EFFECT OF COWPEA CULTIVAR SUPPLEMENTATION ON PRODUCTIVITY OF PEDI GOATS AND DORPER SHEEP FED *AD LIBITUM* BUFFALO GRASS

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DECLARATION

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

Signed: ………………………………… Date: ……………………………………
KE Ravhuhali (Mr.)

[redacted]

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ABSTRACT

Two studies were carried out to investigate the effect of cowpea cultivar supplementation on productivity of Pedi goats and Doper sheep fed *ad libitum* buffalo grass. Experiment 1 investigated the effect of cowpea cultivars supplementation on productivity of Pedi goats fed *ad libitum* buffalo grass hay using twelve goats that were assigned in a completely randomized design. The Pedi goats were fed ad libitum a basal diet of buffalo grass supplemented with four levels each of four cowpea cultivars namely, *Pan 311, Red caloona*, *Black eye* and *Agripes*. The four levels fed were 50, 100, 150 and 200 g/day. The experiment involved a 25 day preliminary period and a five day collection period during which feed intake, digestibility, live weight changes and nitrogen were measured. Based on available data, all the cowpea cultivars contained more than 15 % crude protein and can therefore be used as protein supplements to goats on low quality roughage. *Pan 311* had higher feeding value ($p<0.05$), although it contained the highest concentration of condensed tannins. The concentration of tannins in Pan 311 did not exert negative effects on intake and digestibility. The data on a *in vitro* enzymatic digestibility of the cowpea cultivars and buffalo grass hay demonstrated that the cowpea cultivars had higher *in vitro* DM, OM and protein digestibilities that ranged from 0.64 to 0.75. The cowpea cultivars have high in vitro digestibility values thus implicating their suitability as supplements. Also chemical contents of the cowpea cultivars and the buffalo grass hay had poor capacity to predict forage *in vitro* digestibility. Forage intake and growth rate of Pedi goats were poorly predicted from *in vitro* digestibility. Experiment 11 investigated the intake and relative palatability indices of four cowpea cultivars offered to Pedi goats and Dorper sheep fed low quality buffalo grass hay. The experiment was a 2 (animal species goats and sheep) x 5 diets (four cowpea cultivars and buffalo grass hay) factorial arrangement in a completely randomized design. Intake and palatability of the goats and sheep were higher in *Pan 311*. Sheep had higher voluntary feed intake values than goats, but palatability indices were higher in goats than in sheep. Goats were better than sheep in the palatability indices ranking of the four cowpea cultivars. This seems

to demonstrate that goats are better suited for assessing palatability indices ranking of cowpea hays and other similar legumes. Forage intakes and palatability indices ranking were poorly predicted from their nutrient. Growth of the goats was well predicted by forage *in vivo* digestibility and palatability indices. Also, forage intakes accurately predicted the palatability indices of the cowpea cultivars by the goats and sheep.

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Cowpea, *Vigna unguiculata*, is one of the legumes grown by farmers around Limpopo province of South Africa. The crop is indigenous to Africa and is used in many cropping systems throughout Africa. Cowpea is a drought-tolerant crop with a higher protein content and lower soil fertility requirements than many other crops (Dadson *et al.,* 2005). Cowpea, generally, contains high concentration of most nutritional valuables (Bressani, 2002). Cowpea forages have been looked at as possible alternative sources of protein and energy for livestock during winter and dry seasons (Mokoboki, 2007). However, the use of cowpea cultivars grown in Limpopo province as protein supplements for goats and sheep has not been extensively studied.

1.2 Problem statement

Most of the goats and sheep in rural areas of Limpopo province depend on available low quality roughages during winter and dry months. These low quality roughages are limiting in a number of nutrients, for example proteins, vitamins, etc., thus, they are characterized by low intake and digestibility values when eaten alone by ruminant animals (Reyes *et al.,* 2006). Low productivity is the end result of using low quality roughages as feed and any means of improving their feeding value is potentially valuable. There is, therefore, need for supplementary feeding to improve the productivity of these goats and sheep.

1.3 Motivation

The study will add knowledge to the understanding of the use of cowpea hay as a supplement for goats and sheep fed low quality roughages. Goat and sheep farmers in Limpopo province will utilize this knowledge to improve productivity of their animals. This will, hopefully, improve the nutritional and economic status of the farmers.

1.4 Aim and objectives

The aim of this study was to determine productivity of Pedi goats and Dorper sheep fed buffalo grass and supplemented with cowpea forages.

The objectives of the study were:

1. To determine the chemical composition of different cowpea cultivars.
2. To determine effect of cowpea cultivar on *in vitro* enzymatic digestibility.
3. To determine the effects of cowpea cultivar supplementation on diet intake, digestibility, and the productivity of Pedi goats fed a low quality buffalo grass hay.
4. To determine palatability indices of different cowpea cultivars when offered to Pedi goats and Dorper sheep fed a low quality buffalo grass hay.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Sheep and goats are widely distributed across Limpopo province. These animals are economically and nutritionally very important to rural communities. However, the vast majority of these ruminant livestock in rural areas depend on communal natural pastures and forages for their nutrient requirements (Becholie *et al.,* 2005). In most cases, these pastures are overgrazed and, thus, they do not provide adequate nutrients for a high level of productivity among the ruminant livestock in the Limpopo Province (Mokoboki *et al.,* 2000). Improvements in ruminant productivity and efficiency of feed utilization from low quality pastures, such as buffalo grass, etc., can be achieved by the addition of small amounts of supplements such as cowpeas that can provide limiting nutrients (Leng, 1990; Preston and Leng, 1986). Singh and Tarawali (1997) reported that cowpea is an important fodder crop for livestock. Similarly, Ehlers and Hall (1997) and Mortimore *et al.* (1997) observed that cowpea is an important crop in Africa. Singh *et al.* (1997) reported that Southern Africa is depicted as the most probable centre of speciation of cowpea. However, not much information is available on nutritive, palatability and feeding values of cowpea cultivars grown in Limpopo province when offered to goats and sheep as supplements.

2.2 Palatability and dietary preferences by small ruminants

It has been proposed that animal feed preferences originate from the interrelationship between a feed's taste and its post-ingestive feedback, which is determined by an animal's physiological state and a feed's chemical characteristics (Provenza, 1995). Hadjigeorgiou *et al.* (2003) also observed that the chemical composition of a forage influences its palatability. However, there are other factors of the plant which also influence its palatability. Among such factors are species, intranspecific variation, morphology or physical traits, succulence and or maturation (Marten, 1978). Arnold *et al.* (1980) conducted an experiment which indicated that the sense of smell is critically involved in food selection, probably in complex interactions with the sense of taste. Other factors that also relate to a plant's palatability include the presence of secondary metabolites, such as tannins, volatile oils, alkaloids and glycocides (Bryant *et al.,* 1991; Cheeke and Skull, 1985).

