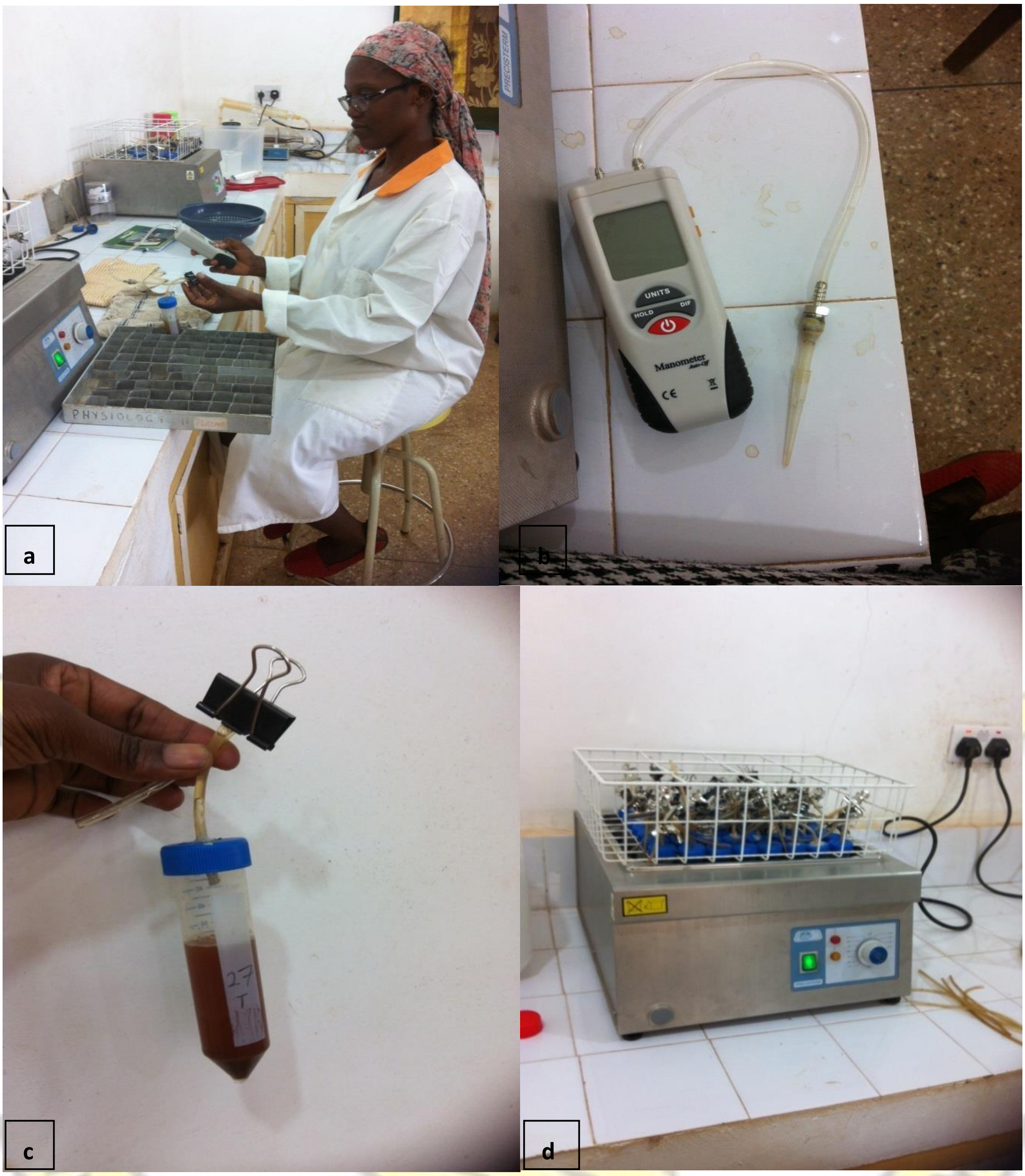

Plate 4.1 A researcher taking gas readings using a Manometer (a) shown in (b), culture bottle fitted with tube and clip (c) and water bath (d)

4.3 RESULTS: EXPERIMENT 2

4.3.1 Overview

Woody plant leaves and pods were collected once in January (wet season), May (early dry season) and September (late dry season) in 2014. Pods samples were obtained from May to September as this was season when they were ripen. Eight species were confined to certain locations and therefore could not be replicated in other study locations. This experiment attempted to measure the CO_2 and CH_4 gas production of woody plants; however, the suction of water in the gas device did not make the results relevant.

4.3.2 Chemical composition of woody plants

The results of chemical composition of leaves and pods of woody plants species are presented in Table 4.1. The results showed that there was a significant difference (P<0.01) in NDF and ST content of woody plants species. The highest mean NDF was noticed in *P. nelsii* leaves (499.9±28.70 g/kg DM) and lowest in *Z. mucronata* leaves (317.9±54.49 g/kg DM). ST concentration was detected most in *D. cinerea* pods at 15.5±3.11 g/100g DM and lowest in *A. karoo* leaves (1.9±3.2 g/100g DM). DM, OM, Ash, CP and ADF content of woody species were not significantly different (P>0.05).

Table 4.2 shows the chemical composition of woody plant species collected by location and season. There was significant differences in DM, OM, NDF and ST content by season (P<0.05). DM content of woody species was higher January (963.9 ±2.43 g/kg) than in September (929.4±2.30 g/kg). Organic matter content was higher in January (901.2±3.79 g/kg DM), and lower in September (872.7±3.59 g/kg DM).

Table 4.1 Chemical composition of leaves and pods of woody plant species

Species	Part	DM g/kg	OM g/kg DM	Ash g/kg DM	CP g/kg DM	NDF g/kg DM	ADF g/kg DM	ST g/100g DM
AE	P	947.3±7.05	893.7±11.03	53.6±8.93	141.4±22.45	400.9±44.1[a]	311.5±59.50	9.3±2.5[b]
AK	P	966.4±12.46	909.4±19.46	56.9±15.77	144.3±38.89	384.5±77.8[b]	233.7±105.05	2.7±4.4[c]
DC	P	960.4±8.64	911.5±13.49	48.8±10.93	161.5±27.48	367.2±54.0[b]	308.2±72.3	15.5±3.1[a]
AH	L	940.6±9.03	873.4±14.11	67.2±11.43	68.6±22.45	366.8±56.4[b]	150.8±76.15	3.0±3.2[c]
AK	L	950.6±9.03	891.4±14.11	59.2±11.43	118.9±22.45	359.6±56.4[b]	178.8±76.15	1.9±3.2[c]
AM	L	944.7±9.03	878.8±14.11	65.9±11.43	118.3±22.45	336.0±56.4[c]	247.7±76.15	0.9±3.2[c]
BM	L	949.3±7.77	907.9±12.14	41.4±9.83	95.4±22.45	422.2±48.5[a]	301.4±65.52	8.1±2.8[b]
BP	L	957.0±5.87	899.1±9.16	57.9±7.42	122.6±19.98	413.2±36.6[a]	352.6±49.46	7.5±2.1[b]
CAX	L	942.6±4.76	880.2±7.44	62.5±6.02	101.0±12.96	400.3±29.7[a]	288.9±40.14	2.9±1.7[c]
CA	L	958.9±5.52	892.4±8.62	66.5±6.99	116.1±18.83	328.2±34.5[c]	240.7±46.55	12.7±1.9[a]
CC	L	955.2±7.77	899.0±12.14	66.2±9.83	80.4±22.45	331.8±48.5[c]	318.6±65.52	9.4±2.8[b]
CM	L	954.2±6.80	894.8±10.62	59.4±8.60	59.6±22.45	361.5±42.5[b]	239.2±57.33	6.5±2.4[b]
DC	L	945.4±7.50	885.9±11.71	59.5±9.48	117.6±22.45	481.3±46.8a	345.7±63.18	6.2±2.7[b]
GB	L	952.8±7.50	885.3±11.71	67.5±9.48	85.6±22.45	486.5±46.8[a]	321.1±63.2	5.1±2.7[c]
PN	L	953.9±4.59	893.1±7.17	60.8±5.81	108.2±12.96	499.9±28.7[a]	370.4±38.70	4.2±1.6[c]
RT	L	933.9±9.03	869.2±14.11	64.2±11.43	82.5±22.45	395.8±56.4[a]	209.5±76.15	2.3±3.2[c]
TP	L	947.5±6.80	874.9±10.62	72.5±8.60	96.1±22.45	348.2±42.5[b]	257.1±57.33	11.2±2.4[a]
TS	L	946.5±4.69	890.8±7.32	55.8±5.93	103.6±13.75	417.9±29.3[a]	392.2±39.52	12.7±1.6[a]
ZM	L	958.1±8.72	871.1±13.62	87.0±11.03	98.2±22.45	317.9±54.4[c]	222.5±73.45	3.9±3.1[c]
Mean		950.8	889.6	61.2	108.1	391.6	278.5	6.6
Sig.		ns	ns	ns	ns	*	ns	**

Legend: DM=Dry Matter; Ash; OM=organic matter; CP=crude protein; NDF= neutral detergent fibre; ADF= acid detergent fibre; ST=soluble tannins; Plant part: P= pods; L=leaves; Mean±s.e;

Species: AE=*Acacia erioloba;* AK=*Acacia karoo;* DC=*Dichrostachys cinerea;* AH=*Acacia hereroensis;* AM=*Acacia mellifera;* BM=*Baphia massiensis;* BP=*Bauhunia petersiana;* CAX=*Cataphractus alexandrii;* CA=*Combretum apiculatum*; CC=*Combretum collinum;* CM=*Colomospermum mopane;* GB=*Grewia bicolor;* PN=*Philenoptera nelsii;* RT=*Rhigozum trichotomum;* TP=*Terminalia prunioides;* TS=*Terminalia sericea;* ZM=*Ziziphus mucronata;*

Mean±s.e; [a,b,c]Column means with same superscripts do not differ (P>0.05), Significance: *(P<0.05); **(P<0.01); ns=not significant

Table 4.2 Chemical composition of woody plant species collected by location and season (month)

	DM g/kg	OM g/kg DM	Ash g/kg DM	CP g/kg DM	NDF g/kg DM	ADF g/kg DM	ST g/100g DM
Location							
Omatako	940.3±6.90	890.2±10.78	50.1±8.73	110.0±26.72	403.9±43.12	256.1±58.15	6.3±2.49
Guinas	951.6±4.26	889.2±6.66	62.5±5.39	90.7±16.51	386.5±26.64	248.9±35.92	5.1±1.54
Tsandi	946.6±3.46	888.4±5.41	58.2±4.38	108.9±13.12	412.9±21.65	326.9±29.19	7.7±1.25
Daurês	953.6±7.01	887.3±10.96	66.3±8.88	146.6±27.18	412.2±43.85	324.9±59.914	7.5±2.53
Gibeon	959.9±7.28	892.3±11.37	67.7±9.21	119.1±28.19	345.6±45.48	280.4±61.34	9.2±2.62
Kongola	952.8±4.90	890.2±7.64	62.6±6.20	73.0±18.97	388.4±30.61	233.3±4.28	4.1±1.77
Sig.	ns	ns	ns	ns	ns	ns	ns
Month							
January	963.9±2.43[a]	901.2±3.79[a]	62.7±3.07	108.1±9.41	410.4±15.18[a]	276.4±20.5	4.9±0.88[c]
May	959.1±2.11[b]	894.9±3.30[b]	64.3±2.67	108.5±8.18	358.0±13.20[c]	278.3±17.81	6.3±0.76[b]
September	929.4±2.30[c]	872.7±3.59[c]	56.7±2.91	107.7±8.89	406.3±14.35[b]	280.7±19.36	8.6±0.83[a]
Mean	950.8	889.6	61.2	108.1	391.6	278.5	6.6
Sig.	***	***	ns	ns	**	ns	**

Legend: DM=Dry Matter; OM=organic matter; CP=crude protein; NDF= neutral detergent fibre; ADF= acid detergent fibre; ST=soluble tannins;

Mean±s.e; [a,b,c]Column means with same superscripts do not differ (P>0.05); Sig=Significance: (P<0.01)**; (P<0.001)***; ns=not significant

The high levels of NDF content in woody species were recorded at 410.4±15.18, 358.0±13.20 and 406.3±14.35 g/kg DM in January, May and September respectively. Woody browse tended to have more tannin concentration in September (8.6±0.83 g/100g DM) which is the dry season, than in January (4.9±0.88 g/100g DM).However, Ash, CP and ADF content of woody species did not vary with season (P>0.05).

There was no variation observed in DM, OM, Ash, CP, NDF, ADF and ST by location (P>0.05). This means that location of the plant sample had no effects on chemical composition of woody plant species leaves and pods.

4.3.3 Mineral composition of woody plant species

The results of mineral composition of woody plants species are presented in Table 4.3. There were highly significant differences in Calcium (Ca), Phosphorus (P) and Selenium (Se) concentration of woody species by season (P<0.001). In January to May which was wet to early dry season, Ca concentration of woody species was higher (9.8±0.65 to 10.4±0.57 g/kg DM) and lowest (4.5±0.62 g/kg DM) in late dry season (September). The mean values for P concentration in September were higher with 1.8±0.31 g/kg DM and lower in May with 0.2±0.28 g/kg DM. Se concentration was higher (1.7±0.09 g/kg DM) in January and lower (0.6±0.08 g/kg DM) in September.

The P concentration of woody plants species was significantly different (P<0.001) by location of the study. The highest P concentration was observed in Kongola (3.6±0.66 g/kg DM) and lowest in Guinas constituency. Ca and Se concentration of woody species did not differ (P>0.05) by locations and Ca, P and Se concentration was not significantly different within woody species (P>0.05).

Table 4.3 Mineral composition (g/kg) of woody leaves and pods by species, location and season (month)

Species	Part	Mineral		
Species	Part	Calcium	Phosphorus	Selenium
A. erioloba	Pods	8.4±1.90	1.3±0.95	1.1±0.26
A. karoo	Pods	15.1±3.36	1.5±1.67	1.1±0.46
D. cinerea	Pods	6.9±2.33	1.1±1.16	1.2±0.32
A. hereroensis	Leaves	11.4±2.43	0.9±1.21	0.9±0.33
A. karoo	Leaves	11.1±2.43	0.9±1.21	0.9±0.33
A. mellifera	Leaves	7.2±2.43	0.9±1.21	0.8±0.33
B. massaiensis	Leaves	5.2±2.09	0.3±1.04	0.9±0.29
B. petersiana	Leaves	6.4±1.58	1.6±0.78	0.9±0.22
C. alexandri	Leaves	8.2±1.28	1.0±0.64	0.8±0.17
C. apiculatum	Leaves	5.9±1.49	0.9±0.74	0.9±0.20
C. collinum	Leaves	8.1±2.09	1.0±1.04	1.7±0.29
C. mopane	Leaves	5.3±1.83	0.1±0.91	1.5±0.25
D. cinerea	Leaves	6.5±2.02	1.3±1.00	1.9±0.27
G. bicolor	Leaves	10.0±2.02	1.2±1.01	1.7±0.27
P. nelsii	Leaves	6.7±1.24	1.3±0.62	0.9±0.17
R. trichotonum	Leaves	9.1±2.43	1.1±1.21	0.9±0.33
T. prunioides	Leaves	11.5±1.83	1.1±0.91	0.9±0.25
T. sericea	Leaves	7.5±1.26	0.9±0.63	0.9±0.17
Z. mucronata	Leaves	6.7±2.35	1.0±1.17	1.1±0.32
Sig.		ns	ns	ns
Location Omatako				
		11.8±1.86	0.9±0.93^{b}	1.1±0.25
Guinas		7.9±1.15	0.2±0.57^{c}	1.0±0.15
Tsandi		8.1±0.93	0.4±0.46^{c}	0.9±0.12
Daurês		6.4±1.86	0.6±0.94^{c}	1.0±0.26
Gibeon		8.6±1.96	0.6±0.97^{c}	1.5±0.27
Kongola		6.7±1.32	3.6±0.66^{a}	1.1±0.18
Sig.		ns	***	ns
Month				
January		9.8±0.65^{a}	1.0±0.33^{b}	1.7±0.09^{a}
May		10.4±0.57^{a}	0.2±0.28^{c}	1.0±0.08^{b}
September		4.5±0.62^{b}	1.8±0.31^{a}	0.6±0.08^{c}
Mean		8.3	1.0	1.1
Sig.		***	***	***

Mean±s.e; ^{a,b,c}Column means with same superscripts do not differ (P>0.05);
Sig=Significance: P<0.001)***; ns=not significant

4.3.4 In-vitro gas production of woody plant species

The cumulative gas production of woody species as a function of incubation time is presented in Figure AP3.1 of the Appendices. The result of the gas production data analysis for the 17 woody plant leaves was analysed per location and is presented in Tables 4.4 and 4.5. There were significant differences in the interaction between woody species and season in the potential gas production and rate of gas production (P=0.0022 for *b* and P=0.0290 for *c*). The potential gas production of plants leaves was more in May at 8.66 and declined to 7.04 ml/0.2 g DM in September, which is late dry season. Conversely, an opposite trend was observed in the rate at which plant species were digested increased with advancement in season thus low rate (0.12 /hour) in wet (January) and higher (0.17 /hour) in dry season.

There was significant differences in the potential gas production and the rate at which woody plant species were digested (P<0.05). Potential gas production ranged between 5.91 ml/0.2 g DM in *C. apiculatum* and 13.89 ml/0.2 g DM in *Z. mucronata* leaves. The leaves of A. *mellifera* were digested at lowest rate 0.068 /hour and *C. apiculatum* highest (0.236 /hour).

There were significant differences among the woody plants species with regards to potential gas production by season. The highest fermentative gas was observed in early dry season at 12.51 ml/0.2 g DM and lowest (6.64 ml/0.2 g DM) in late dry season. However, the rate of gas production was both lowest (0.108 /hour) and highest (0.205 /hour) in wet season.

With regard to location, the potential gas production was highly (13.89, 13.72 ml/0.2g DM) noticed in woody plants species from Omatako, Gibeon respectively and lowest (6.64 ml/0.2g DM) in Kongola. Regardless of the location, *C. alexandri* specie produced better amount of gas.

Table 4.4 Least square means of fitted extent and rate of gas production of leaves of woody species (*b* in ml/0.2g DM and *c* is /hour)

Location		Species (Sp)						Month (Mo)				Significance		
								Jan	May	Sept	s.e.d	Sp	Mo	Sp xMo
		CA	ZM											
Omatako	*b*	7.36^{b}	13.89^{a}					12.23^{a}	7.69^{a}	11.92^{a}	2.317	**	ns	ns
	c	0.236^{a}	0.082^{b}					0.205^{a}	0.150^{b}	0.122^{c}	0.0233	***	*	ns
		DC	BP	GB	PN	TS								
Guinas	*b*	6.92_{a}	8.66_{a}	9.95_{a}	8.49_{a}	8.57_{a}		8.87_{a}	8.20_{a}	8.48_{a}	1.722	ns	ns	ns
	c	0.212^{a}	0.148^{b}	0.094^{c}	0.129^{b}	0.162^{b}		0.120^{a}	0.156^{a}	0.170^{a}	0.0320	**	*	*
		CAX	CA	CM	PN	TP	TS							
Tsandi	*b*	10.45^{a}	5.91^{c}	6.24^{c}	9.88^{a}	8.06^{b}	8.02^{b}	8.58^{a}	8.66^{a}	7.04^{a}	1.46	**	ns	*
	c	0.141^{b}	0.173^{b}	0.167^{b}	0.106^{c}	0.169^{b}	0.222^{a}	0.154^{a}	0.155^{a}	0.181^{a}	0.0313	**	ns	ns

Legend: LSM=least square means; CA=*Combretum apiculatum*; ZM=*Ziziphus mucronata*; DC= *Dichrostachys cinerea*; BP=*Bauhinia petersiana*; GB= *Grewia bicolor*; PN= *Philonoptera nelsii*; TP= *Terminalia prunioides*; TS= *Terminalia sericea*; CM=*Colophospermum mopane* ; CAX= *Catophrates alexandri*; Estimates from the equation : $y= b\ (1-e^{-ct})$,where: *b*= potential gas production, *c*= rate at which *b* is degraded; [a,b,c]Row means with same superscripts do not differ (P>0.05); Significance: (P<0.05)*; (P<0.01)**; (P<0.001)***; ns=not significant; s.e.d = standard error of difference

Table 4.5 Least square means of fitted extent and rate of gas production of leaves of woody species (*b* in ml/0.2g DM and *c* is /hour)

							Month (Mo)				Significance		
Location		Species (Sp)					Jan	May	Sept	s.e.d	Sp	Mo	Sp x Mo
Daurês		AH	AK	CAX									
	b	9.83[a]	8.68[a]	10.99[a]			10.60[a]	11.00[a]	7.90[a]	2.241	ns	ns	ns
	c	0.135[a]	0.176$_a$	0.085[b]			0.120[a]	0.140[a]	0.140[a]	0.0361	**	ns	ns
Gibeon		AM	CAX	RT									
	b	13.72[a]	12.48[a]	8.56[b]			9.95[a]	12.51[a]	12.30[a]	1.822	*	ns	ns
	c	0.068[a]	0.122[b]	0.138[b]			0.108[a]	0.114[a]	0.106[a]	0.0181	***	ns	ns
Kongola		BM	BP	CC	PN	TS							
	b	6.74[a]	8.61[a]	5.94[a]	7.17[a]	7.45[a]	6.78[a]	7.92[a]	6.64[a]	1.222	ns	ns	ns
	c	0.173[b]	0.138[b]	0.217[a]	0.205[a]	0.194[a]	0.189[a]	0.181[a]	0.181[a]	0.0361	*	ns	ns

Legend: LSM=least square means; AH= *Acacia hereroensis* ; AK= *Acacia karoo;* CAX= *Catophractes alexandri*; AM= *Acacia mellifera*; RT= *Rhigozum trichotomum;* BM= *Baphia massaiensis*; BP= *Bauhinia petersiana; CC= Combretum collinum;* PN= *Philenoptera nelsii*; TS=

Terminalia sericea; Estimates from the equation : $y= b\,(1-e^{-ct})$, where: *b*= potential gas production; *c*= rate at which *b* is degraded; [a,b,c]Row means with same superscripts do not differ (P>0.05); Significance: (P<0.05)*; (P<0.01)**; (P<0.001)***; ns=not significant; s.e.d = standard error of difference

The result of the gas production data for 3 woody plant pods is presented in Table 4.6. The data for *A. erioloba* and *A. karoo* was non-estimable as the pods were only collected in May when they were available in Omatako and Daures constituencies. However, *A. karoo* produced more gas (17 ml/0.2 g DM at the highest rate (0.538 h^{-1}). There was no significant difference in the potential gas and rate of gas production of *A. erioloba* and *D. cinerea* pods (P>0.05) by season and location.

Table 4.6 Least square means of fitted extent and rate of gas production of pods of wood species (*b* in ml/0.2g DM and *c* is /hour)

					Month (Mo)			Significance		
Location	Species (Sp)				Jan	May	Sept	Sp	Mo	Sp xMo
Omatako	AE							*b*	14.31	
c	0.085							Guinas		AE
DC										
b	10.72	6.90	nd	7.30	10.32	ns	ns	ns	*c*	0.120
	0.146	nd	0.145	0.120	ns	ns	ns			
Daurês		AK							*b*	
17.45										
c	0.538									

Legend: *AE= Acacia erioloba; AK= Acacia karoo; DC= Dichrostachys cinerea;* Estimates from the equation: $y= b\ (1-e^{-ct})$, where: *b*= potential gas production; *c*= rate at which *b* is degraded; Significance: not significant; nd=not determined

4.3.5 Correlations between chemical composition and in vitro gas production The correlation between chemical composition and *in vitro* gas production constants is presented in Table 4.7. NDF and ADF concentration were significantly and positively correlated (r=0.62: P=0.005). The concentration of ST was positively related to ADF and significant (r= 0.46; P=0.047). Woody plant samples high in cell-wall constituents were high in tannin concentration. ST concentrations were negatively correlated to the potential gas production *b* and significantly different (r= -0.54: P=0.018). There correlation of CP to cellwall constituents (NDF and ADF) and gas production constants was very low and not significant (P>0.05). There was a negative correlation between cell wall constituents and *in vitro* gas production constants (P>0.05). The result on chemical composition and gas production as well as its relationship was further discussed in the next section.

Table 4.7 A Pearson's correlation coefficient between crude protein, cell-wall components, soluble tannins and in vitro gas production after 48 hours of incubation

	CP	NDF	ADF	ST	*In vitro* gas production constants	
					b	*c*
CP						
NDF	0.04^{ns}					
ADF	0.25^{ns}	0.62^{**}				
ST	0.27^{ns}	-0.10^{ns}	0.46^{*}			
b	0.33^{ns}	-0.13^{ns}	-0.27^{ns}	-0.54^{*}		
c	0.29^{ns}	-0.03^{ns}	-0.07^{ns}	0.02^{ns}	0.28^{ns}	

Legend: CP= Crude protein (g/kg DM) NDF= neural detergent fibre (g/kg DM) ADF= acid detergent fibre (g/kg DM) ST= soluble tannins (g/100g DM) *b*= volume of gas produced (ml/ 0.2 g DM) *c*= rate of gas production (/h). Level of significance: $(P<0.05)^{*}$; $(P<0.01)^{**}$; ns=not significant

4.4 DISCUSSION: EXPERIMENT 2

4.4.1 Effect of woody plant species, season and location on chemical composition The mean DM and OM content of woody plants browse was high wet than in dry season. The reason could be that the woody plant samples collected in wet season had low moisture content, due to prolonged dry season, poor or delayed rainfall in 2013/2014 season in Namibia. The results were in agreement with those by Aganga *et al*. (2005) who reported that DM content of woody species slightly increases as dry season advances. Woody species pods of *A. erioloba, A. karoo* and *D. cinerea* CP content were within the range of 100- 280 g/kg as reported by Sibanda and Ndlovu (1993). This suggests that woody pods quality was not affected by season and have potential to be used as protein supplements.

The concentration of NDF among woody species varied with the highest amount in *P. nelsii* leaves and lower in *Z. mucronata* leaves. The values of NDF were in the range as those reported by van Soest (1994). The variation in NDF concentration could also be due to differences in cellwall structure of woody species (IAEA, 2006).

Concentration of NDF in leaves and pods obtained from this study were slightly higher in wet season than in dry season. This result contrasted the normal stage of plant growth as with grasses, whereby NDF and lignin increased in dry season.

Soluble tannins were detected most in of *D. cinerea* and *A. erioloba* pods and in the leaves of *Combretum* and *Terminalia* species. This situation could be attributed to stage of plant growth when the leave samples were collected. Hagerman (1987) reported that the quantity of tannins in woody leaves could be susceptible to change during sample drying at temperature of 40 ºC and also reduce in vitro digestibility. The situation of woody pods is different with regards to pod tannin concentration, which tended to decline as they ripen. Woody pods are most valuable as they ripen and fall well into the dry season (Timberlake *et al*., 1999) from July to September in Southern Africa. Mlambo *et al*. (2004, 2008) and Sikosana *et al*. (2002a) reported high phenolic and tannin content in *D. cinerea* pods and also widely spread in the Acacia species.

As the season advances and plant matures, the protein content decreases and fibre and tannin level increases (IAEA, 2006). Ruminants tended to browse more in dry season when the grazing is poor and this is the time when fibre and tannins are high. Plants synthesized tannins as a defence mechanism against herbivores (Mueller-Harvey and McAllan, 1992) especially when the plant is frequently disturbed.

There was no significant difference in the Ash, CP and ADF content within woody species, season and locations. Woody plants tended to retain considerable amount of protein content and minerals until late dry season. The reason could be that most woody species retain their leaves into the dry season making them useful in the diet of livestock.

This study obtained relative amount of Ca, P and Se in the woody species than those reported in the work by Aganga and Mesho (2008) who found low concentration of Ca and P in browse at an average between 0.69 – 1.89 g/100g DM and 0.03 – 0.40 g/100g DM respectively. Aganga and Mesho *(*2008) reported low concentrations obtained from one district location, and mineral concentration in soil differed, hence the woody species.

Similarly, Topps (1992) reported low values of phosphorus for most of the tree legume forages (Topps, 1992). Concentration of minerals in browse depends on type of woody species, stage of maturity, climate or season, and soil type (Le Houerou, 1980; Topps, 1992). Calcium is closely related to phosphorus metabolism in the formation of bones and a Ca:P ratio of 2:1 is recommended (Topps, 1992).

4.4.2 Effect of woody species, season and location on in vitro gas production

The gas volume obtained from the fermentation of the insoluble but degradable fraction *b* produced more gas in *A. karoo* and *A. erioloba* pods, however leaves of *Z. mucronata*, *A. mellifera and C. alexandri* was slightly higher. The result indicated that, the higher the gas produced, the lower the fractional rate at which the substrate was digested. The reason could be due to differences of species and their cell-wall constituent particularly NDF, lignin and presences of secondary compounds. These factors influence the digestibility and degradation characteristics of feeds. The higher values obtained for the *c* and *b* parameters in the browse, may indicate a better nutrient availability for rumen microorganisms. The rate at which different chemical constituents are fermented is a reflection of microbial growth and accessibility of the feed to microbial enzymes (Getachew *et al.,* 2004). Similarly, Khazaal and Orskov (1994) reported that the intake of a feed is mostly explained by the fractional rate of gas production *c* which affects the rate of passage of the feed through the gastro-intestinal tract whereas the potential gas production *b* is associated with the degradability of the feed.

In this study, seasonal fractional rate of gas production of the browse increased with advancement in season and vice versa. This could be due to stage of plant growth and simply the effect of low rainfall on plant developmental stage. Larbi *et al.* (1998) observed high average values for the volume of gas produced during the main wet season than those from dry season. However, same study, noted an opposite trend with average values for the rate of gas production of woody species. In contrast, Lukhele and Ryssen, (2003) reported no significant effect of *in vitro* gas production of *combretum* species leaves with season.

This study noted more potential gas production on woody plant species obtained from Omatako and Gibeon and lowest on those from Kongola. The author suggested that woody species might be the main contributor to these differences for example; *C. alexandri* produced more gas regardless of where the sample was collected from. On the other hand, some woody plant species were only collected from one location and could not be replicated for more strong comparisons.

4.4.3 Relationship between chemical composition and in vitro gas production

A strong relationship between NDF and ADF content of the woody browse was noted. It was noted that leaves high in NDF were low to moderate in ADF. Negative correlations between potential gas production and NDF, ADF and tannins may be a result of the reduction of microbial activity from increasingly adverse environmental conditions as incubation time progress. Woody plant leaves had low contents of tannins that ranged between 0.9 – 12.7 g/100g which would generally be considered unlikely to significantly affect digestion of nutrients in goats. There was an exception of woody pods, with tannin concentration of 15.5 g/100g DM in

D. cinerea and lowest in *A. karoo* (2.7 g/100g DM). With a much higher value, Mlambo *et al*. (2008) concluded that phenolic in *D. cinerea* fruits account for up to 500 g/kg of DM, which negatively affected *in vitro* fermentation. Tannins are complex polyphenolic compounds with great structural diversity and influence intake and digestibility of protein in ruminants (Aganga *et al*., 1998). However, a positive relationship was recorded between tannin concentration and ADF content. This study also found high average tannin concentration and ADF content in the woody species in September (late dry season), a period when animals tended to browse them. According to Mueller-Harvey and McAllan (1992) plant synthesizes tannins most likely in dry season particularly in disturbed areas in order to defend themselves against herbivores.

On the contrary, positive correlations between NDF and ADF with gas production characteristic have been found by Abdulrazak *et al*. (2000). However, the same study recorded a poor relationship between polyphenolics compounds and the gas production data. Rate of gas production was also negatively related to ADF and NDF content and poorly correlated to tannins. Khazaal and Orskov (1994) found no relationship between phenolic assays to the gas production. Larbi *et al*. (1998) also reported a weak relationship between proanthocyanidins and gas production data of 18 multipurpose trees during the wet and dry season in West Africa. A possible reason could be differences in the nature of tannins, type of woody plant species, season and nutritive value (Abdulrazak *et al*., 2000). The protein content was not related to cell-wall constituents nor to any gas production constants (P>0.05). The result was in agreement with observations in Ndlovu and Nherera (1997). Gas production of feeds negatively correlates with the NDF and tannin concentration, but positively with the CP content (Nsahlai *et al*., 1994; Basha *et al*., 2012).

4.5 CONCLUSIONS

The result showed that woody species have considerable amount of CP and could be used for protein supplement in low quality diets. There was variation in DM, OM, NDF and ST of woody species by season; however, Ash, CP and ADF were not affected by species, season and location. Cell wall content (NDF and ADF) were strongly correlated, but they did not affect CP content of woody species. CP content of woody pods was higher than in leaves, and therefore AE and DC were selected for subsequent animal feeding. *A. karoo* also indicated substantial amount of CP and gas production than AE and DC. Besides, chemical profile and gas kinetics, more work on animal responses is needed to affirm the nutritional characteristics hence the following Experiment 3 is crucial (Chapter 5).

CHAPTER FIVE: EXPERIMENT 3

5. Effect of *Acacia erioloba* and *Dichrostachys cinerea* pods supplementation on performance of does and kids of Namibian Caprivi and Ovambo indigenous goats

5.1 INTRODUCTION

Apart from chemical composition and *in vitro* gas production of woody plant leaves and pods, it was necessary to evaluate their effects on animal performance. Therefore *A. erioloba* and *D. cinerea* pods were considered for animal feeding because of their potential CP content, pod size and availability during 2013/14 season when the pods were collected. In this study, goat was used as a model animal (need less feed and easy to manage) to simulate what could happen in a big cow, enabling the acquisition of data on time for this study.

Goats are mainly kept for meat and milk production which contribute significantly to the livelihood of the poor communal farmers (Peacock, 1996). Among others, major cause of low livestock productivity in semi-arid areas is poor rainfall, insufficient availability of grazing land, shortage of feed supplements and the use of poor quality and low quantity of crop residues offered in the long dry season. This situation results into low milk production, slow growth in young animals and ill-health (Kindness *et al*., 1999). Communal farming areas are located in the Regions of Namibia normally associated with poor road infrastructure which makes it difficult to access commercial feed suppliers. These farmers are resource-poor and have no enough capital to purchase extra feed supplements. Natural rangelands in semi-arid areas are a potential source of less expensive, local feed resource in the form of grazing or browse materials (Mlambo and Mapiye, 2015). However, the uses of woody plant materials are constrained by insufficient knowledge and skills regarding harvesting, storing processing and their inclusion amount in animal feeding rations. The woody browse contain abundant amounts of anti-nutritional factors such as tannins which tend to increase in response to season, temperature and light intensity (Mueller-Harvey, 2006; Waghorn, 2008).

Woody plant pods especially those from Acacia and *Dichrostachys cinerea* are valuable as they ripen and fall well in dry season (Timberlake *et al*, 1999). Pods are a good source of protein that range between 100-190 g/kg DM, and was reported to increase growth of kids and milk production in goats (Mlambo *et al*., 2004; Maphosa *et al*., 2009). A study by Mlambo *et al*. (2004) reported a 60 % reduction in urinary nitrogen excretion in goats that were offered with un-treated *D. cinerea* fruits. In another study, Smith *et al*. (2005b) reported that supplementing lactating goats with 200 g of *D. cinerea* and *Acacia nilotica* fruits per day increased milk yield of does, growth rate and kid survival. Wang *et al*. (1996) observed increased in milk yield, protein and lactose percentage, however, a decline in milk fat percentage of ewes fed *Lotus corniculatus*, which contained moderate amount (44.5 g/kg DM) of condensed tannins compared to the control group.

Increased milk yield and nutrient composition is highly desirable to address the food insecurity and income of farmers from milk sales. Using *D. cinerea and A. erioloba* as supplements might exploit the potential of these woody pods as feed for small ruminants. The objective of this study was to develop dairy goat supplements using *A. erioloba* and *D. cinerea* pods, and to evaluate their animal responses with regards to milk yield, does weight changes and kids growth hence weaning weight. The detailed methodology of Animal

Experiment is presented in the next Section.

5.2 MATERIALS AND METHOD: EXPERIMENT 3

5.2.1 Location of the experiment

An animal feeding experiment was conducted on-station in Namibia at John Pandeni Research Station under the Ministry of Agriculture, Water and Forestry, Directorate of Agricultural Research and Development between January and April 2015. The Research Station is located 20 Kilometres south-west of Grootfontein in Otjozondjupa Region of Namibia. The Station/farm lies at latitude 19º 48'S and longitude of 18º 00'E at an elevation of 1450m above sea level. The size of the farm is 6 559.4 hectares. The mean annual rainfall is about 500 mm and the temperature ranges between 13.5° and 28.7°C. The main rainy season occurs from December/January to April, and the dry season spell from May to December and beyond. The natural vegetation is dominated by shrubs of *Dichrostachys cinerea, Acacia mellifera, Taraconathus camphoratus, Ziziphus mucronata and Grewia* species.

5.2.2 Animal management

Does were mated from July to September (2014) and kidded from December to end of January 2015. The animal experiment commenced in the last week of January 2015. The oldest kid was born on 9th December and the youngest on 2nd January resulting in an age difference of 24 days. Before the onset of the experiment, does were dipped in Alphamethrin to prevent external parasites and injected with 1 % Dectomax against internal worms. Does were fed in individual units fitted with a feeding trough (Plate 5.1). A herder was used to guard the goats during grazing to protect them against predators such as jackals. Kids were kept overnight with their mothers except the night before weighing and milking.

5.2.3 Experimental design

Forty eight (48) indigenous lactating does with average weight of 35 kg, from parity two and three were allocated in a 2x3 factorial arrangement of treatments as a completely randomised design (CRD), with six does (3 Caprivi; 3 Ovambo)per treatment. The main factors were two pod types {AE; DC}, three feeding levels {20; 40; 60 %}, benchmarked against a positive and a negative control. The non-supplemented group or the negative control were denoted "Nosupp" and commercial feed as positive control denoted "Comm" resulting in 8 treatment diets as follows: Nosupp, Comm; AE20; AE40; AE60; DC20; DC40 and DC60.

Phosphate-salt lick (Plate 5.1) and water were available as free choice to all treatment groups.

5.2.4 Feed preparation and feeding

Commercial feed (ram-ewe-lamb pellets), Lucerne and grass hay were obtained from Feed Master a commercial feed supplier whereas AE and DC pods were collected from Guinas, and Omatako constituencies. Lucerne, grass hay, AE and DC pods were air-dried individually milled through 10 mm sieve. These feeds were formulated using data from the chemical composition to attain iso-energetic and iso-nitrogenous diet that ranged between 130–140 g/kg DM of protein content using Try and Error method (Table AP6 of Appendices:).

Does were supplemented with 200 g/day/head and the amount was increased to 10 % based on intake of previous day, until a maximum of 400g was reached due to resources availability. Feed offered and refused from each doe were weighed and recorded daily in order to determine the dry matter intake (Plate 5.1). Samples of refusals per doe were taken daily and pooled over each week. At the end of the experiment the weekly pooled samples were further pooled to yield a composite sample of refusal for each doe. Supplement offered per treatment was sampled following two set of feed formulation for subsequent chemical analyses. Offered and refused samples were analysed for DM, Ash, OM, CP, NDF, and ADF following the methods as outlined in section 4.2.5 of Chapter 4. Does were offered supplement in the morning at 7: 00h before they were allowed out for grazing. In the first 7 days of adaptation period, does were supplemented twice a day, and later adjusted to once a day because consumption was poor after they return from grazing. The total number of adaption days was 14 days. The experiment lasted 91 days (13 weeks) of supplementation when all the kids were weaned.

5.2.5 Doe and kid weight data

Animals identification, mating dates, kidding dates, weight of doe at kidding, kid weight at birth, sex of kid and type of birth (single or twin), and parity of doe at kidding were recorded for evaluation. Initial weights of does and kids were recorded at the beginning of the trial and weekly until weaning. Weights of kids were recorded after birth and thereafter, on weekly basis (Plate 5.1).

5.2.6 Milk yield estimation

Milk consumption of kids per metabolic body weight was used as the best method to estimate milk yield in grazing goats (Economides, 1982). Milk consumption was estimated using the recorded weekly live weights of kids for the period of 13 weeks of lactation. In kids under grazing conditions, voluntary feed (milk)intake (VFI) is estimated to fall between 3 and 6 % of their body weight per day in terms of dry matter(Economides, 1982) with 12 % solid in milk (Peacock, 1996).

An average of 4 % VFI was used in the calculations and the following equation arises:

y = VFI x W ($M^{0.75}$) x 100/ MS Where;

y = the milk consumption of the kid (kg DM/$M^{0.75}$/day);

VFI =the estimated voluntary feed (milk) intake of a kid per day (4 %);

W =weekly metabolic body weight of the kid (kg,) and;

MS =the estimated solid in goat milk (12 %)

5.2.7 Statistical analysis

Data on weight gains, milk consumption of kids per metabolic weight basis and chemical +composition of the feed offered and refused were analysed in a 2 x 3 factorial arrangement of treatments as a CRD using GLM procedure of SAS (1999). The initial weight of does was included in the model as a covariate to account for differences in starting weights. For intake, the data values of the relevant offered feed were subtracted from the values for the refusals to give average daily voluntary consumption of does.

Plate 5.1 Type of feed weighing scale (a),animal feeding crate used (b), digital electronic scale connected to the stand was used to weigh does and kids and (c) and feeding trough used for Phosphate-salt lick

5.3 RESULTS: EXPERIMENT 3

5.3.1 Overview

All does and kids were in good health over the entire period of the experiment. However, one doe was injured by others whilst out browsing and died after four days and her two kids were withdrawn from the experiment. No kid mortality was encountered until weaning. In the first 7 days of adaptation, does were offered supplement twice a day and later changed to once a day because they were not consuming well after returned from grazing. Milk yield was estimated based on kid's metabolic body weights (kg/$M^{0.75}$) over lactation period of 13 weeks. This was very disturbing to the does and kids during grazing. Leaves and twigs samples of the most dominant shrubs at John Pandeni Research Station were collected mimicking grazing and the chemical composition is given in Section below 5.3.2.

5.3.2 Chemical composition of woody plant species at John Pandeni Research Station

Table 5.1 shows chemical composition of the dominant woody plants species at John Pandeni Research Station which were collected only once. There was variation on the DM, Ash, OM, CP, NDF and ADF of the leaves and twigs of woody plant species collected from the goat camps. DM content ranged between 927.5±1.50 g/kg (*Ziziphus mucronata* g/kg) to 944.0±0.70 g/kg in (*Tarconanthus comphoratus*) and Ash content from 51.0±0.80 g/kg DM in *Dichrostachys cinerea* to 92.1±0.70 g/kg DM in *Acacia mellifera.* Organic matter was higher in *D. cinerea* (880.5 g/kg DM) and lowest in *Z. mucronata* (838.2±2.20 g/kg DM). Crude protein content was lowest in *T. comphoratus* (143.5±0.70 g/kg DM) and highest in *A. mellifera* (222.0±0.70 g/kg DM).

Concentration of NDF was highest in *Grewia bicolor* (554.0±0.70 g/kg DM) and lowest in *A. mellifera* (299.4±1.0 g/kg DM). The level of ADF ranged between 187.0±0.70 to 275.6±7.60 g/kg DM in *D.*

cinerea and *G. bicolor* respectively. Chemical composition of offered AE and DC pods were analysed and are shown in the Table 5.1.

Table 5.1 Chemical composition of leaves and twigs of woody plants species collected from grazing veld of John Pandeni Research Station

	Woody plant species				
Item	*Grewia bicolor*	*Ziziphus mucronata*	*Acacia mellifera*	*Tarconanthus comphoratus*	*Dichrostachys cinerea*
Dry Matter, g/kg	941.9±1.30	927.5±1.50	932.5±2.00	944.0±0.70	931.5±0.30
Ash, g/kg DM	77.2±0.40	89.3±0.70	92.1±0.70	78.0±0.80	51.0±0.80
Organic Matter, g/kg DM	863.1±0.70	838.2±2.20	840.4±2.70	866.0±1.60	880.5±0.60
Crude Protein, g/kg DM	167.8±1.70	172.0±2.10	222.0±0.70	143.5±0.70	171.3±0.40
Neutral Detergent Fibre, g/kg DM	554.0±0.70	481.8±0.20	299.4±1.00	528.0±3.70	366.0±0.10
Acid Detergent Fibre, g/kg DM	275.6±7.60	202.2±0.80	208.0±0.70	255.0±1.10	187.0±0.70

Table 5.2 Chemical composition of *A. erioloba* and *D. cinerea* pods

	Woody plant species			
Item	*A. erioloba*		*D. cinerea*	
Plant part	pods	SD	pods	SD
Dry Matter, g/kg	942.73	27.92	954.64	15.41
Ash, g/kg DM	51.27	14.16	49.30	0.71
Organic Matter, g/kg DM	891.46	30.35	905.34	16.12
Crude Protein, g/kg DM	142.50	2.03	161.50	0.71
Neutral Detergent Fibre, g/kg DM	384.27	43.73	352.75	51.27
Acid Detergent Fibre, g/kg DM	297.8	38.45	279.90	65.20
Soluble Tannins, g/100g DM	8.50	4.47	14.80	8.49

Minerals				
Calcium, g/kg DM	9.56	5.96	5.79	3.20
Phosphorus, g/kg DM	0.40	0.15	0.34	0.40

SD= standard deviation

5.3.3 Chemical composition of supplement diets offered

Chemical composition of *Acacia erioloba* (AE) *Dichrostachys cinerea* (DC) pods was analysed for DM, Ash, OM, CP NDF, ADF and ST as outlined in Table 5.2.

DM content for DC was higher (954.6±15.41 g/kg) than in AE (942.7±27.92 g/kg). The Ash and OM content in both plant pods were not different. CP content was slightly higher in DC (161.5±.71 g/kg DM) than in AE (142.5±2.0 g/kg DM).

The NDF level was 384.3±43.73 g/kg DM in AE and 352.8±51.27 g/kg DM in DC whereas ADF was 297.8±38.45 and 279.9±65.20 g/kg DM in AE and DC respectively.

The concentration of ST was not different between AE and DC pods. Calcium and Phosphorus concentration was high in AE (9.56±5.96: 0.4±0.15 g/kg) than in DC (5.79±3.20: 0.3±0.40 g/kg) respectively.

Chemical composition of commercial feed (ram-ewe-lamb-pellets) is shown in Table AP6 of Appendices. Chemical composition of Lucerne and grass hay composition were not determined; however, their energy and protein contribution to the diets is displayed in Table AP7 of the Appendices.

5.3.4 Chemical composition of the supplement offered to does

Table 5.3 shows chemical composition of supplement offered. Samples of supplement offered was drawn after mixing and were analysed for DM, Ash, OM, CP, NDF and ADF analyses.