Secondary metabolites cause ruminants to limit intake of even the most nutritive food (Tanner *et al.,* 1990). An alternative explanation for the lack of a difference in dry matter intake may be found in the interactions between nutrient intake rate and detoxification of plant secondary metabolites such as tyramine and N-methyl -β-phenethylamine (Nantoume *et al.,* 2001). For instance, sheep and goats have been shown to select diets which differ in chemical composition (Gurung *et al.,* 1994; Ngwa *et al.,* 2003; Wilson *et al.,* 1975). They also have the mechanisms which enable them to detoxify harmful components present in certain plants (McArthur *et al.,* 1991), but this capacity is seldom exceeded because the animals quickly experience internal malaise and limit intake before toxicosis occurs.

Malaise from nutrient deficient diets could also cause animals to acquire preferences for feeds that rectify deficits (Rozin, 1976). Attempts have been made to explain the observed differences in diet selection on grounds of nutrient requirements and physiology, which postulate that goats differ from sheep in energy, nitrogen and dietary fibre requirements, digestive capacity and the rate of passage of undigested residues (Alam *et al.,* 1985; Brown and Johnson, 1985; Lu, 1988).

Results from different studies that examined the effects on palatability of the long-term intake of forages by ruminants are equivocal (Doyle, 1988; Gherardi and Black, 1991; Greenhalgh and Reid, 1971; Makkar, 2003; Marten, 1978; Weston and Davis, 1986). In some studies, no relationship was observed between preference for a forage and intake (Minson and Bray, 1986), whereas in other studies palatability was assumed to be responsible for observed differences in intake (Doyle, 1988; Greenhalgh and Reid, 1971; Weston and Davis, 1986). However, strong correlations exist between many of the chemical constituents in plants as well as between chemical composition and herbage morphology or phenology, which limit the interpretation of the differences observed in diets (Minson, 1990; Thompson and Poppi, 1990). Irvins (1955) could not establish the correlation between the relative palatability and the chemical composition of a forage and its preference. Similarly, Kaitho *et al.* (1996) observed the poor relationship between palatability and chemical constituents. It is, therefore, important to determine the palatability of cowpea cultivars when fed with low quality buffalo grass to sheep and goats.

2.3 Nutrient requirements for sheep and goats

Nutrient requirements are based on maintenance of normal body functions over time and they are adjusted accordingly to accommodate other physiological states (growth, pregnancy, lactation and work). Nutrient requirements can also depend on quality of feed, acclimatization, previous nutritional plane and environmental conditions (Sahlu *et al.,* 2004). Temperature, humidity, sunshine and wind velocity may increase or decrease nutrient needs depending upon the region (NRC, 1981). Even animals of uniform breed, age and sex differ from one another in nutritional needs, and the needs of individuals change within a meal, from meal to meal, and across days (Provenza, 1996; Provenza *et al.,* 2003). Nutrient limitations prevent small ruminants from attaining their genetic potential. Thus, an optimum growth rate and feed utilization efficiency according to inherent genetic potentiality of a particular category of animals can be achieved only through accurate evaluation of their nutrient requirements (Mandal *et al.,* 2005).

Nutrient requirements can also provide satisfactory guidelines for formulation of rations for rearing the animals and also provide guidelines in developing supplementary feeding strategies for small ruminants reared under semi-intensive systems. The minimum nutrient requirements for sheep and goats as suggested by NRC (1981; 1985) are presented in Tables 2.01 and 2.02, respectively.

2.4 Cowpeas

2.4.1 The nutritive value of cowpeas

Cowpeas are important legumes and sources of protein in livestock diets (Giami, 2005). Compared to grasses, cowpeas have a relatively higher concentration of crude protein. Bressani (1985) and Nielsen *et al.* (1997) indicated that the crude protein content ranges from 22 to 30% in the grain and leaves, and from 13 to 17% in the haulms with a high digestibility and low fibre level (Tarawali *et al.,* 1997).

Table 2.01 Daily nutrient requirements of sheep (NRC, 1985)

	Mass (kg)	Wt change(g)	DMI (kg)	ME (Mcal)	DE (Mcal)	TDN (kg)	CP (g)	P (g)	Ca (g)	Vit A (IU)
Lamb	30	295	1.0	3.4	4.1	0.94	191	3.2	6.6	1.410
	50	205	1.2	4.4	5.4	1.23	160	3.0	5.6	2.350
Pregnant	70	225	1.9	4.4	5.4	1.24	214	4.5	7.6	5.950
	90	225	2.1	5.0	6.0	1.37	232	5.7	8.9	7650
Lactating	70	-25	2.5	5.9	7.2	1.63	334	7.0	9.3	5.950
	90	-25	2.7	6.3	7.6	1.75	353	7.8	9.6	7.650
Rams	80	290	2.8	6.4	7.8	1.8	268	4.6	8.5	3760
	100	250	3.0	6.9	8.4	1.9	264	4.8	8.2	4.700

DMI: Dry matter intake; ME: Metabolisable energy; DE: Digestible energy; TDN: Total digestible nutrients; CP: Crude protein; P: Phosphorus; Ca: Calcium. Vit A: Vitamin A

The chemical composition and nutritional properties of cowpeas have been shown to vary considerably according to cultivar (Akinyele *et al.,* 1986; Longe, 1983). The chemical composition of cowpea is also influenced by environmental and genetic factors (Singh *et al.,* 2006). Evaluation of the nutritional characteristics of cowpeas is important because of the recent increase in the use of this material in ruminant livestock diets (Reed, 1995). Arora and Das (1976) reported that total soluble sugars, starch, and organic matter of cowpeas range from 179 to 275, 138 to 198, and 507 to 670 g kg^{-1}, respectively. Generally, it has been observed that cowpea leaves have less crude protein than seeds (Gohl, 1981). Table 2.03 presents the protein contents of different cowpea parts.

Table 2.02 Daily nutrient requirements of goats (NRC, 1981)

Mass (kg)	DMI intake (kg)	TDN (g)	DE (Mcal)	ME (Mcal)	CP (g)	DP (g)	C (g)	P (g)	VIT A (1000 IU)
10	0.28	159	0.70	0.57	22	15	1	0.7	0.4
20	0.48	267	1.18	0.96	38	26	1	0.7	0.7
30	0.65	362	1.59	1.30	51	35	2	1.4	0.9
40	0.81	448	1.98	1.61	63	43	2	1.4	1.2
50	0.95	530	2.34	1.91	75	51	3	2.1	1.4
60	1.09	608	2.68	2.19	86	59	3	2.1	1.6
70	1.23	682	3.01	2.45	96	66	4	2.8	1.8
80	1.36	754	3.32	2.71	106	73	4	2.8	2.0
90	1.48	824	3.63	2.96	116	80	4	2.8	2.2
100	1.60	891	3.93	3.21	126	86	5	3.5	2.4

Above: Maintenance only (includes stable feeding conditions and minimal activity)

Below: Maintenance plus low activity (=25 % increment, intensive management, tropical range and early pregnancy)

10	0.36	199	0.87	0.71	27	19	1	0.7	108
20	0.60	334	1.47	1.20	46	32	2	1.4	180
30	0.81	452	1.99	1.62	62	43	2	1.4	243
40	1.01	560	2.47	2.02	77	54	3	2.1	303

DMI: Dry matter intake; TDN: Total digestible nutrients; DE: Digestible energy; ME: Metabolisable energy; CP: Crude protein; DP: Digestible protein; Ca: Calcium; P: Phosphorus; Vit A: Vitamin A

2.4.2 Tannins in cowpeas

Tannins are high-molecular-weight and phenol-rich polymers that exist in many feeds, including legumes (Chang *et al.,* 1994). Although tannins are chemically a diverse and ill-defined group, it is usual to divide them into two types, the hydrolysable and the condensed tannins (Mangan, 1988). Condensed tannins are polymers of flavin-3-ols linked through acid-labile carbon-carbon-bonds; hydrolysable tannins, or tannic acids, are composed of gallic acid or its condensation product, ellagic acid, esterified to the hydroxyl groups of glucose. Tannins are naturally occurring plant polyphenols, which have been reported to have negative nutritive effects on animals consuming them in their diets (Mole *et al.,* 1990). High contents of condensed tannins in forage legumes have been suggested to be possible causes of reduced feeding values for ruminants (Ahn *et al.,* 1989; Palmer and Schlink, 1992).

Table 2.03 Chemical composition of different cowpea parts

	DM (%)	OM (g/kgDM)	CP (%)	NDF (%)	ADF (%)	EE (%)	AUTHORS
Roots		927	9.15	7.7			Savadogo *et al.,* 2000
Stems	91.9	934	7.8				Savadogo *et al.,* 2000
Leaves	88.5	932	14.6				Savadogo *et al.,* 2000
Leaves		393	26.1			1.05	Rivas-Vegas *et al.,* 2006
Leaves			14.7			0.3	Kay, 1979; Tindall, 1983
Leaves			15.4	37.2	21.2		Baloyi *et al.,* 2001
Leaves		909	14.4	51.1		2.3	Van Wyk, 1955
leaves	90.9	919	22.4	50.72	38.67		Chakeredza *et al.,* 2002
Seeds		903.6	20.3			1.9	Onder *et al.,* 2006
Seeds		952	23.8	30.0	6.8	1.7	Singh *et al.,* 2006
Seeds		560	24			1.3	Kay, 1979; Tindall, 1983

DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; CP: Crude protein, EE: Ether extract.

Tannins lead to decreased growth and body weight gain in ruminant animals (Waghorn *et al.,* 1994). The author furthermore, indicated that it can also be involved in the control of bloat. At low to medium concentrations, tannins may increase protein utilization (Reed, 1995). Tannins have also been reported to impair calcium absorption (Chang *et al.,* 1994), which potentially could also affect bone metabolism. Brune *et al.* (1989) showed that tannins can also interfere with iron absorption, an effect that may be related to the presence of galloyl groups. Another major problem in using tanniniferous feeds in animal diets is that they contain anti-nutritional factors such as protease inhibitors and phytic acid that cause the nutrients to be less available for the organisms. For instance, a review by Paterson *et al.* (1993) suggests that the presence of tannins, because of their astringency, alkaloids and their bitter taste, can reduce the feeding value and fodder palatability. Likewise tannin-protein interactions, long believed to be responsible for the formation of astringency in unripe fruits (Patte, 1985), may decrease nutritional quality of some cereals and legumes (Salunkhe *et al.,* 1982) and deactivate certain digestive enzymes (Cooper and Owen-Smith, 1985; Frutos *et al*., 2002; Makkar, 2003; Milic *et al.,* 1972; Oh and Hoff, 1986). However, the effects of tannins on digestion and ruminant performance are variable (Waghorn *et al.,* 1994). Mendoza *et al.* (1980) reported that, in 10 cultivars of cowpeas investigated, trypsin inhibitor levels were lower than in other species of beans, and the hemagglutinating activities were non-detectable.

Cowpea varieties were found with high amount of condensed tannins (Price *et al.,* 1980). This concentration of condensed tannins (0 to 0.7%) was reported to be sufficiently high to be nutritionally harmful. Therefore, to diminish these harmful effects, Cruz-Suárez *et al.* (2001) suggested processes that allow the destruction or inactivation of the anti-nutritional factors.

2.4.3 Feeding values of cowpeas

The feeding value of cowpea hay has long been recognized, as it has been used extensively for all kinds of livestock in Africa (Thompson *et al.,* 1988). The above-ground parts of cowpea, except pods, are harvested for fodder. Cowpeas may be used green or as dry fodder. Digestibility and yield of certain cultivars are satisfactory and if cowpea hay is well-cured, it provides high nutritive value. The principal value of this hay lies in its high percentage of digestible protein. Leng *et al.* (1992) suggested that the role of cowpeas in ruminant diets can be seen as three fold, firstly, as a nitrogen and mineral supplement to enhance fermentative digestion and microbial growth efficiency in the rumen of ruminants on poor quality forage. It can be a source of post-ruminal protein for digestion. Mupangwa *et al*. (2000) indicated that dry matter digestibility was higher for legume hays. The organic matter digestibility ranged from 0.579 for cassia hay to 0.617 for stylo hay and there were no differences among the legume hays.

Cowpeas are also total feeds, supplying almost all the biomass and other nutrients needed to support high levels of animal production. Tarawali *et al.* (1997) found the cowpea species valuable after reviewing the literature on the use of cowpea haulms as fodder in different parts of the world. Several authors (N'Jai, 1998; Singh *et al.,* 2003; Singh *et al.,* 2006) have also described the use of cowpea residues as a supplement to low quality roughages in animal production. The level of supplement required will depend on the quality of the basal diet (Norton *et al.,* 1992). Singh *et al.* (2003) also found that incremental levels of cowpeas as a supplement to poor quality roughages indicate that they are valuable to animals. When cowpeas were fed to lambs under drylot conditions the animals gained weight as well as those receiving an oat-hay-corn- soybean diet (Thompson *et al.,* 1988).