The DM content of the supplement offered ranged between 933.5±4.10 (AE60) to 943±4.67 g/kg DM (DC60). Ash content was highest in DC20 (107.0±10.68 g/kg DM) to slightly lower in DC40 (83.1±8.13 g/kg DM), while the OM ranged between 828.4±17.47 g/kg DM in DC20 to 856.9±3.46 g/kg DM in AE60. CP content was lowest in the commercial feed with 152.8±19.45 g/kg DM and highest (176.0±6.58) in AE20. NDF concentration was detected more in DC20 (494.1±55.30 g/kg DM) and lower in DC60 (401.7±0.21 g/kg DM). The ADF ranged between 221.7±2.97 to 303.6±83.30 g/kg DM in DC60 to DC40 respectively.

Table 5.3 Chemical composition of supplements offered to lactating does

	Treatment						
	Commercial	*Acacia erioloba (AE)*			*Dichrostachys cinerea (DC)*		
Item	-	AE20	AE40	AE60	DC20	DC40	DC60
DM, g/kg	934.0±12.37	934.3±7.35	933.8±0.71	943.0±4.67	935.3±6.79	930.8±4.67	933.5±4.10
Ash, g/kg DM	86.8±10.32	99.5±7.99	83.7±1.41	84.6±8.13	107.0±10.68	83.1±8.13	87.8±0.28
OM, g/kg DM	847.2±2.05	834.8±15.34	850.2±2.12	856.9±3.46	828.4±17.47	847.8±3.46	845.5±4.38
CP, g/kg DM	152.8±19.45	176.0±6.58	156.4±4.24	166.5±19.09	173.0±12.73	161.5±19.09	174.1±6.01
NDF, g/kg DM	459.8±12.80	494.1±55.30	425.1±2.83	420.7±24.04	415.1±29.06	454.8±24.04	401.7±0.21
ADF, g/kg DM	261.1±66.04	283.8±58.76	296.4±5.66	250.8±83.30	295.0±61.59	303.6±83.30	221.7±2.97

Legend: DM= dry matter; Ash=ash; OM= organic matter; CP= crude protein; NDF= neutral detergent fibre; ADF=acid detergent fibre

20, 40 and 60 were inclusion levels (%)

5.3.5 Supplement intake and does weight changes and growth of kids

Table 5.4 shows the effect of supplements diets on intake and growth performance of does and kids. The result shows that supplement significantly (P<0.05) improved intake with does on Comm having the highest (430.9 g DM/day) and lowest (289.3g DM/day) in AE. Does intake based on metabolic body weight was significantly higher in Comm (94.2 g DM/$M^{0.75}$/day) than DC (72.9g DM/$M^{0.75}$/day) and AE (69.3g DM/$M^{0.75}$/day) in a decreasing order. Also, does on Comm absorbed more CP (65.8 g/day), followed by those on DC (52.1 g/day) and least in AE (47.7 g/day).

There was significantly differences in the initial, ADG and final weight changes of does (P<0.05). Does on DC had the highest gain (38.9 g) and lowest on Nosupp group (28.1g). There was no significant difference (P>0.05) in the final weight and ADG of does when calculated on metabolic body weight basis.

Supplement had significantly improved growth and weaning weight (P<0.05) with kids from does on Comm having the highest ADG (114.4 g) followed by Nosupp (111.7 g) and lowest in AE (98.6 g).Initial weight of kids from Nosupp (6.4 kg) was slightly higher than in other treatment groups. Kids from does on AE had the lowest weaning weights. AE and DC were further assessed at three different levels and the results are outlined in Table 5.5

5.4 Effect of supplements on intake and growth performance of lactating does and kids

	Treatment					
Parameter	Nosupp	Comm	AE	DC	s.e.d	Sig.

Table

Supplement intake, g DM/d	-	430.9^{a}	289.3^{c}	307.6^{b}	35.90	**
Supplement, g DM /$M^{0.75}$/d	-	94.2^{a}	69.3^{c}	72.9^{b}	6.32	**
CP consumed, g/d	-	65.8^{a}	47.7^{c}	52.1^{b}	9.43	*
<u>Doe</u>						
Final weight, kg	33.7^{b}	34.8^{a}	35.6^{a}	33.4^{b}	1.28	*
Initial weight, kg	30.8^{b}	32.0^{a}	32.2^{a}	29.9^{b}	1.32	*
ADG, g	28.1^{c}	33.3^{b}	37.7^{a}	38.9^{a}	7.11	*
Final weight [$M^{0.75}$], kg	13.9	14.4	14.5	13.8	0.38	ns
Initial weight [$M^{0.75}$], kg	13.1^{a}	13.4^{a}	13.3^{a}	12.7^{b}	0.41	*
ADG [$M^{0.75}$], g	11.8	13.7	15.5	15.6	2.25	ns
<u>Kid</u>						
Weaning weight, kg	16.4^{a}	15.8^{a}	14.3^{b}	14.9^{b}	0.51	*
Initial weight, kg	6.4^{a}	5.6^{b}	5.4^{b}	5.7^{b}	0.36	*
ADG, g	111.7^{b}	114.4^{a}	98.6^{d}	102.5^{c}	6.50	*

Legend: Nosupp= Not supplemented; Comm= commercial feed; AE= *Acacia erioloba*; DC= *Dichrostachys cinerea*; ADG= average daily gain;

^{a,b,c}Means with different superscripts in the same row differ significantly (P<0.05)*; (P<0.01)**; ns= not significant; s.e.d= standard error of difference

Table 5.5 shows the effect of supplements at different levels on intake and growth of does and kids. The results showed that supplements significantly improved intake and decreased as the rate was increased (P<0.05). Supplement intake was higher on does offered DC20 (360.4 g DM/day), and lowest on DC60 (245.9 g DM/day). Results indicated that intake of does per metabolic body weight basis was 82.5 gDM /$M^{0.75}$/day, which corresponded to the CP consumed (62.3 g/day). Doe offered DC60 had lowest intake on metabolic body weight basis (61.2gDM /$M^{0.75}$/day) and CP consumed was also lowest (42.8 g/day). There was significant difference (P<0.05) in supplementation levels as it was clearly noted that intake decreased as the rate was increased.

The result shows that there were significant differences among the final weight changes and initial weight of does (P<0.05). Does offered AE40 had higher (37.2 kg) final weights, however, does offered DC40 gained more per day (46.3 g) than other groups. Does offered AE40, had slightly higher initial weight (34.8 kg), which could be the reason for higher final weights than other groups. The level of supplementation was significantly different (P<0.05) whereby does offered AE60 (34.0 kg) and DC60 (32.3 kg) had lowest final weights.

There was no significant difference in ADG and weaning weights of kids due to supplementation level (P>0.05). Kids from does offered DC40 had highest ADG (106.9 g) and better weaning weight than other treatments. Also, kids from does offered AE60 and DC60 had lower ADG and weaning weights.

Table

5.5 Effect of supplements at different levels on intake and growth of does and kids

	Treatment									
	Acacia erioloba (AE)			*Dichrostachys cinerea (DC)*				Significance		
Parameter	AE20	AE40	AE60	DC20	DC40	DC60	s.e.d	Supp (S)	Level (L)	S x L
Supplement intake, g DM/d	254.8^{c}	359.4^{a}	253.6^{c}	360.4^{a}	316.6^{b}	245.9^{d}	35.90	**	*	ns
Supplement, g DM /$M^{0.75}$/d	63.5^{c}	81.9^{a}	62.5^{c}	82.5^{a}	75.0^{b}	61.2^{c}	6.30	**	ns	ns
CP consumed, g/d	44.8^{c}	56.2^{b}	42.2^{c}	62.3^{a}	51.1^{b}	42.8^{c}	8.13	*	ns	ns
<u>Doe</u>										
Final weight, kg	35.0^{b}	37.9^{a}	34.0^{c}	34.5^{c}	33.4^{c}	32.3^{c}	1.21	*	ns	ns
Initial weight, kg	31.6^{b}	34.8^{a}	30.4^{b}	30.8^{b}	29.3^{c}	29.7^{c}	1.25	*	ns	ns
ADG, g	38.1	35.2	40.0	41.6	46.3	28.7	7.05	ns	ns	ns
Final weight [$M^{0.75}$], kg	14.4^{b}	15.3^{a}	14.1^{b}	14.2^{b}	13.9^{c}	13.5^{c}	0.37	*	ns	ns
Initial weight [$M^{0.75}$], kg	13.3^{b}	14.3^{a}	12.9^{c}	13.1^{c}	12.6^{c}	12.7^{b}	0.38	**	ns	ns
ADG [$M^{0.75}$], g	15.3	14.1	15.3	16.3	17.4	12.2	2.22	ns	ns	ns
<u>Kid</u>										
Weaning weight, kg	14.5	14.7	13.7	15.4	15.6	13.8	0.65	ns	ns	ns
Initial weight kg	5.6	5.4	5.2	6.0	5.9	5.1	0.36	ns	ns	ns
ADG, g	98.1	103.4	94.4	104.0	106.9	96.5	5.62	ns	ns	ns

[a,b,c]Means with different superscripts within the same row are statistically significant (P<0.05)* (P>0.01)** ns= not significant; s.e.d=standard error of difference

Table

Table

5.3.6 Milk consumption by the kids

Table 5.6 shows the effect of supplements on milk consumption of kids based on metabolic body weight. Supplementation significantly improved milk consumption of kids per metabolic body weight from the first week up to 13th week of lactation ($P<0.001$). However, in week 13, kids from non-supplemented does had slightly higher milk intake (2.74±0.060 kg DM/$M^{0.75}$/day) per metabolic body weight followed by Comm (2.65±0.060) and lowest in AE60 (2.59±0.060 kg DM/$M^{0.75}$/day) and DC(2.57±0.060kg DM/$M^{0.75}$/day).

Figure 5.1 shows the effect of AE and DC supplementation at three different levels on milk consumption of kids per metabolic body weights. Milk consumption of kids per metabolic body weight was significantly different across the treatments ($P<0.05$). As depicted by the line graph, kids from does on AE60 and DC60 had lowest intake of milk per metabolic weight than those from other treatment groups.

Figure 5.2 shows the effect of AE and DC supplementation on milk consumption of kids per metabolic body weights. Supplementation significantly improved milk consumption of kids per metabolic body weight with DC being superior over AE throughout the lactation period ($P<0.05$). In week 6 of lactation, milk consumption of kids per metabolic body weight was similar; however, from week 7 to 13, DC was again above AE.

Figure 5.3 shows effect of AE and DC supplementation levels on milk consumption of kids per metabolic body weights basis. Regardless the type of pod, level of supplement significantly influenced intake of kids per metabolic bodyweights basis throughout the lactation period ($P<0.05$). There was no significant interaction on supplementation and level ($P>0.05$).

5.6 Effect of supplements on milk consumption of kids per metabolic body weight(kg/M$^{0.75}$/week)

Week	Nosupp	Comm	AE	DC	S.E	Sig.
1	1.41^{c}	1.35^{c}	1.42^{c}	1.40^{c}	0.060	**
2	1.59^{c}	1.50^{c}	1.53^{c}	1.53^{c}	0.050	***
3	1.77^{c}	1.65^{c}	1.70^{c}	1.70^{c}	0.060	***
4	1.86^{c}	1.77^{c}	1.80^{c}	1.79^{c}	0.050	***
5	2.00^{b}	2.00^{b}	1.93^{c}	1.95^{b}	0.060	***
6	2.08^{b}	2.02^{b}	2.03^{b}	1.96^{b}	0.060	***
7	2.14^{b}	2.12^{b}	2.09^{b}	2.06^{b}	0.060	***
8	2.25^{b}	2.19^{b}	2.18^{b}	2.10^{b}	0.060	***
9	2.22^{b}	2.21^{b}	2.18^{b}	2.14^{b}	0.050	***
10	2.37^{b}	2.37^{a}	2.31^{a}	2.28^{b}	0.060	***
11	2.45^{a}	2.48^{a}	2.44^{a}	2.38^{a}	0.070	***
12	2.53^{a}	2.54^{a}	2.48^{a}	2.48^{a}	0.060	***
13	2.74^{a}	2.65^{a}	2.59^{a}	2.57^{a}	0.060	***
Mean	2.11	2.07	2.05	2.03		

Legends: Nosupp= Not supplemented; Comm= commercial feed; AE= *Acacia erioloba*; DC= *Dichrostachys cinerea*; ADG= average daily gain

^{a,b,c} Means with different superscripts in the same row differ significantly (P<0.05); Sig=Significant at(P<0.01)** (P<0.001)***; ns= not significant; s.e.d= standard error of difference;

Table

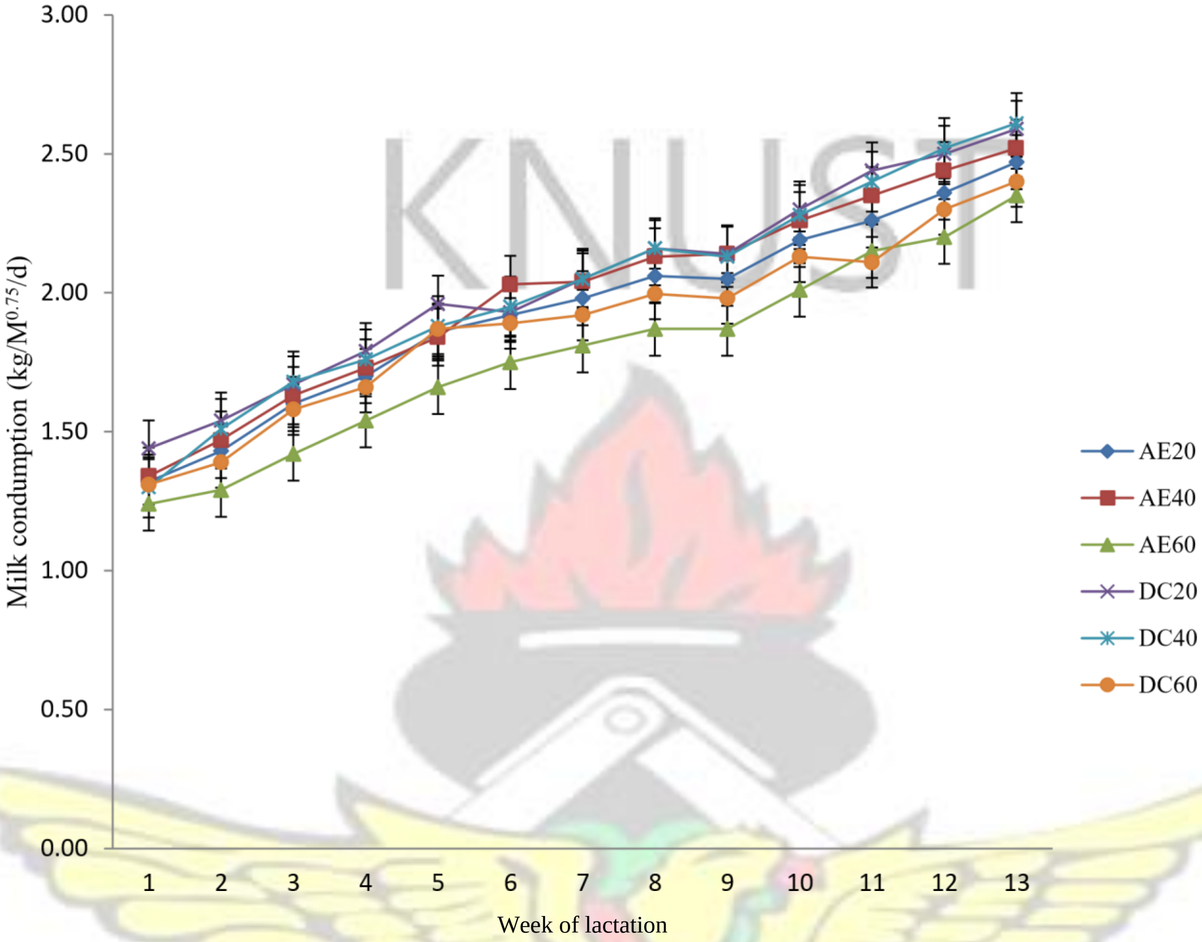

Figure 5.1 Effect of AE and DC supplementation at three different levels on milk consumption of kids per metabolic body weights (kg/M$^{0.75}$/week)

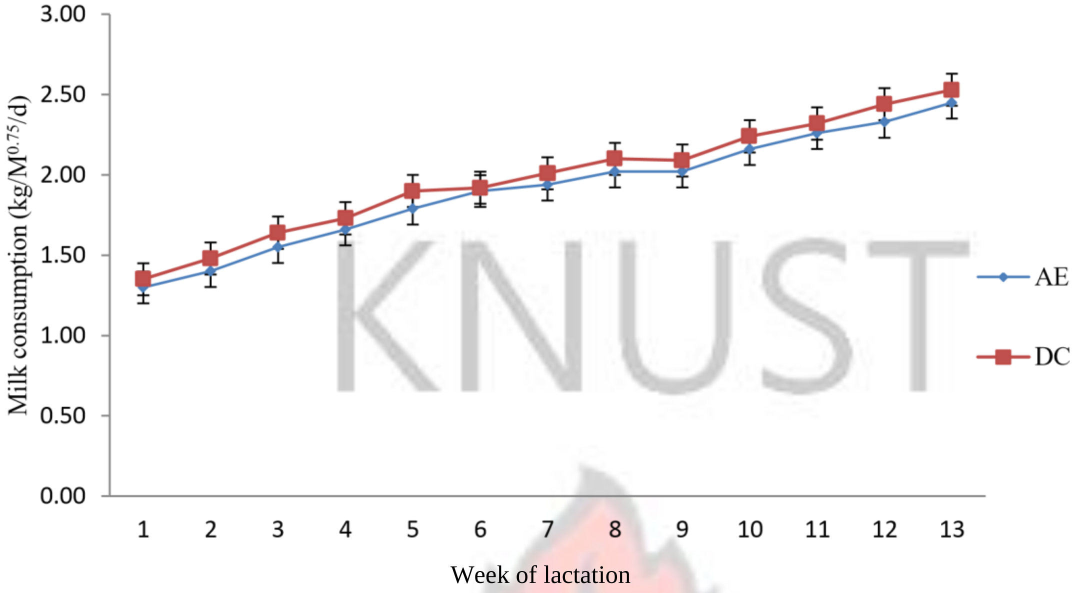

Figure 5.2 Effect of supplementation on milk consumption of kids per metabolic body weights (kg/M$^{0.75}$/week)

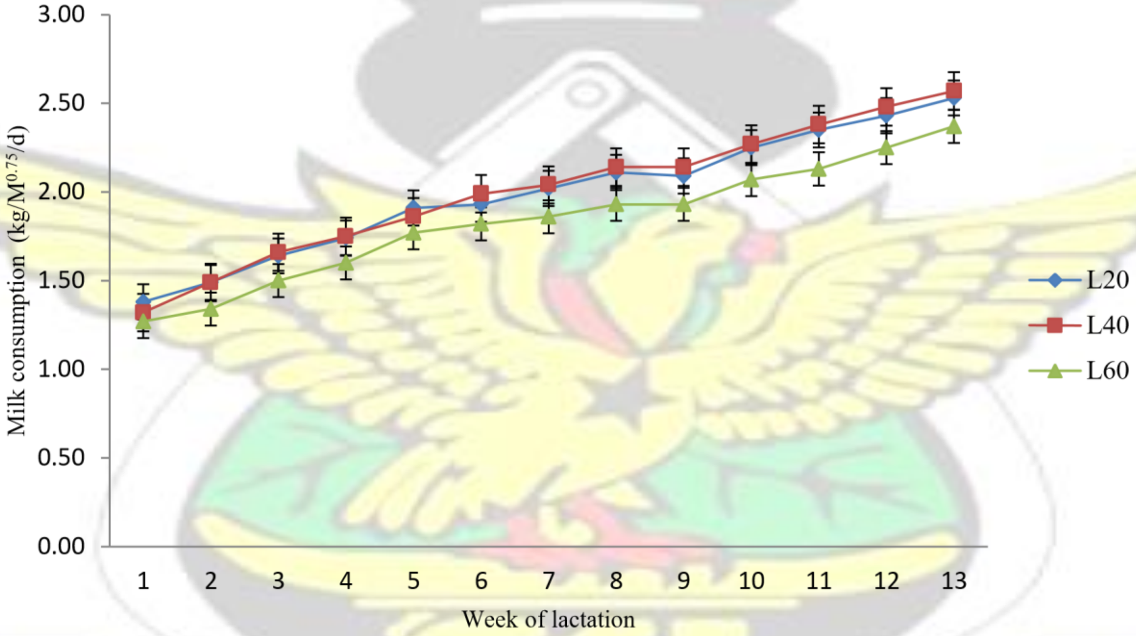

Figure 5.3 Effect of level of supplementation on milk consumption of kids per metabolic body weight (kg/M$^{0.75}$/week)

Figure 5.4a presented the effect of supplementation on milk consumption of kids per metabolic body weight by ecotype. Milk consumption on metabolic body weight basis was successively significant ($P<0.09$) by ecotype with Caprivi kids being superior over the Ovambo ecotype throughout the experimental period.

Figure 5.4b shows the effect of supplementation on milk consumption of kids per metabolic body weight by type of birth. Kids from a single birth showed significantly higher milk consumption on metabolic body basis than the twins (P<0.05).

Figure 5.4c shows the effect of supplementation on milk consumption of kids per metabolic body weight byes of the kid. Sex significantly (P<0.05) influenced milk consumption based on kids metabolic body weight with males having higher consumption than the females.

Figure 5.4d shows the effect of supplementation on milk consumption of kids per metabolic body weight by parity of doe. The results showed that there was significant difference in milk consumption by parity of does (P<0.05). Kids from parity three consumed more milk per metabolic body weight than those from parity two.

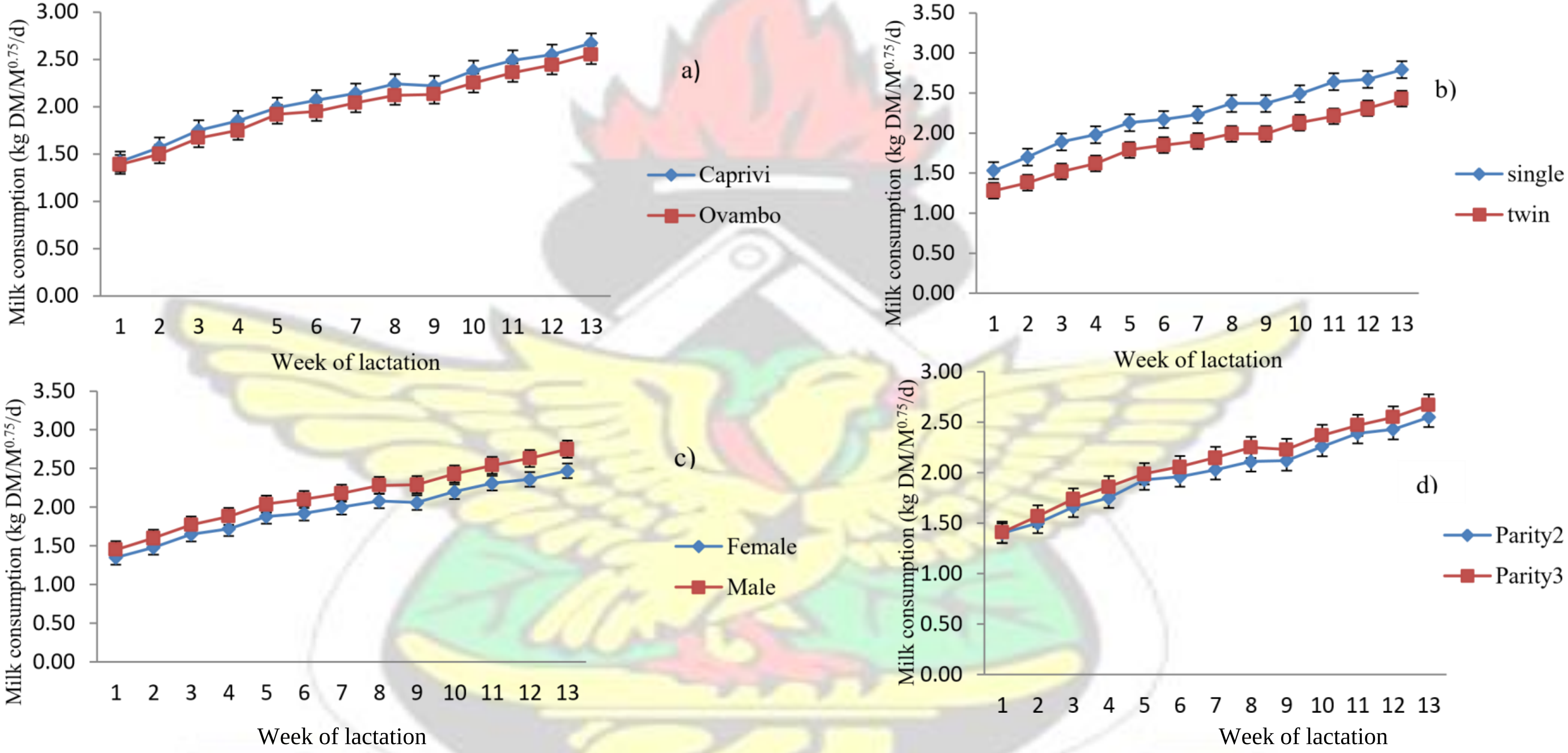

Figure 5.4 Effect of supplementation on milk consumption on kids per metabolic body weight basis by (a) ecotype (b) birth type

(c) sex and (d) parity

5.4 DISCUSSION: EXPERIMENT 3

5.4.1 Effect of supplementation on intake and growth

Supplementation significantly improved intake of does and growth of kids ($P<0.05$). The author assumed that lower growth of kids from does on AE and DC could be attributed lower supplement intake of AE and DC especially at 60 % feeding level. Supplement intake and protein consumption was higher in does offered with commercial feed as a positive control. The commercial feed was formulated at iso-energetic and iso-nitrogenous just as in AE and DC pod supplements. The reasons for higher intake of commercial feed could be due to low concentration of fibres, tannin, and does were acquainted with these feeds compared to AE and DC supplements. Interestingly, does on AE indicated slightly higher final weight (35.6 kg) than those which gained better per day (34.8 kg). The reason for this could be due to significant in differences ($P<0.05$) on initial weight of about 2.3 kg of does from AE and DC.

When pod supplements were compared, intake of DC was 307.6 g/day and 289.3 g/day of AE. The results were lower than those by Sikosana *et al.* (2002a) who reported intake of 844 g/day of *D. cinerea* and *Acacia nilotica* with 491 g/day. The reason for these differences could be explained by the sex and physiological status of the animal used, how pods were offered or their inclusion levels in the rations. Sikosana *et al.* (2002a) observed high levels of tannins in *A. nilotica* than in *D. cinerea* could be the reason for reduced intake and growth. This scenario supported this study, because as the rate of pods was increased, intake reduced and corresponded to lower final weight of does. In contrast, the study by Yayneshet *et al.* (2008) who reported that as the level of DC was increased from 0.5 to 1.5 %, gain also increased from 10 to 21.7 g/day. However, the same study obtained intake that ranged between 83.8 and 94.3 g/kg/M$^{0.75}$/day, whereas intake in this study ranged from 62.5 - 94.2/g/M$^{0.75}$/day). The differences in the minimum intake could be due to low inclusion levels in Yayneshet *et al.* (2008) study which were very low than in this study.

The study also found does on AE and DC gained in weight exceptionally well than those on Comm and Nosupp groups. However, the ADG of kids from Comm and Nosupp were much higher than in AE and DC groups. The reason for high ADG and weaning weight of kids from non-supplemented does could be due to the number of non-supplemented does compared to supplemented ones. Secondly, half of the kids from does on Nosupp were from single births which tended to grow better than twin kids. It is not clear whether the differences observed in the present study are due to differences in solid feed intake, as no data were collected on this aspect.

Studies have reported high tannin content in *D. cinerea* pods (Mlambo *et al.,* 2004; Sikosana *et al.,* 2002a; Smith *et al.*,2005b; Mlambo *et al.*, 2008) and negative responses such as reduced intake, live weight gain, milk yield and other production parameters (Mueller-Harvey, 2006). However, tannin-containing browse were reported to have positive beneficial to the animals when included in limited quantities in the supplement rations (Mlambo *et al*., 2008). The result in this study suggested that does supplementationatDC40 have optimum intake that corresponded with better growth of kids. Despite high tannin amount in DC pods, Mlambo *et al.* (2004) concluded that goats offered with these pods had highest nitrogen retention than PEG treated pods. The same study confirmed that DC pods do not require tannin-inactivation if they are offered in limited quantities to goats. This study confirmed that does on DC40 had high intake hence better milk yield that reflected positively no the growth of their kids. The following section discusses in detail voluntary feed intake in terms of milk consumed as a reflection on growth based on metabolic body weight of kids.

5.4.2 Effect of supplementation on milk yields

As a continuation from the previous section (5.4.1) statistically, the result indicated that supplementation had no effect on kid growth. Nevertheless, milk consumption can be estimated from the average daily gain of the kids or directly through live weight differences (Banda and Phiri, 1990).In this study, milk consumption ranged between 1.35 – 2.74 kg DM/$M^{0.75}$/day over the experimental period. In a study in Malawi by Banda and Phiri (1990), local goats produced 26.0 g milk/day per kg body weight or 63.0 g/day per $kg^{0.75}$.

The trend obtained as depicted in the line graphs was similar as the growth curve because it was estimated from metabolic body weight of kids. This follows the norm situation reported in literature whereby milk yield increase gradually in the early stage of lactation until it reach a peak and decline in the 6 to 8^{th}week of lactation in dairy goats. In this study, a doe produced 120 ml of milk every second week for 5 sessions during the 13 weeks of the experiment for the purpose of milk composition analyses. In addition, a bulk of 16 litres of milk was collected in the last 6^{th} session from all treatments (together 48 does) for sensory evaluation parameters. This means that does were able to produce more than 120 ml without affecting the growth of kids.

This suggested supplement improved milk production of does as reflected in the growth of kids and were still able to maintain their weight through to weaning.

Lengarite *et al. (*2014) reported milk yield that ranged between 300 – 349 g/day on does fed with *Acacia tortilis*. Maphosa *et al*. (2009) reported similar results of milk yield of 308 ml/day on Matebele indigenous goat supplemented with 200/day of *D. cinerea*.

Kids from Caprivi ecotype indicated slightly higher milk yield per metabolic weight than those of Ovambo ecotype. However, ecotype had no significant effect on supplement intake, therefore, the reason could be due to frame size such that Caprivi were slightly heavier than Ovambo ecotype. There was little or no documented study on the milk production of the Caprivi and Ovambo ecotypes in Namibia. Nevertheless, study by Greyling *et al*. (2004) reported higher milk composition in indigenous than in Boer goats.

Male kids had higher weaning weight hence milk yield on metabolic basis than females. The results are in agreement with those by Carnicella *et al*. (2008). Single kids tended to grow faster than twins because they do not have to share the milk. Carnicella *et al.* (2008) reported that does with twins yielded more milk than single kidded does.

Parity had significant effects on supplement intake with does from parity three having a higher intake. The reason could be that milk production of does on parity three was higher hence a higher feed requirement than those on parity two. Consequently, kids from does in parity three had consumed more milk in terms of metabolic body weight basis than those from parity two.

This also resulted in higher weaning weight of kids from does on parity three. Carnicella *et al.* (2008) reported that does in third and fourth lactation yielded 302 kg of milk per lactation compared with 257.4 kg for those in first and second parity respectively.

Over time, studies have observed a typical negative correlation between milk components (fat and protein) and yield (Pulina *et al*., 2008). In the study by Donkin (1997), indigenous goats showed higher percentage of milk components whereas, the Saanen dairy breed yielded more milk. Therefore, this study arrived at the following conclusions summarised in the next section.

5.5 CONCLUSIONS

Supplementation significantly improved voluntary feed intake with does on Comm having the highest values, milk yield and growth of kids. However, when AE and DC were compared at 20, 40 and 60 % feeding levels, DC at 40 % had the highest total intake and weaning weight of kids.

In terms of milk consumption of kids per metabolic body weight, lactating does produced milk between 1.35 and 2.74 kg DM/$M^{0.75}$/day and were able to maintain their weights and provide sufficient milk to their kids.

Therefore, pod supplementation could be used instead of expensive commercial feeds, whose cost is beyond the reach of most communal farmers. This study recommends that collection and grinding of pods allows availability of nutrients and reduces the intact seeds in goat faeces and could be used for managing the DC bush encroachment problem in Namibia.

Besides, animal responses on AE and DC pods supplementation, more work on milk composition and sensory evaluation of milk products is required to confirm the nutritional characteristics therefore, the following experiment is essential (Chapter 6).

CHAPTER SIX: EXPERIMENT 4

6. Milk composition and sensory evaluation of fresh milk, fermented-sour milk and plain yoghurt from indigenous Namibian lactating does supplemented with *Acacia erioloba* and *Dichrostachys cinerea* pods

6.1 INTRODUCTION

Milk samples obtained from Experiment 3 (Chapter 5) were further determined for chemical composition mainly; Total Solids, Fat, Protein, Solid-Non-Fat, Ash, Calcium and Phosphorus. In the last three weeks of Animal Experiment (Chapter 5), two liters of milk were bulked from each treatment group adding up to the total of 16 liters in order to produced fresh milk, fermentedsour milk and plain yoghurt for sensory evaluation. Fresh milk, fermented-sour milk and yoghurt were chosen to be used in the sensory evaluation because these were the major goat milk products consumed locally in Namibia. It was appropriate to use milk products that people were accustomed with in order to minimize people's attitudes towards goat milk (Banda and Phiri, 1990). Goat cheese is also commonly sold in the Namibian local supermarkets, but the milk quantities obtained in the study was not sufficient to produce cheese samples enough for sensory evaluation Therefore, for this reason, the study could not make use of goat milk cheeses.

The study used commercial starter cultures known as *Omaere* and plain yoghurt (products of Namibia Dairies Company) obtained from local supermarket to produce fermented-sour milk and yoghurt respectively. This serves as a way of encouraging rural people to use commercial starter cultures, instead of traditional methods (adding *Boscia albitrunca* roots to the milk) under poor hygienic conditions (Bille *et al*., 2000; Marius *et al*., 2012).

Goats are an integral part of the farming systems in Namibia extending from the commercial to communal farming where they are most abundant. Milk form a major component of human diet and provides rural people with cash income (Greyling *et al*., 2004; Marius *et al*., 2012). Traditionally, in Namibia, goat milk is consumed as fresh, added to tea, and/or fermented and served with porridge (Marius *et al*., 2012). Haenlein (2004) states that the quantities of goat milk consumed in rural communities are very important, although they are not included in official statistics.

In practice, milk yield and composition is influenced mainly by the type of feed consumed (Fedele *et al*., 2007). Milk or cheese from animals fed grasses or woody plants showed different sensory characteristics (Buchin *et al*., 1999). Milk produced from pasture based diets characterized with high fat content because of the fibre-rich forages (Morand-Fehr *et al*., 2007). In addition, the studies outlined that milk obtained from these sources are also rich in micro components such as fatty acids, volatile compounds (i.e. terpenes) and phenolic compounds. These attributes are favorable to human nutrition and health (Tripathi, 2015). Wang *et al.* (1996) reported increases in milk yield, protein and lactose percentage, and decreases in fat percentage from ewe fed *Lotus corniculatus*, which contained moderate amount of condensed tannin (44.5 g/kg DM) compared to the control. In grazing dairy cows, Woodward *et al.* (1999) also demonstrated the positive effects of *Sulla* (*Hedysarum coronarium)* condensed tannin on milk yield and milk protein content. Bwire *et al*. (2004) investigated the effect of *Acacia tortilis* and *Faidherbia albida* pods as protein supplements on milk yield and composition in dual-purpose Mpwapwa breed cows and recorded no effect on milk composition but an increase in milk yield with supplementation. In one of the Italian study, milk from goats grazing pasture composed of *Leguminosae* i.e. *Trifolium* *alexandrinum* and *Vicia* species and 40 % grasses had significantly higher fat content than milk from hay-fed control animals (Morand-Fehr *et al*., 2007). In Ethiopia, Fekadu *et al.* (2005) reported that milk with high milk components resulted in significantly higher cheese yield as compared to milk with lower components. Studies found that goat milk have medicinal properties because they consume woody plant materials such as leaves, twigs, flowers and fruits which are rich in anti-oxidants (Tripathi, 2015).

Goat milk has small size of fat globule that is highly digestible and tended to be less allergic and favorable to feeding infants over cow milk (Tripathi, 2015). Also, if this technology is adopted, fermented-sour milk and yoghurt could be ideal food complements in the diet of rural people and other developing countries. The objective of the study was to determine milk composition and sensory properties of goat milk using fresh milk, fermented-sour milk and plain yoghurt produced from goats fed with *Acacia erioloba* and *Dichrostachys cinerea* pods.

6.2 MATERIALS AND METHOD: EXPERIMENT 4

6.2.1 Location of the experiment

Milk composition analysis, product processing and sensory evaluation were carried out at the Directorate of Agricultural Research and Development Laboratory, Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

6.2.2 Source of milk and sample preparation

Milk samples were obtained from indigenous (Caprivi and Ovambo goat ecotypes) lactating does supplemented with different levels of *Acacia erioloba* and *Dichrostachys cinerea* in Animal Experiment conducted at John Pandeni Research Station in Grootfontein, Namibia (refer to Chapter 5).

Sixteen litres of milk were collected in the 10th week of feeding trial (2 litres per treatments groups to produce fresh milk, fermented-sour milk and plain yoghurt for sensory evaluation. In order to determine the milk composition, milk samples were collected every fortnight, frozen between 0 to -5°C until the experiment was completed. Milk samples were thawed at 20 °C, homogenised before analysis.

6.2.3 Milk composition analysis

The chemical quality of the milk was analysed using the methods of AOAC (2007). Total solid was obtained by evaporating the milk in the oven at 105 °C for 12 hours. Fat was determined by Gerber Method (Product: Funke-Gerber Labortechnik GmbH, Ringstraße 42, 12105, Berlin, Germany). Solid-Non-Fat was calculated by subtracting fat contents from the total solids. Concentration of Nitrogen (N) was determined by Dumas method (Product: CHN628, LECO Corporation, Lakeview Avenue, St Joseph, M1 49085, UK) and protein was calculated using N x 6.38 factor. Ash was obtained by incinerating method at temperature of 550 °C for 4 hours.

Calcium and Phosphorus where determined using flame emission spectrophotometry (Product:

ICAP 6300, Thermo Fisher Corporation, Solaar House, 19 Mercers, UK), standard method of AOAC (2007). All analyses were carried-out at the Ministry of Agriculture, Water and Forestry Laboratory facility in Windhoek, Namibia.

6.2.4 Preparation of the milk products

Two litres of milk from each treatment group was collected in the tenth (10^{th}) week of the feeding experiment. Milk obtained from commercial feed and un-supplemented group was used as the positive and negative control respectively. The milk was stored at 4°C for one day before processing into fresh milk, fermented-sour milk and plain yoghurt.

Each treatment provided 500 ml of fresh milk, 500 g of fermented-sour milk and 500 g of yoghurt. Therefore, 8 treatment diets by 3 products amount to 24 product samples that were offered for testing. Fermented-sour milk and plain yoghurt were prepared according to the procedure of Deeth and Tamime (1981) as outlined below.

6.2.5 Fresh milk

Fresh milk obtained from Animal Experiment was immediately cooled at 4 ºC. Fresh milk was placed in a warm water bath and kept at 20 ºC during the testing exercise which lasted for four hours.

6.2.6 Plain yoghurt

Raw milk obtain from Animal experiment 3 was immediately cooled at 4 ºC before it was processed into yoghurt. Raw milk was first heated at temperature of 80-85 ºC with holding time of 30 minutes. The main reason of heating the milk was to eliminate micro-organisms that might compete with those present in the starter culture added or possibly than may lead to spoilage of the product. Milk was cooled at 42- 43 ºC prior to inoculation with 2 % of commercial starter culture and incubated at 45 ºC for 12 hours. The product was cooled at 4 ºC before it was offered for testing.

6.2.7 Fermented sour-milk

Raw milk was first heated at temperature of 80-85 ºC with holding time of 30 minutes exactly as happen in yoghurt preparation. Milk is cooled at 42- 43 ºC prior to inoculation with 2 % of starter culture and incubated at 30 ºC for 12 hours. A commercial starter culture was used to prepare the fermented sour-milk, locally known as *Omaere* (product of Namibia Dairies). The product was cooled at 4 ºC before it was offered for testing.

6.2.8 Experimental design

Milk composition data was analysed by Completely Randomized Design in a 2 x 3 factorial arrangements of treatments. Sensory evaluation was assessed by 3 x 8 factorial arrangements oftreatments resulting in 24 product samples that were offered for testing.

6.2.9 Sensory evaluation

All three milk products were pre-tested to ensure their safety for human consumption. The product samples were subjected to evaluation by trained panellists (20) using sensory evaluation sheets (Table AP12 of Appendices). Product sample were given random numbers so that panellists judge based on the sensory experiences (Plate 6.1). Sensory evaluation using trained team was carried-out to explore the acceptance of the products and confirm the descriptive characteristics of the products. The individual were asked to score for colour, aroma, flavour, texture, consistency and overall palatability.

A 5-point Hedonic scale ranging from 1 to 5 was used according to Jones *et al*. (1955).

Where;

1=like very much;

2= like;

3= neither like nor dislike;

4=dislike and;

5 = dislike very much.

6.2.10 Statistical analysis

Milk composition data was analysed by Completely Randomized Design in a 2 x 3 factorial arrangements of treatments in order to compute Least Square Means.

Sensory Mean Scores were analysed in a 3 x 8 factorial arrangements of treatments in order to obtain total means scores using PROC GLM of SAS version 9.1.3. The main factors were products and treatment diets assessed over six parameters (color, aroma, flavour, texture, consistency and overall palatability) by 20 panelists.

Plate 6.1 Sensory evaluation of fresh milk, fermented-sour milk and plain yoghurt by panelist at MAWF, Head Office in Windhoek

6.3 RESULTS: EXPERIMENT 4

6.3.1 Overview

Milk samples for composition analysis were collected every fortnight in five rounds, kept frozen and the analysis was executed at the end of Animal Experiment.

In the 10th week of the Animal Experiment, the sixth round was collected and processed into fresh, fermented-sour milk and yoghurt for sensory evaluation. The milk testing exercise was performed successfully using trained staff members of the Ministry of Agriculture, Water and Forestry at the Head Office in Windhoek, Namibia.

6.3.2 Milk composition

Table 6.1 show the effects of supplements on milk composition. Commercial feed (Comm) and not supplemented (Nosupp) were the positive and negative control treatments respectively. Supplementation on milk composition of total solids, fat, protein, solid-non-fat and ash was not significantly different ($P>0.05$) across the four treatment diets. Calcium concentration was significantly different among the treatment diets ($P<0.05$). Calcium was lower on milk obtained from non-supplemented does (0.15 %). Phosphorus concentration among the treatments was significantly different ($P<0.05$).Milk obtained from does supplemented with commercial feed had slightly lower (0.12 %) phosphorus concentration than in other treatments (0.13 %).

Table 6.1 Effects of supplements on milk composition

	Treatment					
	Nosupp	Comm	AE	DC	s.e.d	Sig.
Parameter (%)						
Total solids	15.39	15.08	15.13	14.84	0.450	ns
Fat	4.60	4.40	5.00	4.48	0.380	ns
Protein	4.94	4.94	4.92	4.98	0.210	ns
Solid-Non-Fat	10.79	10.68	10.13	10.37	0.240	ns
Ash	0.87	0.88	0.89	0.88	0.020	ns
Calcium	0.15^{b}	0.16^{a}	0.16^{a}	0.16^{a}	0.011	*
Phosphorus	0.13^{a}	0.12^{b}	0.13^{a}	0.13^{a}	0.011	*

Legend: Nosupp=Not supplemented; Comm= Commercial feed; AE=*Acacia erioloba*; DC=*Dichrostachys cinerea*

^{ab}Mean with different superscripts within the same row are statistically significant (Sig.) (P<0.05)*; ns= not significant; s.e.d=standard error of difference

Effect of ecotype and parity on milk composition of does is shown in Table 6.2. Ecotype significantly influenced total solids, protein and ash (P<0.05). Milk from Ovambo had higher solids (15.66 %), protein (5.11 %) and ash (0.90 %) than those from Caprivi ecotype. Calcium (0.16 %) and phosphorus (0.13 %) concentrations were similar on Caprivi and Ovambo ecotypes.

Parity did not affect milk composition with respect to total solids, fat, protein, solid-non-fat and ash (P>0.05). However, it was noted that phosphorus concentration was significantly affected by the doe parity (P<0.05). Parity two does had milk with slightly higher concentration of P (0.13 %) than those from parity three (0.12 %) respectively.

Table 6.2 Effect of ecotype and parity on milk composition of does

	Ecotype				Parity			
Parameter (%)	Caprivi	Ovambo	s.e.d	Sig.	Two	Three	s.e.d	Sig.
Total solids	14.66^{b}	15.44^{a}	0.552	*	15.07	15.03	0.028	ns
Fat	4.44	4.92	0.339	ns	4.70	4.66	0.028	ns
Protein	4.79^{b}	5.11^{a}	0.226	*	4.82	5.08	0.184	ns
Solid-Non Fat	10.22	10.52	0.212	ns	10.37	10.37	0	ns
Ash	0.86^{b}	0.90^{a}	0.028	**	0.87	0.89	0.014	ns
Calcium	0.16	0.16	0	ns	0.16	0.15	0.007	ns
Phosphorus	0.13	0.13	0	ns	0.13^{a}	0.12^{b}	0.007	*

Legend: ^{ab}Means with different superscripts within the same row are statistically significant (Sig.) (P<0.05)*; ns= not significant; s.e.d=standard error of difference

Table 6.3 shows effect of supplementation at different levels on milk composition. There was significant interaction between supplement and level on calcium and phosphorus (P<0.05).

Calcium and phosphorus concentration increased with increased rate of DC and reduced with increased rate of AE in the diet. Supplementation, level and interactions on total solids, fat, protein, solid-non-fat and ash was not significantly different (P>0.05).

Table 6.3 Effect of supplementation at different levels on milk composition

	Treatment									
	Acacia erioloba			*Dichrostachys cinerea*				Significance		
	AE20	AE40	AE60	DC20	DC40	DC60	s.e.d	Supp(S)	Level(L)	S x L
Parameter (%)										
Total solids	14.85	15.69	14.76	14.52	14.54	15.46	0.430	ns	ns	ns
Fat	4.85	5.04	5.04	4.35	4.12	4.95	0.340	ns	ns	ns
Protein	4.76	5.24	4.90	4.92	4.99	5.10	0.200	ns	ns	ns
Solid-Non-Fat	9.99	10.64	9.72	10.17	10.41	10.51	0.210	ns	ns	ns
Ash	0.86	0.91	0.89	0.88	0.88	0.90	0.017	ns	ns	ns
Calcium	0.16^{b}	0.16^{b}	0.14^{d}	0.15^{c}	0.16^{b}	0.17^{a}	0.005	ns	ns	**
Phosphorus	0.13^{b}	0.13^{b}	0.12^{c}	0.12^{c}	0.13^{b}	0.14^{a}	0.006	ns	ns	*

Legend: AE=*Acacia erioloba*; DC=*Dichrostachys cinerea*; 20, 40 and 60 were the feeding levels; Supp= supplementation;

^{abcd}Means with different superscripts within the same row are statistically significant (P<0.05)*, (P<0.01)**; ns= not significant; s.e.d=standard error of difference

6.3.3 Sensory evaluation of fresh milk, fermented sour-milk and plain yoghurt

Table 6.4 shows effects of pod type on sensory scores of fresh milk, fermented-sour milk and yoghurt obtained from does supplemented with *A. erioloba* (AE) and *D. cinerea* (DC) pods.