Singh *et al.* (2006) found that there were differences in total dietary intake on sheep due to differences in the intake of the basal diet. On the value of legume hays for dairy heifers, Dvorachek (1929) found that cowpea hay was about equal to other leguminous hays (alfalfa hay) for producing body gains on dairy heifers, the tendency being to lay on more fat. Cowpea hay was not as palatable, nor was it consumed with as little waste as alfalfa hay. Cowpeas are likely to be a significant source of minerals when fed in high amounts but animals are likely to require supplementation where dry feeds deficient in minerals make up 20–30% of the total dry matter intake (Goodchild and McMeniman, 1994).

2.5 Buffalo grass

Buffalo grass is important for ruminant livestock in South Africa. The foliage is nutritious and palatable when green, and its nutritional quality does not decline greatly as it cures (Hitchcock, 1951; Kuchler, 1964) but its protein content is low (Table 2.04) and its digestibility diminishes quickly with age (Table 2.05). For instance, early vegetative grass contains protein of high digestibility (76.2 %) as compared to hay digestibility (54.0 %) (French, 1943). However, there have been conflicting reports about the NDF and ADF contents of buffalo grass. For instance, Moore and Mott (1973) observed that the NDF contents of buffalo grass range between 65 and 78 %. Everitt and Alaniz (1982) found that ADF values ranged from 31.7 to 49.9 %. Buffalo grass hay is characterized by the low CP which ranges from 5 to 11 % (Aganga *et al.,* 1999). *In vitro* dry matter digestibility of buffalo grass ranges between 55 and 65 % (Tiwari *et al.,* 2001).

Table 2.04 Chemical composition of buffalo grass at different stages of growth

	DM	CP	CF	Ash	EE	NFE	NDF	Authors
Early vegetative (%)	41.4	9.8	38.4	9.8	5.4	36.6		French, 1943
Fresh mature (%)	21.9	7.8	41.9	8.8	4.8	37.2		French, 1943
Fresh, early bloom (%)	20.0	11.0	31.9	13.2	2.6	41.3		French, 1943
Hay, first cutting (%)	87.0	7.4	35.2	11.7	1.7	44.0		French, 1943
Hay, first cutting (%)	93.2	4.7					76.5	Giacomini *et al.,* 2006
Hay, first cutting (%)	48.9	2.9	13.0	6.1				NAS, 1971.
Hay (g)	933.3	69.7	279.7	11.8	19.6			Aganga *et al.,* 1999

DM: Dry matter; CF: Crude fibre; CP: Crude protein; NFE: Nitrogen free extract; EE: Ether extract

Table 2.05 Digestibility of buffalo grass at different stages of growth by sheep

	Digestibility (%)							
	DM	CP	CF	EE	NFE	ME	NDF	Authors
Fresh, early bloom		76.2	76.2	85.0	72.9	2.50		French, 1943
Hay	47.7	54.0	71.6	47.0	67.5	2.22	54.4	French, 1943
Hay	47.7						54.4	Giacomini *et al.,* 2006

DM: Dry matter; CF: Crude fibre; CP: Crude protein; NFE: Nitrogen free extract; ME: Metabolisable energy; EE: Ether extract

2.6 Conclusion

Goats in Limpopo province depend on low quality roughages which are limiting in protein. The result is poor productivity, particularly during the winter and dry seasons. There is some evidence that supplementation of these low quality roughages with cowpea forages can improve productivity of the roughages. However, data on the utilization of different cowpea cultivars grown in Limpopo province by goats and sheep is not available. Additionally, the effects of tannins in these cultivars on goat productivity have not been extensively analysed. This study will, therefore, determine the effects of cowpea cultivar supplementation on diet intake, palatability and growth of Pedi goats and Dorper sheep.

CHAPTER THREE

EFFECT OF COWPEA CULTIVAR SUPPLEMENTATION ON INTAKE, DIGESTIBILITY AND PRODUCTIVITY OF PEDI GOATS FED *AD LIBITUM* BUFFALO GRASS HAY

3.1 Introduction

Ruminant animals in rural areas of Africa subsist under poor nutritional conditions, utilizing feedstuff from poor natural pastures and crop residues (Osuji and Odenyo, 1997). During the dry season live weight losses do occur because the forages are generally deficient in nutrients such as protein, sulphur, minerals and vitamins (Nsahlai *et al.,* 1998). Animals, usually, gain weight during the rainy season, part of which is lost again during winter and dry seasons (Goodchild, 1990; Nsahlai *et al.,* 1998). The feeding value of these feedstuffs needs to be improved to achieve high productive performance of the animals. Hence, supplementation with on-farm produced forage legumes or with locally available ones is being examined in relation to the ability to overcome nutritional deficiencies in the rumen and on their possible contribution of undegradable but otherwise digestible nutrients, particularly protein.

Legumes have become popular among farmers, not only for use in reinforcement of veld and planted grass pastures but also as protein banks to supplement other poor-quality roughages like maize stover (Matizha *et al.,* 1997). Legumes are known to have high protein contents (Norton, 1994), usually in the range of 120 to 230 g/kg DM. There is increasing interest in making use of legumes as sources of protein-rich supplements to improve the productivity of ruminants given low quality feeds (Ash, 1990; Goodchild, 1990; Scollan *et al.,* 2001; Van Eys *et al.,* 1986). Evaluation of these legumes is, therefore, important in order to design feeding strategies for ruminant animals on low quality roughages. The objective of this study was to determine the effect of cowpea cultivar supplementation on diet intake, digestibility and live weight change of Pedi goats fed with buffalo grass hay.

3.2 Materials and methods

3.2.1 Study site

The study was conducted at the University of Limpopo Experimental Farm situated 10 km west of the Turfloop campus. Temperatures in winter (May to July) range between 5 and 28 ^{o}C, and in summer (November to January) they range between 10 and 36 ^{o}C. Mean annual rainfalls range between 446.8 and 468.44 mm. The dry season is between April and October and the rainy season is between November and March (South African Weather Service, 2007).

3.2.2 Feeds

Four cowpea cultivars were planted at the University of Limpopo Experimental Farm at Syferkuil. Cowpea cultivars that were used in this study were *Pan 311*, *Red caloona*, *Agripes* and *Black eye*, harvested at vegetative stage and dried. The cowpeas were planted in September 2007 and harvested in November, 2007. The cowpea hays were chopped into small pieces of 20 to 30 mm lengths. Buffalo grass hay was harvested in June, 2007, dried, baled and used as a low quality roughage. The buffalo grass was also chopped into pieces of 20 to 30 mm lengths.

3.2.3 Animals, experimental design and diets

The study was divided into five of experiments to ensure accuracy. A completely randomized design (SAS, 2004) was used in each experiment and each treatment within the experiment had three replicates. Experiments were conducted to determine the effect of supplementing buffalo grass with cowpea cultivars on intake, digestibility and live weight change of Pedi goats. Experiments 3.1 to 3.4 involved *Pan 311*, *Red caloona*, *Agripes* and *Black eye*, respectively, while Experiment 3.5 compared the estimated levels of supplementation for optimum intake from each of the first four experiments.

Twelve growing male Pedi goats, weighing 16 ± 3 kg (average) live weight, were used in each experiment. The animals were allocated to one of four dietary treatments as indicated below. The experiments were run for 25 days of adaptation period plus five days of collection period. The animals were housed in individual metabolic cages and given the experimental diets during the study period. Each goat was identified with a numbered ear-tag. All animals were dosed (anthelmintic, Ivomec, Bio Onderstepoort Production) against worms before the start of the experiment. Water was offered *ad libitum* and each animal had access to a mineral mixture (Table 3.01).

The experiments and treatments were as follows:

Experiment 3.1

HP_{50} : *ad libitum* buffalo hay plus 50 g *Pan 311*/goat/day

HP_{100} : *ad libitum* buffalo hay plus 100 g *Pan 311*/goat/ day

HP_{150} : *ad libitum* buffalo hay plus 150 g *Pan 311*/goat/day

HP_{200} : *ad libitum* buffalo hay plus 200 g *Pan 311*/goat/day

Experiments 3.2 to 3.4 had similar rations but with *Red caloona*, *Agripes* and *Black eye*, respectively. Experiment 3.5 compared the estimated levels of supplementation for optimum intake from each of the first four experiments. The treatments for Experiment 3.5 were as follows:

Pan 311 : *ad libitum* buffalo hay plus estimated level of supplementation for optimum intake (161 g/goat/day) of *Pan 311*

Red caloona : *ad libitum* buffalo hay plus estimated level of supplementation for optimum intake(159 g/goat/day) of *Red caloona*

Agripes : *ad libitum* buffalo hay plus estimated level of supplementation for optimum intake (148 g/goat/day) of *Agripes*

Black eye : *ad libitum* buffalo hay plus estimated level of supplementation for optimum intake (119 g/goat/day) of *Black eye*

3.2.4 Faecal collection

During five days of the collection period, faeces were collected in the mornings before feeding and watering. Each experimental animal, housed in a digestibility crate designed for easy collection of urine, was harnessed with a faecal-collection bag four days before the commencement of actual faecal collection. The faecal samples for each experimental animal were thoroughly mixed and put in sealed polythene bags. Faeces collected during the collection period were bulked, weighed, sampled, and dried in an oven at 105 °C for 48 hours to determine dry matter content. The samples were then stored at room temperature until required for nutrient analysis.

Table 3.01 Nutritional composition of the mineral block offered to the experimental animals

Nutrient	Quantity
Calcium	48.0 g/kg max
Phosphorus	10.0 g/kg max
Sulphur	6.0 g/kg
Magnesium	10 mg /kg
Manganese	100 mg/kg
Copper	25mg/kg
Cobalt	0.30 mg/kg
Iron	208 mg/kg
Sodium	2.5 mg/kg
Zink	100 mg/kg
Selenium	0.5 mg/kg
Vitamin A	12750 I.E/kg

Source: *Kanhym* feed company.

3.2.5 Feed intake and live weight changes

The daily feed intake was determined during the collection period by the difference in weight of feed offered and the feed refusals or leftovers. Sub-samples of the feed offered and refusals were dried at 65 °C to constant weight for dry matter determination. The goats were weighed in the beginning and the end of each experiment to reduce stress during the collection period. The weighing of the goats was carried out before morning feeding to avoid feed effect (Sarwatt *et al.,* 2003).

3.2.6 Chemical analysis

Dry matter determination (AOAC, 2000)

Dry matter of feeds, feed refusals and faeces was determined according to AOAC (2000). Thoroughly cleaned crucibles were placed in an oven at 105 °C for 30 minutes and then transferred to a desiccator and cooled to room temperature (25 °C). The metal tong was used to handle the crucibles. The crucibles were then weighed. A sample was weighed accurately into the crucible and placed in the oven for overnight at 105 °C. The crucible containing the dry sample was cooled in a desiccator and weighed. Dry matter was calculated as follows:

DM (%) = Weight of the sample before drying / Weight of the sample after drying x 100

Determination of ash (AOAC, 2000)

Cleaned and labeled crucibles were placed in the muffle furnace at 600 °C for one hour. Crucibles were then transferred to a desiccator and cooled to room temperature (25 °C). Crucibles were weighed. A sample of 1.5 g was weighed into each crucible. The crucible containing the feed was put into the muffle furnace for 24 hours. The muffle furnace was heated up to 600 °C. After 24 hours, the crucibles plus samples were transferred to a desiccator and cooled to room temperature (25 °C). Crucible and the contents were weighed as soon as possible to prevent moisture absorption. Calculations for ash and organic matter were as follows:

Ash weight = (weight of crucible plus ash) - (weight of crucible)

Ash (%) = Weight of Ash / dried sample weight x100

OM (% DM basis) = 100 – Ash %

Determination of NDF (Van Soest *et al.,* 1991)

One gram of the sample was accurately weighed and transferred into the digestion tube. Neutral detergent solution (100 ml) was added. The mixture was heated to boil in a heating block. The refluxed mixture was transferred into a pre-weighed sintered crucible and then filtered. The contents were rinsed twice with hot distilled water and then twice with acetone. The residue was dried in an oven at 105 °C overnight and weighed.

Calculations for NDF were as follows:

NDF (%) as is basis = Weight of crucible +residue - weight of crucible / weight of sample x 100

NDF (% DM basis) = Neutral detergent fibre, % as is basis / dry matter % of sample x 100

Determination of ADF (Van Soest *et al.,* 1991)

One gram of the air-dried plant material was accurately weighed into the digestion tube. Acid detergent solution (100 ml) was added and heated to boil for 60 minutes in a heating block. The refluxed mixture was transferred into pre-weighed crucibles that were set on the filtering unit. The contents were filtered by rinsing twice with hot distilled water and twice with acetone. The residue was dried overnight at 105 °C. The residues was cooled in a desiccator and weighed.