Regardless of the pod type, the overall mean scores for fresh milk, fermented-sour milk and yoghurt was significantly different (P<0.01). Yoghurt was rated highest based on colour, aroma, flavour and overall palatability than fresh milk and fermented-sour milk. Fresh milk was rated best for texture and consistency. The overall mean score of different treatments was significantly different (P<0.01). Product made from DC20 (1.98±0.14) followed by AE20 (1.99±0.14) were rated best across all parameters. Products made from non-supplemented group (Nosupp) were rated lowest (2.42±0.14).

Table 6.4 Effects of pod type on sensory scores of fresh milk, sour milk and yoghurt obtained from does supplemented with AE and DC pods

	Parameter							
Product	Colour	Aroma	Flavour	Texture	Consistency	Overall	Mean	S.E
Fresh milk	1.79[b]	2.11[c]	2.31[b]	2.00[a]	2.06[a]	2.28[b]	2.09	0.08
Sour milk	2.09[c]	2.13[b]	2.51[c]	2.41[b]	2.36[c]	2.43[c]	2.32	0.08
Yoghurt	1.72[a]	1.82[a]	2.01[a]	2.07[a]	2.14[b]	2.21[a]	1.99	0.08
Statistic: F-test=	7.12; P	0.01						
Treatment								
Nosupp	2.13[c]	2.25[c]	2.62[c]	2.55[e]	2.40[c]	2.5[d]	2.42	0.14
Comm	1.98[c]	2.10[b]	2.27[b]	2.07[b]	2.25[b]	2.32[b]	2.16	0.14
AE20	1.78[a]	1.95[a]	2.08[a]	2.00[b]	2.02[a]	2.10[a]	1.99	0.14
AE40	1.75[a]	1.93[a]	2.18[a]	2.13[c]	2.02[a]	2.25[b]	2.04	0.14
AE60	1.90[c]	2.02[b]	2.10[a]	2.18[c]	2.37[c]	2.35[b]	2.14	0.14
AE Mean	**1.81**	**1.97**	**2.12**	**2.10**	**2.14**	**2.23**		
DC20	1.73[a]	1.90[a]	2.13[a]	1.97[a]	2.05[a]	2.08[a]	1.98	0.14
DC40	1.85[b]	2.00[b]	2.20[b]	2.12[c]	2.25[b]	2.22[b]	2.11	0.14
DC60	1.80[b]	2.00[b]	2.62[c]	2.27[d]	2.25[b]	2.52[d]	2.24	0.14
DC Mean	**1.79**	**1.97**	**2.32**	**2.12**	**2.18**	**2.27**		
Mean	1.87	2.02	2.28	2.16	2.19	2.3		
Statistic	F-test= 2.54; P<0.01							

[abcd]Means with different superscripts within the same column are statistically significant (P<0.05); SE= standard error; Mean scores at 5-point scale, 1=like very much and 5=dislike very much; Comm= commercial feed; Nosupp= not supplemented; AE= *Acacia erioloba*; DC=

Dichrostachys cinerea; 20, 40, 60 refers to feeding levels (%); Overall= overall acceptability Effects of pod type and level of supplementation on sensory scores of fresh milk, fermented sour-milk and yoghurt are outlined in Table 6.5. The interaction between fresh milk and different treatments was not significantly different (P>0.05) across all parameters. Fresh milk obtained from AE20 (1.55±0.23) was most desired for colour and those from non-supplemented group (2.05±0.23) indicated the lowest score. The overall palatability sensory score on fermented-sour milk amongst treatments was significantly different (P<0.05). Products made from DC20 (1.80±0.26) was most desired for colour, and aroma as compared to other treatments. Sour milk obtained from Nosupp (2.55±0.26) was least preferred by the panellists. The mean sensory scores on yoghurt and treatment interaction was significantly different (P<0.05). However, yoghurt made from treatment AE40 (1.60±0.22) were rated best for colour, and AE60 (1.50±0.22) for aroma and flavour (1.65±0.22). Yoghurt made from DC40 (1.50±0.22) was rated best for colour and DC20 for aroma than those from other treatment diets.

Table 6.5 Effects of pod type and level of supplementation on sensory scores of fresh milk, fermented sour-milk and yoghurt

	Parameter							
Interaction	Colour	Aroma	Flavour	Texture	Consistency	Overall	Mean	S.E
Fresh milk								
Nosupp	2.05	2.30	2.80	2.25	2.10	2.45	2.33	0.23
Comm	1.95	2.15	2.15	2.00	2.10	2.10	2.07	0.23
AE20	1.55	2.10	1.90	1.80	2.05	1.95	1.89	0.23
AE40	1.65	1.90	2.30	1.90	2.00	2.25	2.00	0.23
AE60	1.85	2.20	2.35	2.05	2.10	2.55	2.18	0.23
DC20	1.80	2.25	2.35	1.85	1.85	2.30	2.07	0.23
DC40	1.80	2.00	2.65	2.20	2.00	2.50	2.02	0.23
DC60	1.70	2.00	2.65	2.00	2.00	2.50	2.18	0.23
Statistic:	F-test= 1.13; P>0.05							
Sour milk								
Nosupp	2.55^{d}	2.20^{c}	2.95^{c}	3.20^{d}	2.80^{c}	3.00^{d}	2.78	0.22
Comm	2.25^{c}	2.10^{c}	2.40^{b}	2.00^{a}	2.15^{b}	2.35^{b}	2.21	0.22
AE20	1.90^{a}	2.20^{c}	2.40^{b}	2.25^{b}	1.85^{a}	2.05^{a}	2.11	0.22
AE40	2.00^{b}	2.25^{c}	2.40^{b}	2.40^{c}	2.30^{b}	2.30^{b}	2.28	0.22
AE60	2.05^{b}	2.35^{d}	2.30^{a}	2.40^{c}	2.70^{c}	2.55^{c}	2.39	0.22
DC20	1.80^{a}	1.80^{a}	2.25^{a}	2.20^{b}	2.30^{b}	2.10^{a}	2.08	0.22
DC40	2.25^{c}	2.05^{b}	2.60^{c}	2.45^{c}	2.45^{b}	2.45^{c}	2.38	0.22
DC60	1.90^{a}	2.05^{b}	2.75^{c}	2.40^{c}	2.35^{b}	2.60^{c}	2.34	0.22
Statistic:	F-test= 1.41; P<0.05							
Yoghurt								
Nosupp	1.80^{b}	2.25^{c}	2.10^{b}	2.20^{c}	2.30^{c}	2.30^{b}	2.16	0.26
Comm	1.75^{b}	2.05^{b}	2.25^{c}	2.20^{c}	2.50^{d}	2.50^{c}	2.21	0.26
AE20	1.90^{c}	1.55^{a}	1.95^{b}	1.95^{a}	2.15^{b}	2.30^{b}	1.97	0.26
AE40	1.60^{a}	1.65^{a}	1.85^{b}	2.10^{b}	1.75^{a}	2.20^{b}	1.86	0.26
AE60	1.80^{b}	1.50^{a}	1.65^{a}	2.10^{b}	2.00^{b}	1.95^{a}	1.83	0.26
DC20	1.60^{a}	1.65^{a}	1.80^{b}	1.85^{a}	2.00_{b}	1.85^{a}	1.79	0.26
DC40	1.50^{a}	1.95^{b}	2.00^{b}	1.95^{a}	2.05^{b}	2.10^{a}	1.93	0.26

DC60	1.80^{b}	1.95^{b}	2.45^{c}	2.20^{c}	2.40^{c}	2.45^{d}	2.21	0.26
Statistic:	F-test= 1.5 ; P<0.05							

[abcd]Means with different superscripts within the same column are statistically significant (P<0.05); SE= standard error; Mean scores at 5-point scale, 1=like very much and 5=dislike very much; Comm= commercial feed; Nosupp= not supplemented; AE= *Acacia erioloba*; DC= *Dichrostachys cinerea*; 20, 40, 60 refers to feeding levels (%); Overall= overall acceptability

6.4 DISCUSSION: EXPERIMENT 4

6.4.1 Effect of supplementation on milk composition

AE and DC pods had no significant effects on milk composition (P>0.05). Even though supplementation did not influence milk compositions of the does, values obtained were slightly higher than the standard values reported by FAO (2002). Contrasting results were reported by Donkin (1997) at Medusa in South Africa, who obtained much higher fat (9.33 %) content from indigenous goats than in this study. However, the same study found that indigenous goats had higher protein and fat content than the exotic Saanen breeds. Protein values obtained from this study were in agreement with those reported in Donkin (1997).

Milk composition was found to be similar between the treatments and the results were in agreement with those by Bwire *et al*. (2004). Though fat content is known to be the most sensitive to nutritional changes of the animal Fekadu *et al.* (2005) the different supplementation levels of AE and DC had the same influence. Wang *et al.* (1996) reported a decline in fat percentage from ewes fed *Lotus corniculatus*, which contained an amount of 44.5 g/kg DM of condensed tannins. This suggested that high amount of tannin depressed fat content of the ewes' milk, as this could be due to animal species tolerance to anti-nutritional substances in the feed (Silanikove *et al*., 2001).

Ecotype had effects on milk composition with respect total solids, protein and ash. Ovambo does produce slightly higher milk components than Caprivi ecotype. The reason for these differences could be due to genetic differences between the two ecotypes. It was noted that parity of does had significant effects on calcium and phosphorus concentration with parity two having slightly higher values than parity three. This could be due to influence of age of the animal. Pulina *et al.* (2008) reported that fat and protein concentration declined with the stage of lactation and age of the animal hence the mineral concentration.

The interaction of supplementation and level on calcium and phosphorus was significantly different ($P<0.05$). The interaction was due to increased rate of DC in the supplement and the decline in Ca and P as the rate of AE was increased in the supplement. In Chapter 5, it was noted that AE60 and DC60 reduced intake and growth of doe and kid, but the same level improves Ca and P concentration in milk. In the pods offered, AE had higher (9.56±5.96 g/kg DM) Ca level than DC (5.79±3.20 g/kg DM) and the concentration of P was 0.40±0.15 and 0.34±0.40 g/kg DM respectively. This means that AE having a higher concentration of Ca and P, an optimal level is reached at AE40, whereas with DC, optimal level could be achieved at more than 60 %.

Specific studies dealing with effect of browse pods on Ca and P concentration in milk are generally lacking making it difficult to compare these results. In a study, Pulina *et al*. (2008) stated that the concentrations of Ca and P in goat milk are not easily modified by feeding. The same study stated that goats have a high Ca and P requirement than sheep especially growing kids. Increased of Ca and P concentration in goat milk is important because about 60-70 % of milk Ca is synthesized into casein as calcium phosphor-caseinate (Pulina *et al*., 2008). In this study, a phosphorus: salt lick at 50:50 ratios was offered *ad libutum* and kids were observed to favour it as compared to does (Plate 5.1 (d)of Chapter 5). Calcium is closely related to phosphorus metabolism in the formation of bones and animal body tissues and Ca: P ratio of 2:1 is recommended.

6.4.2 Sensory scores of fresh milk, fermented-sour milk and yoghurt

Sensory evaluation reported in this study were judged by trained panellists responses to product as perceived through the senses of sight, smell a touch or mouth feel and taste of fresh milk, fermented sour-milk and plain yoghurt obtained from different treatments.

There was variation on the interactions between pod type and level of supplementation by yoghurt and fermented sour-milk across all parameters. Yoghurt made from treatment DC40 and AE60 was rated best for colour and aroma whereas fermented sour-milk from DC20 was most desired for colour, aroma and overall palatability. Surprisingly, products made from nonsupplemented group were rated lowest. However, product made from treatment DC20 and AE20 was rated best based on all parameters. These differences could be attributed to the type of product, type of commercial culture used that resulted in individual taste observations perceived by each panellists.

This suggested that the result could be due to product type that the panellist favoured most over other products but not necessarily because of what was supplemented or the level of pod inclusion in the diet. The results were in agreement with a review by Silanikove *et al.* (2010) who stated that woody plants contain aromatic substances but not all produce unpleasant flavours or odours that can be easily perceived by human senses.

However, in an experiment based on *Acacia tortilis* pods, milk odour was changed significantly at higher inclusion rate (2 kg DM) yet at 1kg of *A. tortilis*, no milk odours were found (Bwire *et al.*, 2004).Regardless of the fact that their pods were first soaked in water over 24 hours before feeding, it had not reduced the level of substances in the pods that were suspected to have contributed to the unpleasant odours in milk. It was also not clear to them that the odour was caused by the amount of *A. tortilis* or substances in the pods. Silanikove *et al.* (2010) outlined that compounds that were identified to accumulate and affect aroma of milk were the terpenes, an aspect that this study did not measure. Milk colour was one of the parameters favoured for in yoghurt and fermented sour-milk. According to Donkin (1997) milk product colour could be given by a combination of different compounds such as casein, carotenoids and fat globules which also are related to breed, parity and physiological stage of the animal. Several studies which supplemented woody plant pods had objectives which focused more on meat characteristics than milk. Yayneshet *et al*. (2008) supplemented *D. cinerea* pods to goats and reported a neutral meat odour. In another study, it was shown that grazing two species of saltbush (*Triplex nummular* -old man saltbush and *Atriplex amnicola*- river saltbush) increased lamb meat colour stability and redness (*Pearce et al*., 2005). Also, Supplementation with *Acacia karoo* fresh leaves to goats improved meat quality (Ngambu *et al*., 2013).

Apart from normal goat milk aroma, the treatment diets did not influence fresh milk, even though the milk was not pasteurised or altered. This indicated that panellists were not really able to distinguish between fresh milk produced from those of supplemented or non-supplemented goats. The result were in agreement with the conclusion in Fedele *et al*. (2007) who reported that it was difficult for consumers to perceive sensory differences due to the use of concentrate supplementation with native forages.

Therefore tannin-containing feeds resulted in production of meat with lighter colour Vasta *et al.* (2008) improved appearance, enhanced sensory quality and extended milk shelf-life in dairy industry (Mlambo and Mapiye, 2015). Goats consume a variety of woody plants enriched with secondary compounds which are antimicrobial and anti-oxidative thus consumption of goat milk and milk products may therefore be beneficial to human health.

6.5 CONCLUSIONS

Supplementation with AE and DC pods had no significant effect on total solids, fat, protein, solid-non-fat and ash of indigenous goat milk. Calcium and phosphorus concentration in milk however increased with supplementation rate of inclusion of DC, but declined as the rate of AE was increased.

Fermented sour-milk and yoghurt were both rated best for colour, aroma and overall palatability. Panellist did not identify any unpleasant odours or flavours in the products. These observations imply that if supplementation with pods is adopted, these products could be ideal food complements in the diet of rural people and other developing countries, who cannot afford buying commercial supplements.

CHAPTER SEVEN

7. GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

The study investigated alternative feed resources that could be used as supplements for ruminants during the dry season. A structured questionnaire was used to obtained common woody plant species that were utilized by ruminants in Omatako, Guinas, Tsandi, Daures, Gibeon and Kongola constituencies located in communal farming areas of Namibia. Seventeen most listed woody plants species were considered and their edible parts of leaves and pods or fruits were collected for chemical quality and *in vitro* gas production. Based on literature and availability of woody plant leaves and pods during the study, two pod types of *Acacia erioloba* and *Dichrostachys cinerea* were selected for supplementation to indigenous lactating goats (Ovambo and Caprivi ecotypes). Goat supplements were developed using *A. erioloba and D. cinerea* and animal responses particularly on milk yield and change in weight of does and growth of kids were evaluated. Furthermore, the effects of supplementation with *A. erioloba and D. cinerea* on milk composition and sensory properties of milk products (fresh milk, fermented-sour milk and yoghurt) were assessed.

A survey (Experiment 1) was conducted through farmer's interviews to understand indigenous knowledge on local feed resources. This exercise was important to the author so as to identify dominant trees and shrubs in each study location, their multiple uses on animal production. The survey supported there view of literature and laboratory analyses on the chemical composition of the woody plants and subsequent animal evaluations.

Feed evaluation (Experiment 2) concentrated on 17 woody plant species (16 leaves and 3 pod types) where the chemical composition and fermentation of leaves and pods using rumen liquor by Menke' *in vitro* gas production technique and Theodorou *et al*. (1994) who suggested accumulation of gas at head space of the culture bottles. This study used rumen digesta from the slaughter abattoir and the results were comparable with other studies where rumen fistulation by cannula method were used.

Experiment 3 (Animal feeding trial) observed supplement intake at three different feeding levels, live weight changes of does and growth of kids and estimates milk consumption by using kids body weights. This experiment aimed at determining potential pod type intake, its optimum feeding level that corresponds to higher milk consumption and growth.

Experiment 4 evaluated milk composition and three dairy products produced from does supplemented with AE and DC in order to assess their sensory (organoleptic) properties. The experiment aimed at determining the effect of AE *and* DC supplementation composition of milk. Finally, the study evaluated the effect of AE and DC supplementation pods on colour, aroma, flavour, texture and consistency of fresh milk, yoghurt and fermented sour-milk and their effects on sensory characteristics of these products.

All the above-mentioned experiments were systematically and separately discussed and subsequent conclusions were made. The following sections highlight the results and discussion of the study.

7.2 GENERAL DISCUSSION

7.2.1 Indigenous knowledge and identification of alternative local feed resources as potential feeds for goats in the communal farming areas of Namibia

Structured questionnaire was used to gain indigenous knowledge on the identification of different woody trees and shrubs which were dominant in the location, their edible parts and habitat. The result indicated that 73 % households were male-headed and 27 % female-headed. The largest group (63 %) covered in the survey aged between 41-60 years and 53 % had primary education and very few uneducated respondents. Studies found that male individual older than 41 years and herders have an impressive knowledge on native woody plants (Chepape *et al*., 2011; Basale, 2013), critical for scientists in the development of new technologies (Haugerud and Collin, 1990). The study observed that 47 % of farmers recognised the importance of local feed resources as feeds for livestock. The author suggests that the on-going harsh condition due to poor rains and high temperatures in Namibia served as a lesson to communal farmers in conditioning their activities for adaptation to the harsh weather condition. In a study by Komwihangilo *et al.* (1995) some farmers collected pods and stored them at their homes for the purpose of feeding young and sick animals.However, in this study, 53 % respondents indicated that pod collection was not part of their animal feeding practice, of which 33 % anticipated that animals would source the pods on their own during grazing. The reason for this could be that farmers had inadequate knowledge on pod collection, storage, and how they should be fed to animals. Kindness *et al.* (1999) reported that some farmers mentioned that certain pods such as for *D. cinerea* do not easily fall on the ground as compared to *A. erioloba pods*, and it was therefore necessary to be picked from the shrubs. Farmers associated different woody plants with ailment they cure in the treatment of animals in medicinal and ethno-veterinary practices. In this study, leaves of *C. mopane*, *Z. mucronata*, roots of *Grewia* species, *A. erioloba* and *T. sericea* were all used in the treatment of animal diarrhea. *Boscia albitrunca* roots were used to improve fertility in bulls, interestingly, Marius *et al*. (2012) reported that *B. albitrunca* roots were used in the fermentation and preservation and flavoring of local sour butter milk (*Omashikwa*) in Namibia. Matlebyane *et al*. (2010) also, reported that roots of *Compretum zeyheri* and *T. sericea* were used in the treatment of diarrhea. Some woody plant species are known to contain biological anti-fungal, anti-bacterial anthelmintic and antioxidant activities which combat internal parasites and other pathogens in the animal (Chepape *et al*. (2011) and also in milk products. However, more research is required to evaluate these woody plants for much broader scientific evidence and use in traditional including ethno-veterinary medicine.The most listed woody plant species in all study locations were summarised in Table 4.5, however, at least 3 to 5 species from each location were collected and analysed for composition and gas production as discussed in the following section.

7.2.2 Chemical composition and *in vitro* gas production characteristics of some woody trees and shrubs of Namibia during wet and dry seasons

Woody plant leaves and pods indicated relative contents of DM, Ash, OM, CP, NDF, ADF, and Tannins. Variation were observed in DM, OM, NDF, and Soluble Tannins by season and are consistent with previous reports on browses in Southern Africa (Ndlovu and Nherera, 1997; Kamupingene and Abate, 2004; Aganga *et al*., 1998, 2005; Mokoboki *et al*., 2005; Mlambo *et al.*, 2008) and other parts of the tropics (Khazzal and Orskov, 1994; Larbi *et al*., 1998; Abdulrazak *et al.*, 2000). Differences in plant cell-wall lignification, content in the edible part, season and the study locations could be partly responsible. In addition, the poor rains and prolonged dry season in Namibia could be another reason for these variations. In this study, CP content obtained in *A. erioloba* and *D. cinerea* pods (Table 4.1) were in agreement with those in Sikosana *et al.* (2002a). However, Mlambo *et al*. (2008) found slightly lower values of CP content in AE (133 g/kg DM) and DC (124 g/kg DM). The differences could be explained by seasonal effect, location of study and analytical method used. Studies that have separated the seeds from the hulls reported high CP in the seed fraction and high fibre content in the hull. In this study, does offered with AE supplement, most of the refusal materials consisted of seed fraction. The reason is attributed to the size and hardiness of AE seeds, and goats were able to isolate them. A high proportion of intact seeds passing through the alimentary tract of reduced their potential protein contribution to the animal (Tanner *et al.,* 1990). The author suggested that crushing pods before feeding improves intake and nutritive value. This could further reduce seed dispersal hence less bush establishment, as this is a big concern in Namibia, particularly with DC shrubs. Tannin concentration in woody plants leaves were detected more in dry season than in wet season. However, Ash, CP and ADF were not significantly affected by season and location of study. The utilization of browse is limited by the high lignin content and the presence of antinutritional factors, which may be toxic (Mlambo *et al.* 2004; 2008) at high quantities and vice versa.

The concentration of Ca, P and Se amongst woody species was not significantly different, but there was variation by season and study locations. Factors such as soil, climate, stage of maturity and season contribute to variations in the concentration of minerals in forages (Le Houerou, 1980; Topps, 1992).

Variation in the *in vitro* gas constants was observed among woody species, season and across study locations. Higher values for *c* and *b* constants of browses may indicate a better nutrient availability for rumen microorganisms (Getachew *et al.,* 2004) hence digestibility of the feed. The high fermentation parameters in the wet season might be associated with the high CP and fibre and low tannins (Basha *et al.,* 2012). Also, species with low gas production were associated with high tannins and vice versa. The correlations between NDF and ADF were positive and significant. This observation was constant with other reports (Ndlovu and Nherera, 1997 and Larbi *et al*., 1998). This could be due to woody species variation in quantity and quality of fibre content and complexation of the fibre with polyphenolics, as type of species studied was of varied genetic background. The cell-wall constituents and tannin concentration negatively correlated to gas production parameters and was not significant. This observation agrees with that of Nsahlai *et al*. (1994) and Khazaal and Orskov (1994) who reported negative correlation between gas production with the NDF and tannin concentration, but positively with the CP content. The mean range of tannin concentration obtained was much lower than those reported in literature (Table 2.3). The Folin-Ciocalteau method used in this study could only detect water soluble phenolics, but not the condensed tannins that are common in woody plants such as *Acacia* species and were not essayed and therefore difficult to draw strong conclusions. AE and DC pods were selected for supplementation to lactating goats and their effect was discussed in detail in the following section.

7.2.3 Effect of *Acacia erioloba* and *Dichrostachys cinerea* pods supplementation on intake, does weight change, growth of kids and milk yield performance of Namibian Caprivi and Ovambo indigenous goats

The study showed that supplementation had significant effect on intake, milk yield and growth of does and kids. Supplement intake was higher on does offered Comm, however, does on DC40 had kids with higher ADG and weaning weight whereas final weight was high on does on AE40. This observation agrees with those in other reports (Smith *et al*., 2005b; Maphosa *et al*., 2009; Ngambu *et al*., 2013; Lengarite *et al*. 2014). This result suggests that does had enough milk which reflected in the growth of their kids.

Milk yield on metabolic weight basis was higher on kids from does on Comm and lower in those from does offered AE60. When AE and DC were compared, intake and CP consumed was highest in does offered with DC supplement and declined with level of supplementation, which also reflected in milk yield on metabolic weight kids.

The findings contrasted the results in Yayneshet *et al*. (2008) who observed intake from 83.8 to 94.3 g/kg $M^{0.75}$ and gain of 10 to 21.7 g/day from DC supplementation as the level was increased from 0.5 to 1.5 % respectively. The reasons for these differences could be the feeding levels between the two studies.

On the other hand, Sikosana *et al*. (2002a) supplemented goats with AE and DC to castrated Matebele goats in Zimbabwe and obtained higher intake on those from DC supplementation group and lower intake on *Acacia nilotica* due to tannin concentration. Supplementation with tanniferous browse to ruminants have been reported to reduce intake, live-weight gain and reduced milk production (Sikosana *et al.,* 2002a; Smith *et al* 2005b; Mueller-Harvey, 2006). However, Silanikove *et al.* (1996) stated that goats have the ability to consume large amounts of tannin rich plants without exhibiting toxic syndromes. This could be due to a detoxifying enzyme in goats' saliva, which is not the case for other ruminant species.

Besides, supplement influenced kid ecotype, parity, and sex and birth type. Caprivi kids, growth rate was slightly higher over the 13 weeks of lactation than those from Ovambo ecotype. This could be due to genetic differences between indigenous goat ecotypes hence more study is required to support this observation.

The effect of parity on milk yield has been reported with doe in third and fourth lactation yielding more than goats in first and second parity (Carnicella *et al.,* 2008). Strong correlation has been reported between milk yield and average daily gain of kids. Carnicella also reported that does kidded twins yielded more milk than those with single kids. This study observed sex to have an effect on kid growth, with males being heavier than females at birth and at weaning. Consistent superiority of males has been widely reported, with similar trends being reported by Carnicella *et al*. (2008) and Maphosa *et al*. (2009). This has been attributed to hormonal differences between sexes and their resultant effects on growth, and perhaps attaining puberty earlier than female kids. In the last 3 weeks of the Animal experiment, male kids were observed to consistently mount on the does during browsing, a situation that could possibly have contributed to kid weaning weights and final weights of does. The author advises that in similar experiments using Namibian indigenous breeds, caution should be adhered to the duration of the experiment as this may result in inbreeding.

Milk samples obtain from Animal experiment was determined for composition and assessed for sensory characteristics in the following section.

7.2.4 Milk composition and sensory evaluation of fresh milk, fermented-sour milk and yoghurt from indigenous Namibian lactating does supplemented with *Acacia erioloba* and *Dichrostachys cinerea* pods

Supplementation had no effects on total solids, fat, protein, solid-non-fat and ash content across the treatment diets, and the results was in agreement with those in Bwire *et al*. (2004). Various studies have been adding poly-ethylene glycol (PEG) to diets to neutralize tannins, improve utilization of tanniferous plants, and to improve milk performance of goats (Decandia *et al.*, 2008). Obviously, milk production was strongly improved, but milk composition particularly fat and protein content remained unchanged. Besides milk, several reports supplemented woody plant pods to goats found enhancement in meat characteristics (Pearce *et al*., 2005; Yayneshet *et al*., 2008; Ngambu *et al*., 2013). Tanniferous feeds result in production of meat with brighter colour (Vasta *et al*., 2008).

The study observed significant interaction on supplementation and level on calcium and phosphorus content. Calcium and phosphorus concentration in milk increased with DC supplementation rate and declined with AE inclusion rate. It was noted that AE had higher Ca and P concentration than DC (Table 6.2).

The study has showed that fresh milk, fermented sour-milk and yoghurt were highly accepted with yoghurt rated highest for colour and aroma. Yoghurt made from treatment DC40 and AE60 was rated best for colour and aroma whereas fermented sour-milk was most desired for colour, aroma from treatment DC20. Literature suggests that the higher levels of vitamin A (beta carotene) gives goat milk its whiter colour than cow milk. Flavour and aroma determines milk quality to the large extend than texture and consistency. Apart from normal goat milk smell, panellists had mixed observations that run across treatment diets that the author found little difficult to explain. Fedele *et al.* (2007) study concluded that consumers would not perceive sensory differences due to the use of concentrate supplementation to native pasture or forage.Interestingly, products made from non-supplemented group were rated lowest.

There was no significant variation found in fresh milk by all treatments and parameters. Supplementation with AE and DC pods at 20, 40, and 60 %; including whatever goats browsed in the camps did not introduced unpleasant odours potentially to be perceived by the panelists. In a study by Bwire *et al*. (2004), unpleasant odours were detected in milk of dairy cows when supplemented with 2 kg of *Acacia tortilis* pods. Type of woody plant pods, and how they were offered (sole or mixed with other feeds) and animal species used could provide more explanation to the situation. Fedele *et al*. (2005) narrated that not all volatile compounds contained in plants have significant effect on the odours in goat milk. However, terpenes are capable to characterize flavour and aroma in dairy products when animals are fed with dicotyledons plants. Study findings and recommendations are summarized in the following section.

7.3 GENERAL CONCLUSIONS

Majority (43 %) of respondents aged between 41 and 60 and above, and mostly males (73 %) with at least basic education had profound knowledge on woody plants available in their constituencies. Indigenous knowledge created effective communication between farmers and the researcher that provided a richer basis for decision on woody plants identification and collection. It is therefore important that indigenous knowledge is documented and evaluated before it is lost. Variation in chemical composition of woody plants was observed on DM, OM, NDF and ST by plant species, season and location of study, however, Ash CP and ADF were not affected by season or location.

Concentration of Ca, P and Se in woody plant browse was high in wet season and lower in dry season, whereas P concentration differs by location. Therefore, inclusion of these minerals in the animal diet is necessary during the dry period in order to improve digestibility of the poor quality grazing/browsing.

NDF and ADF content of the woody plants were positively correlated. A negative correlation between potential gas production and rate of degradation with NDF, ADF and ST could be due to presence or nature of tannins, variation in cell-wall constituents and season. Very low correlation was observed between fibre constituents, water soluble tannins and *in vitro* gas production constants.

Supplementation with protein feeds has been demonstrated to be a good source of protein that improves growth in ruminants. However, cost of commercial protein supplements and transportation or accessibility to the feed supplier has been a big challenge to communal livestock farmers in Namibia.

The research has revealed that supplementation with AE and DC pods improved performance in goats. Supplementing with DC40 was recorded to be superior in improving milk in lactating does and kid growth. Supplementation with AE and DC had no effect on total solids, fat, protein, solid-non-fat and ash of indigenous goat milk. Calcium and phosphorus concentration in milk increased with rate of DC and declined with the rate of AE. Fermented-sour-milk and yoghurt were both favoured for colour and aroma. Panellist did not detect unpleasant flavours or odours in the milk products.

AE and DC pods had appreciable amount of CP (143 g/kg DM), (162 g/kg DM) and Ca and P concentration ratio of 9.6:0.40 and 5.8:0.34 g/kg respectively. This suggests the option and useful effort to collect pods, store and use during time of feed scarcity. This study also showed chemical composition of various potential woody plant species where future feeding strategies could be developed especially in those constituencies where AE and DC species rarely exist.

7.4 RECOMMENDATIONS AND FUTURE WORK

It is useful to investigate ethno-veterinary knowledge of potential woody plant materials, particularly leaves and roots. The presence of secondary compounds in woody plants was observed to have influenced the rate and extend of digestion as well as other chemical constituents. Therefore, when evaluating woody plant species, caution should be adhered to the analytical method, and if possible, addition of PEG to bind tannins.

A. erioloba and *D. cinerea* pods are recommended to be fed to goats as supplements at 40 % feeding level for optimal intake, improved milk yield and growth of kids as for most resources farmers cannot afford commercial supplements. Collection and grinding of pods allows availability of nutrients and reduces the intact seeds in goat faeces and could be used for managing the DC bush encroachment problem in Namibia. Fermented-sour milk and yoghurt could be ideal food complement in the diet of rural people.

LITERATURE CITED

Abdulrazak, S.A., Fujihara, T., Ondiek, J.K. and Ørskov, E.R. 2000. Nutritive evaluation of some acacia tree leaves from Kenya. Animal Feed Science and Technology, **85:** 89-98.

Aganga, A.A., Tsopito, C.M. and Adogla-Bessa, T. 1998. Feed potential of Acacia species to ruminants in Botswana. Archivos de Zootecnia, **47:** 659-688.

Aganga, A.A., Omphile, U.J. and Beleseng, L. 2001. Performance of Tswana goats fed *Acacia mellifera*, *Euclea undulate* and *Peltophorum africanum* as a supplement to Buffel grass. Archivos de Zootecnia, **50:** 383 – 386.

Aganga, A. A. and Tswenyane, S.O. 2003. Feeding value and anti-nutritive factors of forage tree legumes. Pakistan Journal of Nutrition, **2**: 170-177.

Aganga, A.A., Omphile, U.J. and Ntshontsi, T.F. 2005. Forage value of browses and its implication to traditional management of goats in Kgatleng District of Botswana. Journal of Biological Sciences, **5**: 506-510.

Aganga, A.A. and Mesho, F.O. 2008. Mineral contents of browse plants in Kweneng District in Botswana. Agricultural Journal, **3:** 93-98.

Akinsoyinu, A.O., Mba, A.U. and Olubajo, F.O. 1977. Studies on milk yield and composition of the West African Dwarf goat in Nigeria. Journal of Dairy Research. **44**: 57-62.

Ansah, T and Nagbila, D.A. 2011. Utilization of local trees and shrubs for sustainable livestock production in the Talensi-Nabdam district of the upper east region of Ghana. Livestock Research for Rural Development, **23:** 1-7.

Antwi, C. 2010. Some factors influencing the biomass yield and nutritional value of improved Cowpea Haulm from four improved dual purpose cowpea. *PhD Thesis*. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Asfari, Z., Burgard, M. And Vicens, J. 1993. Synthetic calixarene and natural polyphenolics: Common grounds for future research: In: Polyphenolic phenolic Phenomena. Scalbert, A. (ed). INRA editions. Paris, pp 49-62.

Association of Official Analytical Chemists (AOAC). 2007. Official Methods of Analysis. Agricultural Laboratory Association of Southern Africa (AgriLASA) 2nd Edn. Washington DC, USA.

Attoh-Kotoku, V. 2011. Feeding two Nerica rice straw varieties to sheep: Effects of supplementation with leguminous foliage on digestibility, nutrient utilization and growth performance. *PhD Thesis.* Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Babayemi, O.J., Bamikole, M.A. and Daodu, M.O. 2009. In vitro gas production and its prediction on metabolizable energy, organic matter digestibility and short chain fatty acids of some tropical seeds. Pakistan Journal of Nutrition, **8:** 1078 – 1082.

Banda, J.W. and Phiri, C.D. 1990. Investigations into the factors influencing the choice and consumption of milk and milk products in Malawi. Journal of Consumer Studies and Home Economics, **14**: 123-131.

Basha, N.A.D., Scogings, P.F., Dziba, L.E. and Nsahlai, I.V. 2012. Diet selection of Nguni goats in relation to season, chemistry and physical proportions of browse in Sub-humid Subtropical Savanna. Small Ruminant Research, **102**: 163-171.

Barnes, R. D., Fagg, C.W. and Milton, S.J. 1997. *Acacia erioloba*: Monograph and annotatedbibliography. Tropical forestry papers, **35.** Oxford Forestry Institute, Oxford.

Barry, T. N. and Manley, T.R. 1986. Interrelationships between the concentrations of condensed tannins, free condensed tannins and lignin in lotus spp and their possible consequences in ruminant nutrition. Journal of the Science of Food and Agriculture, **37**: 248-254.

Bille, P.G., Vovor, M.N., Goreseb, J. and Keya, E.L. 2000. Evaluating the feasibility of adding value togoat's milk by producing yoghurt using low cost technology method for rural Namibia. Journal of Food Technology in Africa, **5:** 139 -143.

Bryant, J. P., Reichardt P.B. and Clausen, T.P. 1992. Chemically mediated interactions between woody plants and browsing mammals. Journal of Range Management, **45**:18-24.

Bwire, J.M.N., Wiktorsson, H. and Shayo, C.M. 2004. Effect of level of *Acacia tortilis* and *Faidherbia albida* pods supplementation on the milk quality of dual-purpose dairy cows fed grass hay-based diets. Livestock Production Science, **87**: 229-236.

Buchin, S., Martin, B., Dupont, D., Bornard, A. and Achilleos, C. 1999. Influence of the composition of alpine highland pasture on the chemical, rheological, and sensory properties of cheese. Journal of Dairy Research, **66**: 579-588.

Carnicella, D., Dario, M., Ayres, M.C., Laudadio, V. and Dario, C. 2008. The effect of diet, parity, year and number of kids on milk yield and milk composition in Maltese goat. Small Ruminant Research, **77**: 71-74.

Cheikhyoussef, A., Shapi, M., Matengu, K. and Ashekele, H.M. 2011. Ethnobotanical study of indigenous knowledge on medicinal plant use by traditional healers in Oshikoto region, Namibia. Journal of Ethnobiology and Ethnomedicine, **7:**10. Accessed online at: http://www.ethnobiomed.com/content/7/1/10

Chepape, R.M., Mbatha, K.R. and Luseba, D. 2011. Local use and knowledge validation of fodder trees and shrubs browsed by livestock in Bushbuckridge area in South Africa. Livestock Research for Rural Development, **23:** 1-11. Available online at: http://www.lrrd.org/lrrd23/6/chep23132.htm. Accessed date on 9/8/2012.

Curtis, B.A. and Mannheimer, C.A. 2005. Tree Atlas of Namibia. Windhoek: National Botanical Research Institute. pp 688.

Deeth, H. C. and Tamine, A. Y. 1981. Yoghurt: Nutritive and therapeutic aspects. Journal of Food Protection, **44**: 78-86.

Decandia, M., Yiakoulaki, M.D., Pinna, G., Cabiddu, A. and Molle, G. 2008. Foraging behaviour and intake of goats browsing on Mediterranean shrublands. In: Dairy goats and feeding and nutrition, Eds Cannas A and Pulina G. Department of Animal Science, Italy.

de Klerk, J.N. 2004. Bush encroachment in Namibia. First Edition, Ministry of Environment and Tourism, Namibia

Donkin, E.F. 1997. Milk production from goats for households and small-scale farmers in South Africa Department of Animal Health and Production, Faculty of Veterinary Science Medical University of Southern Africa, MEDUNSA, RSA. Available online at: http://www.library.up.ac.za/vet/goat/documents/sec21.pdf. Accessed date: 11/07/12.

Dube, J.S., Reed, J.D. and Ndlovu, L.R. 2001. Proanthocyanidins and other phenolics in Acacia leaves of Southern Africa. Animal Feed Science and Technology, **91:** 59 - 67.

Economides, S. 1982. Nutrition and management of sheep and goats. Food and Agriculture Organizations. Available online at:http://www.fao.org/docrep/009/ah221e/AH221E05.htm. Accessed date: 10/12/2015

Food and Agriculture Organization (FAO). 1992. Composition and yield of milk from non-dairy goats and sheep in Malawi, In: *Proceedings of the First Biennial Conference of the African*. Banda W, Steinbach J and Zerfas H-P 1992. Small Ruminant Research Small ruminant research and development in Africa. ILCA, Nairobi, Kenya

Food and Agriculture Organization (FAO). 2002. Milk Producer GroupResource Book a practical guide to assist milk producer groups.Available online at:

http://www.fao.org/docrep/007/y3548e/y3548e00.htm Accessed date: 8/9/2009

Food and Agriculture Organization (FAO). 2011. FAOSTAT, Statistic database, FAO, Rome, Italy

Fedele, V., Rubino, R., Claps, S., Sepe, L. and Morone, G. 2005. Seasonal evolution of volatile compounds content and aromatic profile in milk and cheese from grazing goats. Small Ruminant Research, **59:** 273 – 279.

Fedele V., Pizzillo M., Claps S. and Cifuni, G.F. 2007. Effect of types of forage on terpenes content and profilein goat milk. In : Priolo A. (ed.), Bion di L. (ed.), Ben Salem H. (ed.), Moran d-Feh r P. (ed.).*Advanced nutrition and feeding strategies to improve sheep and goat* . Zaragoza: CIHEAM, p19 -24 (Option s Méditerranéennes : Série A. Séminaires Méditerranéens; no.7 4)

Fekadu, B., Soryal, K., Zeng, S., van Hekken, D., Bah, B. and Villaquiran, M. 2005. Changes in goat milk composition during lactation and their effecton yield and quality of hard and semihard cheeses. Small Ruminant Research, **59**: 55-63.

Foo, L.Y., Newman, R., Waghorn, G.C., McNabb, W.A. and Ulyatt, M.J. 1996. Proanthocyanidins from lotus corniculatus. Phytochemistry**, 41**: 617-624.

France, J., Dhanoa, M.S., Theodorou, M.K., Lister, S.J., Davies, D. and Isac, D. 1993. A model to interpret gas accumulation profiles associated with in-vitro degradation of ruminants feeds. Journal of Theoretical Biology, **163**: 99-111.

Getachew, G., Blümmel, M., Makkar, H.P.S. and Becker, K. 1998. *In vitro* gas measuring techniques for assessment of nutritional quality of feeds: a review. Animal Feed Science and Technology, **72**: 261-281.

Getachew, G., Edward, P., Robinson, J. and Peter, H. 2004. In vitro gas production provides effective method for assessing ruminant feeds. California Agriculture, **58:** 54-58.

Giess, W. 1998. A Preliminary Vegetation Map of Namibia. 3rd Revised Edition. Dinteria **4:** 1-112.

Greyling, J.P.C., Mmbengwa, V.M., Schwalbach, L.M.J. and Muller, T. 2004. Comperative milk production potential of Indigenous and Boer goats under two feeding systems in South Africa. Small Ruminant Research, **55:** 97-105.

Haenlein, G. F. W. 2004. Goat milk in human nutrition. Small Ruminant Research, **51(2)**: 155-163

Hagerman, A.E. 1987. Radial diffusion method for determining tannins in plant extracts. Journal of Chemical Ecology, **13:** 437 - 449.

Haslam, E. 1993. Polyphenol complexation. In: Polyphenolic phenomena. Scalbert A. (Ed) INRA, France.

Haugerud, A. and Collinson, M. P. 1990. Plants, genes, and people: Improving the relevance of plant breeding in Africa. Exploration Agriculture, **26**: 341-362.

Henke, L.A. 1958. Value of *Leucaena glauca* as a feed for cattle. Proceedings of the Eighth Pacific Science Congress, IVB: 591-600.

Hamilton, R.I., Fraser, J. and Armitt, P.A. 1969. Preliminary assessment of tropical pasture species for taint in milk. Australian Journal of Dairy Technology, **24:** 62-65.

International Atomic Energy Agency (IAEA). 2006. Improving animal productivity for supplementary feeding of multi-nutrient blocks. Controlling international parasites and enhancing utilization of alternative feed resources. IAEA TECDOC Series No. 1495. IAEA, Vienna, Austria, pp 80.

Jones, L.V., Peryam, D.R., and Thurstone, L.L. 1955. Development of a scale for measuring soldiers food preferences. Food Research, **20**: 512-520.

Jürgens, N., Haarmeyer, D.H., Luther-Mosebach, J., Dengler, J., Finch, M. and Schmiedel, U. 2010. Patterns at local scale the BIOTA Observatories. Biodiversity in Southern Africa, Klaus Hess Publishers, **1:** 223-245.

Kamupingene, G.T and Abate, A. L. 2004. Nutritive value of goat diets in Okondjatu communal area of east-central Namibia. South African Journal of Animal Science, **34:** 72-75.

Kindness, H., Sikosana, J. L. N., Mlambo, V. and Morton, J. F. 1999. Socio-economic surveysof goat keeping in Matobo and Bubi Districts. Natural Resources Institute Report No. 2451. UK: Chatham Maritime.

Kasale, F. 2013. Determination of nutritive values of browsable plants utilised by cattle during the dry season in Sibbinda constituency of Zambezi region in Namibia. *MSc. Thesis*. University of Namibia.

Katjiua, M.L.J and Ward, D. 2006. Cattle diet selection during the hot-dry season in a semi-arid region of Namibia. African Journal of Range and Forage Science, **23(1)**: 59-67.

Kavana, P.Y. and Msangi, B.S.J. 2005. On farm dairy cattle feeding experience in eastern zone of Tanzania. Livestock Research for Rural Development, **16**: 6. Available online at: http://www.lrrd.org/lrrd17/6/kava17062.htm. Accessed date 10/07/2014

Komwihangilo, D.M., Goromela, E.H. and Bwire, J.M.N. 1995. Indigenous knowledge in utilization of local trees and shrubs for sustainable livestock production in central Tanzania. Livestock Research for Rural Development, **6**:3.

Komwihangilo, D.M., Sendalo, D.S.C., Lekule, F.P., Mtenga, L.A. and Temu, V.K. 2001. Farmers'knowledge in the utilization of indigenous browse species for feeding of goats in semi arid central Tanzania. Livestock Research for Rural Development, **13(6)**. Available online at:http://www.cipav.org.co/lrrd /lrrd13/6/komw136.htm Accessed date 10/04/2014

Khazaal, K. and Orskov, E.R. 1994. The in vitro gas production technique: an investigation on its potential use with insoluble polyvinylpolyrrolidone for the assessment of phenolic-related antinutritive factors in browse species. Animal Feed Science and Technology, **47**: 305-320.

Kruger, B. and Lammerts-Imbuwa, L. 2008. Namibia National Farmers Union. Training Manual. Livestock Marketing Advisors Training Project funded by the European Commission through Oxfam Solidarity in Belgium.

Larbi, A., Smith, J.W., Kurdi, I.O., Adekunle, I.O., Raji, A.M. and Ladipo, D.O. 1998. Chemical composition, rumen degradation, and gas production characteristics of some multipurpose fodder trees and shrubs during wet and dry seasons in the humid tropics. Animal Feed Science and Technology, **72**: 81-96.

Lengarite, M.I., Getachew, G., Akudabweni, L. and Hoag, D. 2014. Supplementary feeding of lactating goats with processed and unprocessed *Acacia tortilis* pods and local grass in the dry season in northern Kenya. Agricultural Science Research Journal, **4(3)**: 63-71. Available online at: http://www.resjournals.com/AR

Le Houerou, H.N. 1980. Browse in Africa. The current state of knowledge. International Livestock Centre for Africa. Addis Ababa, Ethiopia.