Calculations for ADF were as follows:

ADF % as is basis = Weight of crucible +residue - weight of crucible / weight of sample x 100

ADF (% DM basis) = Neutral detergent fibre, % as is basis / dry matter % of sample x 100

Determination of crude protein (AOAC, 2000)

Nitrogen content was determined for feeds and faeces using the Kjedahl method (AOAC, 2000). Air-dried sample (1.0 g) was weighed on a tared ashless filter paper. The folded filter paper was quantitatively transferred into a Kjedahl flask with two Kjedahl catalyst tablets and 25 ml of sulphuric acid. The contents were digested for two hours. Sodium hydroxide was added and ammonia was distilled over into 50 ml of boric acid solution (40 g of boric acid per litre of distilled water). The solution was subsequently titrated with 0.1N hydrochloric acid using both bromothymol red and green mixture as indicators. The observed end colour was pale pink.

The calculations were as follows:

N (%) = (ml acid titrated – ml blank titrated) x (acid N x 0.014 x 10) /weight of sample in gram or volume of sample in ml.

CP (%) = [N (%) x 6.25]

CP (as % DM) = (CP % / DM %) x 100

Extraction of polyphenolics

Extraction of polyphenolics from plant material was done using the procedures of Hagerman and Butler (1989), Makkar *et al.* (1995), Reed (1995) and Waterman and Mole (1994). Air-dried plant material (0.2 g) was accurately weighed into 25 ml capacity glass beaker. Ten milliliters of aqueous acetone (70 %) was added and then the beaker was suspended in an ultrasonic water bath for 20 minutes at room temperature (25 °C). The contents of the beaker were transferred to centrifugation for 10 minutes at 3000 g at 4 °C. The supernatant was collected and kept on ice or refrigerated until required for analysis.

Extracted condensed tannins (Porter *et al.,* 1986)

A sample of 0.2 mml of tannin extract diluted with 0.3 ml of 70 % acetone was pipetted into a 100 x 12 mm test tube and 3.0 ml of Butanol–HCL reagent and 0.1 ml of the ferric acid were added. The tubes were vortexed and then the mouths of the tubes were covered with glass marbles and put in the heating block at 97 to 100 °C for 60 minutes. The tubes were allowed to cool and absorbance was recorded at 550 nm. The formula for calculating percentage of condensed tannin as leucoanthocyanidin equivalent= (absorbance 550 nm x 78.26 x dilution factor) / (% DM).

3.2.7 Statistical analysis

General linear model (GLM) procedures of SAS (2004) were used to test the effect of cowpea hay cultivar supplementation on intake, digestibility and live weight change of Pedi goats fed with buffalo grass hay. Means were separated using the Duncan multiple range test. The responses in optimum intake, digestibility and live weight changes to level of supplementation were modeled using the following quadratic equation:

$$Y=a + b_1x + b_2x^2$$

Where Y= optimum intake, digestibility or growth rate; a = intercept; b = coefficients of the quadratic equation; x = dietary level and $-b_1/2b^2$ = x value for optimum response. The quadratic model was fitted to the experimental data by means of the NLIN procedure of SAS (SAS, 2004). The quadratic model was used because it gave the best fit. Only figures on live gain are given because of page restrictions.

3. 3 Results

Nutrient composition

The results of the nutrient composition of cowpea cultivars and buffalo grass hay are presented in Table 3.02. Cowpea cultivars had higher ($P<0.05$) crude protein contents than buffalo grass hay. Among the cowpea cultivars, *Black eye* had higher ($P<0.05$) protein content than *Pan 311*, *Red caloona* and *Agripes*. Buffalo grass hay had higher ($P<0.05$) NDF values than cowpea cultivars which had similar ($P>0.05$) NDF contents. *Pan 311*, *Red caloona*, *Agripes* and buffalo grass had similar ($P>0.05$) ADF contents. However, *Black eye* had lower ($P<0.05$) ADF contents than those of *Agripes* and buffalo grass. All the cowpea cultivars contained similar ($P>0.05$) amounts of total polyphenols. *Pan 311* had highest ($P<0.05$) condensed tannin contents followed by *Agripes* and *Black eye* and then *Red caloona*. However, there were no traces of polyphenols and condensed tannins in buffalo grass.

Table 3.02 The nutrient composition of cowpea hay cultivars and buffalo grass hay.

Nutrient	Treatments					SE
	Pan 311	*Red caloona*	*Agripes*	*Black eye*	Buffalo grass	
Dry matter (g/ kg)	933[a]	867[b]	880[b]	895[b]	943[a]	0.964
Crude protein (g/ kg DM)	229[c]	195[d]	245[b]	260[a]	33[e]	0.139
Organic matter (g/ kg DM)	867[b]	880[ab]	873[ab]	813[c]	907[a]	0.964
Neutral detergent fibre (g/ kg DM)	453[b]	449[b]	472[b]	426[b]	596[a]	1.687
Acid detergent fibre (g/ kg DM)	303[ab]	289[ab]	333[a]	236[b]	357[a]	2.087
Polyphenols (mg/0.5 ml)	0.075[a]	0.077[a]	0.071[a]	0.081[a]	0.000 [b]	0.0067
Condensed tannins (% DM)*	0.113[a]	0.074[c]	0.085[b]	0.085[b]	0.000[d]	0.0006

[a, b, c] means in the same row not sharing a common superscript are significantly different (P<0.05)

SE: Standard error

* Percentage DM leucocyanidin equivalent

Experiment 3.1 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Pan 311*

The results for dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Pan 311* are presented in Table 3.03 and Figure 3.1. Daily dry matter intakes were different (P<0.05) across dietary treatments, ranging from 339 to 541 g DM per goat per day. Goats on 150 g level of supplementation had the highest (P<0.05) dry matter intakes compared to those on other levels of supplementation. Similarly, crude protein intakes were different (P<0.05) across dietary treatments. Goats on 200 g dietary treatment level had the highest (P<0.05) crude protein intakes compared to those on other treatments. Goats on 150 g and 200 g dietary treatments had similar

(P>0.05) amounts of crude protein intakes per metabolic weight. However, goats on 100 g dietary treatment had the highest (P<0.05) value of crude protein intake per kg metabolic weight compared to those of the other dietary treatments.

Pan 311 supplementation amounts had similar (P>0.05) dry matter digestibility values. Goats on 200 g dietary treatment had similar values (P<0.05) of organic matter digestibility when compared with 150 and 100 g dietary treatments but differed significantly (P<0.05) from 50 g dietary treatment. Goats on 200 g dietary treatment had higher (P<0.05) crude protein digestibility values than those on other amounts of supplementation. Goats on 100 and 150 g dietary treatments had similar (P>0.05) crude protein digestibility values. Furthermore, goats on 50 and 100 g dietary treatments had similar (P>0.05) crude protein digestibility values. Neutral detergent fibre digestibility values of goats on 150 and 200 g dietary treatments were higher (P<0.05) than those on other levels of supplementation. Goats on 100, 150 and 200 g of supplementation attained similar (P>0.05) live weight gains while those on 50 g attained live weight gains lower (P<0.05) than those on 150 and 200 g.

The results of series of regression equations that predict the level of supplementation of *Pan 311* for optimum dietary DM intake, DM digestibility and live weight changes in Pedi goats on a basal diet of buffalo grass are presented in Table 3.04 and Figure 3.1. Dietary intake, digestibility and live weight gain were optimized at supplementation levels of 161, 147 and 212 g/goat/day, respectively.

Table 3.03 Dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Pan 311*

	Treatments				
Variable	50 g	100 g	150 g	200 g	S.E
Intake (g/goat/day)					
DM	339^{d}	441^{c}	541^{a}	496^{b}	6.40
OM	305^{d}	396^{c}	485^{a}	441^{b}	5.80
CP	20^{d}	33^{c}	45^{b}	53^{a}	0.21
NDF	195^{c}	249^{b}	302^{a}	269^{b}	3.82
ADF	118^{c}	152^{b}	186^{a}	167^{b}	2.29
Intake (g/kgW $^{-0.75}$)					
DM	40.55^{b}	47.47^{ab}	53.37^{a}	52.43^{a}	1.870
OM	36.48^{b}	42.63^{ab}	49.64^{a}	46.62^{ab}	1.680
CP	2.39^{c}	3.55^{b}	4.61^{a}	5.60^{a}	0.160
NDF	23.33^{b}	26.80^{ab}	30.91^{a}	28.44^{ab}	1.050
ADF	14.11^{b}	16.36^{ab}	19.04^{a}	17.65^{ab}	0.640
Digestibility (decimal)					
DM	0.64	0.65	0.67	0.65	0.007
OM	0.67^{c}	0.75^{b}	0.79^{a}	0.77^{ab}	0.005
CP	0.70^{c}	0.71^{bc}	0.73^{b}	0.76^{a}	0.003
NDF	0.49^{c}	0.53^{b}	0.55^{a}	0.56^{a}	0.003
ADF	0.36^{c}	0.37^{bc}	0.38^{ab}	0.39^{a}	0.003
Live weight changes					
Initial (kg)	16.46	18.80	19.93	19.00	0.806
Final (kg)	16.96	19.53	20.90	20.00	0.778
Weight gain (g/goat/day)	100^{b}	146^{ab}	194^{a}	200^{a}	0.943

DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; CP: Crude protein.

[a, b, c d] Means with different superscripts within a row are significantly different at 5 % level (P<0.05).

SE: Standard error

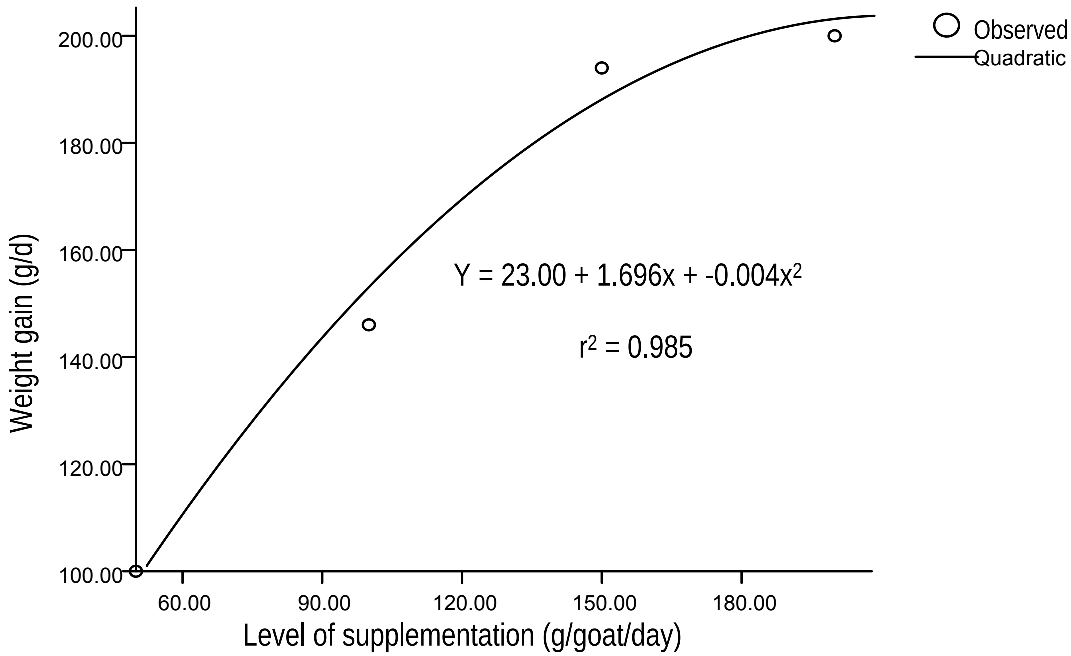

Fig. 3.1 Effect of *Pan 311* supplementation level on live weight change of indigenous Pedi goats fed *ad libitum* buffalo grass hay

Table 3.04 Levels of supplementation of *Pan 311* for optimum dietary DM intake (g/goat/day), DM digestibility (decimal) and live weight change (g/goat/day) in Pedi goats on a basal diet of buffalo grass

Factor	Formula	Optimal level (g/goat/day)	r^2	P
Intake	$Y = 127.75 + 4.817x + -0.015x^2$	161	0.955	0.212
Digestibility	$Y = 0.594 + 0.001x + -0.0000034x^2$	147	0.712	0.536
Live weight change	$Y = 23.00 + 1.696x + -0.004x^2$	212	0.985	0.122

P: Probability;
r^2: Regression co-efficient

Experiment 3.2 Dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Red caloona*

The results for dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Red caloona* are presented in Table 3.05 and Figure 3.2. Goats on diets supplemented with 100, 150 and 200 g dietary treatments had similar (P>0.05) DM, OM, NDF and ADF intakes. There were differences (P<0.05) in crude protein intakes among dietary treatments. Goats on 200 g dietary treatment had the highest (P<0.05) crude protein intake values compared to those on other dietary treatments. However, goats on 50 g dietary treatment had the lowest (P<0.05) crude protein intake values.