López, S., Dhanoa, M.S., Djikstra, J., Bannink, A., Kebreab, E. and France, J. 2007. Some methodological and analytical considerations regarding applications of the gas production technique. Animal Feed Science and Technology, **135:** 139-156.

Lukhele, M. S and Ryssen, J.B.J. 2003. The chemical composition and potential nutritive value of the foliage of four subtropical tree species in Southern Africa for ruminants. South African Journal of Animal Science**, 33:** 132-141.

Luginbuhl, J.M. and Poore, M.H. 1998. Nutrition of meat goats. Available online at:

www.cals.ncsu.edu/an_sci/extension/animal/meatgoat/MGNutr.htm. Accessed date: 12/9/2012.

Makkar, H. P. S. 2003. Effects and fate of tannins in ruminant animals, adaptation totannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds.Small Ruminant Research, **49**: 241-256.

Mannheimer, C.A. and Curtis, B.A. 2009. Le Roux and Müller's Field Guide to the Trees and Shrubs of Namibia. Windhoek: Macmillan Education Namibia.

Marius, L.N., Kandjou-Hambeka, M. and Jakob, A.M. 2012. Characterization of the Dairy Production System Practiced by the Livestock keepers in the selected constituencies of Namibia: A Case of Omuthiya-Guinas and Ovitoto. In: Agricola 2012. Directorate of Agricultural Research and Development, Ministry of Agriculture, Water and Forestry, Windhoek, Namibia

Maphosa, V., Sikosana, J.L.N. and Muchenje, V. 2009. Effect of doe milking and supplementation of *Dichrostachys cinerea* pods on kid and doe performance in grazing goats during the dry season. Tropical Animal Health Production, **41**: 535-541.

Matlebyane, M.M., Ng'ambi, J.W.W and Aregheore, E.M. 2010. Indigenous knowledge ranking of available browse and grass species and some shrubs used in medicinal and ethnoveterinary practices in ruminant livestock production in Limpopo province, South Africa. Livestock Research for Rural Development, **22(54)**.

Matlebyane, M. M., Ng'ambi, J. W. W. and Aregheore, E. M. 2009. Relationships between chemical composition and *in vitro* digestibility of some common forage species used for ruminant livestock production in three chief areas of Capricorn Region, Limpopo Province, South Africa. Research Journal of Agriculture and Biology Science, **5**: 138-149.

Mendelsohn, J. 2006. Farming systems in Namibia. National Farmers Union publisher, Windhoek, Namibia.

Menke, K.H. and Steingass, H. 1988. Estimation of the energetic feed value obtained from chemical analyses and gas production using rumen fluid. Animal Research and Development, **28**: 7.

Menke, K.H., Raab, L., Salewski, A., Steingass, H., Fritz, D. and Schneider, W. 1979. The estimation of the digestibility and metabolizable energy content of ruminant feedstuffs from the gas production when they are incubated with rumen liquor in vitro. Journal of AgriculturalScience, **92**: 217-222.

Ministry of Agriculture, Water and Forestry (MAWF). 2014. Livestock Census database 20002014. Directorate of Veterinary Science, Windhoek, Namibia.

Mlambo, V., Smith, T., Owen, E., Mould, F.L., Sikosana, J.L.N. and Mueller-Harvey, I. 2004. Tanniniferous *Dichrostachys cinerea* fruits do not require detoxification for goat nutrition: *in sacco* and *in* vivo evaluations. Livestock Production Science, **90**: 135-144.

Mlambo, V., Mould, F. L., Sikosana, J. L. N., Smith, T., Owen, E. and Mueller-Harvey, I. 2008. Chemical composition and in vitro fermentation of tannin-rich tree fruits. Animal Feed Science and Technology, **140**: 402-417.

Mlambo, V. and Mapiye, C. 2015. Towards household food and nutrition security in semi-arid areas: What role for condensed tannin-rich ruminant feedstuffs? Food Research International, Available online at: http://dx.doi.org/10.1016/j.foodres.2015.04.011.

Mokoboki, H.K., Ndlovu, L.R., Ngambi, J.W., Malatje, M.M. and Nikolovav, R.V. 2005. Nutritive value of Acacia tree foliages growing in the Limpopo Province of South Africa. South African Journal Animal Science, **35:** 221–228.

Moleele, N.M. 1998. Encroacher woody plant browse as feed for cattle. Cattle diet composition for three seasons at Olifants Drift, south-east Botswana. Journal of Arid Environments, **40**: 255268.

Morand-Fehr, P. 2005. Recent developments in goat nutrition and application: A review. Small Ruminant Research, **60**: 25-43.

Morand-Fehr, P., Fedele, V., Decandia, M. and Le Frileux, Y. 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. Small Ruminant Research, **68:** 20-34.

Mueller-Harvey, I. and McAllan, A.B. 1992. Tannins: their biochemistry and nutritional properties. Advance Plant Cell Biochemistry. Biotechnology, **1**: 151-182.

Mueller-Harvey, I., 2006. Review Unravelling the conundrum of tannins in animal nutrition and health. Journal of the Science of Food and Agriculture, **86**: 2010-2037.

Namibia Livestock Census Report (NLCR). 2010. Ministry of Agriculture, Water and Forestry. Directorate of Veterinary Services, Windhoek, Namibia

Namibia Meat Board Annual Report (NMBAR). 2011. Slaughtering and Marketing Statistics of Livestock at Abattoirs in Namibia, Windhoek, Namibia.

National Development Plan (NDP4). 2012. Namibia's Fourth National Development Plan. National Planning Commission. Windhoek, Namibia.

National Research Council (NRC). 2001. Nutrient Requirements of Dairy. Cattle. 7th Revised Edition. National Academy of Science, Washington, DC, USA.

Ndlovu, L.R., Sibanda, H.M., Sibanda, L.M. and Hove, E. 1995. Nutritive value of pods of indigenous browsable tree species in a semi-arid areas of Zambabwe. AnnalesDe Zootechnie, **44 (51)**

Ndlovu, L.R. and Nherera, F.V. 1997. Chemical composition and relationship to *in vitro* gas production of Zimbabwean browsable indigenous tree species. Animal Feed Science and Technology, **69**: 121-129.

Ngambu, S. Muchenje, V. and Marume, U. 2013. Effect of Acacia karoo supplementation on growth ultimate pH, colour and cooking losses of meat from indigenous Xhosa Lop-eared goats. Asian-Australasian Journal of Animal Science, **23**: 128-133.

Norton, B.W. 1994. Anti-nutritive and toxic factors in forage tree legumes. In: Forage Tree Legumes in Tropical Agriculture. Eds. Gutteridge, R.G. &Shelton, H.M., CAB, London. International, Wallingford, Oxon, UK. pp 202-215.

Njarui, D.M.G. and Mureithi, J.G. 2004. Forage Production Systems for Dairy Production in the Coastal Lowlands of Kenya. Biomedical and Life Sciences**,** 195-218.

Nsahlai, I.V., Siaw, D.E.K.A. and Osuji, P.O. 1994. The relationship between gas production and chemical composition of 23 browses of the genus Sesbania. Journal Science and Food Agriculture, **65**: 13.

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

Osuji, P.O., Nsahlai, I.V. and Khalili, H. 1993. Feed Evaluation. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Otsyina, R. M., Norton, B. W. and Djimde, M. 2000. Fodder trees and shrubs in arid and semi-arid livestock production systems. **23** Grasslands in Arid and Semi-Arid Regions. Available online at: http://www.internationalgrasslands.org/files/igc/publications/1997/iii-429.pdf. Accessed date: 7/3/2012

Peacock, C. 1996. Improving Goat Production in the Tropics. A manual for development workers. FARM-Africa and Oxfam (UK and Ireland). pp 65-91.

Pearce, K.L., Masters, D.G., Smith, G.M., Jacob, R.H. and Pethick, D.W. 2005. Plasma and tissueocopherol concentrations and meatcolour stability in sheep grazing saltbush (Atriplex spp.). Australian Journal of Agricultural Ressearch, **56**: 663-672

Pulina, G., Nudda, A., Battacone, G., Fancellu, S. and Francesconi, A.H.D. 2008. Nutrition and Quality of goat's milk, In: Dairy goat feeding and nutrition Eds. Cannas, A. and Pulina, G. CAB International 2008, Cambridge, USA.

Reed, J.D. 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. Journal of Animal Science, **73:** 1516-1528. Available online at: http://www.journalofanimal science.org/content/73/5/1516. Accessed date: 9/10/2013.

Rothauge, A. 2006. Newsletter of the Grassland Society of Southern Africa, 11th Agrisson Congress. **6(2).** Available online at: www.grassland.org.za. Accessed date: 7/04/2014

Routray, W. and Mishra, H.N. 2011. Scientific and Technical Aspects of Yogurt Aroma and Taste: A Review. Comprehensive Reviews in Food Science and Food Safety, **10:** 208-220.

Salem, B., Norman, H. and Nefzaoui, H.C. 2010. Potential use of oldman saltbush (*Atriplex Nummularia* Lindl.) in sheep and goat feeding. Small Ruminant Research, **91**: 13-28.

Salem, B. and Smith, T. 2008. Feeding strategies to increase small ruminant production in dry environments. Small Ruminant Research, **77**: 174-194

Sanon, H.O., Kabore-Zoungrana, C. and Ledin, I. 2007. Behaviour of goats, sheep and cattle and their selection of browse species on natural pasture in a Sahelian area. Small Ruminant Research, **67:** 64-74.

Santini, F. J., Lu, C. D., Potchoiba, M. J., Fernandez, J. M. and Coleman, S.W. 1992. Dietary fiber and milk yield, mastication, digestion and rate of passage in high Alpine goats fed alfalfa hay. Journal of Dairy Science, **75**: 209-219.

Sebata, A., Ndlovub, L.R. and Dube, J.S. 2011. Chemical composition, in vitro dry matter digestibility and in vitro gasproduction of five woody species browsed by Matebele goats(Capra hircus L.) in a semi-arid savanna, Zimbabwe. Animal Feed Science and Technology, **170**: 122-125.

Scalbert, A. 1991. Antimicrobial properties of tannins. Phytochemistry, **30 (12)**: 3875-388.

Shenkute, B., Hassen, A., Assafa, T., Amen, N. and Ebro, A. 2012. Identification and nutritive value of potential fodder trees and shrubs in the Mid Lift Valley of Ethiopia. Journal of Animal and Plant Science **22(4)**: 1126-1132.

Sibanda, H.M and Ndlovu L R. 1993. The value of indigenous browseable tree species in livestock production in semi-arid communal grazing areas of Zimbabwe. In: *The complementarity of feed resources for animal production in Africa*. Proceedings of the joint feed resources networks workshop held in Gaborone, Botswana 4-8 March 1991. Stares J E S. Said AN and Kategile J A (eds). 1992. African Feeds Research Network. ILCA (International Livestock Centre for Africa), Addis Ababa. Ethiopia. pp 430.

Sikosana, J.L.N., Maphosa, V., Smith, T., Owen, E. and Mueller-Harvey, I. 2002a. Use of local browse tree pods as dry season supplements for goats in the south-west region of Zimbabwe. In: Responding to the increasing global demand for animal products; an international Conference organized by the British Society of Animal Science (BSAS), American Society of Animal Science andthe Mexican Society of Animal production, 12-15 November 2002 at UADY Merida. BSAS, pp193

Sikosana, J.L.N., Smith, T., Mlambo, V., Owen, E., Mueller-Harvey, I. and Mould, F. 2002b. Acacia and other tree pods as dry season feed supplements for goats. In: (eds. T. Smith, P.J. Buttery and E. Owen): Strategies to relieve nutritional and health constraints in smallholder owned goats; Proceedings of the second Link Project Meeting, 8-10 January2002, Sokoine University ofAgriculture, Morogoro, Tanzania. Natural Resources International Ltd., pp 6975.

Silanikove, N., Gilboa, N., Perevolotsky, A. and Nitsan, Z. 1996. Goats fedtannin-containing leaves do not exhibit toxic syndromes. SmallRuminant Research, **21**: 195–201.

Silanikove, N., Perevolotsky, A. and Provenza, F.D. 2001. Use of tannin-binding chemicals to essay for tannins and their negative postingestive effects in ruminants. Animal Feed Science and Technology, **91**: 69-81.

Silanikove, N., Leitnerb, G., Merinc, U. and Prosserd, C.G. 2010. Recent advances in exploiting goat's milk: Quality, safety andproduction aspects. Small Ruminant Research, **89**: 110-124.

Smith, T., Owen, E., Mueller-Harvey, I., Sikosana, J.L.N. and Mlambo, V. 2005a. Increasing the productivity of smallholder owned goats through supplementation with tree fruits. University of York, 4-6 April 2005, Proceedings British Society of Animal Science, pp 33.

Smith, T., Mlambo, V., Sikosana, J. L. N., Maphosa, V., Mueller-Harvey, I. and Owen, E. 2005b. *Dichrostachys cinerea* and *Acacia nilotica* fruits as dry season feed supplements for goats in a semi-arid environment. Animal Feed Science and Technology, **122:**149-157.

Statistical Analysis System (SAS). 1999. Statistics Software. Release 9.1.3, SAS Institute Inc., Cary, NC, USA.

Statistical Software for Social Sciences (SPSS). 2013. IBM SPSS Statistics for Windows, Version 21.0, Armonk, NY: IBM Corp.

Steele, M.1996. The Tropical Agriculturalist. Goats. Macmillan education Publisher, The Netherlands. CTA.

Soyinka, A., Cronje, P.B. and Kotze, A. 1997. Genetic relationship between indigenous goat population of Southern Africa. Agricultural Research Council, Republic of South Africa.

Stobbs, T.H. and Fraser, J.S. 1971. Comparison and processing quality of milk produced from cows grazing some tropical pasture species.Australian Journal of Dairy Technology, **26:**100.

Sweet, J. and A. Burke., 2006. Country Pasture/Forage Resource Profiles. Available online at: http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Namibia/namibia.htm. Accessed date: 22/11/12.

Tamime, A.Y. and Robinson, R.K. 2007. Yoghurt: Science and Technology. 3rd Ed. CRC, Boca Raton, Florinda.Woodhead Publishing Series in Food Science, Technology and Nutrition.

Tanner, T.C., Reed, J.D. and Owen, E. 1990. The nutritive value of fruits (Pods and Seeds) from Acacia species compared with extracted Nough (*Guizonia abysinica*) meal as supplement to maize stover for Ethiopian highland sheep. Animal Production, **51**: 122-133.

Tefera, S., Mlambo, V., Dlamini, B.J., Dlamini, A.M., Koralagama, K.D.N. and Mould, F.L. 2008. Chemical composition and *in vitro* ruminal fermentation of common tree forages in the semi-arid rangelands of Swaziland. Animal Feed Science and Technology, **142:** 99-110.

Thapa, B., Walker, D.H. and Sinclair, F.L. 1997. Indigenous knowledge of the feeding value of tree fodder. Animal Feed Science and Technology, **67**: 97-114.

Theodorou, M.K., Williams, B.A., Dhanoa, M.S. McAllan, A.B. and France, J. 1994. A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. Animal Feed Science and Technology, **48**: 185.

Thorne, P.J., Subba, D.B., Walker, D.H., Thapa, B., Wood, C.D. and Sinclair, F.L. 1999. The basis of indigenous knowledge of tree fodder quality and its implications for improving the use of tree fodder in developing countries. Animal Feed Science and Technology, **81**: 119 131.

Tilley, J.M.A. and Terry, R.A. 1963. A two-stage technique for the *in vitro* digestion of forage crops. Journal of the British Grassland Society, **18:** 104-111.

Timberlake, J., Fagg, C. and Barnes, R. 1999. Field guide to the Acacias of Zimbabwe. Harare, Zimbabwe: CBC Publishing.

Topps, J.H. 1992. Potential composition and use of legume shrubs and trees as fodder for livestock in the tropics (Review). Journal of Agricultural Science, **118:** 1-8.

Tripathi, M.K. 2015. Comforts in quality and production of goat milk. Journal Advances in Dairy Research, **3:**1.

van Soest, P. J., Robertson, J.B. and Lewis, B. A. 1991. Symposium: Carbohydrate Methodology, Metabolism, and Nutritional Implications In: Dairy Cattle. Journal of Dairy Science, **74:**10. Available online at:http://webpages.icav.up.pt/PTDC/CVT/098487/2008/Van%20Soest,%201991.pdf. Accessed date: 9/25/2012.

van Soest, P.J. 1994. Nutritional ecology of ruminants. 2ndEdition. Cornell University Press, USA. pp 474.

van Wyk, A. J., Opperman, D. P. J. and Kok, O. B. 1985. Availability, quality and utilization of the riverine vegetation of the lower Kuiseb and canyon area. In: The Kuiseb environment: The development of a monitoring baseline. Foundation for Research Development, Pretoria. pp 107-112.

Vasta, V., Nuddab, A., Cannas, A., Lanza, M. and Priolo, A. 2008. Alternative feed resources and their effects on the quality of meat and milk from small ruminants. Animal Feed Science and Technology, **147:** 223-246.

Waghorn, G. 2008. Beneficial and detrimental effects of dietary condensed tannins forsustainable sheep and goat production – Progress and challenges. Animal FeedScience and Technology, **147**: 116–139.

Wahome, R.G., Carles, A.B. and Schwartz, H.J. 1994. An analysis of the variation of the lactation curve of Small East African goats. Small Ruminant Research, **15**: 1-7.

Wang Y., Douglas G.B., Waghorn G.C., Barry T.N. and Foote A.G. 1996. Effect of condensed tannins in *Lotus corniculatus* upon lactation performance in ewes. Journal Agricultural Science Cambrige, **126:** 353-362.

Wikimedia. 2015. Map of Africa. Available online at: https://commons.wikimedia.org/wiki/File:Namibia_in_Africa. Accessed date: 10/01/2016.

Woodward, S. L., Auldist, M. J., Laboyrie, P. J.and Jansen, E. B. L. 1999. Effect of *Lotus corniculatus* and condensed tannins on milk yield and milk composition of dairy cows. Proceedings of New Zealand Society of Animal Production, **59**: 152-155.

Yayneshet, T., Eik, L.O. and Moe, S.R. 2008. Influences of fallow age and season on the foraging behaviour and diet selection pattern of goats (*Capra hircus L*.). Small Ruminant Research, **77:** 25-37.

APPENDICES

AP1 Experiment 1: Questionnaire used for Survey

Communal farmers' questionnaire

Region: ---

Constituency: --

Village: --

Name of Household Head. ---------------------------------------

Date of interview |__|__|__|__|__|__|__|
Day Month Year
Interviewee: -------------------------------

Name of Enumerator: ------------------------------------
(for record only)

Guidelines for introducing yourself and the purpose of the interview:
• My Name is and I am a researcher from
• Your household has been selected subjectively by chance from all households in the area for this interview. The purpose of this interview is to obtain basic information on common trees and shrubs that are utilised by sheep/goats/cattle during the dry period.
• The survey is voluntary and the information that you give will be confidential. The information will be used for Dairy project, but will not include any specific names. There will be no way to identify that you gave this information.
• Could you please spare some time (around 20 minutes) for the interview?
NB to enumerator: DO NOT suggest in any way that household entitlements could depend on the outcome of the interview, as this will prejudice the answers.

A. HOUSEHOLD DEMOGRAPHICS

Name of respondent ______________________________ *(for record only) Respondent should be household head or spouse of household head.*

A1.	Age of Head of Household		A2. Sex of the head of Household	M
B.	Total Number of People Living in the Household [ ]		C. What is your level of education? 1. Primary	

2. Secondary

3. Tertiary: specify…………..

4. never went to school

F

D.	What are your major sources of income?	1. Agriculture	3. Formal employment		
		2. Non-agricultural	4. Pensioner 5. others		
E.	Which livestock species do you have?	Specify the number			
		1 = cattle		7 = chickens	
		2 = sheep		8 = other	
		3 = goats			
		4 = donkey			
		5 = pigs			

	B. LOCAL FEED RESOURCES		
F.	How much land is reserved for?	cropping	grazing

G.	Common tree/shrubs browsed by goats/cattle during the dry period						
	Common/Local Name	**Botanical Name**	**Shrub/Tree (ignore grasses)**	**Animal species**	**Part/s utilised**	**Time available**	**Age of the tree/shrub**
1.	e. i. Omupanda	*Philenoptera nelsii*	Tree	Cattle	Leaves	Sept	mature tree
2.							
3.							
4.							
5.							
H.	Do you harvest pods or leaves for your animals?						

	1) Yes	2) No		
I.	If no, What are your problems of accessing the trees or shrubs for your animals?	1= falling from tree	5= Distance of trees	
		2= Bulkiness	6= Skin irritation	
		3= Tree height	7= Scarcity of tres or shrubs	
		4= Snake bite	8= Old age	
		Others.	9= No time	
J.	If yes, do you process the leaves or pods or mix them with other feeds before feeding	1) Yes	2) No	
	If yes, explain how			
K.	How do you store feeds?	1= In bags	2= Top of roof-house	3= Top of a tree
		4 = Do not store	5= under the shade	6= others
L.	Is there any medicinal properties of shrub leaves or pods for livestock (give examples)			

	Local Name	Botanical Name	Animal	Usage form	Nature of disease
	i.e. Omughudi	*Boscia spp*	goats	plants roots are soaked in water and the solution is offered to the animal	internal parasites
	1.				
	2.				
M.	Does local shrub leaves or pods have any positive or negative effects on the animal performance? i.e. fertility				
N.	Are you aware of the sustainable use of this resources?				

	1)yes 2) no
O.	Are you prepared to take part in planting more of the useful tree or shrubs?
	1)yes 2)no
P.	Are you prepared to harvest the pods in large quantities if it is proven that they improve animal productivity? i.e. milk yield
	1)yes 2)no

At the end of each questionnaire, if possible ask the farmer to identify the plant parts for you and collect a sample for nutritional analysis

Table AP2 Experiment 2: Data for chemical composition of woody plant species

Location	Month	Species	Part	DM	OM	Ash	CP	NDF	ADF	ST	Ca	P	Se
Gibeon	Jan	*A.mellifera*	L	966.70	17.10	82.90	130.50	297.20	211.70	2.50	13.20	0.66	1.92
Gibeon	Jan	*R.trichotomum*	L	965.80	24.60	75.40	94.30	302.40	223.10	2.50	13.40	0.71	2.09
Gibeon	Jan	*C.alexandri*	L	960.50	22.00	78.00	98.00	339.20	265.90	4.60	15.10	0.60	1.76
Gibeon	May	*C.alexandri*	L	958.80	28.70	71.30	121.30	359.80	353.10	5.40	7.16	0.34	1.30
Gibeon	May	*A.mellifera*	L	955.90	13.70	113.70	142.60	231.00	231.70	4.20	6.12	0.27	1.07
Gibeon	May	*R.trichotomum*	L	963.40	15.60	84.40	53.00	309.50	175.60	5.10	10.56	0.40	1.15
Gibeon	Sept	*C.alexandri*	L	936.00	42.50	57.50	66.30	364.00	253.70	6.40	3.31	0.66	0.56
Gibeon	Sept	*A.mellifera*	L	939.00	37.80	62.20	81.70	341.90	305.50	3.80	3.39	0.53	0.57
Gibeon	Sept	*R.trichotomum*	L	900.00	46.30	53.70	100.10	437.70	235.80	7.00	4.40	0.97	0.81
Guinas	Jan	*D.cinerea*	L	959.70	39.30	60.70	170.30	498.30	260.30	2.50	10.70	0.13	3.28
Guinas	Jan	*P.nelsii*	L	947.70	37.80	62.20	170.80	566.70	414.30	1.60	6.10	0.16	1.09
Guinas	Jan	*B.petersiana*	L	965.60	39.90	60.10	108.80	464.70	311.30	2.90	4.30	0.75	1.12
Guinas	Jan	*T.sericea*	L	961.80	47.80	52.20	97.90	514.70	303.00	9.00	7.30	0.23	1.33
Guinas	Jan	*G.bicolor*	L	965.50	19.60	80.40	20.20	610.70	317.20	2.20	12.20	0.28	1.65
Guinas	May	*G.bicolor*	L	959.50	31.40	68.60	120.10	428.90	312.30	5.30	13.25	0.25	2.51
Guinas	May	*P.nelsii*	L	964.40	18.50	118.50	78.60	474.70	390.00	4.20	10.97	0.22	1.11
Guinas	May	*D.cinerea*	L	963.00	45.00	55.00	87.50	411.50	334.10	6.90	3.21	0.43	1.18
Guinas	May	*D.cinerep*	P	965.50	51.20	48.80	161.00	316.50	233.80	8.80	8.05	0.05	0.64
Guinas	May	*T.sericea*	L	962.00	40.40	59.60	53.70	359.70	358.90	11.20	9.87	0.34	0.80
Guinas	May	*B.petersiana*	L	962.60	44.10	55.90	78.80	372.50	359.60	5.60	8.94	0.15	1.16
Guinas	May	*A.erioloba*	P	961.90	34.90	65.10	142.00	434.70	342.20	5.90	10.74	0.28	0.63
Guinas	Sept	*T.sericea*	L	937.50	54.50	45.50	97.70	364.70	269.10	11.50	4.92	0.83	0.33

Guinas	Sept	*P.nelsii*	L	942.90	56.80	43.20	144.20	393.10	360.90	3.40	4.81	1.00	0.44
Guinas	Sept	*D.cinerea*	L	916.00	33.60	66.40	94.90	518.90	354.60	4.50	4.72	0.81	1.02
Guinas	Sept	*D.cinerea*	P	943.70	50.20	49.80	162.00	389.00	326.00	20.80	3.53	0.62	0.86
Guinas	Sept	*G.bicolor*	L	935.70	42.90	57.10	116.40	404.70	245.30	3.20	3.76	0.69	0.49
Guinas	Sept	*B.petersiana*	L	945.70	23.20	76.80	176.20	418.20	261.80	7.50	2.79	0.62	0.27
Guinas	Sept	*A.erioloba*	P	910.70	48.10	51.90	143.00	356.80	275.20	13.70	3.10	0.56	0.48
kongola	Jan	*B.maSSiensis*	L	973.50	73.50	26.50	76.50	490.50	339.70	5.10	3.20	0.80	1.09
kongola	Jan	*C.collinum*	L	962.50	33.90	66.10	28.00	304.80	226.10	7.20	8.50	2.00	3.32
kongola	Jan	*P.nelsii*	L	975.20	21.80	78.20	78.60	530.90	385.10	2.30	1.15	3.90	1.47
kongola	Jan	*B.petersiana*	L	964.30	53.00	47.00	171.40	460.30	324.70	5.30	0.70	6.60	1.82
kongola	May	*B.maSSiensis*	L	969.70	60.30	39.70	151.80	420.90	115.10	3.90	4.78	0.06	0.72
kongola	May	*T.sericea*	L	952.30	21.30	78.70	88.40	388.90	297.40	11.20	7.50	0.09	0.44
kongola	May	*B.petersiana*	L	965.40	10.40	110.40	66.30	366.30	265.60	5.30	11.38	0.21	0.55
kongola	May	*C.collinum*	L	960.10	48.30	51.70	137.10	287.60	251.10	8.90	6.94	0.48	0.81
kongola	May	*P.nelsii*	L	960.80	29.50	70.50	91.10	427.30	343.50	6.30	8.23	0.34	0.66
kongola	Sept	*B.maSSiensis*	L	910.70	38.00	62.00	58.00	405.60	313.80	7.60	2.95	5.90	0.75
kongola	Sept	*T.sericea*	L	929.70	56.00	44.00	81.00	505.10	368.60	2.30	2.82	5.30	0.41
kongola	Sept	*B.petersiana*	L	947.00	37.90	62.10	134.20	372.20	368.60	6.30	4.61	6.70	0.38
kongola	Sept	*C.collinum*	L	949.00	45.20	54.80	76.20	393.40	343.00	4.50	4.20	8.40	0.84
kongola	Sept	*P.nelsii*	L	934.10	57.00	43.00	68.40	480.00	240.50	3.10	4.06	8.00	0.73
Tsandi	Jan	*C.apiculatum*	L	964.40	45.90	54.10	141.30	394.30	237.40	8.30	8.40	0.11	1.37
Tsandi	Jan	*C.alexandri*	L	952.50	50.10	49.90	31.60	468.20	339.30	2.40	8.50	0.14	1.18
Tsandi	Jan	*P.nelsii*	L	963.90	45.10	54.90	170.80	624.80	471.60	1.50	7.40	0.29	1.24
Tsandi	Jan	*C.mopane*	L	953.60	49.60	50.40	22.60	352.00	264.10	6.00	4.40	0.40	2.49

Tsandi	Jan	*T.sericea*	L	952.90	51.90	48.10	164.90	461.10	283.40	11.10	8.40	0.38	1.02
Tsandi	Jan	*T.prunioides*	L	963.60	19.30	80.70	103.50	334.70	370.70	12.20	15.70	0.38	1.30
Tsandi	May	*T.sericea*	L	933.10	44.50	55.50	147.30	372.90	246.00	9.60	9.15	0.03	0.60
Tsandi	May	*C.apicula*	L	960.70	45.00	55.00	64.80	253.90	205.30	8.80	9.40	0.06	0.80
Tsandi	May	*T.prunio*	L	951.90	32.10	67.90	70.50	271.70	296.30	10.00	14.00	0.07	0.75
Tsandi	May	*C.mopane*	L	964.90	52.40	47.60	78.80	368.20	265.80	5.40	8.98	0.09	0.93
Tsandi	May	*P.nelsii*	L	961.50	17.60	82.40	92.20	521.90	378.20	3.00	8.15	0.11	0.57
Tsandi	May	*C.alex*	L	948.10	39.20	60.80	166.00	395.70	349.30	5.10	10.82	0.08	0.51
Tsandi	Sept	*T.sericea*	L	923.90	41.60	58.40	97.70	400.10	380.00	31.10	4.31	0.85	0.41
Tsandi	Sept	*C.apicula*	L	949.50	27.50	72.50	130.20	381.90	373.50	21.50	0.25	0.50	0.30
Tsandi	Sept	*T.prunio*	L	914.50	40.00	60.00	114.40	502.20	249.80	14.50	4.28	0.75	0.38
Tsandi	Sept	*C.mopane*	L	931.50	28.90	71.10	77.70	428.30	333.10	11.10	2.14	0.37	0.59
Tsandi	Sept	*P.nelsii*	L	930.50	58.90	41.10	78.90	519.10	270.80	3.40	3.62	0.68	0.29
Tsandi	Sept	*C.alex*	L	914.80	32.20	67.80	57.40	400.80	323.70	4.20	4.67	0.67	0.24
Daurês	Jan	*C.alex*	L	962.00	41.90	58.10	97.10	454.60	339.10	2.00	9.90	0.57	1.31
Daurês	Jan	*A.karool*	L	970.40	29.60	70.40	116.80	406.30	236.80	1.60	13.20	0.63	1.40
Daurês	Jan	*A.herero*	L	965.40	28.40	71.60	44.80	245.70	163.20	2.40	11.80	0.83	1.62
Daurês	May	*C.alex*	L	947.40	35.10	64.90	167.80	388.70	329.70	4.90	6.45	0.39	0.57
Daurês	May	*A.karool*	L	955.30	31.90	68.10	95.30	360.80	213.90	3.10	11.59	0.18	0.72
Daurês	May	*A.karoop*	P	977.50	34.90	65.10	144.30	371.60	280.00	3.30	15.48	0.20	0.92
Daurês	May	*A.herero*	L	962.30	10.50	89.50	46.90	476.40	155.90	5.40	14.66	0.10	0.41
Daurês	Sept	*C.alex*	L	926.80	20.30	79.70	103.20	419.30	337.40	4.30	2.65	0.60	0.34
Daurês	Sept	*A.karool*	L	934.40	45.60	54.40	144.70	373.50	225.20	3.60	2.97	0.59	0.51
Daurês	Sept	*A.herero*	L	902.30	44.30	55.70	114.10	440.10	272.60	3.80	2.18	0.49	0.51
Omatako	Jan	*C.apicula*	L	975.30	35.60	64.40	113.70	320.70	304.10	7.60	9.00	0.59	1.35

Omatako	Jan	*Z.mucro*	L	957.90	0.90	99.10	96.10	274.30	165.90	2.10	14.90	1.59	1.53
Omatako	May	*Z.mucro*	L	953.90	29.10	129.10	105.00	357.30	174.60	4.70	12.62	0.26	1.26
Omatako	May	*C.apicula*	L	948.00	37.40	62.60	149.70	247.00	180.00	11.50	13.20	0.32	0.79
Omatako	May	*Aeriolo*	P	955.60	63.20	36.80	139.10	361.30	237.60	6.00	14.85	0.35	1.26
Omatako	Sept	*Z.mucro*	L	931.10	58.40	41.60	94.30	359.10	260.00	3.70	2.99	0.64	0.50
Omatako	Sept	*C.apicula*	L	911.40	52.20	47.80	107.10	472.30	222.40	20.40	5.21	1.06	0.40

DM= Dry Matter, OM= Organic Matter, CP= Crude Protein, NDF= Neutral Detergent Fibre, ADF=Acid Detergent Fibre, ST= Soluble Tannins, Ca= Calcium, P= Phosphorus, SE= Selenium, Sept= September, Jan= January, L= Leaves, P= Pods

Table AP2.1 Experiment 2: Analysis of variance for chemical composition of woody plants

Table AP2.1.1 Analysis of variance for Dry Matter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	57	24524.64091	430.25686	5.25	0.0001
Error	19	1557.28039	81.96213		
Corrected Total	76	26081.92130			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	730.06794	146.01359	1.78	0.1649
Month	2	17159.88936	8579.94468	104.68	<.0001
Shrub	18	2328.22984	129.34610	1.58	0.1661
Month*Species	32	3853.60519	120.42516	1.47	0.1901

Table AP2.1.2 Analysis of variance for Organic matter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	57	29364.94529	515.17448	3.32	0.0027
Error	19	2948.95783	155.20831		
Corrected Total	76	32313.90312			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	105.21384	21.04277	0.14	0.9820
Month	2	10763.60898	5381.80449	34.67	<.0001
Species	18	4373.23829	242.95768	1.57	0.1704
Month*Species	32	10253.48898	320.42153	2.06	0.0495

Table AP2.1.3 Analysis of v ıriance for Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	5494.43959	219.77758	1.29	0.2145
Error	51	8662.41132	169.85120		
Corrected Total	76	14156.85091			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	425.935313	85.187063	0.50	0.7736
Month	2	835.306005	417.653003	2.46	0.0956
Species	18	2927.123668	162.617982	0.96	0.5195

Table AP2.1.4 Analysis of variance for Crude Protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	57	96578.3946	1694.3578	1.40	0.2091
Error	19	22936.1000	1207.1632		
Corrected Total	76	119514.4945			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	5769.86001	1153.97200	0.96	0.4687
Month	2	496.60927	248.30464	0.21	0.8159
Species	18	30706.68544	1705.92697	1.41	0.2305
Month*Species	32	58261.59646	1820.67489	1.51	0.1741

Table AP2.1.5 Analysis of v ıriance for Neutral Detergent Fibre

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	57	470919.6764	8261.7487	3.75	0.0012
Error	19	41914.9160	2206.0482		
Corrected Total	76	512834.5925			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	10853.4623	2170.6925	0.98	0.4531
Month	2	33105.9953	16552.9977	7.50	0.0040
Species	18	153772.1749	8542.8986	3.87	0.0026
Month*Species	32	169503.0386	5296.9700	2.40	0.0238

Table AP2.1.6 Analysis of variance for Acid Detergent Fibre

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	57	470068.4498	8246.8149	0.83	0.7182
Error	19	189735.8533	9986.0975		
Corrected Total	76	659804.3031			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	49024.8150	9804.9630	0.98	0.4542
Month	2	9550.8906	4775.4453	0.48	0.6272
Species	18	135832.5944	7546.2552	0.76	0.7218
Month*Species	32	194767.1111	6086.4722	0.61	0.8946

Table AP2.1.7 Analysis of variance for Soluble Tannins

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	52	1533.284113	29.486233	1.55	Error 0.1232
24	457.956667	19.081528			
Corrected Total	76	1991.240779			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Month	2	116.134448	58.067224	3.04	0.0664
Species	18	1025.397663	56.966537	2.99	0.0066
Month*Species	32	294.494474	9.202952	0.48	0.9728

Table AP2.1.8 Analysis of variance for Calciu n

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	52	1216.705200	23.398177	5.10	<.0001
Error	24	110.090117	4.587088		
Corrected Total	76	1326.795317			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Month	2	560.6595426	280.3297713	61.11	<.0001
Species	18	269.3898528	14.9661029	3.26	0.0038
Month*Species	32	327.7856156	10.2433005	2.23	0.0226

Table AP2.1.9 Analysis of variance for Phosphorus

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	149.3439323	5.9737573	3.13	0.0003
Error	51	97.4113379	1.9100262		
Corrected Total	76	246.7552701			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	56.42018886	11.28403777	5.91	0.0002
Month	2	35.98891901	17.99445950	9.42	0.0003
Species	18	8.03060740	0.44614486	0.23	0.9993

Table AP2.1.10 Analysis of variance for Selenium

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	23.09612487	0.92384499	6.47	<.0001
Error	51	7.28176344	0.14277968		
Corrected Total	76	30.37788831			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	5	0.66459517	0.13291903	0.93	0.4689
Month	2	15.28402793	7.64201397	53.52	<.0001
Species	18	5.49902034	0.30550113	2.14	0.0174

Table AP3 Experiment 2: Data for in-vitro gas production of woody plant species

Location	Month	Species	Part	Rep	3hr	6hr	9hr	12hr	24hr	36hr	48hr	*b*	*c*
.	.	Blank	.	1	3.81	4.67	4.86	8.67	12.48	12.48	16.29	16.56	0.053
.	.	Blank	.	2	3.01	3.69	3.82	3.82	3.82	3.96	3.96	3.89	0.494
.	.	Blank	.	3	1.47	1.96	2.09	2.11	2.11	2.11	2.11	2.12	0.406
.	.	Blank	.	4	4.12	4.76	4.87	4.87	4.87	4.87	4.87	4.87	0.624
.	.	Blank	.	5	4.43	5.69	5.69	5.69	5.69	5.69	5.69	5.73	0.519
Gibeon	Jan	*Amellif*	L	1	3.80	5.44	7.26	8.73	12.54	16.35	18.38	19.83	0.049
Gibeon	Jan	*Amellif*	L	2	0.52	0.70	1.03	1.87	3.51	5.46	6.65	55.68	0.003
Gibeon	Jan	*Amellif*	L	3	4.48	6.59	7.98	9.43	12.36	12.36	12.36	12.54	0.123
Gibeon	Jan	*Amellif*	L	4	3.46	5.03	5.61	6.48	7.60	8.94	10.65	9.50	0.105
Gibeon	Jan	*Amellif*	L	5	4.19	6.48	7.54	8.72	8.80	12.61	15.34	13.56	0.085
Gibeon	Jan	*Rtricho*	L	1	0.02	0.13	0.78	1.62	2.49	2.73	3.09	4.19	0.030
Gibeon	Jan	*Rtricho*	L	2	2.16	3.88	4.58	5.41	6.41	6.41	6.41	6.49	0.144
Gibeon	Jan	*Rtricho*	L	3	1.49	3.26	4.50	5.51	6.37	6.44	6.44	6.62	0.121
Gibeon	Jan	*Rtricho*	L	4	3.75	5.49	6.53	7.17	8.25	8.29	8.29	8.26	0.183
Gibeon	Jan	*Rtricho*	L	5	3.18	5.37	6.53	7.48	7.48	7.54	7.63	7.68	0.203
Gibeon	Jan	*Calex*	L	1	3.81	6.63	9.30	11.43	15.24	19.05	22.86	23.76	0.051
Gibeon	Jan	*Calex*	L	2	0.89	1.60	2.46	2.70	4.06	4.35	4.56	4.72	0.075
Gibeon	Jan	*Calex*	L	3	4.64	7.57	8.61	9.49	12.44	13.60	14.04	13.68	0.116

Gibeon	Jan	*Calex*	L	4	3.30	5.35	6.06	6.17	7.42	8.27	8.27	7.97	0.161
Gibeon	Jan	*Calex*	L	5	4.17	7.01	8.03	8.85	10.35	10.46	10.46	10.44	0.171
Gibeon	May	*Calex*	L	1	1.51	2.39	2.98	3.29	3.29	3.97	4.01	3.81	0.164
Gibeon	May	*Calex*	L	2	4.53	6.46	7.50	8.19	10.13	12.01	12.43	11.84	0.116
Gibeon	May	*Calex*	L	3	4.21	6.16	7.67	8.76	10.88	13.96	15.42	14.84	0.078
Gibeon	May	*Calex*	L	4	3.41	5.71	6.65	7.13	7.73	7.82	7.86	7.84	0.205
Gibeon	May	*Calex*	L	5	3.25	5.29	6.23	6.78	7.53	7.53	7.53	7.55	0.194
Gibeon	May	*Amellif*	L	1	3.49	6.34	8.23	10.90	14.70	17.64	19.25	19.97	0.061
Gibeon	May	*Amellif*	L	2	4.03	5.53	6.62	8.25	10.88	13.53	14.84	14.77	0.069
Gibeon	May	*Amellif*	L	3	0.14	1.39	3.54	5.10	8.91	12.59	14.30	28.85	0.015
Gibeon	May	*Amellif*	L	4	3.97	6.05	7.24	8.44	10.25	12.20	13.95	13.00	0.091
Gibeon	May	*Amellif*	L	5	3.68	6.54	8.21	9.65	12.70	15.18	16.73	16.49	0.074
Gibeon	May	*Rtricho*	L	1	0.05	1.73	2.70	3.65	4.34	5.58	6.61	7.16	0.046
Gibeon	May	*Rtricho*	L	2	2.50	3.94	5.36	6.06	7.98	7.98	7.98	8.16	0.117
Gibeon	May	*Rtricho*	L	3	4.07	6.75	8.70	10.21	12.43	12.63	12.67	12.82	0.128
Gibeon	May	*Rtricho*	L	4	3.87	5.65	7.14	8.39	10.38	10.54	10.78	10.74	0.128
Gibeon	May	*Rtricho*	L	5	4.68	7.51	8.54	9.05	9.24	9.61	10.36	9.76	0.229
Gibeon	Sept	*Calex*	L	1	0.31	0.38	2.54	4.25	7.98	8.89	12.66	37.09	0.009
Gibeon	Sept	*Calex*	L	2	2.26	3.43	3.94	4.44	5.30	5.86	6.01	5.79	0.137

Gibeon	Sept	*Calex*	L	3	4.41	6.24	7.65	8.75	10.89	12.78	14.31	13.44	0.094
Gibeon	Sept	*Calex*	L	4	4.08	6.39	7.62	8.45	10.34	10.72	10.80	10.70	0.144
Gibeon	Sept	*Calex*	L	5	4.60	7.43	9.01	10.08	12.34	13.59	14.33	13.77	0.119
Gibeon	Sept	*Amellif*	L	1	3.47	5.94	7.92	9.88	13.69	16.15	17.42	17.94	0.065
Gibeon	Sept	*Amellif*	L	2	3.86	5.82	6.94	8.07	9.58	11.30	12.65	11.76	0.101
Gibeon	Sept	*Amellif*	L	3	0.09	0.20	0.50	0.63	1.12	1.18	1.57	2.06	0.028
Gibeon	Sept	*Amellif*	L	4	4.74	6.71	7.77	8.81	10.89	12.55	14.08	13.03	0.106
Gibeon	Sept	*Amellif*	L	5	1.04	3.41	4.52	5.67	8.05	10.13	11.36	12.46	0.047

Gibeon	Sept	*Rtricho*	L	1	1.33	3.81	5.34	6.90	8.68	9.41	9.93	10.10	0.082
Gibeon	Sept	*Rtricho*	L	2	3.62	4.48	5.12	6.03	7.50	7.74	7.74	7.65	0.147
Gibeon	Sept	*Rtricho*	L	3	3.69	5.22	6.59	7.91	9.36	9.36	9.53	9.53	0.141
Gibeon	Sept	*Rtricho*	L	4	4.32	5.84	6.98	8.09	9.37	9.72	9.72	9.62	0.160
Gibeon	Sept	*Rtricho*	L	5	4.52	6.83	7.98	9.21	9.21	9.45	9.83	9.58	0.212
Guinas	Jan	*Dcinerel*	L	1	3.55	4.98	6.24	6.90	8.43	9.40	10.45	9.73	0.114
Guinas	Jan	*Dcinerel*	L	2	0.91	2.03	2.63	3.14	4.92	6.15	7.29	8.35	0.040
Guinas	Jan	*Dcinerel*	L	3	4.58	6.72	7.69	8.11	9.15	11.41	12.09	11.05	0.136
Guinas	Jan	*Dcinerel*	L	4	0.64	6.24	6.49	6.55	6.55	7.07	7.79	7.38	0.173
Guinas	Jan	*Dcinerel*	L	5	0.51	1.96	2.19	2.20	2.20	3.33	3.78	3.39	0.093
Guinas	Jan	*Pnelsii*	L	1	3.57	5.31	6.34	7.29	8.18	9.91	11.29	10.24	0.109

Guinas	Jan	*Pnelsii*	L	2	4.94	7.42	8.17	8.78	9.62	11.66	13.13	11.58	0.145
Guinas	Jan	*Pnelsii*	L	3	4.71	7.54	9.37	10.67	12.72	14.91	15.76	15.09	0.107
Guinas	Jan	*Pnelsii*	L	4	0.54	1.71	1.83	1.91	1.91	1.97	3.23	2.46	0.136
Guinas	Jan	*Pnelsii*	L	5	4.17	5.73	6.14	6.56	6.82	8.74	10.30	8.65	0.154
Guinas	Jan	*Bpeter*	L	1	0.18	0.26	0.35	0.56	1.42	1.95	2.29	9.08	0.006
Guinas	Jan	*Bpeter*	L	2	3.12	4.62	4.93	5.25	5.25	6.34	6.50	5.95	0.226
Guinas	Jan	*Bpeter*	L	3	2.10	4.41	5.86	6.89	9.34	11.84	12.52	13.00	0.062
Guinas	Jan	*Bpeter*	L	4	2.06	2.86	3.02	3.02	3.02	3.82	4.38	3.64	0.233
Guinas	Jan	*Bpeter*	L	5	3.60	4.86	5.18	5.39	5.39	6.38	7.20	6.18	0.247
Guinas	Jan	*Tsericea*	L	1	0.12	2.49	4.10	4.98	7.15	8.79	10.26	11.72	0.041
Guinas	Jan	*Tsericea*	L	2	4.64	6.45	6.79	7.06	7.85	9.04	9.93	8.77	0.197
Guinas	Jan	*Tsericea*	L	3	4.84	7.96	9.33	9.98	11.12	12.90	13.45	12.62	0.149
Guinas	Jan	*Tsericea*	L	4	0.60	1.47	1.72	1.78	1.78	2.60	3.18	2.77	0.088
Guinas	Jan	*Tsericea*	L	5	4.53	6.47	6.95	7.00	7.02	8.54	9.54	8.20	0.237
Guinas	Jan	*Gbicol*	L	1	2.08	3.53	5.22	6.44	7.17	9.48	11.85	11.55	0.057
Guinas	Jan	*Gbicol*	L	2	1.10	2.51	3.01	3.35	3.35	4.60	5.75	5.04	0.088
Guinas	Jan	*Gbicol*	L	3	0.75	1.66	3.30	4.89	7.35	11.14	13.02	25.40	0.015
Guinas	Jan	*Gbicol*	L	4	0.22	0.88	0.97	1.03	1.03	1.61	1.89	1.73	0.074
Guinas	Jan	*Gbicol*	L	5	2.63	3.63	4.03	5.30	5.47	6.96	9.50	8.26	0.077

Guinas	May	*Gbicol*	L	1	1.29	1.32	2.46	3.55	5.01	8.36	10.76	42.34	0.006
Guinas	May	*Gbicol*	L	2	1.69	4.38	5.42	5.90	6.73	8.79	12.26	11.46	0.056
Guinas	May	*Gbicol*	L	3	4.05	6.13	7.50	8.46	8.68	10.88	12.37	11.00	0.126
Guinas	May	*Gbicol*	L	4	2.70	3.88	4.37	4.41	4.41	4.60	4.62	4.56	0.310
Guinas	May	*Gbicol*	L	5	2.89	4.25	5.39	5.81	6.03	6.17	6.41	6.25	0.205
Guinas	May	*Pnelsii*	L	1	1.92	3.60	4.42	4.57	6.32	8.82	10.66	11.23	0.046
Guinas	May	*Pnelsii*	L	2	0.02	0.02	0.41	1.12	2.13	3.95	6.53	0.00	0.000
Guinas	May	*Pnelsii*	L	3	1.12	2.84	3.97	4.79	6.66	8.58	9.37	10.15	0.051
Guinas	May	*Pnelsii*	L	4	3.42	4.66	4.86	5.10	5.10	6.13	7.38	6.06	0.223
Guinas	May	*Pnelsii*	L	5	4.71	6.80	7.65	8.90	10.34	12.51	13.56	12.57	0.112
Guinas	May	*Dcinerel*	L	1	2.65	4.78	6.27	7.44	9.37	10.36	11.43	11.08	0.091
Guinas	May	*Dcinerel*	L	2	4.92	6.93	7.50	7.81	7.81	8.75	8.97	8.40	0.280
Guinas	May	*Dcinerel*	L	3	1.83	3.32	4.03	4.08	3.91	4.77	5.17	4.67	0.189
Guinas	May	*Dcinerel*	L	4	2.69	3.98	4.37	4.49	4.49	4.49	4.60	4.56	0.317
Guinas	May	*Dcinerel*	L	5	4.09	4.81	5.02	5.42	5.42	5.42	5.42	5.35	0.447
Guinas	May	*Dcinerep*	P	1	0.06	0.79	1.15	1.86	1.97	2.53	2.68	2.83	0.060
Guinas	May	*Dcinerep*	P	2	0.19	0.19	0.19	0.19	0.19	0.60	1.43	0.00	0.000
Guinas	May	*Dcinerep*	P	3	4.33	5.96	6.38	6.73	9.34	10.56	10.64	10.32	0.119
Guinas	May	*Dcinerep*	P	4	0.53	1.48	1.76	1.93	1.93	1.93	2.17	2.07	0.178

Guinas	May	*Dcinerep*	P	5	4.04	5.23	5.53	5.96	5.96	5.96	6.53	6.08	0.341
Guinas	May	*Tsericea*	L	1	2.38	3.93	4.75	5.63	7.03	8.52	10.10	9.56	0.074
Guinas	May	*Tsericea*	L	2	1.35	3.36	4.03	4.31	4.31	4.91	4.95	4.83	0.170
Guinas	May	*Tsericea*	L	3	0.70	2.56	3.29	3.39	4.20	4.39	4.55	4.52	0.120
Guinas	May	*Tsericea*	L	4	4.03	5.97	6.54	6.89	6.89	6.89	6.89	6.95	0.306
Guinas	May	*Tsericea*	L	5	3.18	5.10	5.67	6.16	6.55	6.93	6.93	6.80	0.213
Guinas	May	*Bpeter*	L	1	0.76	2.04	2.86	3.98	6.01	9.22	11.22	22.05	0.015
Guinas	May	*Bpeter*	L	2	0.32	0.78	0.95	1.04	1.04	2.29	2.93	6.47	0.012
Guinas	May	*Bpeter*	L	3	3.84	6.46	8.03	8.76	10.74	13.06	14.47	13.62	0.093
Guinas	May	*Bpeter*	L	4	2.63	4.03	4.49	4.73	4.76	4.87	5.26	4.97	0.261
Guinas	May	*Bpeter*	L	5	2.73	4.52	5.17	5.30	5.81	6.39	7.36	6.53	0.173
Guinas	May	*Aeriolo*	P	1	2.46	4.46	4.71	5.78	8.31	11.04	12.48	13.31	0.049
Guinas	May	*Aeriolo*	P	2	3.42	4.50	5.25	5.74	5.93	6.78	7.14	6.58	0.197
Guinas	May	*Aeriolo*	P	3	0.56	2.55	4.07	5.06	8.87	10.93	11.52	14.42	0.037
Guinas	May	*Aeriolo*	P	4	4.21	6.60	7.26	7.69	8.87	10.77	11.55	10.54	0.136
Guinas	May	*Aeriolo*	P	5	4.30	5.88	6.23	6.44	6.81	6.95	7.05	6.83	0.318
Guinas	Sept	*Tsericea*	L	1	0.01	0.07	1.13	2.28	4.62	6.43	6.60	16.14	0.012
Guinas	Sept	*Tsericea*	L	2	4.69	7.39	8.14	8.87	9.56	9.92	11.02	10.13	0.198
Guinas	Sept	*Tsericea*	L	3	4.84	7.68	9.21	10.04	11.95	13.61	13.86	13.37	0.131
Guinas	Sept	*Tsericea*	L	4	4.76	6.82	7.46	7.70	7.70	7.84	7.94	7.85	0.322

Guinas	Sept	*Tsericea*	L	5	1.61	2.97	3.30	3.62	4.20	4.33	4.39	4.32	0.168
Guinas	Sept	*Pnelsii*	L	1	1.02	2.18	2.86	3.91	4.08	4.24	4.43	4.42	0.122
Guinas	Sept	*Pnelsii*	L	2	0.07	1.26	1.85	1.85	1.85	1.85	1.85	1.94	0.159
Guinas	Sept	*Pnelsii*	L	3	3.84	6.76	8.23	9.13	10.61	12.26	12.62	12.16	0.123
Guinas	Sept	*Pnelsii*	L	4	4.07	5.55	6.04	6.34	6.34	7.31	8.00	7.09	0.249
Guinas	Sept	*Pnelsii*	L	5	4.28	6.66	7.32	8.10	8.39	9.61	10.48	9.49	0.181
Guinas	Sept	*Dcinerel*	L	1	1.93	4.09	5.57	6.98	9.74	10.59	11.38	11.67	0.073
Guinas	Sept	*Dcinerel*	L	2	2.73	3.40	3.53	3.53	3.53	3.59	3.74	3.60	0.475
Guinas	Sept	*Dcinerel*	L	3	4.28	6.11	6.68	6.84	6.88	7.90	8.23	7.56	0.262
Guinas	Sept	*Dcinerel*	L	4	0.31	1.11	1.36	1.38	1.38	1.38	1.38	1.43	0.197
Guinas	Sept	*Dcinerel*	L	5	2.96	4.96	5.24	5.42	5.42	5.52	5.80	5.62	0.288
Guinas	Sept	*Dcinerep*	P	1	3.81	5.03	6.99	8.73	12.53	15.88	16.24	17.46	0.058
Guinas	Sept	*Dcinerep*	P	2	1.32	1.97	2.43	3.44	3.66	3.83	4.02	3.95	0.125
Guinas	Sept	*Dcinerep*	P	3	3.59	5.28	5.74	6.21	9.64	11.50	11.51	11.75	0.079
Guinas	Sept	*Dcinerep*	P	4	3.98	4.96	5.07	5.13	7.92	8.00	8.25	7.97	0.135
Guinas	Sept	*Dcinerep*	P	5	4.40	5.80	5.91	6.27	6.64	6.64	6.64	6.51	0.358
Guinas	Sept	*Gbicol*	L	1	0.08	2.63	4.67	7.33	11.14	14.81	16.82	24.60	0.025
Guinas	Sept	*Gbicol*	L	2	0.77	1.47	2.01	2.39	2.39	3.19	3.45	3.23	0.098
Guinas	Sept	*Gbicol*	L	3	2.87	5.84	7.34	7.91	9.71	12.11	13.00	12.50	0.089

Guinas	Sept	*Gbicol*	L	4	0.16	0.34	1.81	1.99	1.99	2.04	2.04	2.16	0.105
Guinas	Sept	*Gbicol*	L	5	3.92	6.02	7.66	9.34	11.54	13.49	15.04	14.46	0.085
Guinas	Sept	*Bpeter*	L	1	3.81	5.53	6.86	7.66	9.29	11.09	12.86	11.83	0.093
Guinas	Sept	*Bpeter*	L	2	3.08	4.14	4.59	5.41	5.41	5.99	5.99	5.77	0.216
Guinas	Sept	*Bpeter*	L	3	3.18	5.20	6.20	6.58	7.12	7.94	8.05	7.74	0.176
Guinas	Sept	*Bpeter*	L	4	2.23	3.22	3.60	3.78	4.61	4.63	4.84	4.63	0.184
Guinas	Sept	*Bpeter*	L	5	4.28	6.41	7.03	7.45	8.36	8.39	8.58	8.35	0.227
Guinas	Sept	*Aeriolo*	P	1	0.15	2.39	3.82	5.46	9.27	13.08	15.20	28.07	0.017

Guinas	Sept	*Aeriolo*	P	2	0.00	0.00	0.00	0.00	0.00	0.13	0.20	0.00	0.000
Guinas	Sept	*Aeriolo*	P	3	4.09	6.16	7.41	8.53	11.09	14.34	15.08	14.96	0.075
Guinas	Sept	*Aeriolo*	P	4	1.85	2.51	2.77	3.02	3.24	4.20	5.05	4.30	0.121
Guinas	Sept	*Aeriolo*	P	5	4.57	6.38	6.75	7.34	8.12	8.44	8.47	8.19	0.239
kongola	Jan	*BmaSSie*	L	1	2.34	2.37	2.41	2.61	2.93	4.90	6.81	7.20	0.038
kongola	Jan	*BmaSSie*	L	2	1.72	2.35	2.71	2.93	2.93	3.22	3.34	3.15	0.238
kongola	Jan	*BmaSSie*	L	3	4.65	7.32	8.43	9.02	9.74	11.65	12.39	11.35	0.154
kongola	Jan	*BmaSSie*	L	4	2.40	3.78	4.13	4.26	4.26	4.38	4.62	4.44	0.282
kongola	Jan	*BmaSSie*	L	5	2.73	3.52	3.81	4.14	4.14	5.41	5.66	5.00	0.192
kongola	Jan	*Ccolli*	L	1	3.42	4.30	4.93	5.23	5.77	9.01	9.69	8.97	0.084
kongola	Jan	*Ccolli*	L	2	2.44	3.82	4.32	4.79	4.79	4.92	4.98	4.93	0.239

kongola	Jan	*Ccolli*	L	3	1.05	2.49	3.08	3.44	3.44	3.80	4.47	4.02	0.144
kongola	Jan	*Ccolli*	L	4	2.24	3.04	3.31	3.42	3.42	3.42	3.50	3.46	0.350
kongola	Jan	*Ccolli*	L	5	3.41	4.56	4.96	5.12	5.12	5.12	5.19	5.16	0.361
kongola	Jan	*Pnelsii*	L	1	3.78	5.34	6.10	6.70	7.97	8.35	9.33	8.57	0.151
kongola	Jan	*Pnelsii*	L	2	3.61	5.48	5.80	5.87	7.16	7.16	7.73	7.20	0.206
kongola	Jan	*Pnelsii*	L	3	0.02	0.81	1.25	1.54	4.83	5.30	5.44	8.79	0.023
kongola	Jan	*Pnelsii*	L	4	2.04	2.92	3.09	3.35	3.35	3.41	3.45	3.40	0.307
kongola	Jan	*Pnelsii*	L	5	3.05	3.99	4.21	4.54	4.54	4.55	4.59	4.54	0.358
kongola	Jan	*Bpeter*	L	1	3.34	4.88	6.57	7.43	8.90	11.22	12.82	12.12	0.080
kongola	Jan	*Bpeter*	L	2	4.08	6.09	6.49	6.68	6.68	7.64	8.27	7.43	0.257
kongola	Jan	*Bpeter*	L	3	3.85	4.57	5.93	6.99	8.67	11.36	12.48	12.14	0.073
kongola	Jan	*Bpeter*	L	4	1.92	2.97	3.27	3.36	3.91	5.14	6.04	5.31	0.103
kongola	Jan	*Bpeter*	L	5	3.81	5.44	5.88	6.28	6.82	8.42	9.79	8.41	0.146
kongola	May	*BmaSSie*	L	1	3.05	3.13	4.08	4.81	5.28	7.39	8.78	8.08	0.075
kongola	May	*BmaSSie*	L	2	1.46	1.93	2.35	2.48	3.75	3.77	4.63	4.30	0.088
kongola	May	*BmaSSie*	L	3	1.42	3.76	4.86	5.37	6.48	9.12	10.84	10.96	0.053
kongola	May	*BmaSSie*	L	4	0.81	1.76	2.00	2.17	2.17	2.20	2.23	2.25	0.215
kongola	May	*BmaSSie*	L	5	3.57	4.85	5.34	5.59	5.87	6.97	8.88	7.22	0.165
kongola	May	*Tsericea*	L	1	0.17	3.98	4.00	4.00	4.76	5.26	6.41	5.75	0.111

kongola	May	*Tsericea*	L	2	0.89	2.47	3.02	3.27	3.64	3.64	3.64	3.72	0.160
kongola	May	*Tsericea*	L	3	4.63	7.01	7.79	7.94	8.11	8.11	8.11	8.17	0.302
kongola	May	*Tsericea*	L	4	0.34	1.16	2.92	3.18	3.18	3.38	3.41	3.52	0.117
kongola	May	*Tsericea*	L	5	3.46	5.14	5.80	6.05	6.36	6.41	6.41	6.39	0.264
kongola	May	*Bpeter*	L	1	3.62	6.29	7.95	9.25	12.48	15.24	16.61	16.62	0.070
kongola	May	*Bpeter*	L	2	3.74	4.68	5.33	5.98	6.28	7.60	8.12	7.32	0.167
kongola	May	*Bpeter*	L	3	4.78	7.36	8.68	9.50	11.56	14.27	15.73	14.65	0.098
kongola	May	*Bpeter*	L	4	2.94	4.36	4.38	4.53	5.01	5.82	6.57	5.67	0.200
kongola	May	*Bpeter*	L	5	3.64	5.91	6.72	7.33	8.61	10.19	11.29	10.33	0.119
kongola	May	*Ccolli*	L	1	3.81	7.62	11.43	15.24	16.48	20.29	20.46	20.67	0.087
kongola	May	*Ccolli*	L	2	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.042
kongola	May	*Ccolli*	L	3	4.62	6.37	7.11	7.26	7.26	7.37	7.37	7.37	0.335
kongola	May	*Ccolli*	L	4	2.65	3.66	3.96	4.54	4.54	4.54	4.54	4.54	0.278
kongola	May	*Ccolli*	L	5	3.68	5.05	5.52	6.16	6.32	6.32	6.36	6.31	0.274
kongola	May	*Pnelsii*	L	1	3.75	4.64	4.94	4.96	6.22	6.79	10.60	8.35	0.099
kongola	May	*Pnelsii*	L	2	4.37	5.90	6.23	6.41	6.97	6.97	6.97	6.84	0.323
kongola	May	*Pnelsii*	L	3	4.69	6.69	7.13	7.15	7.88	7.90	7.90	7.77	0.305
kongola	May	*Pnelsii*	L	4	2.36	3.21	3.42	3.75	3.86	3.96	3.96	3.89	0.291
kongola	May	*Pnelsii*	L	5	3.22	4.65	4.85	5.02	5.22	5.22	5.38	5.24	0.326

kongola	Sept	*BmaSSie*	L	1	1.87	3.16	4.93	5.35	5.45	7.46	8.74	7.99	0.084
kongola	Sept	*BmaSSie*	L	2	2.44	3.65	3.96	6.78	6.78	7.36	7.36	7.42	0.120
kongola	Sept	*BmaSSie*	L	3	4.55	6.77	7.54	7.68	7.94	8.87	9.19	8.58	0.243
kongola	Sept	*BmaSSie*	L	4	3.55	4.81	5.31	5.46	5.46	5.70	5.71	5.61	0.329
kongola	Sept	*BmaSSie*	L	5	4.53	6.67	7.11	7.31	7.31	7.50	7.55	7.48	0.330
kongola	Sept	*Tsericea*	L	1	3.81	6.58	8.45	10.09	13.90	16.64	18.47	18.65	0.065
kongola	Sept	*Tsericea*	L	2	4.47	6.12	6.66	7.73	7.73	8.73	8.73	8.33	0.220
kongola	Sept	*Tsericea*	L	3	4.78	7.19	8.24	8.40	8.65	10.26	10.97	9.89	0.202
kongola	Sept	*Tsericea*	L	4	4.48	6.16	6.76	7.15	7.23	7.31	7.95	7.45	0.294
kongola	Sept	*Tsericea*	L	5	1.99	3.73	4.45	4.95	5.05	5.05	5.05	5.14	0.205
kongola	Sept	*Bpeter*	L	1	0.34	1.06	1.83	2.65	3.07	4.01	4.29	4.64	0.053
kongola	Sept	*Bpeter*	L	2	3.00	4.50	4.80	5.04	5.04	5.82	5.88	5.52	0.255
kongola	Sept	*Bpeter*	L	3	3.41	5.78	6.90	7.61	8.96	10.35	11.01	10.40	0.120
kongola	Sept	*Bpeter*	L	4	0.05	0.10	0.13	0.15	0.17	0.29	0.31	0.33	0.047
kongola	Sept	*Bpeter*	L	5	4.69	6.93	7.40	7.75	7.78	8.23	8.81	8.21	0.283
kongola	Sept	*Ccolli*	L	1	0.03	1.17	1.93	2.56	2.66	2.77	3.07	3.05	0.095
kongola	Sept	*Ccolli*	L	2	1.29	2.10	2.56	2.98	2.98	4.11	4.79	4.27	0.096
kongola	Sept	*Ccolli*	L	3	2.09	3.88	4.46	4.71	4.71	4.71	4.71	4.80	0.243
kongola	Sept	*Ccolli*	L	4	2.95	4.00	4.64	4.94	4.94	4.94	4.94	4.97	0.293
kongola	Sept	*Ccolli*	L	5	4.17	5.82	6.32	6.47	6.47	6.47	6.84	6.61	0.340

kongola	Sept	*Pnelsii*	L	1	1.58	4.06	5.93	7.54	9.43	11.16	12.41	12.56	0.066
kongola	Sept	*Pnelsii*	L	2	3.19	4.14	4.74	4.92	6.19	6.19	6.19	6.08	0.189
kongola	Sept	*Pnelsii*	L	3	0.14	0.87	1.95	2.76	3.71	5.21	5.72	7.58	0.030
kongola	Sept	*Pnelsii*	L	4	4.00	5.45	6.02	6.35	6.37	7.50	8.41	7.32	0.221
kongola	Sept	*Pnelsii*	L	5	4.57	6.47	7.00	7.75	8.33	9.49	10.44	9.36	0.179
Tsandi	Jan	*Capicula*	L	1	2.85	3.92	4.53	4.88	5.52	6.05	6.24	5.90	0.177
Tsandi	Jan	*Capicula*	L	2	4.57	6.13	6.80	7.16	7.62	7.62	7.62	7.54	0.289
Tsandi	Jan	*Capicula*	L	3	1.27	2.60	3.27	3.68	3.68	4.71	6.38	5.44	0.088
Tsandi	Jan	*Capicula*	L	4	0.58	1.51	1.69	1.83	1.83	1.83	1.83	1.88	0.211
Tsandi	Jan	*Capicula*	L	5	2.42	3.74	3.99	4.07	4.25	4.25	4.25	4.25	0.305
Tsandi	Jan	*Calex*	L	1	1.33	3.77	5.81	7.52	11.33	15.14	18.95	26.64	0.025
Tsandi	Jan	*Calex*	L	2	4.12	6.14	7.56	8.70	11.43	12.95	15.09	14.25	0.083
Tsandi	Jan	*Calex*	L	3	4.81	7.65	9.61	11.31	13.99	17.19	20.13	19.16	0.074
Tsandi	Jan	*Calex*	L	4	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.424
Tsandi	Jan	*Calex*	L	5	3.64	6.10	7.07	7.90	9.81	10.77	11.13	10.79	0.123
Tsandi	Jan	*Pnelsii*	L	1	3.81	5.22	6.65	8.29	11.65	15.21	17.26	18.45	0.049
Tsandi	Jan	*Pnelsii*	L	2	4.55	6.82	7.77	8.64	9.93	12.36	14.07	12.70	0.107
Tsandi	Jan	*Pnelsii*	L	3	4.22	6.45	7.94	8.98	11.53	14.20	14.88	14.56	0.086
Tsandi	Jan	*Pnelsii*	L	4	2.07	3.20	3.44	3.46	3.46	5.21	7.51	6.25	0.074

Tsandi	Jan	*Pnelsii*	L	5	3.83	5.75	6.47	6.93	8.66	10.14	12.61	11.15	0.095
Tsandi	Jan	*Cmopane*	L	1	0.93	1.71	2.09	2.45	6.26	6.72	7.25	9.43	0.034
Tsandi	Jan	*Cmopane*	L	2	0.47	0.76	0.80	0.86	0.86	1.01	1.35	1.08	0.165
Tsandi	Jan	*Cmopane*	L	3	4.60	6.27	6.80	6.97	6.97	7.74	7.74	7.39	0.311
Tsandi	Jan	*Cmopane*	L	4	0.24	0.84	1.06	1.26	1.26	1.34	3.09	3.94	0.021
Tsandi	Jan	*Cmopane*	L	5	0.04	0.11	0.14	0.17	0.17	0.29	0.83	0.00	0.000
Tsandi	Jan	*Tsericea*	L	1	3.77	6.10	7.59	8.96	11.93	14.56	16.29	16.11	0.069
Tsandi	Jan	*Tsericea*	L	2	4.83	6.77	7.40	7.59	7.59	7.73	7.73	7.71	0.337

Tsandi	Jan	*Tsericea*	L	3	4.73	7.16	8.11	8.62	9.91	10.89	11.12	10.60	0.172
Tsandi	Jan	*Tsericea*	L	4	0.52	1.32	1.54	1.55	1.55	1.64	1.67	1.66	0.209
Tsandi	Jan	*Tsericea*	L	5	4.28	5.71	5.80	5.88	6.87	8.44	9.32	8.07	0.169
Tsandi	Jan	*Tprunio*	L	1	2.81	4.20	4.65	5.03	6.14	9.95	10.35	10.57	0.059
Tsandi	Jan	*Tprunio*	L	2	0.01	0.06	0.08	0.08	0.67	1.26	1.26	0.00	0.000
Tsandi	Jan	*Tprunio*	L	3	4.48	6.70	7.76	8.38	9.52	10.03	10.23	9.90	0.181
Tsandi	Jan	*Tprunio*	L	4	3.07	4.50	4.79	4.82	4.83	4.83	4.83	4.88	0.361
Tsandi	Jan	*Tprunio*	L	5	4.43	6.11	6.65	6.83	7.21	7.21	7.21	7.15	0.316
Tsandi	May	*Tsericea*	L	1	3.81	7.62	11.43	11.50	11.61	11.78	15.59	13.40	0.151
Tsandi	May	*Tsericea*	L	2	1.98	3.50	4.51	5.04	6.52	6.75	6.75	6.84	0.117
Tsandi	May	*Tsericea*	L	3	3.41	5.89	7.34	7.94	9.82	11.31	11.63	11.30	0.112

Tsandi	May	*Tsericea*	L	4	3.05	4.34	4.74	4.92	4.92	4.92	4.92	4.96	0.331
Tsandi	May	*Tsericea*	L	5	3.12	4.70	5.30	5.70	6.17	6.17	6.17	6.15	0.233
Tsandi	May	*Capicula*	L	1	2.25	4.08	4.81	5.55	7.07	8.32	8.33	8.30	0.098
Tsandi	May	*Capicula*	L	2	0.66	1.71	2.10	2.22	2.85	2.85	3.07	3.00	0.122
Tsandi	May	*Capicula*	L	3	3.82	6.22	7.05	7.61	8.62	9.50	9.50	9.21	0.169
Tsandi	May	*Capicula*	L	4	1.08	1.72	2.08	2.36	2.96	4.30	4.30	4.40	0.068
Tsandi	May	*Capicula*	L	5	4.57	6.38	7.10	7.49	8.26	8.26	8.42	8.21	0.248
Tsandi	May	*Tprunio*	L	1	0.19	1.68	2.23	2.82	4.53	6.22	7.33	10.52	0.025
Tsandi	May	*Tprunio*	L	2	3.55	5.23	6.49	7.02	8.00	8.55	8.55	8.40	0.164
Tsandi	May	*Tprunio*	L	3	2.54	4.68	5.45	5.47	6.70	6.84	6.86	6.80	0.169
Tsandi	May	*Tprunio*	L	4	3.67	5.22	5.86	6.12	6.44	7.02	7.16	6.80	0.238
Tsandi	May	*Tprunio*	L	5	4.66	6.64	7.03	7.14	7.42	7.67	7.67	7.52	0.327
Tsandi	May	*Cmopane*	L	1	2.68	3.74	5.50	7.08	9.87	11.90	12.79	13.49	0.059

Tsandi	May	*Cmopane*	L	2	3.12	4.54	5.31	5.85	5.85	6.88	7.34	6.70	0.185
Tsandi	May	*Cmopane*	L	3	1.23	2.81	3.72	4.18	4.60	5.87	6.08	5.87	0.099
Tsandi	May	*Cmopane*	L	4	0.89	1.79	2.33	3.60	3.60	3.75	4.45	4.18	0.103
Tsandi	May	*Cmopane*	L	5	4.66	6.69	7.26	7.47	8.14	8.31	8.31	8.14	0.272
Tsandi	May	*Pnelsii*	L	1	3.81	7.62	7.83	8.96	10.71	11.66	13.92	12.46	0.118
Tsandi	May	*Pnelsii*	L	2	3.25	5.07	6.17	6.92	7.69	9.56	10.88	9.86	0.106

Tsandi	May	*Pnelsii*	L	3	4.65	7.11	8.49	9.34	10.90	11.27	12.43	11.62	0.151
Tsandi	May	*Pnelsii*	L	4	3.33	4.74	5.16	5.37	5.37	6.26	7.48	6.28	0.217
Tsandi	May	*Pnelsii*	L	5	3.73	5.62	6.58	7.23	8.42	10.61	12.27	11.09	0.097
Tsandi	May	*Calex*	L	1	2.86	5.16	7.60	9.31	13.12	16.93	20.06	22.39	0.042
Tsandi	May	*Calex*	L	2	0.56	1.01	1.46	2.03	3.22	3.52	3.52	3.94	0.058
Tsandi	May	*Calex*	L	3	4.47	6.84	8.08	8.99	11.42	12.52	12.68	12.45	0.122
Tsandi	May	*Calex*	L	4	3.09	5.20	5.28	5.84	6.33	6.44	6.44	6.36	0.234
Tsandi	May	*Calex*	L	5	4.13	6.76	7.87	8.48	9.06	9.24	9.34	9.25	0.209
Tsandi	Sept	*Tsericea*	L	1	3.81	5.37	6.27	6.44	6.65	7.19	7.64	7.11	0.238
Tsandi	Sept	*Tsericea*	L	2	2.81	3.54	4.05	4.12	4.18	4.18	4.18	4.17	0.355
Tsandi	Sept	*Tsericea*	L	3	4.46	6.69	7.52	7.96	9.15	9.73	9.73	9.46	0.190
Tsandi	Sept	*Tsericea*	L	4	3.18	4.34	4.79	5.08	5.08	5.08	5.08	5.09	0.324
Tsandi	Sept	*Tsericea*	L	5	4.65	6.89	7.24	7.30	7.66	7.66	7.81	7.68	0.328
Tsandi	Sept	*Capicula*	L	1	0.86	1.16	2.46	3.03	4.06	4.90	6.63	7.58	0.035
Tsandi	Sept	*Capicula*	L	2	2.91	4.14	4.47	4.65	5.39	5.50	5.79	5.45	0.220
Tsandi	Sept	*Capicula*	L	3	4.14	6.30	7.19	7.64	8.97	9.74	9.74	9.45	0.168
Tsandi	Sept	*Capicula*	L	4	3.63	4.73	5.04	5.07	5.07	6.27	6.27	5.70	0.296
Tsandi	Sept	*Capicula*	L	5	0.21	1.30	1.46	1.62	2.18	2.24	2.24	2.30	0.105

Tsandi	Sept	*Tprunio*	L	1	1.24	4.24	6.07	7.84	11.65	14.05	15.40	17.20	0.047

Tsandi	Sept	*Tprunio*	L	2	3.01	4.17	4.62	5.36	6.33	6.66	6.87	6.61	0.157
Tsandi	Sept	*Tprunio*	L	3	0.06	1.30	2.42	2.65	3.35	3.98	4.30	4.43	0.066
Tsandi	Sept	*Tprunio*	L	4	4.63	6.60	7.27	7.65	8.53	8.53	8.53	8.42	0.247
Tsandi	Sept	*Tprunio*	L	5	4.98	8.19	9.10	9.87	11.05	11.80	12.22	11.68	0.179
Tsandi	Sept	*Cmopane*	L	1	3.81	3.89	4.54	5.61	6.37	7.23	7.58	7.09	0.142
Tsandi	Sept	*Cmopane*	L	2	2.62	3.43	3.62	3.82	3.82	4.14	4.67	4.12	0.301
Tsandi	Sept	*Cmopane*	L	3	3.36	5.33	6.13	6.41	6.41	7.76	8.02	7.40	0.196
Tsandi	Sept	*Cmopane*	L	4	4.18	5.77	6.58	6.90	6.90	6.90	6.90	6.94	0.308
Tsandi	Sept	*Cmopane*	L	5	4.57	6.79	7.40	7.72	7.72	7.78	7.78	7.82	0.312
Tsandi	Sept	*Pnelsii*	L	1	1.49	1.49	2.78	4.10	5.22	6.90	7.92	9.02	0.041
Tsandi	Sept	*Pnelsii*	L	2	0.90	1.57	1.93	2.44	2.44	3.41	4.08	3.75	0.076
Tsandi	Sept	*Pnelsii*	L	3	2.51	3.87	4.75	5.30	5.79	7.46	8.19	7.50	0.108
Tsandi	Sept	*Pnelsii*	L	4	4.46	6.11	6.78	7.12	7.38	8.44	9.54	8.33	0.211
Tsandi	Sept	*Pnelsii*	L	5	0.03	1.41	2.57	3.34	4.14	4.46	5.12	5.23	0.065
Tsandi	Sept	*Calex*	L	1	0.09	1.53	2.83	4.25	8.06	11.87	15.68	0.00	0.000
Tsandi	Sept	*Calex*	L	2	2.76	4.60	5.05	5.60	5.89	6.64	7.51	6.71	0.167
Tsandi	Sept	*Calex*	L	3	0.47	2.29	3.08	3.64	4.60	5.77	6.80	6.91	0.056
Tsandi	Sept	*Calex*	L	4	4.11	6.12	6.92	7.29	7.37	7.48	7.56	7.51	0.274
Tsandi	Sept	*Calex*	L	5	3.34	5.59	6.43	7.33	9.00	10.17	11.02	10.42	0.111
Daurês	Jan	*Calex*	L	1	0.03	3.84	5.23	6.76	9.21	11.48	14.01	15.90	0.040

Daurês	Jan	*Calex*	L	2	1.24	3.29	4.47	5.28	6.96	7.69	9.11	8.89	0.071
Daurês	Jan	*Calex*	L	3	4.78	7.55	9.44	11.29	15.10	18.91	22.03	22.08	0.059
Daurês	Jan	*Calex*	L	4	0.56	2.11	2.67	2.98	4.42	5.70	6.09	6.60	0.052

Daurês	Jan	*Calex*	L	5	3.55	5.62	6.97	8.70	11.13	13.65	16.04	15.75	0.064
Daurês	Jan	*Akarool*	L	1	1.94	3.50	3.65	4.24	6.01	8.45	10.09	11.07	0.042
Daurês	Jan	*Akarool*	L	2	0.58	1.08	1.47	1.88	2.48	3.34	3.82	4.18	0.045
Daurês	Jan	*Akarool*	L	3	0.62	2.00	2.97	3.91	6.56	8.35	9.74	13.11	0.028
Daurês	Jan	*Akarool*	L	4	2.25	3.18	3.56	3.76	3.76	3.76	4.14	3.89	0.285
Daurês	Jan	*Akarool*	L	5	3.81	5.45	5.76	6.17	6.28	7.11	7.37	6.81	0.250
Daurês	Jan	*Aherero*	L	1	0.67	2.27	3.58	5.19	9.00	11.48	12.96	18.58	0.026
Daurês	Jan	*Aherero*	L	2	2.94	4.43	4.95	5.21	5.37	7.25	8.03	7.00	0.140
Daurês	Jan	*Aherero*	L	3	4.36	6.29	7.66	8.80	11.70	13.16	14.55	13.96	0.090
Daurês	Jan	*Aherero*	L	4	3.24	4.52	4.99	5.25	5.25	6.62	7.96	6.59	0.173
Daurês	Jan	*Aherero*	L	5	3.26	3.70	4.18	4.49	4.49	4.49	4.87	4.54	0.360
Daurês	May	*Calex*	L	1	3.57	5.56	7.38	8.59	12.07	15.88	19.62	21.44	0.042
Daurês	May	*Calex*	L	2	3.94	5.65	6.43	7.08	7.88	8.22	8.22	8.05	0.198
Daurês	May	*Calex*	L	3	4.77	7.54	9.20	10.39	13.37	14.51	15.85	15.15	0.105
Daurês	May	*Calex*	L	4	3.45	5.75	6.60	7.07	7.37	7.41	7.65	7.53	0.225
Daurês	May	*Calex*	L	5	0.58	2.76	3.48	3.83	4.52	4.52	4.52	4.66	0.129

Daurês	May	*Akarool*	L	1	2.48	3.56	4.31	5.18	8.02	11.83	14.22	19.67	0.026
Daurês	May	*Akarool*	L	2	0.91	1.80	2.04	2.18	2.18	2.75	2.81	2.62	0.163
Daurês	May	*Akarool*	L	3	4.77	7.54	9.20	10.39	13.37	16.27	17.05	16.66	0.088
Daurês	May	*Akarool*	L	4	2.89	4.10	4.60	4.76	4.76	4.84	5.15	4.92	0.297
Daurês	May	*Akarool*	L	5	4.47	5.84	6.62	7.05	7.05	7.42	7.82	7.37	0.282
Daurês	May	*Akaroop*	P	1	3.59	5.19	6.47	8.26	11.88	15.69	18.23	20.33	0.042
Daurês	May	*Akaroop*	P	2	4.04	5.73	6.76	7.71	10.74	14.34	18.15	19.26	0.043
Daurês	May	*Akaroop*	P	3	3.87	5.61	7.39	8.97	12.78	16.59	18.43	19.72	0.051
Daurês	May	*Akaroop*	P	4	2.63	4.18	4.88	5.29	5.78	8.20	9.48	8.59	0.085
Daurês	May	*Akaroop*	P	5	3.46	5.79	7.14	8.71	11.82	15.63	18.31	19.36	0.048
Daurês	May	*Aherero*	L	1	3.81	5.41	5.49	7.06	10.86	14.67	17.11	19.65	0.039
Daurês	May	*Aherero*	L	2	1.91	3.24	3.86	4.30	5.29	6.26	6.83	6.45	0.100
Daurês	May	*Aherero*	L	3	4.67	6.71	7.67	8.49	11.86	14.45	16.19	15.69	0.074
Daurês	May	*Aherero*	L	4	2.63	3.78	4.50	4.76	5.07	6.07	6.76	6.01	0.155
Daurês	May	*Aherero*	L	5	4.35	5.66	6.18	6.80	8.28	9.48	9.69	9.15	0.145
Daurês	Sept	*Calex*	L	1	1.93	2.61	3.20	3.75	6.75	10.56	14.37	86.84	0.004
Daurês	Sept	*Calex*	L	2	1.04	2.59	2.99	5.61	6.63	7.99	9.91	10.71	0.044
Daurês	Sept	*Calex*	L	3	3.56	5.72	7.05	7.90	9.53	10.59	12.12	11.19	0.109
Daurês	Sept	*Calex*	L	4	0.80	1.65	2.19	2.42	3.36	3.71	3.98	3.97	0.083

Daurês	Sept	*Calex*	L	5	1.52	3.83	5.22	6.39	8.64	10.56	12.38	12.86	0.053
Daurês	Sept	*Akarool*	L	1	3.76	6.35	8.70	10.54	14.02	16.15	17.62	17.63	0.074
Daurês	Sept	*Akarool*	L	2	1.90	2.36	2.43	2.51	2.51	3.34	3.47	2.98	0.258
Daurês	Sept	*Akarool*	L	3	3.87	5.32	5.98	6.23	7.02	8.37	8.90	8.06	0.163
Daurês	Sept	*Akarool*	L	4	4.19	5.41	6.20	6.37	6.37	6.52	6.95	6.57	0.317
Daurês	Sept	*Akarool*	L	5	2.79	4.16	4.47	4.65	4.65	4.65	4.65	4.69	0.326
Daurês	Sept	*Aherero*	L	1	3.81	6.13	7.73	9.48	13.21	15.93	17.75	18.09	0.062
Daurês	Sept	*Aherero*	L	2	0.78	1.37	1.57	2.01	2.46	3.46	3.68	3.79	0.060
Daurês	Sept	*Aherero*	L	3	2.75	3.68	4.36	4.40	5.63	7.19	8.32	7.59	0.089
Daurês	Sept	*Aherero*	L	4	3.68	4.72	5.05	5.09	5.09	5.27	5.49	5.24	0.396
Daurês	Sept	*Aherero*	L	5	1.91	2.58	3.17	3.54	4.97	5.10	5.10	5.15	0.113
Omatako	Jan	*Capicula*	L	1	3.81	4.69	8.50	8.80	9.87	10.55	10.59	10.59	0.137
Omatako	Jan	*Capicula*	L	2	4.55	5.72	6.17	6.37	6.37	7.48	7.48	6.92	0.311

Omatako	Jan	*Capicula*	L	3	4.71	6.62	7.03	7.35	7.42	7.42	7.42	7.43	0.345
Omatako	Jan	*Capicula*	L	4	3.29	4.61	4.85	4.90	4.90	4.90	4.90	4.94	0.389
Omatako	Jan	*Capicula*	L	5	4.10	5.97	6.35	6.70	6.70	6.70	6.70	6.73	0.329
Omatako	Jan	*Zmucro*	L	1	2.95	4.93	6.57	9.01	12.82	16.61	19.64	22.77	0.038
Omatako	Jan	*Zmucro*	L	2	3.66	5.54	5.99	6.32	7.22	7.55	8.21	7.57	0.195
Omatako	Jan	*Zmucro*	L	3	0.02	1.31	3.03	4.62	8.43	12.02	14.14	38.31	0.010

Omatako	Jan	*Zmucro*	L	4	2.54	3.87	4.58	5.11	7.06	7.86	9.26	8.73	0.082
Omatako	Jan	*Zmucro*	L	5	4.46	6.14	6.76	7.13	7.93	8.13	9.19	8.28	0.218
Omatako	May	*Zmucro*	L	1	1.00	2.50	3.57	4.50	8.31	12.12	15.93	60.26	0.006
Omatako	May	*Zmucro*	L	2	0.54	1.21	1.58	1.83	1.88	2.34	3.20	2.79	0.078
Omatako	May	*Zmucro*	L	3	4.62	6.88	8.34	9.49	13.30	16.67	18.95	18.98	0.062
Omatako	May	*Zmucro*	L	4	3.52	5.21	6.29	6.80	7.83	8.13	8.34	8.10	0.170
Omatako	May	*Zmucro*	L	5	4.60	7.00	8.28	9.31	12.64	14.84	15.92	15.52	0.086
Omatako	May	*Capicula*	L	1	3.81	7.62	7.68	7.68	7.74	7.75	7.76	7.92	0.303
Omatako	May	*Capicula*	L	2	0.60	1.46	1.90	2.07	2.39	2.39	2.39	2.44	0.145
Omatako	May	*Capicula*	L	3	4.66	7.09	8.44	9.48	10.86	11.32	11.32	11.21	0.164
Omatako	May	*Capicula*	L	4	1.59	2.68	3.01	3.08	3.50	3.50	3.50	3.49	0.217
Omatako	May	*Capicula*	L	5	3.41	5.38	5.88	6.32	6.44	6.44	6.44	6.48	0.269
Omatako	May	*Aeriolo*	P	1	3.81	6.83	8.92	11.82	15.63	19.44	21.17	22.08	0.059
Omatako	May	*Aeriolo*	P	2	3.50	4.84	5.60	5.95	6.17	8.10	10.02	8.39	0.121
Omatako	May	*Aeriolo*	P	3	0.94	3.16	4.85	6.10	9.91	11.88	12.23	14.22	0.046
Omatako	May	*Aeriolo*	P	4	4.45	6.55	7.49	7.96	10.22	12.13	13.93	12.76	0.098
Omatako	May	*Aeriolo*	P	5	4.64	7.70	8.69	9.33	10.65	13.68	15.78	14.11	0.103
Omatako	Sept	*Zmucro*	L	1	0.16	3.97	4.71	4.90	7.36	10.54	13.60	18.85	0.024
Omatako	Sept	*Zmucro*	L	2	0.60	1.79	2.42	3.02	4.70	5.03	5.03	5.46	0.067

Omatako	Sept	*Zmucro*	L	3	4.41	7.41	9.46	11.19	15.00	18.16	20.58	20.45	0.066
Omatako	Sept	*Zmucro*	L	4	3.28	5.82	7.42	9.27	12.42	14.09	15.53	15.49	0.074
Omatako	Sept	*Zmucro*	L	5	2.66	5.14	6.79	8.26	12.07	14.24	16.04	16.77	0.056
Omatako	Sept	*Capicula*	L	1	3.81	4.67	5.41	6.38	8.47	9.80	9.83	9.73	0.101
Omatako	Sept	*Capicula*	L	2	2.69	3.62	4.00	4.49	5.13	5.39	5.68	5.35	0.181
Omatako	Sept	*Capicula*	L	3	4.41	6.19	6.81	7.14	10.07	11.08	11.19	10.94	0.117
Omatako	Sept	Capicula	L	4	4.70	6.38	7.04	7.35	7.39	7.90	8.16	7.74	0.295
Omatako	Sept	Capicula	L	5	4.71	6.71	7.11	7.23	8.23	8.77	8.89	8.42	0.243

Rep= Replicate, *b*= potential gas production, c= rate of gas production, Sept= September, Jan= January, hr= hours, L=leaves

AP3.1 Experiment 2: Cumulative *in-vitro* gas production of woody plant species

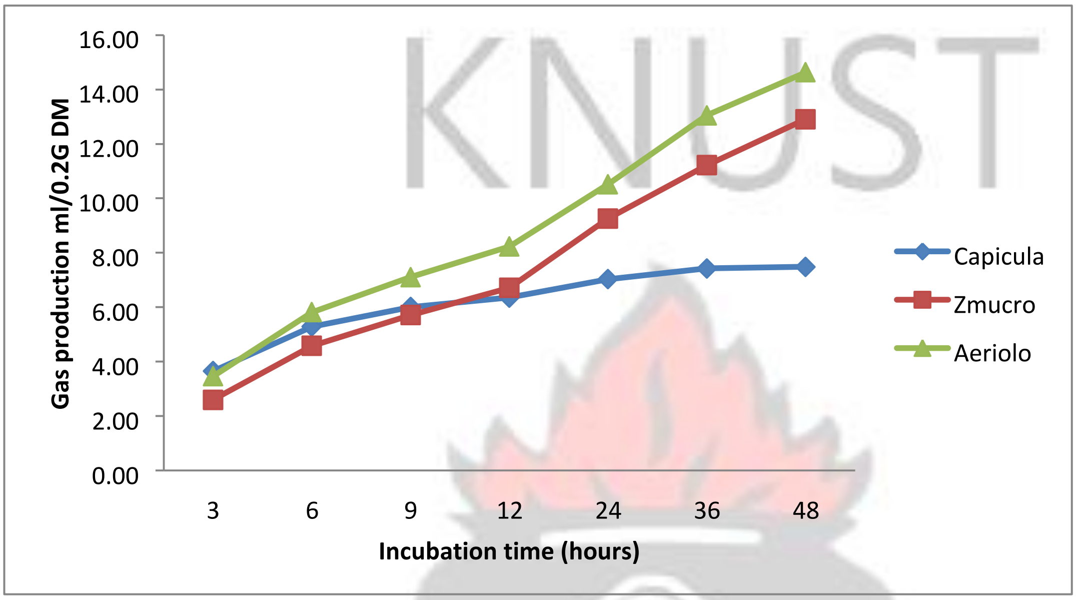

Figure AP3.1.1 Gas production profiles of leaves and pods of woody species in Omatako

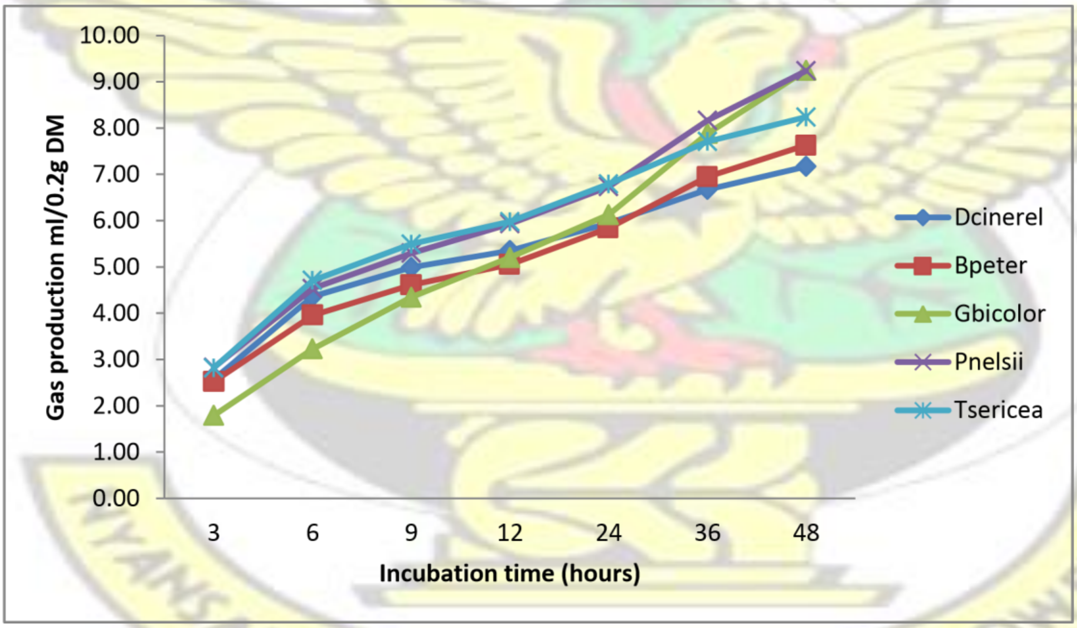

Figure AP3.1.2 Gas production profiles of leaves and twigs of woody species in Guinas

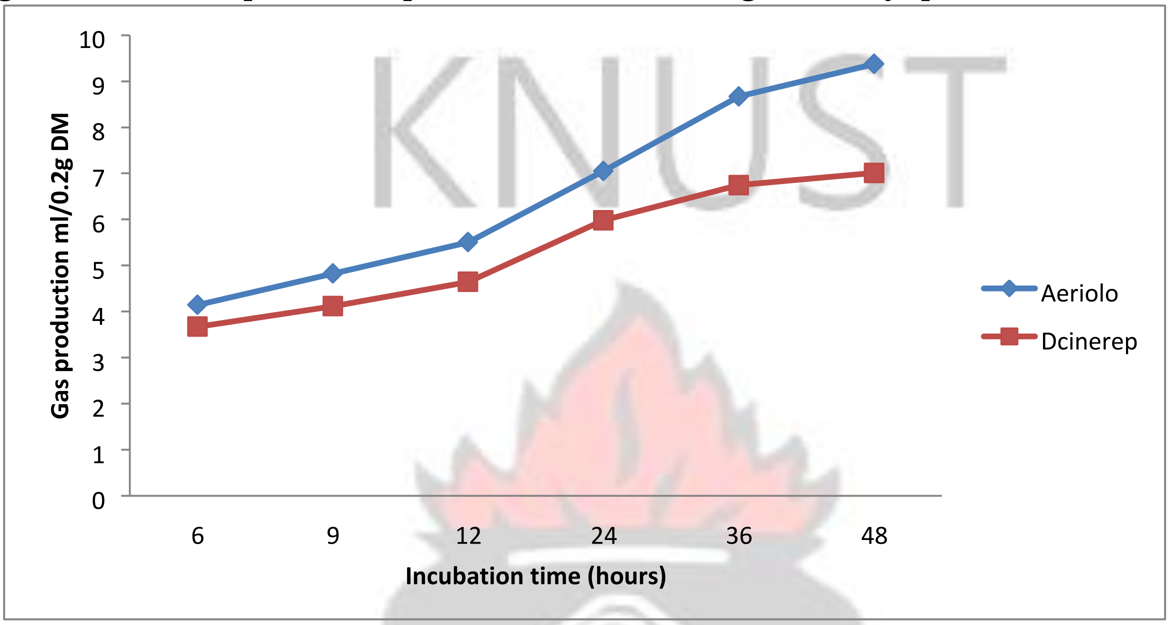

Figure AP3.1.3 Gas production profiles of pods of woody species in Guinas

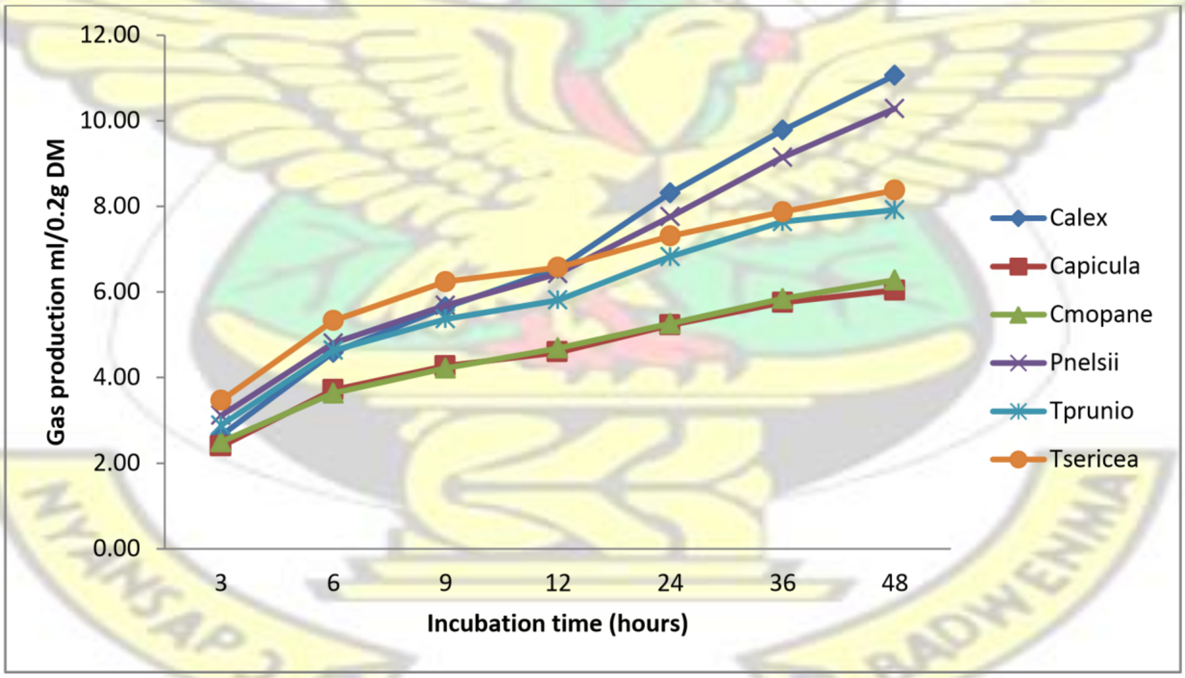

Figure AP3.1.4 Gas production profiles of leaves and twigs of woody species inTsandi

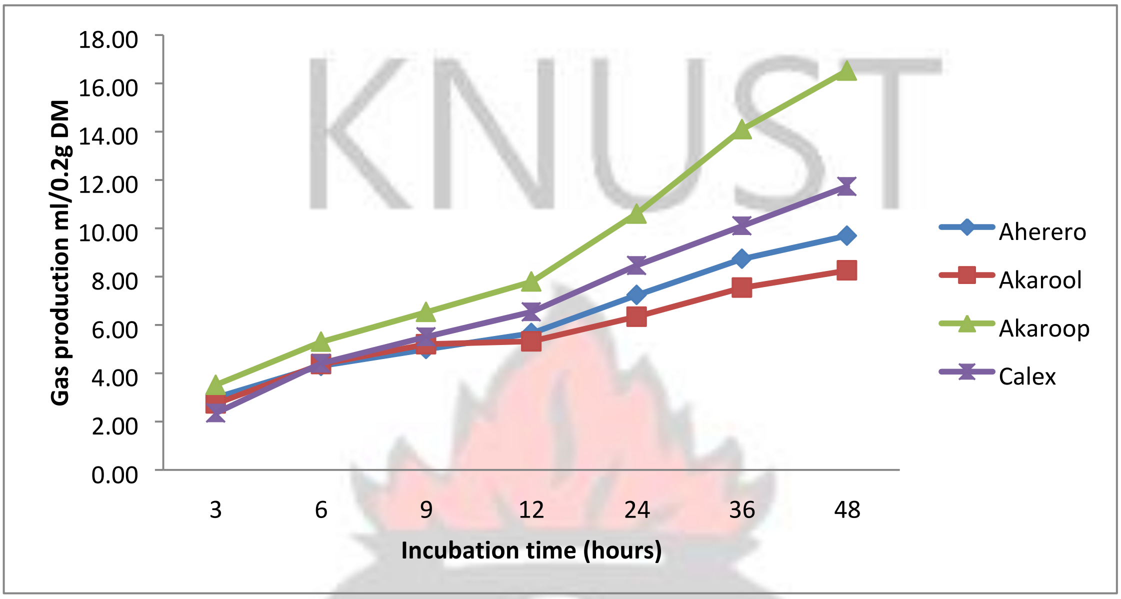

Figure AP3.1.5 Gas production profiles of leaves and twigs of woody species in Daurês

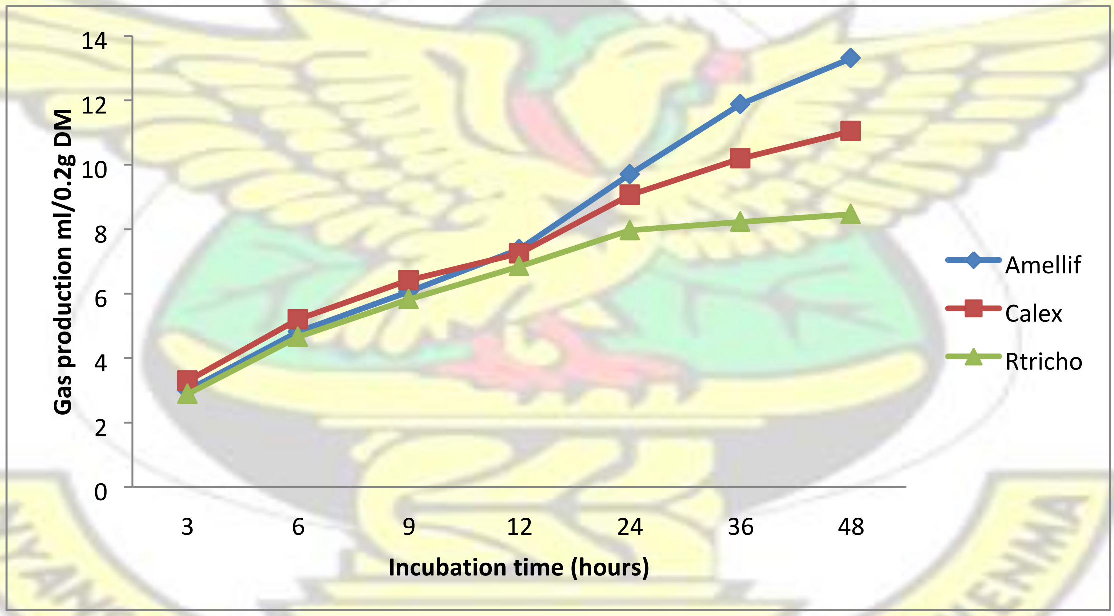

Figure AP3.1.6 Gas production profiles of leaves and twigs of woody species in

Gibeon

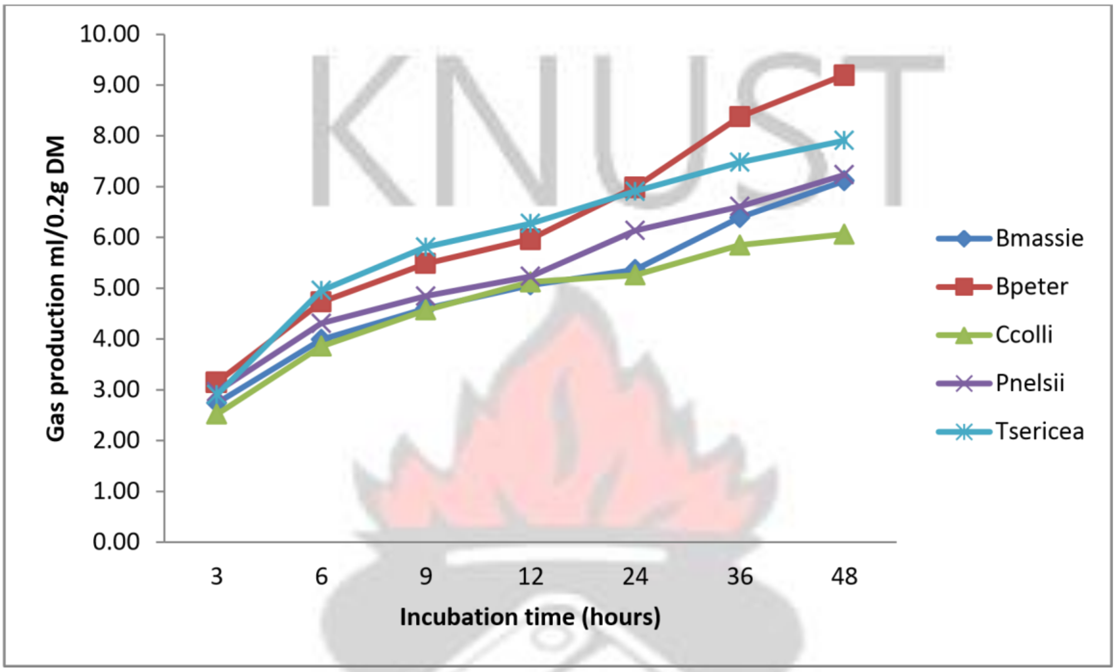

Figure AP3.1.7 Gas production profiles of leaves of woody species in Kongola

***b* of woody plants species**

Table AP3.2 Experiment 2: Mixed procedure for gas production in Omatako

Table AP3.2a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	1	20	9.65	0.0056
Month	2	20	1.94	0.1691
Species*Month	2	20	0.95	0.4037

Table AP3.2b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Capicula		7.3561	2.3763	20	3.10	0.0057
Species	Zmucro		13.8712	2.3763	20	5.84	<.0001
Month		1	12.2271	2.5974	20	4.71	0.0001
Month		5	7.6942	2.5974	20	2.96	0.0077
Month		9	11.9196	2.5974	20	4.59	0.0002

ants species in

Table AP3.3 Mixed procedure of rate of gas production *c* Omatako

Table AP3.3a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	1	20	42.27	<.0001
Month	2	20	4.23	0.0294
Species*Month	2	20	0.70	0.5086

Table AP3.3b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Capicula		0.2364	0.02335	20	10.12	<.0001
Species	Zmucro		0.08213	0.02335	20	3.52	0.0022
Month		1	0.2054	0.02619	20	7.84	<.0001
Month		5	0.1500	0.02619	20	5.73	<.0001
Month		9	0.1224	0.02619	20	4.67	0.0001

***b* of woody plants species**

Table AP3.4 Experiment 2: Mixed procedure for gas production in Guinas

Table AP3.4a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	4	56	1.15	0.3427
Month	2	56	0.19	0.8284
Species*month	8	56	1.00	0.4490

Table AP3.4b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Bpeter		8.6547	1.7159	56	5.04	<.0001
Species	Dcinerel		6.9226	1.7159	56	4.03	0.0002
Species	Gbicol		9.9541	1.7159	56	5.80	<.0001
Species	Pnelsii		8.4896	1.7159	56	4.95	<.0001
Species	Tsericea		8.5706	1.7159	56	4.99	<.0001
Month		1	8.8725	1.5943	56	5.57	<.0001
Month		5	8.1998	1.5943	56	5.14	<.0001
Month		9	8.4827	1.5943	56	5.32	<.0001

roduction *c* ' woody plants

Table AP3.5 Experiment 2: Mixed procedure of rate of gas p species in Guinas

Table AP3.5a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	4	56	5.93	0.0005
Month	2	56	3.53	0.0358
Species *Month	8	56	2.36	0.0290

b of woody plants species

Table AP3.5b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Bpeter		0.1483	0.03158	56	4.70	<.0001
Species	Dcinerel		0.2117	0.03158	56	6.70	<.0001
Species	Gbicol		0.09440	0.03158	56	2.99	0.0041
Species	Pnelsii		0.1286	0.03158	56	4.07	0.0001
Species	Tsericea		0.1617	0.03158	56	5.12	<.0001
Month		1	0.1202	0.02951	56	4.07	0.0001
Month		5	0.1563	0.02951	56	5.30	<.0001
Month		9	0.1703	0.02951	56	5.77	<.0001

Table AP3.7 Experiment 2: Mixed procedure for gas production in Kongola

Table AP3.7a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	3	44	2.51	0.0714
Month	2	44	1.32	0.2780
Species*Month	6	44	2.04	0.0796

Table AP3.7b Least Squares Means

Effect	Species	month	Estimate	S Error	DF	t Value	Pr > |t|
Species	BmaSSie		6.7350	1.2267	44	5.49	<.0001
Species	Bpeter		8.6071	1.2267	44	7.02	<.0001
Species	Ccolli		5.9418	1.2267	44	4.84	<.0001
Species	Pnelsii		7.1648	1.2267	44	5.84	<.0001
Month		1	6.7791	1.1747	44	5.77	<.0001
Month		5	7.9190	1.1747	44	6.74	<.0001
Month		9	6.6385	1.1747	44	5.65	<.0001

Table AP3.8 Experi nent 2: Mixe procedure of rate of gas production *c* woody plants species in Kongola

Table AP3.8a Type 3 Tests of Fixe l Effects

***b* of woody plants species**

Effect	Num DF	Den DF	F Value	Pr > F
Species	3	44	3.17	0.0334
Month	2	44	0.08	0.9195
Species*Month	6	44	2.05	0.0789

Table AP3.8b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Bmassie		0.1737	0.03612	44	4.81	<.0001
Species	Bpeter		0.1381	0.03612	44	3.82	0.0004
Species	Ccolli		0.2174	0.03612	44	6.02	<.0001
Species	Pnelsii		0.2049	0.03612	44	5.67	<.0001
Month		1	0.1893	0.03472	44	5.45	<.0001
Month		5	0.1805	0.03472	44	5.20	<.0001
Month		9	0.1808	0.03472	44	5.21	<.0001

Table AP3.9 Experiment 2: Mixed procedure for gas production *b* of woody plants species in Gibeon

Table AP3.9a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	2	32	3.23	0.0529
Month	2	32	0.90	0.4181
Species*Month	4	32	2.00	0.1177

Table AP3.9b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Amellif		13.7170	1.8233	32	7.52	<.0001
Species	Calex		12.4813	1.8233	32	6.85	<.0001
Species	Rtricho		8.5578	1.8233	32	4.69	<.0001
Month		1	9.9503	1.8233	32	5.46	<.0001
Month		5	12.5053	1.8233	32	6.86	<.0001
Month		9	12.3005	1.8233	32	6.75	<.0001

Table AP3.10 Experiment 2: Mixed procedure of rate of gas production *c* of woody plants species in Gibeon

Table AP3.10a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	2	32	13.26	<.0001
Month	2	32	0.18	0.8343
Species*Month	4	32	1.24	0.3141

Table AP3.10b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Amellif		0.06813	0.01807	32	3.77	0.0007
Species	Calex		0.1223	0.01807	32	6.77	<.0001
Species	Rtricho		0.1381	0.01807	32	7.64	<.0001
Month		1	0.1080	0.01807	32	5.98	<.0001
Month		5	0.1143	0.01807	32	6.33	<.0001

Month	9	0.1061	0.01807	32	5.87	<.0001

Table AP3.11 Experiment 2: Mixed procedure for gas production *b* of woody plants species in Daures

Table AP3.11a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	2	32	1.19	0.3170
Month	2	32	2.55	0.0941
Species*Month	4	32	0.86	0.5010

Table AP3.11b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Aherero		9.8309	2.2401	32	4.39	0.0001
Species	Akarool		8.6825	2.2401	32	3.88	0.0005
Species	Calex		10.9867	2.2401	32	4.90	<.0001
Month		1	10.5969	2.2401	32	4.73	<.0001
Month		5	11.0011	2.2401	32	4.91	<.0001
Month		9	7.9020	2.2401	32	3.53	0.0013

Table AP3.12 Experiment 2: Mixed procedure of rate of gas production *c* of woody plants species in Daures

Table AP3.12a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	2	32	6.55	0.0041
Month	2	32	0.71	0.4970
Species*Month	4	32	2.51	0.0610

Table AP3.12b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|

Species	Aherero		0.1348	0.03611	32	3.73	0.0007
Species	Akarool		0.1763	0.03611	32	4.88	<.0001
Species	Calex		0.08520	0.03611	32	2.36	0.0246
Month		1	0.1150	0.03611	32	3.18	0.0032
Month		5	0.1379	0.03611	32	3.82	0.0006
Month		9	0.1434	0.03611	32	3.97	0.0004

Table AP3.13 Experiment 2: Mixed procedure for gas production *b* of woody plants species in Tsandi

Table AP3.13a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	5	68	4.21	0.0022
Month	2	68	2.08	0.1330
Species*Month	10	68	2.19	0.0283

Table AP3.13b Least Squares Means

Effect	Species	Month	Estimate	S Error	DF	t Value	Pr > |t|
Species	Calex		10.4533	1.4538	68	7.19	<.0001
Species	Capicula		5.9065	1.4538	68	4.06	0.0001
Species	Cmopane		6.2393	1.4538	68	4.29	<.0001
Species	Pnelsii		9.8832	1.4538	68	6.80	<.0001
Species	Tprunio		8.0593	1.4538	68	5.54	<.0001
Species	Tsericea		8.0207	1.4538	68	5.52	<.0001
Month		1	8.5812	1.3075	68	6.56	<.0001
Month		5	8.6631	1.3075	68	6.63	<.0001
Month		9	7.0368	1.3075	68	5.38	<.0001

Table AP3.14 Experiment 2: Mixed procedure of rate of gas production *c* of woody plants species in Tsandi

Table AP3.14a Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Species	5	68	3.34	0.0093

Month	2	68	1.09	0.3415
Species*Month	10	68	1.57	0.1354

Table AP3.14b Least Squares Means

Effect	Species	Month	Estimate	Error	DF	t Value	Pr > |t|
Species	Calex		0.1408	0.03130	68	4.50	<.0001
Species	Capicula		0.1733	0.03130	68	5.54	<.0001
Species	Cmopane		0.1672	0.03130	68	5.34	<.0001
Species	Pnelsii		0.1067	0.03130	68	3.41	0.0011
Species	Tprunio		0.1691	0.03130	68	5.40	<.0001
Species	Tsericea		0.2223	0.03130	68	7.10	<.0001
Month		1	0.1538	0.02757	68	5.58	<.0001
Month		5	0.1548	0.02757	68	5.62	<.0001
Month		9	0.1811	0.02757	68	6.57	<.0001

Table AP4 Experiment 3: Value for feed offered to does

OBS	DOEID	ECOTY	PARITY	TRT	POD	LEVEL	REP	Off Wk1	Off Wk2	Off Wk3	Off Wk4	Of fWk5	Off Wk6	Off Wk7	Off Wk8	Off Wk9	OffWk10	OffWk11	OffWk12	OffWk13
1	1732	Ova	3	1	pelt	60	1	1420	1740	2000	2320	2540	2800	2800	2100	2100	2100	2100	2100	2100
2	1747	Ova	3	1	pelt	60	2	1368	2500	2800	2800	2800	2800	2800	2300	2800	2800	2800	2800	2800
3	2034	Ova	2	1	pelt	60	3	1400	1900	2480	2800	2800	2800	2800	2140	2220	2240	2240	2240	2240
4	1023	Cap	3	1	pelt	60	1	1660	2500	2800	2800	2800	2800	2800	2400	2800	2800	2800	2800	2800
5	2005	Cap	**2**	1	pelt	60	2	1600	2320	2800	2800	2800	2800	2800	2280	2580	2760	2800	2800	2800
6	2007	Cap	2	1	pelt	60	3	1400	1400	1420	1980	2600	2800	2800	2160	2220	2240	2240	2240	2240
7	0925	Ova	4	2	AE	20	1	1400	1400	1640	2040	2200	2400	2660	2100	2100	2100	2100	2100	2100
8	1750	Ova	3	2	AE	20	2	1400	1480	2280	2660	2660	2680	2800	2140	2220	2250	2130	2100	2100
9	1728	Ova	3	2	AE	20	3	1480	1920	2460	2800	2800	2800	2800	2180	2220	2160	2100	2100	2100
10	1714	Cap	3	2	AE	20	1	1420	2060	2640	2800	2800	2800	2800	2100	2100	2100	2100	2100	2100
11	1722	Cap	3	2	AE	20	2	1400	1480	1780	1820	1920	2400	2760	2100	2100	2100	2100	2100	2100
12	2009	Cap	2	2	AE	20	3	1400	1460	1540	1540	1640	1700	2060	2100	2000	1400	1400	1400	1400
13	1476	Ova	4	3	AE	40	1	1400	1420	1900	2300	2500	2680	2800	2100	2100	1940	1820	1880	1880
14	1731	Ova	3	3	AE	40	2	1400	1400	1620	2060	2260	2380	2600	2100	2100	2420	2660	2660	2660
15	2029	Ova	2	3	AE	40	3	1400	1400	1400	1400	1900	2400	2720	2100	2100	2100	2100	2100	2100
16	1515	Cap	4	3	AE	40	1	1620	2600	2800	2800	2800	2800	2800	2140	2580	2800	2800	2800	2800
17	1718	Cap	3	3	AE	40	2	1420	1660	2300	2800	2800	2800	2800	2120	2100	2300	2380	2380	2380
18	2003	Cap	2	3	AE	40	3	1400	800	760	1040	1620	2080	2240	2100	2100	2100	2100	2100	2100
19	1727	Ova	3	4	AE	60	1	1400	1400	1540	1540	1640	1700	1980	2320	2520	2520	2520	2520	2520
20	1457	Ova	4	4	AE	60	2	1300	1100	700	700	760	840	1640	1960	1880	1960	1960	1960	1960

21	1021	Ova	3	4	AE	60	3	1400	800	1000	0	0	0	0	0	0	0	0	0	0
22	1706	Cap	3	4	AE	60	1	1400	1540	1780	2040	2560	2800	2800	2600	1800	1400	1400	1400	1400
23	2010	Cap	2	4	AE	60	2	1300	700	700	700	840	1050	1280	1600	1640	1680	1680	1680	1680
24	2006	Cap	2	4	AE	60	3	1200	800	700	700	700	700	700	800	1300	1480	1400	3206	3206
25	1469	Ova	4	5	DC	20	1	1680	2500	2800	2800	2800	2800	2800	2100	2160	2240	2240	2240	2240
26	1725	Ova	3	5	DC	20	2	1420	1460	1880	2420	2780	2800	2800	2100	2100	2100	2100	2100	2100
27	2025	Ova	2	5	DC	20	3	1500	2080	2340	2560	2760	2800	2800	2100	2100	2100	2100	2100	2100
28	0914	Cap	4	5	DC	20	1	1400	1460	1740	1760	2660	2660	2160	2100	2100	2100	2100	2100	2100
29	1025	Cap	5	5	DC	20	2	1520	2020	2180	2380	2620	2660	2780	2100	2100	2100	2100	2100	2100
30	0810	Cap	5	5	DC	20	3	1400	1460	1540	2480	2520	2520	2520	1830	2100	2100	2100	2100	2100
31	1737	Ova	3	6	DC	40	1	1420	1880	2060	2240	2340	2600	2800	2100	2100	2100	2100	2100	2100
32	1746	Ova	3	6	DC	40	2	1400	1400	1640	2100	2560	2740	2800	2160	2100	2100	2100	2100	2100
33	2033	Ova	2	6	DC	40	3	1400	1460	1640	2360	2480	2740	2800	2100	2100	2100	2100	2100	2100
34	1519	Cap	4	6	DC	40	1	1420	1820	1980	2320	2700	2800	2800	2100	2100	2100	2100	2100	2100
35	1030	Cap	3	6	DC	40	2	1420	1680	1680	1840	2520	2640	2660	2100	2100	2100	2100	2100	2100
36	1723	Cap	3	6	DC	40	3	1400	1440	1540	1540	1640	1700	1880	2100	2100	2100	2000	2100	2100
37	2031	Ova	2	7	DC	60	1	1400	1400	1520	1760	1820	1820	2160	2600	2660	1940	1340	1400	1400
38	2024	Ova	2	7	DC	60	2	1200	1400	1400	1400	1400	1520	1540	1540	1520	1220	1180	980	980
39	2043	Ova	2	7	DC	60	3	1200	720	840	1060	1280	1680	2080	2200	2120	2320	2160	2620	2620

40	1724	Cap	3	7	DC	60	1	1200	700	700	920	980	980	980	980	1040	900	1620	1040	1040
41	1160	Cap	2	7	DC	60	2	1200	700	700	700	700	700	700	700	700	700	700	700	700
42	2013	Cap	2	7	DC	60	3	1200	700	700	780	840	1180	1420	1540	1520	1060	700	700	700

OBS= Observation, DOEID= Doe identity number, ECOTY= Ecotype, TRT= Treatment, REP= Replicate, OffWk1 –OffWk13= Feed offered from week 1-1

Table AP5 Experiment 3: Value for feed refusals of does

OBS	DOEID	ECOTY	PARITY	TRT	POD	LEVEL	REP	RefWk1	RefWk2	RefWk3	RefWk4	RefWk5	RefWk6	RefWk7	RefWk8	RefWk9	RefWk10	RefWk11	RefWk12	Ref Wk13
1	1732	Ova	3	1	pelt	60	1	130	180	95	140	77	540	430	205	375	690	680	900	810
2	1747	Ova	3	1	pelt	60	2	35	10	0	7	20	162	95	20	52	100	50	250	280
3	2034	Ova	2	1	pelt	60	3	193	61	70	48	240	360	610	360	510	650	690	840	830
4	1023	Cap	3	1	pelt	60	1	240	5	0	0	0	0	185	10	180	300	180	210	270
5	2005	Cap	2	1	pelt	60	2	265	35	10	35	10	95	280	80	180	260	300	330	350
6	2007	Cap	2	1	pelt	60	3	505	420	520	58	36	600	455	330	400	740	750	670	620
7	0925	Ova	4	2	AE	20	1	340	335	90	250	280	450	750	1210	1850	2030	1350	1590	1710
8	1750	Ova	3	2	AE	20	2	320	200	210	500	378	294	340	285	400	720	890	1040	810
9	1728	Ova	3	2	AE	20	3	200	110	60	340	60	105	210	330	500	540	290	670	540
10	1714	Cap	3	2	AE	20	1	188	33	43	55	140	0	190	250	450	830	350	720	710
11	1722	Cap	3	2	AE	20	2	400	265	270	215	70	200	355	420	760	1210	760	1290	1360
12	2009	Cap	2	2	AE	20	3	315	295	480	250	250	102	680	1010	1100	900	760	1010	990

13	1476	Ova	4	3	AE	40	1	400	155	45	160	215	170	340	355	290	410	360	280	240
14	1731	Ova	3	3	AE	40	2	990	640	83	103	315	190	505	680	510	880	730	750	720
15	2029	Ova	2	3	AE	40	3	700	370	240	145	50	132	330	510	390	680	360	530	490
16	1515	Cap	4	3	AE	40	1	25	15	0	20	5	5	260	135	170	540	450	160	160
17	1718	Cap	3	3	AE	40	2	243	77	30	40	50	20	220	350	240	510	510	360	290
18	2003	Cap	2	3	AE	40	3	1050	750	105	90	145	110	540	430	400	750	650	680	700
19	1727	Ova	3	4	AE	60	1	440	228	640	275	230	125	132	200	420	780	490	650	680

20	1457	Ova	4	4	AE	60	2	1020	950	530	430	280	300	460	700	780	1070	960	1040	1020
21	1021	Ova	3	4	AE	60	3	620	220	200	0	0	0	0	0	0	0	0	0	0
22	1706	Cap	3	4	AE	60	1	183	80	70	165	170	390	1165	1530	1090	670	600	910	720
23	2010	Cap	2	4	AE	60	2	1050	800	650	430	170	120	155	255	490	790	610	610	460
24	2006	Cap	2	4	AE	60	3	1200	760	610	530	385	250	170	160	150	480	250	420	490
25	1469	Ova	4	5	DC	20	1	0	5	20	0	60	30	110	220	205	510	350	360	220
26	1725	Ova	3	5	DC	20	2	105	125	70	68	123	60	280	305	545	680	440	650	500
27	2025	Ova	2	5	DC	20	3	62	167	105	130	260	280	235	490	530	680	520	770	750
28	0914	Cap	4	5	DC	20	1	140	110	105	67	320	320	225	720	720	920	790	780	760
29	1025	Cap	5	5	DC	20	2	143	130	133	100	410	260	330	680	750	1070	910	1050	910
30	0810	Cap	5	5	DC	20	3	180	125	110	485	420	460	370	740	630	730	680	780	680
31	1737	Ova	3	6	DC	40	1	88	125	300	370	250	295	510	510	420	860	700	790	750
32	1746	Ova	3	6	DC	40	2	255	280	90	105	105	220	380	270	270	780	770	580	550
33	2033	Ova	2	6	DC	40	3	195	250	250	200	115	60	385	580	480	1080	900	690	630
34	1519	Cap	4	6	DC	40	1	260	115	100	105	175	270	370	460	610	870	670	960	860

35	1030	Cap	3	6	DC	40	2	155	440	380	245	430	520	680	670	800	1040	890	810	610
36	1723	Cap	3	6	DC	40	3	385	550	580	475	230	280	465	905	890	1160	900	1000	1000
37	2031	Ova	2	7	DC	60	1	310	240	140	200	320	152	110	410	1220	1270	830	1170	910
38	2024	Ova	2	7	DC	60	2	590	835	760	640	530	400	460	360	650	855	700	740	640
39	2043	Ova	2	7	DC	60	3	900	177	280	130	145	165	240	340	450	310	180	210	200
40	1724	Cap	3	7	DC	60	1	750	435	263	503	500	370	400	455	470	490	480	850	760
41	1160	Cap	2	7	DC	60	2	930	470	450	430	550	410	430	460	590	540	490	700	580
42	2013	Cap	2	7	DC	60	3	910	430	430	290	230	135	200	375	740	590	430	600	430

Legend: OBS= Observation, RefWk1-RefWk13= Refusal from week 1-13

Table AP6 Experiment 3: Try and Error Method for Feed Formulation an example for *D. cinerea* pods at 40 % feeding level

Nutrient	Raw Material		CP %	Inclusion Rate	CP Contributed	60 day Total kgs needed /goat	90 day Total kgs needed /goat Contributed
Energy source	Lucrene Hay		14	50.35	7.049	27.189	46.2213
Energy source	Molasses		4	0	0	0	0
Energy source	Dry Hay as filler		4	9.5	0.38	5.13	8.721
Protein source	*D.cinerea*		16.1	40	6.44	21.6	36.72
Micronutrient	Rock Salt (iodised)		0	0.05	0	0.027	0.0459
	FINAL COMPOSITION			**100**	**13.869**	**54**	**91.8**
	TARGET			**100 %**	**14%**	per animal for 60 days	per animal for 90 days

SUMMARY SATISTICS

INGREDIENT	**60 day Amount req/anim**	**Number of Animals**	**Total kgs req for 60 days**		**90 day Amount req/anim**	**Number of Animals**	**Total kgs req for 90 days**
Lucerne Hay	27.189	6	163.134		46.2213	6	277.3278
Molasses	0	6	0		0	6	0
Dry Hay as filler	5.13	6	30.78		8.721	6	52.326
D. cinerea	21.6	6	129.6		36.72	6	220.32
Vitamin mineral Pre mix	0.027	6	0.162		0.0459	6	0.2754
Limestone flour	0.027	6	0.162		0.0459	6	0.2754
Rock Salt (iodised)	0.027	6	0.162		0.0459	6	0.2754
Total	**54**	**6**	**324**		**91.8**	**6**	**550.8**

Table AP7 Experiment 3: Chemical composition (g/kg) of commercial feed (ram ewe pellets) from Feed Master Supplier (50kg bag)

Item		
Protein	140	0
Protein Ex NPN	0	19.75
Urea (g)	0	10
ME estimate	11.5MJ/kg	0
Moisture	0	150
Fibre	0	90
Fat	25	85
Vitamin A	6500 IU/kg	0
Calcium	10	15
Phosphorus	6	0
Magnesium (Mg)	11	0
Potasium (K)	6	0
Sodium (Na)	2	0
Chlorine (Cl)	3	0
Cobalt (Co)	1mg/kg	0
Iodine (I)	1mg/kg	0
Selenium (Se)	0.3mg/kg	0
	Min	Max

Table AP8 Experiment 3: Analysis of variance for supplement feed intake of does

Table AP8.1a Analysis of variance of supplement intake daily

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	231437.1101	28929.6388	4.07	0.0020
Error	32	227510.5203	7109.7038		
Corrected Total	40	458947.6304			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	1889.8339	1889.8339	0.27	0.6097
Parity	1	31654.9199	31654.9199	4.45	0.0428
Treatment	6	172292.2778	28715.3796	4.04	0.0040

Table AP8.1b Analysis of variance of supplement intake daily on metabolic basis

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	7450.60699	931.32587	4.24	0.0015
Error	32	7029.22054	219.66314		
Corrected Total	40	14479.82753			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	84.477630	84.477630	0.38	0.5396
Parity	1	970.180602	970.180602	4.42	0.0436
Treatment	6	5496.679613	916.113269	4.17	0.0033

Table AP9 Experiment 3: Values for doe weights

OBS	DOEID	ECOTY	PARITY	TRT	SUPP	LEVEL	REP	DWK	DW0	WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9	WK10	WK11	WK12	WK13
1	1732	Ova	3	1	Com	80	1	34.5	35	38	38	38	38	38.5	38.7	38.9	37.8	37.3	37.3	37.3	37.5	38.5
2	1747	Ova	3	1	Com	80	2	32.5	31	35.5	37	33.5	35	34	34.9	36.4	34.8	33.5	34.3	33.6	33.3	33.5
3	2034	Ova	2	1	Com	80	3	32	32	34	35.5	34	34	34	33	32.9	32.7	32.4	32	31.9	31.5	33
4	1023	Cap	3	1	Com	80	1	37	36.5	40	42.5	40.5	41	40.5	39.1	39.5	39.4	38.6	37.8	38.9	39.4	39.5
5	2005	Cap	2	1	Com	80	2	36.5	34	36.5	37.5	37	37.5	37.5	38.5	37.6	37.6	36	35.6	36.7	36.4	37.5
6	2007	Cap	2	1	Com	80	3	29	23.5	26.5	28.5	28.5	27	27.5	28.8	27.1	28.4	26.2	26.1	26.8	27.3	28
7	0_925	Ova	4	2	AE	20	1	35	33	35.6	31	36.5	36.5	36.5	37.1	36.6	36.1	35.1	35.5	36.2	36.4	37.5
8	1750	Ova	3	2	AE	20	2	30	31	35	37	35.5	34	34	34.7	34	32.8	32.2	33.7	34.4	34.2	34
9	1728	Ova	3	2	AE	20	3	37	36	39.5	41.5	41	40	39	39.5	40.7	39	36.8	37.5	37.9	38.4	38.5
10	1714	Cap	3	2	AE	20	1	31	31	34	37.5	37	34.5	37.5	35	35.8	34.7	33.5	33.7	32.8	33.5	35
11	1722	Cap	3	2	AE	20	2	36.5	33.5	38	39.5	35.5	36.5	39.5	37.5	36.8	37.1	35	35.5	36.6	36.1	36
12	2009	Cap	2	2	AE	20	3	27	25	29.5	32	27	28.5	28.5	29.6	29.8	27.8	26.5	27.4	28.6	29.3	29
13	1476	Ova	4	3	AE	40	1	37.5	35	40	39.5	40	38.5	38.5	38.6	38.2	37.9	34.8	35.1	34.9	35.9	35.5
14	1731	Ova	3	3	AE	40	2	32	31	33.5	36	35	33.5	33.5	34.9	34.6	33.6	31.3	32.9	32.3	32.9	34

15	2029	Ova	2	3	AE	40	3	35.5	31	37	37.5	37	35.5	35.5	36.7	36.4	33.9	33.4	34.5	34.6	35.4	36
16	1515	Cap	4	3	AE	40	1	45.5	44	48	50	49.5	48	46.5	48.8	47.8	47.8	46.5	46.1	47.5	47.1	47.5
17	1718	Cap	3	3	AE	40	2	37.5	36	40.5	41	39.5	41	39	40.2	41.1	38.6	37.1	37.3	37.9	37.6	38
18	2003	Cap	2	3	AE	40	3	35	31.5	31	37.5	35	36.5	37	36	36	35.8	34.6	34.3	34.4	35.5	36.5

19	1727	Ova	3	4	AE	60	1	26.5	28	30	31.5	31	31	31.5	30.8	30.7	30.4	29.2	30.2	30	30.3	31.5
20	1457	Ova	4	4	AE	60	2	32.5	29.5	33	36.5	34.5	34	35	35.8	35.6	33.6	34.1	34.6	35.2	34.8	36.5
21	1021	Ova	3	4	AE	60	3	35	33	34.5	39.5	39.5	0	0	0	0	0	0	0	0	0	0
22	1706	Cap	3	4	AE	60	1	31	34.5	38	40.5	40	37.5	38	38.5	38.9	34.5	33.7	33.1	33.5	33.9	35
23	2010	Cap	2	4	AE	60	2	35.5	30	34.5	31	30.5	31	32	33.2	33.3	30.8	30.3	31.8	32	32.1	33.5
24	2006	Cap	2	4	AE	60	3	34	30	30.5	36.5	35	33	33	33.8	34.5	33.4	31	31.2	33.3	33.7	33.5
25	1469	Ova	4	5	DC	20	1	33	33	35.5	37	36.5	36.5	35.5	36.9	37.1	36.4	34.4	35.6	36	36	38
26	1725	Ova	3	5	DC	20	2	30.5	30	34	33.5	32.5	32.5	31.5	32.8	33.2	32.5	31.5	31.5	31	31.9	32
27	2025	Ova	2	5	DC	20	3	31	28.5	32	33.5	32	33	32	32.7	33.6	32.6	30.6	31	31.8	32.7	32.5
28	0_914	Cap	4	5	DC	20	1	30	28	33	34	33.5	32.5	32	32.3	33.2	31.9	30.4	30.9	30.7	31.8	31.5
29	1025	Cap	5	5	DC	20	2	34.5	31.5	36.5	38	37	37	36	36.6	35.3	33.5	32.9	33.8	35	35.6	35
30	0_810	Cap	5	5	DC	20	3	36	33.5	38	39.5	39	38.5	38	38.7	39.3	38.7	36.5	36.2	37.2	38.4	38
31	1737	Ova	3	6	DC	40	1	31	27.5	30.5	32	31	31	31	30.4	30.7	30.3	29.3	29.7	30.3	31.7	32
32	1746	Ova	3	6	DC	40	2	33.5	29.5	33	33	33.5	32.5	32.5	31.9	32.3	32.5	30.6	31.2	33.4	32.8	34

33	2033	Ova	2	6	DC	40	3	32.5	29.5	32.5	35	34	34	33	34.5	34.4	32.4	32.3	33.8	34.5	35.1	35.5
34	1519	Cap	4	6	DC	40	1	33	31.5	34	36	33.5	34	33	35.2	34.5	34.1	32.9	33.3	33.8	34.4	32.5
35	1030	Cap	3	6	DC	40	2	32	30	35	36	36	35	34	34.3	34.5	34.9	33.4	33.4	33.9	34	33.5
36	1723	Cap	3	6	DC	40	3	28.5	27.5	32.5	33.5	32.5	29.5	32.5	32.3	32.1	31.2	30.4	31.2	31.7	32.6	33
37	2031	Ova	2	7	DC	60	1	30	27.5	31.5	32.5	31	32	30.5	31.4	30.4	29.2	29.2	30	30.7	31.5	32
38	2024	Ova	2	7	DC	60	2	30.4	32	34	35.5	35	33.5	32	33.7	33.7	33.8	31.8	31.8	32.7	33.7	33.5
39	2043	Ova	2	7	DC	60	3	31.5	31	32	34.5	34.5	33	33	34	33.4	31.9	31.3	33.6	33.7	34	35
40	1724	Cap	3	7	DC	60	1	31	29.5	33.5	33.5	34.5	33.5	33.5	33.1	32.5	32.6	31.2	30.9	31.2	31.2	31.5
41	1160	Cap	2	7	DC	60	2	31	28.5	31	33	32	32	31	31.9	31.8	30	30.5	29.9	30.3	30.3	30.5
42	2013	Cap	2	7	DC	60	3	29.5	29.5	32.5	34	32.5	31	32	31.9	32	30.9	29.9	29.4	30.3	31.6	31
43	2042	Ova	2	8	NS	0	1	27	25	29.5	31	30	28.5	28.5	28.6	29.7	29	26.6	28.2	29.5	29.7	30.5
44	2011	Cap	2	8	NS	0	1	32	31.5	35	35.5	33	35.5	35.5	35.2	35.4	34.5	32.4	32.8	33.8	34.2	35
45	2037	Ova	2	8	NS	0	2	36.5	35	37.5	38.5	37.5	37	36	37.1	36.2	35.9	35.5	35.1	35.8	36.7	35
46	2001	Cap	2	8	NS	0	2	28.5	27.5	31	33.5	31.5	30.5	30	31.2	31.6	30.7	29.3	29.1	29.4	29.6	30.5
47	2049	Ova	2	8	NS	0	3	31.5	29	34.5	34.5	34	33	32.5	34.5	32.5	31.7	32.1	32	31.8	33.2	32.5
48	1716	Cap	3	8	NS	0	3	36	31	35	36	36	35	34	35.9	35.3	32.9	32.8	31.4	33	33.5	33

OBS=Observation, DOEID= Doe identity number, TRT=Treatment, REP= Replicate, DWK= Doe weight at kidding, DW0= Doe weight initial, WK1-WK13= Week 1-13

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Table AP9.1 Experiment 3: Analysis of variance for weekly doe weights

Table AP9.1.1 Analysis of variance for doe initial weights

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	202.4591889	22.4954654	2.27	0.0385
Error	37	366.4557047	9.9042082		
Corrected Total	46	568.9148936			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	1.1816598	1.1816598	0.12	0.7317
Parity	1	69.1639534	69.1639534	6.98	0.0120
Treatment	7	126.4730019	18.0675717	1.82	0.1116

Table AP9.1.2 Analysis of variance for doe weights week 1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	257.5931240	28.6214582	2.87	0.0113
Error	37	369.1166632	9.9761260		
Corrected Total	46	626.7097872			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	2.9527135	2.9527135	0.30	0.5897
Parity	1	106.5602599	106.5602599	10.68	0.0023
Treatment	7	132.5684472	18.9383496	1.90	0.0977

Table AP9.1.3 Analysis of variance for doe weights week 2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	252.3887846	28.0431983	2.70	0.0158
Error	37	383.7707899	10.3721835		
Corrected Total	46	636.1595745			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	17.5616966	17.5616966	1.69	0.2012
Parity	1	64.8873298	64.8873298	6.26	0.0169
Treatments	7	150.5252669	21.5036096	2.07	0.0713

Table AP9.1.4 Analysis of variance for doe weights week 3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	276.9597528	30.7733059	2.93	0.0101
Error	37	389.2423749	0.5200642		

Corrected Total	46	666.2021277			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	3.5138921	3.5138921	0.33	0.5668
Parity	1	111.2298474	111.2298474	10.57	0.0024
Treatment	7	145.7510005	20.8215715	1.98	0.0845

Table AP9.1.5 Analysis of variance for doe weights week 4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	268.2136035	29.8015115	2.92	0.0103
Error	37	378.2651199	10.2233816		
Corrected Total	46	646.4787234			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	4.7680779	4.7680779	0.47	0.4989
Parity	1	81.1771878	81.1771878	7.94	0.0077
Treatment	7	161.0657949	23.0093993	2.25	0.0517

Table AP9.1.6 Analysis of variance of doe weights week 5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	275.7526073	30.6391786	3.58	0.0028
Error	37	316.8537756	8.5636156		
Corrected Total	46	592.6063830			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	13.1870441	13.1870441	1.54	0.2224
Parity	1	80.3321218	80.3321218	9.38	0.0041
Treatment	7	146.2500099	20.8928586	2.44	0.0367

Table AP9.1.7 Analysis of variance of doe weights week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	247.4520105	27.4946678	2.97	0.0092
Error	37	342.5926703	9.2592614		
Corrected Total	46	590.0446809			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	7.5945451	7.5945451	0.82	0.3710
Parity	1	64.6470733	64.6470733	6.98	0.0120

Treatment	7	151.6746357	21.6678051	2.34	0.0440

Table AP9.1.8 Analysis of variance of doe weight week 7

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	256.6388163	28.5154240	3.13	0.0067
Error	37	336.8386305	9.1037468		
Corrected Total	46	593.4774468			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	6.7241202	6.7241202	0.74	0.3956
Parity	1	68.5570105	68.5570105	7.53	0.0093
Treatment	7	145.5447638	20.7921091	2.28	0.0487

Table AP9.1.9 Analysis of variance of doe weights week 8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	256.5364801	28.5040533	3.18	0.0061
Error	37	331.8630944	8.9692728		
Corrected Total	46	588.3995745			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	6.3911400	6.3911400	0.71	0.4040
Parity	1	69.1391279	69.1391279	7.71	0.0086
Treatment	7	146.3875681	20.9125097	2.33	0.0447

Table AP9.1.10 Analysis of variance of doe weights week 9

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	210.8314451	23.4257161	2.49	0.0245
Error	37	347.8085549	9.4002312		
Corrected Total	46	558.6400000			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	3.8817906	3.8817906	0.41	0.5244
Parity	1	68.7870861	68.7870861	7.32	0.0103
Treatment	7	117.8676722	16.8382389	1.79	0.1184

Table AP9.1.11 Analysis of variance of doe weights week 10

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	192.1006620	21.3445180	2.50	0.0239

Error	37	315.6167848	8.5301834		
Corrected Total	46	507.7174468			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.0933236	0.0933236	0.01	0.9173
Parity	1	52.2896254	52.2896254	6.13	0.0180
Treatment	7	106.1957830	15.1708261	1.78	0.1211

Table AP9.1.12 Analysis of variance of doe weights week 11

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	161.5618651	17.9513183	1.80	0.1010
Error	37	368.6547306	9.9636414		
Corrected Total	46	530.2165957			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.78928022	0.78928022	0.08	0.7799
Parity	1	43.45826083	43.45826083	4.36	0.0437
Treatment	7	86.63963531	12.37709076	1.24	0.3053

Table AP9.1.13 Analysis of variance of doe weights week 12

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	146.5833414	16.2870379	1.76	0.1098
Error	37	342.3762331	9.2534117		
Corrected Total	46	488.9595745			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.70027778	0.70027778	0.08	0.7848
Parity	1	33.94684387	33.94684387	3.67	0.0632
Treatment	7	83.65001300	11.95000186	1.29	0.2816

Table AP9.1.14 Analysis of variance of doe weights week 13

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	161.4558388	17.9395376	1.97	0.0720
Error	37	337.3952251	9.1187899		
Corrected Total	46	498.8510638			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.06869770	0.06869770	0.01	0.9313
Parity	1	32.25007408	32.25007408	3.54	0.0679

Treatment	7	99.13190428	14.16170061	1.55	0.1803

Table AP9.1.15 Analysis of variance of doe weights for ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	2441.00197	271.22244	0.96	0.4899
Error	37	10486.50000	283.41892		
Corrected Total	46	12927.50197			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	224.714830	224.714830	0.79	0.3790
Parity	1	858.862459	858.862459	3.03	0.0900
Treatment	7	2143.830648	306.261521	1.08	0.3952

Table AP9.2 Analysis of variance of doe weights by 2 x 3 factorial design

Table AP9.2.1 Analysis of variance of doe initial weights

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	117.3761905	23.4752381	2.52	0.0520
Error	29	270.3666667	9.3229885		
Corrected Total	34	387.7428571			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	48.32688172	48.32688172	5.18	0.0304
Level	2	22.18541667	11.09270833	1.19	0.3187
Supplement*Level	2	43.76875000	21.88437500	2.35	0.1135

Table AP9.2.2 Analysis of variance of doe weights week 1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	141.8587619	28.3717524	2.52	0.0517
Error	29	326.3166667	11.2522989		
Corrected Total	34	468.1754286			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	42.58172043	42.58172043	3.78	0.0615
Level	2	49.95888021	24.97944010	2.22	0.1267
Supplement*Level	2	45.85054687	22.92527344 s	2.04	0.1486

Table AP9.2.3 Analysis of variance of doe weight week 2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	159.2000000	31.8400000	2.79	0.0357

Error	29	331.3000000	11.4241379		
Corrected Total	34	490.5000000			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	59.88817204	59.88817204	5.24	0.0295
Level	2	43.06718750	21.53359375	1.88	0.1700
Supplement*Level	2	52.02552083	26.01276042	2.28	0.1206

Table AP9.2.4 Analysis of variance of doe weights week 3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	149.6523810	29.9304762	2.30	0.0709
Error	29	377.6333333	13.0218391		
Corrected Total	34	527.2857143			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	50.16774194	50.16774194	3.85	0.0593
Level	2	40.27617188	20.13808594	1.55	0.2301
Supplement*Level	2	55.63033854	27.81516927	2.14	0.1363

Table AP9.2.5 Analysis of variance of doe weights week 4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	166.7761905	33.3552381	3.25	0.0188
Error	29	297.4666667	10.2574713		
Corrected Total	34	464.2428571			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	46.96881720	46.96881720	4.58	0.0409
Level	2	49.31718750	24.65859375	2.40	0.1081
Supplement*Level	2	66.81718750	33.40859375	3.26	0.0530

Table AP9.2.6 Analysis of variance of doe weights week 5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	158.9666667	31.7933333	3.55	0.0127
Error	29	260.0333333	8.9666667		
Corrected Total	34	419.0000000			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	82.50430108	82.50430108	9.20	0.0051

Level	2	41.17500000	20.58750000	2.30	0.1187
Supplement*Level	2	29.85208333	14.92604167	1.66	0.2068

Table AP9.2.7 Analysis of variance of doe weights week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	163.7727619	32.7545524	3.39	0.0157
Error	29	280.5346667	9.6736092		
Corrected Total	34	444.3074286			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	68.60941935	68.60941935	7.09	0.0125
Level	2	39.93200000	19.96600000	2.06	0.1452
Supplement*Level	2	50.60741667	25.30370833	2.62	0.0903

Table AP9.2.8 Analysis of variance of doe weights week 7

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	166.1455238	33.2291048	3.57	0.0123
Error	29	269.8133333	9.3039080		
Corrected Total	34	435.9588571			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	71.02043011	71.02043011	7.63	0.0098
Level	2	41.83500000	20.91750000	2.25	0.1237
Supplement*Level	2	48.34208333	24.17104167	2.60	0.0917

Table AP9.2.9 Analysis of variance of doe weights week 8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	158.6156667	31.7231333	3.13	0.0221
Error	29	293.6803333	10.1269080		
Corrected Total	34	452.2960000			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	45.05601075	45.05601075	4.45	0.0437
Level	2	65.75292188	32.87646094	3.25	0.0534
Supplement*Level	2	43.68313021	21.84156510	2.16	0.1339

Table AP9.2.10 Analysis of variance of doe weights week 9

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	117.9470952	23.5894190	2.50	0.0534

Error	29	273.7803333	9.4407011		
Corrected Total	34	391.7274286			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supp	1	38.12568817	38.12568817	4.04	0.0539
Level	2	43.59018750	21.79509375	2.31	0.1174
Supp*Level	2	33.10768750	16.55384375 ts	1.75	0.1910

Table AP9.2.11 Analysis of variance of doe weighweek 10

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	119.5924286	23.9184857	2.86	0.0320
Error	29	242.1430000	8.3497586		
Corrected Total	34	361.7354286			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	41.68775269	41.68775269	4.99	0.0333
Level	2	48.00400521	24.00200260	2.87	0.0726
Supplement*Level	2	26.35692188	13.17846094 ts	1.58	0.2235

Table AP9.2.12 Analysis of variance of doe weighweek 11

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	102.8900476	20.5780095	2.11	0.0932
Error	29	283.3516667	9.7707471		
Corrected Total	34	386.2417143			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	36.20672043	36.20672043	3.71	0.0641
Level	2	45.87500000	22.93750000	2.35	0.1135
Supplement*Level	2	17.56052083 f	8.78026042 ts	0.90	0.4182

Table AP9.2.13 Analysis o variance of doe weigh week 12

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	101.8343810	20.3668762	2.45	0.0572
Error	29	241.0953333	8.3136322		
Corrected Total	34	342.9297143			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	25.43488172	25.43488172	3.06	0.0908
Level	2	50.37292187	25.18646094	3.03	0.0639
Supplement*level	2	23.41292188	11.70646094	1.41	0.2608

Table AP9.2.14 Analysis of variance of doe weights week 13

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	110.1797619	22.0359524	2.50	0.0531
Error	29	255.2916667	8.8031609		
Corrected Total	34	365.4714286			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	44.09274194	44.09274194	5.01	0.0331
Level	2	37.59375000	18.79687500	2.14	0.1364
Supplement*Level	2	25.05468750	12.52734375	1.42	0.2573

Table AP9.2.15 Analysis of varianc e of doe weights wee ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1077.454439	215.490888	0.72	0.6127
Error	29	8661.522634	298.673194		
Corrected Total	34	9738.977072			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	11.9806186	11.9806186	0.04	0.8427
Level	2	268.5185185	134.2592593	0.45	0.6423
Supplement*Level	2	738.2330247	369.1165123	1.24	0.3054

Table AP9.2.16 Analysis of variance of does initial weig t on metabolic basis

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11.38281712	2.27656342	2.50	0.0532
Error	29	26.39389948	0.91013446		
Corrected Total	34	37.77671660			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	4.69524269	4.69524269	5.16	0.0307
Level	2	2.12322284	1.06161142	1.17	0.3257
Supplement*Level	2	4.26415094	2.13207547	2.34	0.1140

Table AP9.2.17 Analysis of variance of does final weight on metabolic basis

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	10.23678191	2.04735638	2.51	0.0523
Error	29	23.61714571	0.81438433		
Corrected Total	34	33.85392762			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	4.11864666	4.11864666	5.06	0.0323
Level	2	3.50668212	1.75334106	2.15	0.1343
Supplement*Level	2	2.28900088	1.14450044	1.41	0.2615

Table AP9.2.18 Analysis of variance of does ADG on metabolic basis

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	99.7106965	19.9421393	0.67	0.6485
Error	29	861.7430956	29.7152792		
Corrected Total	34	961.4537921			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	1.74222529	1.74222529	0.06	0.8104
Level	2	29.84473854	14.92236927	0.50	0.6104
Supplement*Level	2	62.51447868	31.25723934	1.05	0.3622

Table AP10 Experiment 3: Value for kid weights

OBS	DOEID	KIDID	SEX	KIDBM	ECOTYPE	BTYPE	PARITY	SUPP	LEVEL	TRT	iwt	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk 10	wk11	wk12	wk13
1	1025	1441	M	2.0	Cap	t	5	DC	20	5	4.0	6.0	7.0	7.5	8.5	12.0	10.0	10.7	11.7	11.8	13.1	12.8	15.5	16.0
2	1025	1442	F	2.0	Cap	t	5	DC	20	5	4.5	5.0	6.0	7.0	7.5	9.5	8.0	9.7	10.9	10.4	11.5	12.9	13.3	13.0
3	914	1402	M	2.5	Cap	t	4	DC	20	5	7.5	8.5	10.0	1.0	13.5	11.5	13.1	15.1	16.1	15.9	17.1	18.4	18.5	18.0
4	914	1403	F	2.0	Cap	t	4	DC	20	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	1515	1431	M	2.5	Cap	s	4	AE	40	3	8.5	8.0	10.5	12.0	13.0	12.5	14.2	15.1	16.4	16.4	17.2	18.5	19.2	18.0
6	1519	1422	M	3.0	Cap	s	4	DC	40	6	8.0	9.0	10.5	11.5	12.0	13.0	14.1	14.5	16.0	15.8	17.1	17.6	18.1	20.0
7	1724	1457	F	2.5	Cap	s	3	DC	60	7	5.0	6.0	9.0	10.0	11.0	13.5	12.5	13.7	14.6	14.2	15.7	16.9	17.0	18.0
8	1714	1414	M	2.5	Cap	t	3	AE	20	2	6.5	7.0	8.0	9.0	9.5	10.5	11.2	12.1	12.3	12.5	13.8	14.7	14.6	15.0
9	1714	1415	M	2.0	Cap	t	3	AE	20	2	7.0	7.5	8.5	9.5	11.0	12.5	12.0	13.3	14.3	13.7	15.6	15.9	16.4	16.5
10	1722	1465	F	2.5	Cap	t	3	AE	20	2	5.0	6.0	6.5	8.5	8.5	9.0	9.0	10.4	11.1	11.7	12.2	13.2	12.6	16.5
11	1722	1466	F	2.0	Cap	t	3	AE	20	2	4.0	5.0	5.0	6.0	9.0	9.5	7.9	9.2	9.5	9.4	10.3	11.1	11.8	12.5
12	1030	1432	M	3.0	Cap	s	3	DC	40	6	9.0	9.0	11.5	12.0	13.0	15.5	14.5	15.0	16.3	16.3	17.3	19.1	19.2	20.0
13	1723	1418	M	2.0	Cap	t	3	DC	40	6	6.0	6.5	7.0	8.0	9.0	8.0	9.1	9.7	11.1	11.3	12.3	13.5	14.4	15.0
14	1723	1419	F	2.0	Cap	t	3	DC	40	6	6.0	6.5	7.0	8.5	9.0	8.5	10.3	11.7	12.3	11.7	13.1	12.2	15.0	15.0
15	810	1443	M	3.0	Cap	t	5	DC	20	5	6.5	7.0	8.0	9.5	10.0	9.5	10.9	11.8	12.9	13.1	13.6	14.1	16.4	16.5
16	810	1444	F	2.1	Cap	t	5	DC	20	5	5.5	5.5	6.0	7.0	7.5	12.0	8.5	9.0	10.3	10.1	11.1	11.7	12.6	13.0
17	1706	1451	M	2.5	Cap	t	3	AE	60	4	5.5	9.0	7.0	8.0	9.0	8.0	9.5	11.3	11.3	11.6	12.1	13.0	14.4	14.5
18	1706	1452	F	2.0	Cap	t	3	AE	60	4	6.5	5.0	6.5	6.0	8.0	9.5	9.1	9.5	10.1	9.8	10.5	11.6	12.3	12.0
19	1718	1467	M	2.5	Cap	t	3	AE	40	3	5.5	6.0	7.0	8.0	9.0	10.0	11.0	12.0	12.6	14.1	14.1	14.0	15.8	14.5

20	1718	1468	F	2.5	Cap	t	3	AE	40	3	4.5	5.5	6.0	7.0	7.5	11.5	9.3	9.9	10.6	10.7	11.4	11.5	12.5	13.6
21	1716	1427	M	2.0	Cap	t	3	NS	0	8	4.5	5.0	7.5	8.0	9.0	10.0	11.2	11.7	12.5	12.3	13.2	14.6	15.0	19.5
22	1716	1428	F	2.5	Cap	t	3	NS	0	8	5.0	6.0	7.0	8.0	8.5	10.0	9.0	10.1	11.1	10.6	11.2	11.9	12.7	13.0
23	1023	1429	M	3.0	Cap	t	3	Com	80	1	6.5	7.0	8.0	9.0	10.0	12.5	12.0	12.6	13.4	13.5	14.7	16.1	16.3	17.0
24	1023	1430	F	3.0	Cap	t	3	Com	80	1	4.5	6.0	7.0	7.5	9.0	9.5	9.8	10.4	11.2	10.5	12.1	12.6	13.3	14.5
25	1160	1445	M	2.0	Cap	t	2	DC	60	7	5.0	8.5	6.0	8.0	8.5	12.0	10.0	10.1	11.1	10.8	11.4	12.3	13.3	14.0
26	1160	1446	F	2.5	Cap	t	2	DC	60	7	5.0	5.5	6.5	8.0	8.0	11.0	9.2	10.1	10.4	9.9	11.0	12.1	12.7	13.5
27	2010	1433	M	2.5	Cap	t	2	AE	60	4	5.0	6.0	7.0	7.5	8.0	10.5	9.4	10.5	10.7	10.9	13.0	13.7	15.0	17.0
28	2010	1434	M	2.5	Cap	t	2	AE	60	4	6.5	7.0	7.5	10.5	9.5	10.0	10.2	11.2	11.7	12.0	12.9	13.9	14.7	15.5
29	2013	1420	M	2.0	Cap	t	2	DC	60	7	7.5	6.5	7.0	10.0	8.5	11.0	9.2	10.7	11.2	11.3	11.8	12.9	13.3	15.5
30	2013	1421	F	1.5	Cap	t	2	DC	60	7	4.0	5.0	6.5	6.5	7.5	10.5	8.5	9.7	10.7	10.3	11.2	11.8	12.4	13.0
31	2003	1439	M	2.5	Cap	t	2	AE	40	3	3.5	7.5	6.0	7.5	7.5	7.0	9.0	10.0	10.5	10.7	11.8	12.8	13.6	15.5
32	2003	1440	F	2.0	Cap	t	2	AE	40	3	4.5	5.0	6.0	6.5	7.5	6.5	8.5	9.1	9.5	9.9	10.5	10.8	11.7	13.0
33	2005	1479	M	2.5	Cap	t	2	Com	80	1	4.5	4.5	8.0	7.5	9.0	11.0	10.1	11.3	11.4	11.5	13.0	14.1	14.0	15.5
34	2005	1480	M	2.5	Cap	t	2	Com	80	1	3.5	5.5	5.5	7.0	8.0	9.5	10.0	11.1	12.0	12.3	13.5	14.5	15.1	16.0
35	2011	1404	M	2.5	Cap	t	2	NS	0	8	7.5	6.0	6.5	7.0	7.5	10.5	8.9	9.4	10.2	11.8	10.9	10.8	11.6	13.5
36	2011	1405	M	2.0	Cap	t	2	NS	0	8	6.0	6.0	8.5	10.5	10.5	12.0	12.0	12.8	14.6	14.1	15.0	14.8	15.5	17.5
37	2001	1423	F	1.5	Cap	s	2	NS	0	8	7.5	8.0	8.5	10.0	10.5	11.0	11.7	12.8	13.1	13.0	13.6	14.6	14.6	15.5
38	2009	1406	F	2.0	Cap	t	2	AE	20	2	5.0	5.0	5.5	6.0	7.0	11.0	8.1	8.5	9.3	9.4	10.1	9.6	11.5	12.5
39	2009	1407	F	2.0	Cap	t	2	AE	20	2	5.5	6.0	7.5	8.5	8.5	8.5	9.2	9.5	10.3	9.5	10.8	11.7	12.7	12.5

40	2006	1461	M	2.5	Cap	t	2	AE	60	4	6.0	6.0	6.5	7.5	8.0	8.5	9.0	10.2	10.4	10.6	12.0	12.7	13.9	16.0
41	2006	1462	F	2.0	Cap	t	2	AE	60	4	6.5	5.0	5.5	6.5	7.0	10.0	7.8	8.2	8.6	8.6	9.1	13.2	10.0	10.0
42	2007	1455	F	2.0	Cap	s	2	Com	80	1	6.0	6.0	8.0	8.5	8.5	12.0	10.0	11.4	12.2	12.5	13.5	14.3	14.6	15.5
43	925	1443	M	2.0	Ova	t	4	AE	20	2	5.5	6.0	7.0	8.0	9.0	11.5	10.5	11.6	12.6	12.5	13.2	15.0	15.4	16.5

44	925	1444	F	2.0	Ova	t	4	AE	20	2	5.5	6.0	7.5	8.0	9.0	11.0	10.4	11.0	11.3	11.8	12.7	12.5	14.1	17.0
45	1457	1458	M	2.0	Ova	t	4	AE	60	4	4.0	4.5	5.0	5.5	6.5	8.0	8.0	8.7	9.1	9.4	10.0	11.1	12.5	14.0
46	1457	1459	F	2.0	Ova	t	4	AE	60	4	3.5	3.5	5.0	6.0	6.0	9.5	7.7	8.3	9.6	9.4	10.2	10.8	11.8	12.0
47	1728	1435	M	2.5	Ova	t	3	AE	20	2	6.5	6.5	8.0	8.0	10.5	10.5	10.7	11.9	12.6	12.6	13.7	13.2	15.3	16.5
48	1728	1436	F	2.5	Ova	t	3	AE	20	2	5.5	6.0	7.0	8.0	8.5	9.5	10.0	10.9	11.5	11.8	12.5	13.3	14.1	13.0
49	1021	1420	M	2.0	Ova	t	3	AE	60	4	7.5	8.5	9.5	10.5	.	.	.	.	.	.	.	.	.	.
50	1021	1421	F	2.0	Ova	t	3	AE	60	4	6.5	6.5	7.0	7.5	.	.	.	.	.	.	.	.	.	.
51	1732	1477	F	2.0	Ova	s	3	Com	80	1	5.0	6.5	7.5	9.5	9.0	11.0	11.1	11.6	12.4	12.6	13.6	14.1	15.1	16.0
52	1750	1425	F	2.0	Ova	t	3	AE	20	2	5.5	6.0	6.5	7.5	8.0	10.5	9.0	9.7	10.8	10.4	10.9	11.7	12.4	12.5
53	1750	1426	F	2.0	Ova	t	3	AE	20	2	6.0	7.0	7.0	10.5	7.0	9.0	8.0	10.6	11.4	10.8	11.4	12.0	12.7	12.5
54	1476	1460	M	2.0	Ova	t	4	AE	40	3	4.5	5.5	6.5	7.5	8.5	7.5	9.4	10.4	10.5	11.0	11.7	12.0	12.3	14.0
55	1476	1461	F	2.0	Ova	t	4	AE	40	3	5.5	5.5	7.0	8.5	8.5	9.0	9.0	10.6	11.4	10.9	11.8	12.7	13.8	13.0
56	1469	1405	M	2.0	Ova	t	4	DC	20	5	7.0	9.5	8.0	9.0	9.0	12.0	10.8	10.7	11.8	11.4	12.4	13.4	13.8	15.0
57	1469	1406	M	1.5	Ova	t	4	DC	20	5	6.5	6.5	8.0	9.0	9.5	9.0	11.0	11.8	12.2	12.2	12.5	14.2	15.4	15.5
58	1727	1416	F	2.0	Ova	t	3	AE	60	4	4.0	5.0	5.0	6.5	7.0	8.5	6.5	8.4	8.8	8.8	9.7	10.2	10.7	14.5
59	1727	1417	F	1.5	Ova	t	3	AE	60	4	3.0	3.5	3.0	4.0	3.5	3.5	3.5	4.0	3.8	4.0	4.6	4.8	5.2	5.0
60	1727	1418	F	2.0	Ova	t	3	AE	60	4	4.5	5.0	6.0	7.0	7.5	6.0	8.0	8.7	9.6	9.4	10.1	10.4	10.6	11.5
61	1747	1438	M	2.0	Ova	t	3	Com	80	1	5.5	6.5	7.0	8.5	9.0	12.0	10.2	10.9	11.5	11.8	12.6	13.7	15.1	15.5
62	1747	1439	F	2.0	Ova	t	3	Com	80	1	5.0	4.0	6.0	7.0	7.5	9.0	8.1	9.5	9.8	9.9	11.3	11.6	12.1	12.5
63	1737	1468	M	2.4	Ova	t	3	DC	40	6	4.5	5.0	6.0	6.5	7.0	10.0	8.8	9.7	9.7	9.5	10.1	11.3	11.9	12.5

64	1737	1469	F	2.0	Ova	t	3	DC	40	6	5.0	6.0	6.0	7.0	7.5	7.5	7.5	9.3	9.6	9.8	11.0	11.4	12.3	13.0
65	1725	1419	F	2.0	Ova	s	3	DC	20	5	7.5	8.0	9.5	10.5	10.0	12.0	11.2	12.1	12.5	12.1	13.3	13.7	13.9	16.0
66	1731	1428	F	2.5	Ova	t	3	AE	40	3	7.5	8.5	10.0	11.0	11.0	10.5	12.5	13.7	14.2	14.0	14.6	15.3	15.9	16.5
67	1746	1450	M	2.0	Ova	t	3	DC	40	6	4.5	5.5	6.5	7.5	8.0	8.5	10.0	11.0	11.6	11.2	12.3	13.7	16.8	15.0

68	1746	1451	M	2.0	Ova	s	3	DC	40	6	4.5	5.5	6.0	8.0	7.5	10.0	7.5	9.5	9.9	10.2	11.6	12.2	12.7	14.0
69	2034	1455	F	2.0	Ova	s	2	Com	80	1	6.5	9.0	8.0	9.0	10.0	12.5	11.6	12.5	13.3	13.5	14.0	14.9	15.1	15.5
70	2049	1454	F	2.0	Ova	s	2	NS	0	8	6.5	7.5	8.0	9.0	9.5	8.5	11.2	11.6	12.3	12.7	13.2	13.9	14.6	16.5
71	2037	1475	M	3.0	Ova	s	2	NS	0	8	7.0	8.0	8.5	10.0	11.5	11.0	12.4	13.6	14.7	15.3	16.2	17.1	17.8	19.0
72	2031	1452	F	1.5	Ova	t	2	DC	60	7	4.0	5.0	5.0	7.0	7.0	6.0	8.2	8.6	8.7	10.4	9.8	10.5	11.3	11.0
73	2031	1453	F	2.0	Ova	t	2	DC	60	7	5.0	5.5	6.0	7.0	7.5	10.0	8.5	9.2	10.0	9.9	10.6	11.0	12.4	13.0
74	2029	1462	M	2.0	Ova	t	2	AE	40	3	5.0	6.0	8.0	7.5	8.5	11.5	10.3	11.4	12.3	12.2	12.8	13.2	14.3	15.0
75	2029	1463	M	2.0	Ova	t	2	AE	40	3	5.0	5.5	6.5	8.0	8.5	11.0	9.3	10.1	10.9	11.0	11.9	13.2	13.5	14.0
76	2024	1411	M	3.0	Ova	s	2	DC	60	7	6.5	7.0	8.5	8.5	9.5	11.0	11.0	11.8	12.2	12.4	13.2	13.8	15.1	15.0
77	2025	1466	M	2.5	Ova	t	2	DC	20	5	5.0	6.5	7.0	8.0	8.5	12.5	10.9	11.9	12.1	12.5	13.6	15.0	15.3	15.5
78	2025	1467	M	2.0	Ova	t	2	DC	20	5	4.5	5.0	6.0	6.5	8.0	7.0	6.5	7.8	8.4	8.9	10.1	15.0	11.5	14.0
79	2043	1448	M	2.0	Ova	t	2	DC	60	7	5.0	5.5	6.0	7.0	8.0	11.5	8.7	9.4	10.2	9.8	11.3	11.4	12.2	13.5
80	2043	1449	M	2.0	Ova	t	2	DC	60	7	5.5	5.5	6.5	7.5	8.0	10.5	9.3	9.9	9.9	10.4	11.3	12.1	13.2	12.5
81	2033	1440	M	2.5	Ova	s	2	DC	20	6	7.5	8.5	10.0	10.0	11.0	13.5	11.5	13.3	14.2	14.2	15.5	17.0	17.5	16.5
82	2042	1437	M	2.0	Ova	s	2	NS	0	8	7.5	8.5	9.5	11.0	11.5	14.5	11.5	14.1	14.9	14.6	15.4	17.9	17.5	18.0

OBS= Observation, DOEID= Doe identity number, KIDID= Kid identity number, KIBM= Kid birth maSS, BTYPE= Birth type, SUPP= supplementation, TRT= Treatment, IWT= initial weight, WK1-WK13= Week 1-12, AE= *Acacia erioloba*, DC= *Dichrostachys cinerea*, NS= Not supplemented, Com= Commercial feed, Cap= Caprivi, Ova= Ovambo, F= Female, M=Male

Table AP10.1 Experiment 3: Analysis of variance of kid weights by CRD

Table AP10.1.1 Analysis of variance of kid initial weights

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	43.6237488	3.9657953	3.67	0.0005
Error	64	69.1755934	1.0808686		
Corrected Total	75	112.7993421			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	2.18004666	2.18004666	2.02	0.1604
Sex	1	3.64178651	3.64178651	3.37	0.0711
Birth type	1	27.34923811	27.34923811	25.30	<.0001
Parity	1	0.23582077	0.23582077	0.22	0.6420
Treatment	7	7.97961558	1.13994508	1.05	0.4029

Table AP10.1.2 Analysis of variance of kid at weaning

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	198.6012913	18.0546628	8.54	<.0001
Error	64	135.2875245	2.1138676		
Corrected Total	75	333.8888158			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	13.94268473	13.94268473	6.60	0.0126
Sex	1	78.11183641	78.11183641	36.95	<.0001
Birth type	1	68.59537405	68.59537405	32.45	<.0001
Parity	1	11.78555804	11.78555804	5.58	0.0213
Treatment	7	18.46824570	2.63832081	1.25	0.2904

Table AP10.1.3 Analysis of variance of kid ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	10319.28100	938.11645	2.79	0.0051
Error	64	21547.51562	336.67993		
Corrected Total	75	31866.79662			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	629.169347	629.169347	1.87	0.1764
Sex	1	5928.561196	5928.561196	17.61	<.0001
Birth type	1	1150.402481	1150.402481	3.42	0.0692
Parity	1	1072.486991	1072.486991	3.19	0.0790
Treatment	7	1875.414625	267.916375	0.80	0.5936

Table AP10.2 Experiment 3: Analysis of variance of kid weights by 2 x 3 factorial design

Table AP10.2.1 Analysis of variance of kid initial weights

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	6.38612288	1.27722458	0.83	0.5348
Error	53	81.65625000	1.54068396		
Corrected Total	58	88.04237288			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	1.12361195	1.12361195	0.73	0.3970
Level	2	4.47535502	2.23767751	1.45	0.2432
Supplement*Level	2	0.90574545	0.45287272	0.29	0.7465

Table AP10.2.2 Analysis of variance of kid weight at weaning

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	27.2482008	5.4496402	1.29	0.2834
Error	53	224.4311212	4.2345495		
Corrected Total	58	251.6793220			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	5.60364578	5.60364578	1.32	0.2552
Level	2	19.94085699	9.97042850	2.35	0.1048
Supplement*Level	2	1.84031391	0.92015696	0.22	0.8054

Table AP10.2.3 Analysis of variance of kid ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	5	1116.11759	223.22352	0.59	0.7081
Error	53	20074.67546	378.76746		
Corrected Total	58	21190.79305			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	210.9583440	210.9583440	0.56 1.12	0.4588
Level	2	845.7238600	422.8619300	0.05	0.3350
Supplement*Level	2	37.9870170	18.9935085		0.9511

Table AP11 Experiment 3: Value for milk yield per metabolic weight of kids (kg, DM/M$^{0.75}$/d)

OBS	DOEID	KIDID	SEX	KID BM	ECOTY	BTYPE	PARITY	SUPP	LEVEL	TRT	vficon1	vficon2	vficon3	vficon4	vficon5	vficon6	vficon7	vficon8	vficon9	vficon10	vficon11	vficon12	vficon13
1	1025	1441	M	2	Cap	t	5	DC	20	5	1.32	1.43	1.55	1.66	2.01	1.88	1.97	2.11	2.09	2.35	2.36	2.57	2.70
2	1025	1442	F	2	Cap	t	5	DC	20	5	1.11	1.28	1.40	1.51	1.77	1.70	1.83	1.95	1.85	2.08	2.24	2.30	2.26
3	0_914	1402	M	2.5	Cap	t	4	DC	20	5	1.70	1.87	1.87	2.28	2.12	2.32	2.57	2.68	2.65	2.80	2.94	2.97	2.97
4	0_914	1403	F	2	Cap	t	4	DC	20	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	1515	1431	M	2.5	Cap	s	4	AE	40	3	1.62	1.84	2.18	2.41	2.35	2.49	2.56	2.72	2.72	2.80	2.98	3.03	2.97
6	1519	1422	M	3	Cap	s	4	DC	40	6	1.03	1.94	2.08	2.18	2.31	2.45	2.50	2.67	2.59	2.80	2.90	2.93	3.09
7	1724	1457	F	2.5	Cap	s	3	DC	60	7	1.32	1.73	2.01	2.01	2.12	2.24	2.37	2.52	2.41	2.64	2.77	2.79	2.91
8	1714	1414	M	2.5	Cap	t	3	AE	20	2	1.47	1.62	1.73	1.80	1.87	2.20	2.16	2.18	2.22	2.39	2.48	2.49	2.60
9	1714	1415	M	2	Cap	t	3	AE	20	2	1.51	1.62	1.87	1.98	2.15	2.19	2.33	2.43	2.39	2.57	2.65	2.72	2.82
10	1722	1465	F	2.5	Cap	t	3	AE	20	2	1.32	1.36	1.62	1.66	1.77	1.79	1.94	2.01	2.03	2.18	2.28	2.29	2.66
11	1722	1466	F	2	Cap	t	3	AE	20	2	1.16	1.16	1.32	1.62	1.70	1.58	1.74	1.82	1.79	1.91	2.01	2.11	2.19
12	1712	1432	M	3	Cap	s	3	DC	40	6	1.77	2.08	2.25	2.31	2.54	2.48	2.56	2.70	2.69	2.83	3.03	3.03	3.18
13	1723	1418	M	2	Cap	t	3	DC	40	6	1.36	1.47	1.59	1.73	1.70	1.78	1.83	2.05	2.05	2.19	2.33	2.47	2.57
14	1723	1419	F	2	Cap	t	3	DC	40	6	1.36	1.43	1.73	1.73	1.70	2.07	2.11	2.17	2.05	2.30	2.25	2.52	2.60

15	0_810	1443	M	3	Cap	t	5	DC	20	5	1.47	1.59	1.80	1.87	1.91	2.01	2.15	2.28	2.26	2.43	2.44	2.68	2.72
16	0_811	1444	F	2.1	Cap	t	5	DC	20	5	1.20	1.28	1.43	1.55	1.91	1.67	1.73	1.90	1.88	2.10	2.07	2.16	2.31
17	1706	1451	M	2.5	Cap	t	3	AE	60	4	1.73	1.43	1.51	1.73	1.70	1.84	2.06	2.02	2.03	2.13	2.28	2.42	2.46
18	1706	1452	F	2	Cap	t	3	AE	60	4	1.16	1.32	1.40	1.59	1.73	1.92	1.81	1.90	1.85	1.87	2.07	2.14	2.19
19	1718	1467	M	2.5	Cap	t	3	AE	40	3	1.28	1.47	1.62	1.77	1.87	2.35	2.14	2.24	2.36	2.43	2.49	2.59	2.55
20	1718	1468	F	2.5	Cap	t	3	AE	40	3	1.20	1.28	1.47	1.55	1.91	1.86	1.87	1.99	1.98	2.07	2.12	2.22	2.36
21	1716	1427	M	2	Cap	t	3	NS	0	8	1.11	1.51	1.59	1.77	1.87	2.16	2.10	2.20	2.12	2.37	2.46	2.53	3.11
22	1716	1428	F	2.5	Cap	t	3	NS	0	8	1.32	1.43	1.59	1.66	1.84	1.75	1.88	2.01	1.90	2.08	2.14	2.27	2.31
23	1023	1429	M	3	Cap	t	3	Com	80	1	1.47	1.59	1.77	1.84	2.12	2.15	2.22	2.33	2.35	2.49	2.67	2.70	2.78
24	1023	1430	F	3	Cap	t	3	Com	80	1	1.28	1.43	1.55	1.73	1.80	1.97	1.94	2.05	1.97	2.15	2.22	2.33	2.48
25	1160	1445	M	2	Cap	t	2	DC	60	7	1.66	1.28	1.47	1.66	1.98	1.91	1.88	2.01	1.92	2.01	2.19	2.31	2.44
26	1160	1446	F	2.5	Cap	t	2	DC	60	7	1.20	1.36	1.55	1.59	1.84	1.82	1.89	1.92	1.82	2.11	2.16	2.24	2.35
27	2010	1433	M	2.5	Cap	t	2	AE	60	4	1.32	1.40	1.55	1.59	1.87	1.90	1.92	2.01	2.03	2.31	2.35	2.50	2.70
28	2010	1434	M	2.5	Cap	t	2	AE	60	4	1.47	1.51	1.84	1.80	1.80	1.99	2.05	2.13	2.15	2.28	2.41	2.48	2.61
29	2013	1420	M	2	Cap	t	2	DC	60	7	1.36	1.43	1.80	1.66	1.87	1.78	1.93	2.03	1.97	2.21	2.26	2.31	2.51
30	2013	1421	F	1.5	Cap	t	2	DC	60	7	1.16	1.36	1.40	1.55	1.80	1.69	1.83	1.94	1.83	2.10	2.12	2.18	2.35
31	2003	1439	M	2.5	Cap	t	2	AE	40	3	1.47	1.28	1.47	1.51	1.43	1.73	1.85	1.94	2.01	2.16	2.24	2.37	2.54
32	2003	1440	F	2	Cap	t	2	AE	40	3	1.16	1.36	1.36	1.47	1.47	1.73	1.72	1.81	1.84	1.97	2.01	2.14	2.32

33	2005	1479	M	2.5	Cap	t	2	Com	80	1	1.03	1.47	1.55	1.70	1.91	2.02	2.05	2.08	2.10	2.32	2.43	2.46	2.64
34	2005	1480	M	2.5	Cap	t	2	Com	80	1	1.20	1.20	1.47	1.59	1.80	1.89	2.04	2.18	2.16	2.43	2.48	2.54	2.66
35	2011	1404	M	2.5	Cap	t	2	NS	0	8	1.28	1.32	1.36	1.55	1.84	1.90	1.79	1.92	1.96	2.10	2.03	2.15	2.35
36	2011	1405	M	2	Cap	t	2	NS	0	8	1.32	1.70	1.98	1.98	2.18	2.15	2.26	2.44	2.36	2.55	2.61	2.68	2.88
37	2001	1423	F	1.5	Cap	s	2	NS	0	8	1.59	1.70	1.94	1.98	2.05	2.13	2.26	2.29	2.22	2.42	2.49	2.48	2.67
38	2009	1406	F	2	Cap	t	2	AE	20	2	1.16	1.20	1.40	1.43	1.80	1.99	1.71	1.78	1.79	1.90	1.90	2.07	2.18
39	2009	1407	F	2	Cap	t	2	AE	20	2	1.32	1.51	1.47	1.66	1.70	1.82	1.83	1.92	1.83	2.07	2.10	2.20	2.22
40	2006	1461	M	2.5	Cap	t	2	AE	60	4	1.28	1.36	1.43	1.59	1.70	1.81	1.92	1.95	1.99	2.15	2.22	2.40	2.60
41	2006	1462	F	2	Cap	t	2	AE	60	4	1.16	1.20	1.36	1.43	1.70	1.64	1.64	1.68	1.67	1.83	2.35	1.85	1.93
42	2007	1455	F	2	Cap	s	2	Com	80	1	1.32	1.55	1.66	1.73	2.05	1.93	2.10	2.19	2.16	2.35	2.44	2.52	2.68
43	0_925	1443	M	2	Ova	t	4	AE	20	2	1.28	1.47	1.59	1.77	1.98	2.08	2.12	2.22	2.20	2.41	2.53	2.59	2.73
44	0_925	1444	F	2	Ova	t	4	AE	20	2	1.32	1.51	1.59	1.73	1.98	1.97	2.03	2.05	2.10	2.25	2.28	2.43	2.70
45	1457	1458	M	2	Ova	t	4	AE	60	4	1.07	1.11	1.20	1.40	1.43	1.73	1.69	1.76	1.80	1.91	2.01	2.17	2.33
46	1457	1459	F	2	Ova	t	4	AE	60	4	0.90	1.07	1.20	1.32	1.66	1.60	1.64	1.75	1.77	1.87	2.01	2.12	2.22
47	1728	1435	M	2.5	Ova	t	3	AE	20	2	1.36	1.55	1.70	1.87	1.91	1.99	2.12	2.24	2.19	2.40	2.37	2.58	2.73
48	1728	1436	F	2.5	Ova	t	3	AE	20	2	1.28	1.40	1.59	1.70	1.80	1.89	1.98	2.10	2.07	2.20	2.33	2.41	2.33
49	1021	1420	M	2	Ova	t	3	AE	60	4	1.70	1.84	1.94	.	.	.	.	.	.	.	.	.	.
50	1021	1421	F	2	Ova	t	3	AE	60	4	1.40	1.47	1.47	.	.	.	.	.	.	.	.	.	.

51	1732	1477	F	2	Ova	s	3	Com	80	1	1.40	1.47	1.73	1.73	1.94	2.05	2.11	2.15	2.17	2.35	2.43	2.52	2.64
52	1750	1425	F	2	Ova	t	3	AE	20	2	1.28	1.36	1.51	1.59	1.80	1.77	1.84	1.94	1.94	1.96	2.12	2.22	2.22
53	1750	1426	F	2	Ova	t	3	AE	20	2	1.43	1.40	1.80	1.59	1.80	1.73	1.99	2.03	1.99	2.06	2.12	2.24	2.25
54	1476	1460	M	2	Ova	t	4	AE	40	3	1.16	1.32	1.51	1.62	1.66	1.87	1.93	1.99	1.93	2.15	2.20	2.24	2.48
55	1476	1461	F	2	Ova	t	4	AE	40	3	1.24	1.43	1.59	1.66	1.73	1.91	1.99	2.04	1.96	2.12	2.22	2.35	2.26
56	1469	1405	M	2	Ova	t	4	DC	20	5	1.80	1.59	1.73	1.77	2.01	2.00	1.99	2.12	2.03	2.20	2.33	2.39	2.53
57	1469	1406	M	1.5	Ova	t	4	DC	20	5	1.40	1.62	1.80	1.84	1.87	2.05	2.11	2.22	2.18	2.28	2.43	2.55	2.62
58	1727	1416	F	2	Ova	t	3	AE	60	4	1.16	1.16	1.32	1.43	1.62	1.43	1.64	1.75	1.69	1.92	1.90	1.97	2.33
59	1727	1417	F	1.5	Ova	t	3	AE	60	4	0.85	0.81	0.99	0.85	0.90	0.85	0.93	0.95	0.99	1.05	1.11	1.17	1.16
60	1727	1418	F	2	Ova	t	3	AE	60	4	1.16	1.32	1.43	1.47	1.43	1.62	1.70	1.77	1.72	1.87	1.93	1.97	2.14
61	1747	1438	M	2	Ova	t	3	Com	80	1	1.32	1.47	1.62	1.73	2.12	1.96	2.01	2.07	2.14	2.27	2.39	2.52	2.55
62	1747	1439	F	2	Ova	t	3	Com	80	1	0.99	1.28	1.32	1.47	1.66	1.67	1.80	1.85	1.85	2.01	2.07	2.16	2.24
63	1737	1468	M	2.4	Ova	t	3	DC	40	6	1.11	1.24	1.40	1.47	1.77	1.72	1.81	1.87	1.83	1.91	2.05	2.14	2.21
64	1737	1469	F	2	Ova	t	3	DC	40	6	1.28	1.24	1.43	1.51	1.55	1.59	1.78	1.83	1.86	2.07	2.10	2.19	2.30
65	1725	1419	F	2	Ova	s	3	DC	20	5	1.62	1.73	1.91	1.87	2.08	2.10	2.16	2.22	2.21	2.31	2.37	2.41	2.60
66	1731	1428	F	2.5	Ova	t	3	AE	40	3	1.70	1.84	1.98	2.05	2.05	2.26	2.37	2.43	2.43	2.52	2.62	2.66	2.78
67	1746	1450	M	2	Ova	t	3	DC	40	6	1.24	1.36	1.51	1.62	1.70	1.89	1.99	2.08	2.09	2.20	2.36	2.60	2.54
68	1746	1451	M	2	Ova	s	3	DC	40	6	1.24	1.28	1.47	1.51	1.77	1.61	1.81	1.88	1.91	1.97	2.17	2.24	2.40

69	2034	1455	F	2	Ova	s	2	Com	80	1	1.73	1.59	1.70	1.91	2.15	2.12	2.24	2.31	2.37	2.42	2.52	2.52	2.64
70	2049	1454	F	2	Ova	s	2	NS	0	8	1.51	1.62	1.73	1.80	1.80	2.20	2.13	2.20	2.27	2.28	2.42	2.57	2.70
71	2037	1475	M	3	Ova	s	2	NS	0	8	1.59	1.66	1.98	2.08	2.12	2.28	2.35	2.47	2.58	2.69	2.82	2.89	3.12
72	2031	1452	F	1.5	Ova	t	2	DC	60	7	1.16	1.16	1.40	1.47	1.43	1.71	1.66	1.74	1.86	1.85	1.95	1.95	2.00
73	2031	1453	F	2	Ova	t	2	DC	60	7	1.24	1.32	1.47	1.51	1.77	1.84	1.79	1.85	1.85	1.96	2.03	2.17	2.30
74	2029	1462	M	2	Ova	t	2	AE	40	3	1.28	1.55	1.55	1.66	1.98	2.03	2.04	2.15	2.16	2.24	2.35	2.44	2.53
75	2029	1463	M	2	Ova	t	2	AE	40	3	1.24	1.36	1.55	1.66	1.91	2.10	1.88	2.01	2.02	2.15	2.30	2.35	2.42
76	2024	1411	M	3	Ova	s	2	DC	60	7	1.47	1.59	1.70	1.84	1.98	2.01	2.14	2.18	2.22	2.32	2.41	2.53	2.60
77	2025	1466	M	2.5	Ova	t	2	DC	20	5	1.36	1.47	1.59	1.70	2.05	2.01	2.16	2.19	2.18	2.35	2.54	2.57	2.63
78	2025	1467	M	2	Ova	t	2	DC	20	5	1.16	1.32	1.40	1.59	1.59	1.46	1.56	1.65	1.72	1.87	2.30	2.09	2.32
79	2043	1448	M	2	Ova	t	2	DC	60	7	1.20	1.32	1.51	1.59	1.98	1.71	1.80	1.86	1.87	2.10	1.23	2.17	2.30
80	2043	1449	M	2	Ova	t	2	DC	60	7	1.20	1.32	1.51	1.59	1.84	1.86	1.85	1.89	1.92	2.05	2.14	2.27	2.27
81	2033	1440	M	2.5	Ova	s	2	DC	20	6	1.70	1.77	1.91	2.01	2.25	2.08	2.32	2.44	2.48	2.61	2.79	2.84	2.84
82	2042	1437	M	2	Ova	s	2	NS	0	8	1.70	1.80	2.01	2.12	2.38	2.18	2.43	2.53	2.46	2.59	2.84	2.85	2.91

OBS= Observation, DOEID= Doe identity number, KIDID= Kid identity number, ECOTY= Ecotype, BTYPE= Birth type, SUPP= Supplement, TRT= Treatment, VFICON1-13= Voluntary Feed Intake Consumption week 1 – 13; F= Female, M= Male, Cap= Caprivi, Ova= Ovambo, AE= *Acacia erioloba*, DC= *Dichrostachys cinerea*, Comm= Commercial feed, NS= Not supplemented, t= twins, s= single

Table AP11.1 Experiment 3: Value for milk yield on metabolic weight by CRD

Table AP11.1.1 Analysis of variance for milk yield kid metabolic weight week1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	0.94124712	0.08556792	2.60	0.0084
Error	64	2.10444104	0.03288189		
Corrected Total	75	3.04568816			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.01340297	0.01340297	0.41	0.5252
Sex	1	0.15445615	0.15445615	4.70	0.0339
Birth type	1	0.59487281	0.59487281	18.09	<.0001
Parity	1	0.00035313	0.00035313	0.01	0.9178
Treatment	7	0.21483661	0.03069094	0.93	0.4872

Analysis of variance for milk yield kid metabolic weight week 2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	1.70076650	0.15461514	6.98	<.0001
Error	64	1.41810060	0.02215782		
Corrected Total	75	3.11886711			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.09053587	0.09053587	4.09	0.0474
Sex	1	0.22682326	0.22682326	10.24	0.0021
Birth Type	1	0.94604298	0.94604298	42.70	<.0001
Parity	1	0.05888309	0.05888309	2.66	0.1080
Treatment	7	0.25253071	0.03607582	1.63	0.1436

Analysis of variance for milk yield kid metabolic weight week 3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.11339474	0.19212679	7.33	<.0001
Error	64	1.67670394	0.02619850		
Corrected Total	75	3.79009868			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.11402466	0.11402466	4.35	0.0409
Sex	1	0.24580074	0.24580074	9.38	0.0032
Birth type	1	1.23262644	1.23262644	47.05	<.0001
Parity	1	0.11944797	0.11944797	4.56	0.0366

Treatment	7	0.29529745	0.04218535	1.61	0.1486

Analysis of variance for milk yield kid metabolic weight week 5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.21074088	0.20097644	8.89	<.0001
Error	64	1.44739991	0.0226156		
Corrected Total	75	3.65814079			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.17880528	0.17880528	7.91	0.0065
Sex	1	0.45335065	0.45335065	20.05	<.0001
Birth type	1	1.16421040	1.16421040	51.48	<.0001
Parity	1	0.15684845	0.15684845	6.94	0.0106
Treatment	7	0.30487320	0.04355331	1.93	0.0798

Analysis of variance for milk yield kid metabolic weight week 5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.09803444	0.19073040	7.11	<.0001
Error	64	1.71661819	0.02682216		
Corrected Total	75	3.81465263			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.09828386	0.09828386	3.66	0.0601
Sex	1	0.44287236	0.44287236	16.51	0.0001
Birth type	1	1.03515322	1.03515322	38.59	<.0001
Parity	1	0.05194759	0.05194759	1.94	0.1688
Treatment	7	0.38707840	0.05529691	2.06	0.0607

Analysis of variance for milk yield kid metabolic weight week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.14248475	0.19477134	6.66	<.00
Error	64	1.87291920	0.02926436		
Corrected Total	75	4.01540395			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.23082215	0.23082215	7.89	0.0066
Sex	1	0.53374948	0.53374948	18.24	<.0001
Birth type	1	0.89508980	0.89508980	30.59	<.0001
Parity	1	0.12010360	0.12010360	4.10	0.0470
Treatment	7	0.49484317	0.07069188	2.42	0.0293

Analysis of variance for milk yield kid metabolic weight week 7

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.50235693	0.22748699	8.30	<.0001
Error	64	1.75408518	0.02740758		
Corrected Total	75	4.25644211			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.15910539	0.15910539	5.81	0.0189
Sex	1	0.56989994	0.56989994	20.79	<.0001
Birth type	1	1.27582444	1.27582444	46.55	<.0001
Parity	1	0.19593741	0.19593741	7.15	0.0095
Treatment	7	0.33079783	0.04725683	1.72	0.1191

Analysis of variance for milk yield kid metabolic weight week 8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.89768522	0.26342593	9.52	<.0001
Error	64	1.77123452	0.02767554		
Corrected Total	75	4.66891974			

Source	DF	TYPE III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.25024851	0.25024851	9.04	0.0038
Sex	1	0.64920643	0.64920643	23.46	<.0001
Birth type	1	1.30899717	1.30899717	47.30	<.0001
Parity	1	0.24418740	0.24418740	8.82	0.0042
Treatment	7	0.39445891 **k**	0.05635127	2.04	0.0639

yield kid metabolic weight week 9

Analysis of variance for mil

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.94037295	0.26730663	10.32	<.0001
Error	64	1.65760073	0.02590001		
Corrected Total	75	4.59797368			

Source	DF	TYPE III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.13567712	0.13567712	5.24	0.0254
Sex	1	0.81551136	0.81551136	31.49	<.0001
Birth type	1	1.39613227	1.39613227	53.90	<.0001
Parity	1	0.13708935	0.13708935	5.29	0.0247
Treatment	7	0.39711574	0.05673082	2.19	0.0466

Analysis of variance for milk yield kid metabolic weight week 10

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	2.96429038	0.26948094	9.51	<.0001
Error	64	1.81378725	0.02834043		
Corrected Total	75	4.77807763			

Source	DF	TYPE III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.30247915	0.30247915	10.67	0.0017
Sex	1	0.86100787	0.86100787	30.38	<.0001
Birth type	1	1.18774094	1.18774094	41.91	<.0001
Parity	1	0.13550290	0.13550290	4.78	0.0324
Treatment	7	0.39738435 **k**	0.05676919	2.00	0.0683

yield kid metabolic weight week 11

Analysis of variance for mil

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	3.62011276	0.32910116	7.48	<.0001
Error	64	2.81456487	0.04397758		
Corrected Total	75	6.43467763			

Source	DF	TYPE III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.31762282	0.31762282	7.22	0.0092
Sex	1	0.84550515	0.84550515	19.23	<.0001
Birth type	1	1.69368085	1.69368085	38.51	<.0001
Parity	1	0.07980952	0.07980952	1.81	0.1827
Treatment	7	0.44692872	0.06384696	1.45	0.2007

weight week 12

Analysis of variance for mill
metabolic

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	3.24851869	0.29531988	10.11	<.0001
Error	64	1.86877999	0.02919969		
Corrected Total	75	5.11729868			

Source	DF	TYPE III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.21164316	0.21164316	7.25	0.0090
Sex	1	1.19065767	1.19065767	40.78	<.0001
Birth type	1	1.18374698	1.18374698	40.54	<.0001
Parity	1	0.18584730	0.18584730	6.36	0.0141
Treatment	7	0.30413537	0.04344791	1.49	0.1875

Table AP11.1.2 Analysis of variance for milk yield kid metabolic weight at weaning

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	3.44736645	0.31339695	10.08	<.0001
Error	64	1.99013224	0.03109582		
Corrected Total	75	5.43749868			

Source	DF	TYPE III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.26907233	0.26907233	8.65	0.0045
Sex	1	1.27510714	1.27510714	41.01	<.0001
Birth type	1	1.16230450	1.16230450	37.38	<.0001
Parity	1	0.19265319	0.19265319	6.20	0.0154
Treatment	7	0.34823364	0.04974766	1.60	0.1516

: **Analysis of variance**

factorial design

Table AP10.2.1 Analysis of variance for milk yield kid metabolic weight week 1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.22496113	0.04499223	1.16	0.3415
Error	53	2.05730667	0.03881711		
Corrected Total	58	2.28226780			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.03360344	0.03360344	0.87	0.3564
Level	2	0.12180912	0.06090456	1.57	0.2178
Supplement*Level	2	0.05870458	0.02935229	0.76	0.4745

Table AP10.2.2 Analysis of variance for milk yield kid metabolic weight week 2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.41289502	0.08257900	1.97	0.0975
Error	53	2.21626091	0.04181624		
Corrected Total	58	2.62915593			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.09220195	0.09220195	2.20	0.1435

Level	2	0.28046019	0.14023010	3.35	0.0425
Supplement*Level	2	0.01690017	0.00845009	0.20	0.8177

Table AP10.2.3 Analysis of variance for milk yield kid metabolic weight week 3

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.43202436	0.08640487	1.78	0.1320
Error	53	2.56675530	0.04842935		
Corrected Total	58	2.99877966			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.12617738	0.12617738	2.61	0.1124
Level	2	0.25828938	0.12914469	2.67	0.0788
Supplement*Level	2	0.02520721	0.01260361	0.26	0.7718

Table AP10.2.4 Analysis of variance for milk yiel d kid metabolic weig ıt week 4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.40733512	0.08146702	1.65	0.1638
Error	53	2.62164455	0.04946499		
Corrected Total	58	.02897966			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.08501089	0.08501089	1.72	0.1955
Level	2	0.27301359	0.13650679	2.76	0.0724
Supplement*Level	2	0.02338840	0.01169420	0.24	0.7903

Table AP10.2.5 Analysis of variance for milk yield kid metabolic weight week 5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.49121977	0.09824395	2.06	0.0855
Error	53	2.53162091	0.04776643		
Corrected Total	58	3.02284068			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.20007930	0.20007930	4.19	0.0457

Level	2	0.20441951	0.10220976	2.14	0.1277
Supplement*Level	2	0.05764394	0.02882197	0.60	0.5507

Table AP10.2.6 Analysis of variance for milk yield kid metabolic weight week 6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.43681582	0.08736316	1.57	0.1850
Error	53	2.95214689	0.05570088		
Corrected Total	58	3.38896271			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.00856690	0.00856690	0.15	0.6965
Level	2	0.27274520	0.13637260	2.45	0.0962
Supplement*Level	2	0.11158474	0.05579237	1.00	0.3741

Table AP10.2.7 Analysis of variance for milk yield kid metabolic weight week 7

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.44635208	0.08927042	1.54	0.1930
Error	53	3.07032250	0.05793061		
Corrected Total	58	3.51667458			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.06201207	0.06201207	1.07	0.3055
Level	2	0.33413044	0.16706522	2.88	0.0647
Supplement*Level	2	0.02303563	0.01151782	0.20	0.8203

Table AP10.2.8 Analysis of variance for milk yield kid metabolic weight week 8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.62122703	0.12424541	2.02	0.0906
Error	53	3.25889500	0.06148858		
Corrected Total	58	3.88012203			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.09892351	0.09892351	1.61	0.2102
Level	2	0.46207356	0.23103678	3.76	0.0298
Supplement*Level	2	0.02453462	0.01226731	0.20	0.8197

Table AP10.2.9 Analysis of variance for milk yield kid metabolic weight week 9

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Model	5	0.58515426	0.11703085	1.97	0.0980
Error	53	3.14605591	0.05935955		
Corrected Total	58	3.73121017			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.06445687	0.06445687	1.09	0.3021
Level	2	0.44395511	0.22197755	3.74	0.0303
Supplement*Level	2	0.03835255	0.01917628	0.32	0.7254

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Table AP10.2.10 Analysis of yi

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.60583663	0.12116733	1.92	0.1057
Error	53	3.33750235	0.06297174		
Corrected Total	58	3.94333898			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.10364083	0.10364083	1.65	0.2051
Level	2	0.44020586	0.22010293	3.50	0.0375
Supplement*Level	2	0.02677724	0.01338862	0.21	0.8092

Table AP10.2.11 Analysis of variance for milk yield kid metabolic weight week 11

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.82778265	0.16555653	1.96	0.0995
Error	53	4.47101735	0.08435882		
Corrected Total	58	5.29880000			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.04954062	0.04954062	0.59	0.4469
Level	2	0.66217764	0.33108882	3.92	0.0257
Supplement*Level	2	0.12035382	0.06017691	0.71	0.4946

Table AP10.2.12 Analysis of variance for milk yi ld kid metabolic wei ht week 12

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.71032949	0.14206590	2.13	0.0755
Error	53	3.52808068	0.06656756		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Corrected Total	58	4.23841017			
Supplement	1	0.16197160	0.16197160	2.43	0.1247
Level	2	0.51039773	0.25519886	3.83	0.0279
Supplement*Level	2	0.01067007	0.00533504	0.08	0.9231

Table AP10.2.13 Analysis of variance for milk yield kid metabolic weight week 13

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.50796242	0.10159248	1.53	0.19
Error	53	3.52923758	0.06658939		
Corrected Total	58	4.03720000			
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Supplement	1	0.10600636	0.10600636	1.59	0.2126
Level	2	0.37988120	0.18994060	2.85	0.0666
Supplement*Level	2	0.01466655	0.00733328	0.11	0.8959

Table AP11 Experiment 4: Value for Milk composition

OBS	DOEID	ECOTY	PARITY	TRT	SUPP	LEVEL	REP	ROUND	FAT	CP	TS	SNF	ASH	Ca	P
1	1732	Ova	3	1	com	0	1	2	5.50	6.04	17.25	11.75	1.00	0.17	0.10
1	1732	Ova	3	1	com	0	1	3	4.50	5.08	15.14	10.64	0.86	0.18	0.12
1	1732	Ova	3	1	com	0	1	4	4.00	5.98	14.38	10.38	0.89	0.16	0.16
1	1732	Ova	3	1	com	0	1	5	3.90	5.04	14.49	10.59	0.98	0.10	0.09
2	1747	Ova	3	1	com	0	2	2	6.40	4.95	18.51	12.11	0.80	0.16	0.11
2	1747	Ova	3	1	com	0	2	3	3.10	4.84	13.52	10.42	0.85	0.13	0.12
2	1747	Ova	3	1	com	0	2	4	3.80	6.66	14.00	10.20	0.87	0.14	0.14
2	1747	Ova	3	1	com	0	2	5	4.40	5.04	15.30	10.90	0.80	0.17	0.13
3	2034	Ova	2	1	com	0	3	2	8.00	5.82	17.97	9.97	0.87	0.20	0.10
3	2034	Ova	2	1	com	0	3	3	5.20	5.11	15.56	10.36	0.98	0.18	0.13
3	2034	Ova	2	1	com	0	3	4	5.10	4.41	15.35	10.25	0.90	0.17	0.13
3	2034	Ova	2	1	com	0	3	5	5.80	6.62	21.93	16.13	1.12	0.18	0.12
4	1023	Cap	3	1	com	0	1	2	7.50	2.69	16.95	9.45	0.89	0.16	0.11
4	1023	Cap	3	1	com	0	1	3	3.00	4.91	12.65	9.65	0.91	0.16	0.13
4	1023	Cap	3	1	com	0	1	4	3.20	6.21	12.95	9.75	0.87	0.12	0.14

4	1023	Cap	3	1	com	0	1	5	4.30	4.44	14.07	9.77	0.97	0.14	0.07
5	2005	Cap	2	1	com	0	2	2	4.40	4.63	14.48	10.08	0.84	0.19	0.12
5	2005	Cap	2	1	com	0	2	3	3.10	4.91	13.27	10.17	0.85	0.17	0.14
5	2005	Cap	2	1	com	0	2	4	2.70	5.58	12.61	9.91	0.79	0.14	0.15
5	2005	Cap	2	1	com	0	2	5	3.20	6.06	14.84	11.64	0.97	0.15	0.12
6	2007	Cap	2	1	com	0	3	2	4.00	2.99	15.35	11.35	0.79	0.17	0.10
6	2007	Cap	2	1	com	0	3	3	3.10	3.78	13.43	10.33	0.80	0.15	0.13
6	2007	Cap	2	1	com	0	3	4	3.10	2.59	13.00	9.90	0.78	0.16	0.16
6	2007	Cap	2	1	com	0	3	5	4.40	4.47	15.03	10.63	0.77	0.17	0.13
7	0925	Ova	4	2	AE	20	1	2	6.30	4.94	19.70	13.40	0.92	0.20	0.15
7	0925	Ova	4	2	AE	20	1	3	3.20	5.50	14.19	10.99	0.87	0.19	0.15
7	0925	Ova	4	2	AE	20	1	4	4.00	5.80	14.93	10.93	0.95	0.20	0.19
7	0925	Ova	4	2	AE	20	1	5	6.50	7.20	16.00	9.50	0.91	0.16	0.07
8	1750	Ova	3	2	AE	20	2	2	7.10	4.19	15.75	8.65	0.84	0.20	0.11
8	1750	Ova	3	2	AE	20	2	3	4.20	4.18	14.21	10.01	0.81	0.16	0.13
8	1750	Ova	3	2	AE	20	2	4	4.30	4.79	14.53	10.23	0.81	0.16	0.15
8	1750	Ova	3	2	AE	20	2	5	5.40	5.20	15.86	10.46	0.87	0.13	0.09
9	1728	Ova	3	2	AE	20	3	2	8.50	4.72	18.01	9.51	0.88	0.18	0.10
9	1728	Ova	3	2	AE	20	3	3	4.10	4.11	13.68	9.58	0.87	0.17	0.12
9	1728	Ova	3	2	AE	20	3	4	3.00	3.94	12.86	9.86	0.86	0.15	0.14
9	1728	Ova	3	2	AE	20	3	5	6.00	4.22	16.13	10.13	1.00	0.16	0.11
10	1714	Cap	3	2	AE	20	1	2	4.40	3.95	14.23	9.83	0.82	0.19	0.15
10	1714	Cap	3	2	AE	20	1	3	2.80	4.90	13.07	10.27	0.87	0.17	0.13
10	1714	Cap	3	2	AE	20	1	4	4.30	5.72	12.12	7.82	0.75	0.15	0.16
10	1714	Cap	3	2	AE	20	1	5	4.80	4.66	15.32	10.52	0.95	0.17	0.11
11	1722	Cap	3	2	AE	20	2	2	6.70	4.88	15.43	8.73	0.80	0.14	0.12
11	1722	Cap	3	2	AE	20	2	3	3.80	5.18	13.88	10.08	0.83	0.17	0.14
11	1722	Cap	3	2	AE	20	2	4	2.40	5.93	13.04	10.64	0.86	0.14	0.14
11	1722	Cap	3	2	AE	20	2	5	4.80	4.87	15.59	10.79	0.92	0.16	0.11
12	2009	Cap	2	2	AE	20	3	2	7.10	3.86	16.18	9.08	0.79	0.15	0.11
12	2009	Cap	2	2	AE	20	3	3	3.80	4.00	13.47	9.67	0.86	0.14	0.12
12	2009	Cap	2	2	AE	20	3	4	3.50	3.74	12.90	9.40	0.81	0.12	0.13

12	2009	Cap	2	2	AE	20	3	5	5.50	3.80	15.21	9.71	0.89	0.17	0.12
13	1476	Ova	4	3	AE	40	1	2	7.30	5.32	17.79	10.49	1.01	0.01	0.01
13	1476	Ova	4	3	AE	40	1	3	3.10	5.26	13.32	10.22	0.94	0.18	0.14
13	1476	Ova	4	3	AE	40	1	4	3.90	5.12	14.43	10.53	0.87	0.14	0.13
13	1476	Ova	4	3	AE	40	1	5	6.80	6.84	18.99	12.19	1.11	0.22	0.10
14	1731	Ova	3	3	AE	40	2	2	8.20	3.98	17.62	9.42	0.87	0.17	0.13
14	1731	Ova	3	3	AE	40	2	3	3.90	5.70	13.83	9.93	0.89	0.15	0.14
14	1731	Ova	3	3	AE	40	2	4	3.70	5.10	14.10	10.40	0.83	0.16	0.16
14	1731	Ova	3	3	AE	40	2	5	5.80	5.14	16.72	10.92	0.93	0.16	0.11
15	2029	Ova	2	3	AE	40	3	2	6.00	5.05	17.47	11.47	0.85	0.17	0.13
15	2029	Ova	2	3	AE	40	3	3	4.00	5.85	15.49	11.49	0.90	0.20	0.16
15	2029	Ova	2	3	AE	40	3	4	5.20	6.99	15.86	10.66	0.90	0.19	0.18
15	2029	Ova	2	3	AE	40	3	5	6.20	6.41	18.36	12.16	0.98	0.16	0.10
16	1515	Cap	4	3	AE	40	1	2	9.00	5.35	19.09	10.09	0.87	0.17	0.13
16	1515	Cap	4	3	AE	40	1	3	4.10	5.46	14.77	10.67	0.91	0.17	0.16
16	1515	Cap	4	3	AE	40	1	4	3.30	4.80	14.27	10.97	0.85	0.17	0.20
16	1515	Cap	4	3	AE	40	1	5	7.60	6.62	19.59	11.99	0.99	0.18	0.09
17	1718	Cap	3	3	AE	40	2	2	3.90	4.10	17.23	13.33	1.00	0.16	0.13
17	1718	Cap	3	3	AE	40	2	3	3.10	3.97	12.91	9.81	0.87	0.16	0.15
17	1718	Cap	3	3	AE	40	2	4	3.30	5.38	12.84	9.54	0.81	0.12	0.13
17	1718	Cap	3	3	AE	40	2	5	3.20	5.24	14.10	10.90	0.95	0.16	0.11
18	2003	Cap	2	3	AE	40	3	2	8.00	3.71	16.89	8.89	0.82	0.15	0.10
18	2003	Cap	2	3	AE	40	3	3	3.20	4.66	12.82	9.62	0.84	0.16	0.14
18	2003	Cap	2	3	AE	40	3	4	3.60	4.87	13.12	9.52	0.82	0.14	0.15
18	2003	Cap	2	3	AE	40	3	5	4.60	4.94	14.83	10.23	0.94	0.16	0.14
19	1727	Ova	3	4	AE	60	1	2	8.00	5.10	17.14	9.14	0.82	0.16	0.13
19	1727	Ova	3	4	AE	60	1	3	3.80	5.16	14.11	10.31	0.86	0.13	0.12
19	1727	Ova	3	4	AE	60	1	4	4.50	6.03	12.64	8.14	0.86	0.16	0.15
19	1727	Ova	3	4	AE	60	1	5	6.30	5.92	17.94	11.64	1.08	0.14	0.09
20	1457	Ova	4	4	AE	60	2	2	7.90	5.52	16.55	8.65	0.94	0.14	0.10
20	1457	Ova	4	4	AE	60	2	3	3.20	4.31	12.94	9.74	0.91	0.15	0.13
20	1457	Ova	4	4	AE	60	2	4	2.80	4.88	12.67	9.87	0.82	0.14	0.15

20	1457	Ova	4	4	AE	60	2	5	3.00	5.77	13.99	10.99	1.03	0.15	0.09
21	1021	Ova	3	4	AE	60	3	2	.	.	.	.	.	.	.
21	1021	Ova	3	4	AE	60	3	3	.	.	.	.	.	.	.
21	1021	Ova	3	4	AE	60	3	4	.	.	.	.	.	.	.
21	1021	Ova	3	4	AE	60	3	5	.	.	.	.	.	.	.
22	1706	Cap	3	4	AE	60	1	2	7.00	4.05	16.66	9.66	0.86	0.14	0.09
22	1706	Cap	3	4	AE	60	1	3	2.70	5.12	12.81	10.11	0.90	0.15	0.14
22	1706	Cap	3	4	AE	60	1	4	6.60	5.08	16.52	9.92	0.98	0.17	0.17
22	1706	Cap	3	4	AE	60	1	5	3.90	4.47	14.10	10.20	0.92	0.13	0.09
23	2010	Cap	2	4	AE	60	2	2	6.80	4.52	16.02	9.22	0.83	0.16	0.12
23	2010	Cap	2	4	AE	60	2	3	4.00	4.72	12.93	8.93	0.80	0.14	0.13
23	2010	Cap	2	4	AE	60	2	4	4.80	4.50	13.82	9.02	0.80	0.13	0.14
23	2010	Cap	2	4	AE	60	2	5	5.70	4.81	15.90	10.20	0.97	0.14	0.12
24	2006	Cap	2	4	AE	60	3	2	7.00	3.31	17.06	10.06	0.81	0.15	0.11
24	2006	Cap	2	4	AE	60	3	3	4.00	5.05	12.89	8.89	0.83	0.15	0.14
24	2006	Cap	2	4	AE	60	3	4	3.50	4.31	13.09	9.59	0.84	0.15	0.16
24	2006	Cap	2	4	AE	60	3	5	5.20	5.34	15.35	10.15	0.92	0.11	0.09
25	1469	Ova	4	5	DC	20	1	2	6.20	4.09	16.51	10.31	0.99	0.16	0.12
25	1469	Ova	4	5	DC	20	1	3	4.60	5.76	14.50	9.90	0.80	0.17	0.12
25	1469	Ova	4	5	DC	20	1	4	3.40	4.83	13.88	10.48	0.88	0.17	0.14
25	1469	Ova	4	5	DC	20	1	5	3.80	5.07	14.25	10.45	1.00	0.13	0.07
26	1725	Ova	3	5	DC	20	2	2	7.30	5.35	17.29	9.99	0.89	0.18	0.14
26	1725	Ova	3	5	DC	20	2	3	4.40	5.11	14.98	10.58	0.90	0.17	0.15
26	1725	Ova	3	5	DC	20	2	4	4.40	5.44	15.10	10.70	0.85	0.15	0.14
26	1725	Ova	3	5	DC	20	2	5	4.90	5.26	16.18	11.28	1.01	0.11	0.08
27	2025	Ova	2	5	DC	20	3	2	7.70	4.65	17.53	9.83	0.84	0.20	0.15
27	2025	Ova	2	5	DC	20	3	3	2.30	5.85	14.14	11.84	0.87	0.17	0.15
27	2025	Ova	2	5	DC	20	3	4	3.90	4.18	14.03	10.13	0.87	0.15	0.15
27	2025	Ova	2	5	DC	20	3	5	4.30	4.84	15.81	11.51	0.90	0.14	0.13
28	0914	Cap	4	5	DC	20	1	2	8.20	4.97	17.33	9.13	0.78	0.17	0.12
28	0914	Cap	4	5	DC	20	1	3	3.00	5.14	12.99	9.99	0.87	0.16	0.13
28	0914	Cap	4	5	DC	20	1	4	4.30	4.74	14.00	9.70	0.82	0.10	0.10
28	0914	Cap	4	5	DC	20	1	5	3.90	5.77	15.41	11.51	0.96	0.15	0.05

29	1025	Cap	5	5	DC	20	2	2	5.90	4.67	15.55	9.65	0.81	0.16	0.11
29	1025	Cap	5	5	DC	20	2	3	4.20	4.59	12.18	7.98	0.86	0.16	0.13
29	1025	Cap	5	5	DC	20	2	4	3.20	4.30	13.56	10.36	0.82	0.15	0.15
29	1025	Cap	5	5	DC	20	2	5	2.90	4.65	13.38	10.48	0.88	0.12	0.07
30	0810	Cap	5	5	DC	20	3	2	4.50	5.41	14.27	9.77	0.88	0.18	0.12
30	0810	Cap	5	5	DC	20	3	3	2.00	5.12	11.36	9.36	0.84	0.16	0.12
30	0810	Cap	5	5	DC	20	3	4	2.30	3.74	11.75	9.45	0.81	0.13	0.13
30	0810	Cap	5	5	DC	20	3	5	2.70	4.65	12.48	9.78	0.92	0.12	0.03
31	1737	Ova	3	6	DC	40	1	2	6.00	4.25	17.12	11.12	0.87	0.16	0.15
31	1737	Ova	3	6	DC	40	1	3	2.60	3.95	12.26	9.66	0.90	4.69	0.12
31	1737	Ova	3	6	DC	40	1	4	2.70	4.69	12.74	10.04	0.90	0.18	0.18
31	1737	Ova	3	6	DC	40	1	5	2.50	5.85	13.51	11.01	1.06	0.15	0.13
32	1746	Ova	3	6	DC	40	2	2	3.60	4.56	15.79	12.19	0.96	0.17	0.14
32	1746	Ova	3	6	DC	40	2	3	1.80	4.74	11.95	10.15	0.93	0.18	0.14
32	1746	Ova	3	6	DC	40	2	4	3.10	6.19	13.34	10.24	0.92	0.11	0.09
32	1746	Ova	3	6	DC	40	2	5	3.60	5.07	14.29	10.69	1.05	0.15	0.10
33	2033	Ova	2	6	DC	40	3	2	6.50	5.66	18.36	11.86	0.88	0.19	0.15
33	2033	Ova	2	6	DC	40	3	3	3.90	5.62	14.57	10.67	0.88	0.18	0.15
33	2033	Ova	2	6	DC	40	3	4	5.30	4.60	15.99	10.69	0.88	0.16	0.16
33	2033	Ova	2	6	DC	40	3	5	5.20	5.28	16.32	11.12	0.96	0.15	0.12
34	1519	Cap	4	6	DC	40	1	2	9.00	3.85	17.39	8.39	0.80	0.17	0.13
34	1519	Cap	4	6	DC	40	1	3	2.80	4.27	12.94	10.14	0.88	0.13	0.11
34	1519	Cap	4	6	DC	40	1	4	2.30	4.04	11.83	9.53	0.74	0.14	0.15
34	1519	Cap	4	6	DC	40	1	5	4.40	5.44	15.55	11.15	1.01	0.14	0.08
35	1030	Cap	3	6	DC	40	2	2	6.60	4.64	16.34	9.74	0.80	0.16	0.14
35	1030	Cap	3	6	DC	40	2	3	2.00	3.92	11.66	9.66	0.79	0.18	0.14
35	1030	Cap	3	6	DC	40	2	4	2.10	6.25	12.08	9.98	0.79	0.11	0.11
35	1030	Cap	3	6	DC	40	2	5	4.50	5.12	15.69	11.19	0.94	0.15	0.07
36	1723	Cap	3	6	DC	40	3	2	5.80	4.58	15.02	9.22	0.75	0.19	0.15
36	1723	Cap	3	6	DC	40	3	3	3.50	4.97	13.24	9.74	0.79	0.16	0.12
36	1723	Cap	3	6	DC	40	3	4	4.40	6.13	14.31	9.91	0.77	0.13	0.12
36	1723	Cap	3	6	DC	40	3	5	4.70	6.03	16.56	11.86	0.89	0.12	0.07

37	2031	Ova	2	7	DC	60	1	2	6.00	4.93	17.65	11.65	0.85	0.18	0.11
37	2031	Ova	2	7	DC	60	1	3	2.20	4.12	11.85	9.65	0.87	0.18	0.15
37	2031	Ova	2	7	DC	60	1	4	3.30	4.39	13.12	9.82	0.87	0.17	0.10
37	2031	Ova	2	7	DC	60	1	5	3.20	4.44	13.52	10.32	0.96	.	.
38	2024	Ova	2	7	DC	60	2	2	8.00	5.36	18.96	10.96	0.85	0.18	0.11
38	2024	Ova	2	7	DC	60	2	3	4.50	5.76	15.36	10.86	0.87	0.18	0.15
38	2024	Ova	2	7	DC	60	2	4	5.80	5.40	16.62	10.82	0.87	0.17	0.10
38	2024	Ova	2	7	DC	60	2	5	6.00	6.12	17.58	11.58	0.96	.	.
39	2043	Ova	2	7	DC	60	3	2	8.00	4.32	16.09	8.09	0.83	0.19	0.15
39	2043	Ova	2	7	DC	60	3	3	4.50	5.28	12.58	8.08	0.83	0.16	0.13
39	2043	Ova	2	7	DC	60	3	4	5.80	4.52	12.58	6.78	0.83	0.18	0.20
39	2043	Ova	2	7	DC	60	3	5	6.00	5.20	13.76	7.76	0.89	.	.
40	1724	Cap	3	7	DC	60	1	2	9.00	9.00	4.98	-4.02	0.83	0.16	0.16
40	1724	Cap	3	7	DC	60	1	3	4.40	4.40	5.24	0.84	0.90	.	.
40	1724	Cap	3	7	DC	60	1	4	4.50	4.50	5.28	0.78	0.89	0.16	0.16
40	1724	Cap	3	7	DC	60	1	5	6.30	6.30	5.04	-1.26	0.97	.	.
41	1160	Cap	2	7	DC	60	2	2	6.00	4.88	15.83	9.83	0.79	0.16	0.13
41	1160	Cap	2	7	DC	60	2	3	4.80	4.76	14.62	9.82	0.92	0.27	0.20
41	1160	Cap	2	7	DC	60	2	4	5.20	4.89	16.23	11.03	0.85	0.19	0.17
41	1160	Cap	2	7	DC	60	2	5	6.80	5.97	18.54	11.74	0.97	.	.
42	2013	Cap	2	7	DC	60	3	2	7.00	5.00	17.61	10.61	0.89	0.17	0.13
42	2013	Cap	2	7	DC	60	3	3	3.30	4.99	13.26	9.96	0.91	0.17	0.15
42	2013	Cap	2	7	DC	60	3	4	4.70	5.17	15.02	10.32	0.92	0.12	0.12
42	2013	Cap	2	7	DC	60	3	5	4.00	6.42	16.20	12.20	1.04	.	.
43	2042	Ova	2	8	NS	0	1	2	6.10	4.31	15.31	9.21	0.80	0.15	0.11
43	2042	Ova	2	8	NS	0	1	3	5.10	4.82	14.65	9.55	0.86	0.17	0.14
43	2042	Ova	2	8	NS	0	1	4	4.80	5.20	14.39	9.59	0.90	0.14	0.14
43	2042	Ova	2	8	NS	0	1	5	5.50	5.98	16.57	11.07	0.96	.	.
44	2011	Cap	2	8	NS	0	1	2	4.00	3.35	16.11	12.11	0.90	0.18	0.15
44	2011	Cap	2	8	NS	0	1	3	3.10	5.49	12.24	9.14	0.80	0.15	0.14
44	2011	Cap	2	8	NS	0	1	4	2.60	3.88	12.14	9.54	0.80	0.13	0.15
44	2011	Cap	2	8	NS	0	1	5	2.10	5.37	15.37	13.27	0.97	.	.
45	2037	Ova	2	8	NS	0	2	2	8.00	4.82	15.88	7.88	0.76	0.15	0.11

45	2037	Ova	2	8	NS	0	2	3	3.60	4.38	14.82	11.22	0.83	.	.
45	2037	Ova	2	8	NS	0	2	4	5.30	4.02	14.49	9.19	0.73	0.16	0.14
45	2037	Ova	2	8	NS	0	2	5	6.00	4.25	16.51	10.51	0.84	.	.
46	2001	Cap	2	8	NS	0	2	2	4.40	4.13	16.73	12.33	0.82	0.17	0.13
46	2001	Cap	2	8	NS	0	2	3	3.10	4.19	12.57	9.47	0.84	0.16	0.13
46	2001	Cap	2	8	NS	0	2	4	2.30	6.05	12.74	10.44	0.82	0.14	0.13
46	2001	Cap	2	8	NS	0	2	5	2.80	5.74	15.86	13.06	0.96	.	.
47	2049	Ova	2	8	NS	0	3	2	7.00	4.78	19.73	12.73	0.88	0.18	0.14
47	2049	Ova	2	8	NS	0	3	3	5.70	5.12	15.99	10.29	0.86	.	.
47	2049	Ova	2	8	NS	0	3	4	5.00	4.66	15.13	10.13	0.88	0.10	0.18
47	2049	Ova	2	8	NS	0	3	5	5.50	5.31	16.04	10.54	0.91	.	.
48	1716	Cap	3	8	NS	0	3	2	3.60	4.79	18.20	14.60	0.90	0.17	0.12
48	1716	Cap	3	8	NS	0	3	3	5.70	4.61	15.26	9.56	0.83	0.16	0.14
48	1716	Cap	3	8	NS	0	3	4	4.70	4.93	14.99	10.29	0.76	.	0.15
48	1716	Cap	3	8	NS	0	3	5	5.01	6.28	18.07	13.06	0.97	.	.

OBS= Observation, DOEID= Doe identity number, ECOTY= Ecotype, TRT= Treatment, SUPP= Supplement, REP= Replicates, CP= Crude Protein, TS= Total Solids, SNF= Solid-Non-Fat, Ca= Calcium, P= Phosphorus, Com=commercial, AE=A. erioloba, DC=D. cinerea, NS=not supplemente

Table AP11.1 Experiment 4: Analysis of Variance for Milk composition by CRD

Table AP11.1.1 Analysis of variance for Fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	7.68996411	0.85444046	1.05	0.4177
Error	37	29.97979733	0.81026479		
Corrected Total	46	37.66976144			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	2.60721700	2.60721700	3.22	0.0810
Parity	1	0.01008648	0.01008648	0.01	0.9118
Treatment	7	5.05109500	0.72158500	0.89	0.5237

Table AP11.1.2 Analysis of variance for Protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	2.74830802	0.30536756	1.24	0.3028
Error	37	9.12776325	0.24669630		

Corrected Total	46	11.87607128			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	1.25661917	1.25661917	5.09	0.0300
Parity	1	0.58490015	0.58490015	2.37	0.1321
Treatment	7	1.18071856	0.16867408	0.68	0.6848

Table AP11.1.3 Analysis of variance of Total Solids

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	15.22630913	1.69181213	1.50	0.1851
Error	37	41.79356109	1.12955571		
Corrected Total	46	57.01987021			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	7.03033815	7.03033815	6.22	0.0172
Parity	1	0.01363411	0.01363411	0.01	0.9131
Treatment	7	6.69587798	0.95655400	0.85	0.5564

Table AP11.1.4 Analysis of variance for Solid-Non-Fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	6.50598520	0.72288724	2.14	0.0503
Error	37	12.48873129	0.33753328		
Corrected Total	46	18.99471649			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	1.07493472	1.07493472	3.18	0.0825
Parity	1	0.00026679	0.00026679	0.00	0.9777
Treatment	7	4.76207263	0.68029609	2.02	0.079

Table AP11.1.5 Analysis of variance for Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	0.03068885	0.00340987	2.07	0.0583
Error	37	0.06094998	0.00164730		
Corrected Total	46	0.09163883			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.01572419	0.01572419	9.55	0.0038
Parity	1	0.00416829	0.00416829	2.53	0.1202
Treatment	7	0.01273493	0.00181928	1.10	0.3808

Table AP11.1.6 Analysis of variance for Calcium

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	0.00313879	0.00034875	2.28	0.0381
Error	37	0.00566860	0.00015321		
Corrected Total	46	0.00880739			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.00025678	0.00025678	1.68	0.2035
Parity	1	0.00028388	0.00028388	1.85	0.1817
Treatment	7	0.00229106	0.00032729	2.14	0.0636

Table AP11.1.7 Analysis of variance for Phosphorus

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	0.00388595	0.00043177	2.44	0.0271
Error	37	0.00654177	0.00017680		
Corrected Total	46	0.01042772			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ecotype	1	0.00004434	0.00004434	0.25	0.6195
Parity	1	0.00086353	0.00086353	4.88	0.0334
Treatment	7	0.00148567	0.00021224	1.20	0.3268

Table AP11.2 The GLM Procedure for Milk composition by 2 x 3 Factorial designs

Table AP11.2.1 Analysis of variance for Fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	4.54751190	0.90950238	1.31	0.2876
Error	29	20.14741667	0.69473851		
Corrected Total	34	24.69492857			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	2.20654839	2.20654839	3.18	0.0852
Level	2	1.22597689	0.61298844	0.88	0.4246
Supplement*Level	2	1.00830762	0.50415381	0.73	0.4926

Table AP11.2.2 Analysis of variance for Protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.84422107	0.16884421	0.69	0.6351
Error	29	7.09738250	0.24473733		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Corrected Total	34	7.94160357			
Supplement	1	0.01167422	0.01167422	0.05	0.8286
Level	2	0.45024803	0.22512402	0.92	0.4099
Supplement*Level	2	0.38175637	0.19087818	0.78	0.4678

Table AP11.2.2 Analysis of variance of Total Solids

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	7.18624149	1.43724830	1.29	0.2965
Error	29	32.38682208	1.11678697		
Corrected Total	34	39.57306357			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.57601185	0.57601185	0.52	0.4784
Level	2	1.43708234	0.71854117	0.64	0.5328
Supplement*Level	2	4.91697616	2.45848808	2.20	0.1288

Table AP11.2.3 Analysis of variance of Solid-Non-Fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	3.31805220	0.66361044	2.53	0.0508
Error	29	7.59334708	0.26183955		
Corrected Total	34	10.91139929			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.52778927	0.52778927	2.02	0.1663
Level	2	1.47222824	0.73611412	2.81	0.0766
Supplement*Level	2	1.47881151	0.73940576	2.82	0.0758

Table AP11.2.4 Analysis of variance for Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.00697795	0.00139559	0.79	0.5687
Error	29	0.05153563	0.00177709		
Corrected Total	34	0.05851357			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.00000732	0.00000732	0.00	0.9493
Level	2	0.00419387	0.00209693	1.18	0.3216
Supplement*Level	2	0.00268417	0.00134208	0.76	0.4789

Table AP11.2.5 Analysis of variance of Calcium

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.00246899	0.00049380	2.84	0.0329
Error	29	0.00503347	0.00017357		
Corrected Total	34	0.00750246			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.00014325	0.00014325	0.83	0.3711
Level	2	0.00001193	0.00000596	0.03	0.9663
Supplement*Level	2	0.00233771	0.00116885	6.73	0.0040

Table AP11.2.6 Analysis of variance of Phosphorus

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.00220991	0.00044198	2.03	0.1035
Error	29	0.00630743	0.00021750		
Corrected Total	34	0.00851734			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Supplement	1	0.00002339	0.00002339	0.11	0.7453
Level	2	0.00068167	0.00034083	1.57	0.2258
Supplement*Level	2	0.00140446	0.00070223	3.23	0.0542

Table AP12 Experiment 4: GOAT MILK SENSORY EVALUATION SHEET

Objective: To determine the effect of supplementation on sensory parameters of goat milk

The evaluation ratings were scored at 5-point-scale where; **1= like very much; 2= like; 3= neither like nor dislike; 4=dislike and 5= dislike very much**

Product F: Fresh milk

Parameter	Product 1F	Product 2F	Product 3F	Product 4F	Product 5F	Product 6F	Product 7F	Product 8F
Colour								
Aroma								
Flavour								
Texture								
Consistency								
Overall palatability								

Product M: Fermented sour-milk/*Omaere*

Parameter	Product 1M	Product 2M	Product 3M	Product 4M	Product 5M	Product 6M	Product 7M	Product 8M
Colour								
Aroma								
Flavour								
Texture								
Consistency								
Overall palatability								

Product Y: Plain Yoghurt

Parameter	Product 1y	Product 2y	Product 3y	Product 4y	Product 5y	Product 6y	Product 7y	Product 8y
Colour								
Aroma								
Flavour								
Texture								
Consistency								
Overall palatability								

Thank you for your time and support to the milk taste-test exercise Have a nice day!

Table AP13 Experiment 4: CONSUMER ACCEPTANCE PANEL CONSENT FORM

GOAT MILK SENSORY EVALUATION

By signing this document, I declare that:

I have been informed about and understand the purpose of this study

I have been given the opportunity to ask questions

I understand that I can withdraw at any time without negative consequence or prejudice

I understand that any information which might potentially identify me will not be used in the published materials

I understand that all data from the consumer test will be confidential and stored in a secure location within the Directorate of Agricultural Research and Development, Division of Livestock Research, Analytical Service and Product Development, Ministry of Agriculture, Water and Forestry, Government Office Park.

I declare that I am not allergic or intolerant to milk and milk products I agree to participate in the study as outlined to me.

Name: ……………………

Signature: ………………… Date: ……………………..

Table AP14 Experiment 4: Analysis of variance tables for Sensory Evaluation

(Data Table for Sensory mean scores was too large and therefore it was not included in the appendices)

Table AP14.1 Sensory mean scores for products

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	135.189236	7.952308	7.12	<.0001
Error	2862	3197.268750	1.117145		
Corrected Total	2879	3332.457986			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Product	2	53.73819444	26.86909722	24.05	<.0001
Character	5	65.48923611	13.09784722	11.72	<.0001
Product*Character	10	15.96180556	1.59618056	1.43	0.1609

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Product	2	53.73819444	26.86909722	24.05	<.0001
Character	5	65.48923611	13.09784722	11.72	<.0001
Product*Character	10	15.96180556	1.59618056	1.43	0.1609

Table AP14.2 Sensory mean score for treatments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	134.841319	2.868964	2.54	<.0001
Error	2832	3197.616667	1.129102		
Corrected Total	2879	3332.457986			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	53.94409722	7.70629960	6.83	<.0001
Character	5	65.48923611	13.09784722	11.60	<.0001
T*C	35	15.40798611	0.44022817	0.39	0.9995

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	7	53.94409722	7.70629960	6.83	<.0001
Character	5	65.48923611	13.09784722	11.60	<.0001
T*C	35	15.40798611	0.44022817	0.39	0.9995

Table AP14.3 Sensory mean score for Fresh Milk

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	60.233333	1.281560	1.18	0.1898
Error	912	987.700000	1.083004		
Corrected Total	959	1047.933333			
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	14.96666667	2.13809524	1.97	0.0557
Character	5	28.99583333	5.79916667	5.35	<.0001
T*C	35	16.27083333	0.46488095	0.43	0.9986
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	7	14.96666667	2.13809524	1.97	0.0557
Character	5	28.99583333	5.79916667	5.35	<.0001
T*C	35	16.27083333	0.46488095	0.43	0.9986

Table AP14.4 Sensory mean score for Fermented-sour milk

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	87.073958	1.852637	1.41	0.0394
Error	912	1201.750000	1.317708		
Corrected Total	959	1288.823958			
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	41.11562500	5.87366071	4.46	<.0001
Character	5	23.70520833	4.74104167	3.60	0.0031
T*C	35	22.25312500	0.63580357	0.48	0.9954
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	7	41.11562500	5.87366071	4.46	<.0001
Character	5	23.70520833	4.74104167	3.60	0.0031
T*C	35	22.25312500	0.63580357	0.48	0.9954

Table AP14.5 Sensory mean score for Yoghurt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	69.0625000	1.4694149	1.54	0.0131
Error	912	872.9000000	0.9571272		
Corrected Total	959	941.9625000			
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Treatment	7	25.14583333	3.59226190	3.75	0.0005
Character	5	28.75000000	5.75000000	6.01	<.0001
T*C	35	15.16666667	0.43333333	0.45	0.9976
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment	7	25.14583333	3.59226190	3.75	0.0005
Character	5	28.75000000	5.75000000	6.01	<.0001
T*C	35	15.16666667	0.43333333	0.45	0.9976