Goats on 100, 150 and 200 g dietary treatments had similar (P<0.05) values in dry matter intake per metabolic weight. However, the goats on 50 dietary treatment were not different (P>0.05) from those on 100 and 200 g dietary treatments in DM intakes per metabolic weight. Goats on the 200 g dietary treatment had the highest (P<0.05) values of crude protein intake per metabolic weight compared to those on other dietary treatments. However, goats on 50 g dietary treatment had the least values (P<0.05) of crude protein intake per metabolic weight. Goats had similar (P>0.05) DM digestibilities across dietary treatments. Goats on 100, 150 and 200 g dietary treatments had similar (P>0.5) organic matter digestibility values. Goats on 200 g dietary treatment had higher (P<0.05) crude protein digestibility values than those on other dietary treatments. However, 100 and 150 g dietary treatments had similar (P>0.05) crude protein digestibility values. Goats on 100, 150 and 200 g of supplementation had similar (P>0.05) live weight change. However, goats on 50 g attained lower (P<0.05) live weight change than those on 150 and 200 g.

Daily dietary intake, digestibility and live weight gain in Pedi goats were optimized at supplementation levels of 159, 167 and 210 g/goat/day, respectively (Table 3.06 and Figure 3.2).

Table 3.05 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Red caloona*

	Treatments				
Variable	50 g	100 g	150 g	200 g	SE
Intake (g/goat/day)					
DM	294[b]	360[ab]	415[a]	379[ab]	13.0
OM	265[b]	324[ab]	372[a]	339[ab]	11.8
CP	17[d]	26[c]	34[b]	38[a]	0.5
NDF	169[b]	202[ab]	228[a]	200[ab]	7.8
ADF	102[b]	123[ab]	139[a]	124[ab]	4.7
Intake (g/kg $W^{-0.75}$)					
DM	35.34[b]	39.30[ab]	43.73[a]	40.32[ab]	0.880
OM	31.85	35.37	39.19	36.06	0.080
CP	2.04[d]	2.84[c]	3.58[b]	4.05[a]	0.070
NDF	20.31	22.05	24.03	21.28	0.530
ADF	12.26	13.43	14.65	13.19	0.320
Digestibility (decimal)					
DM	0.65	0.67	0.68	0.67	0.012
OM	0.62[b]	0.69[ab]	0.73[a]	0.70[a]	0.011
CP	0.68[c]	0.73[b]	0.73[b]	0.75[a]	0.002
NDF	0.44[b]	0.45[b]	0.53[a]	0.55[a]	0.005
ADF	0.33[c]	0.35[b]	0.37[ab]	0.38[a]	0.004
Live weight changes					
Initial (kg)	16.56	18.63	19.33	19.03	0.721
Final (kg)	16.87[b]	19.17[ab]	20.10[a]	19.83[a]	0.710
Weight gain (g/goat/day)	62[b]	108[ab]	154[a]	160[a]	0.850

DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; CP: Crude protein.

[a, b, c d] Means with different superscripts within a row are significantly different at 5 % level (P<0.05).

SE: Standard error

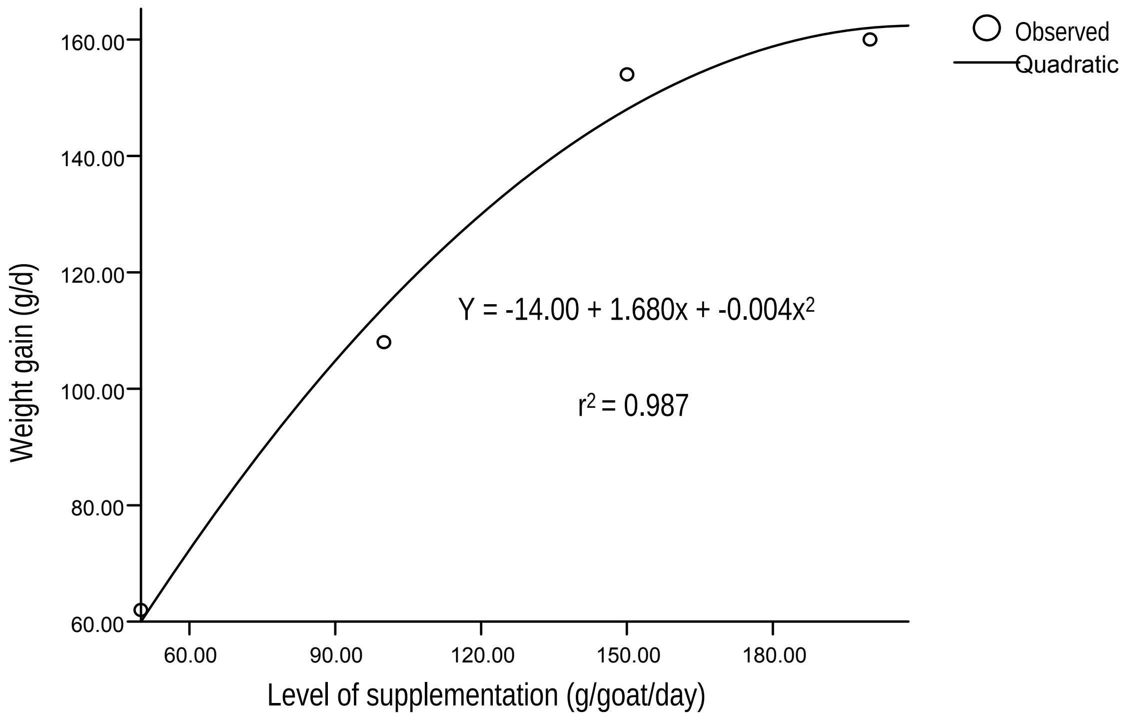

Fig. 3.2 Effect of *Red caloona* supplementation level on live weight change in indigenous Pedi goats fed *ad libitum* buffalo grass hay

Table 3.06 Levels of supplementation of *Red caloona* for optimum dietary DM intake (g/goat/day), DM digestibility (decimal) and live weight change (g/goat/day) in Pedi goats on a basal diet of buffalo grass

Factor	Formula	Optimal Level (g/goat/day)	r^2	P
Intake	$Y = 157.00 + 3.170x + -0.010x^2$	159	0.959	0.204
Digestibility	$Y = 0.593 + 0.001x + -0.000003x^2$	167	0.989	0.103
Live weight change	$Y = -14.00 + 1.680x + -0.004x^2$	210	0.987	0.113

P: Probability;
r^2: Regression co-efficient

Experiment 3.3 Dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Agripes*.

The results for dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Agripes* are presented in Table 3.07 and Figure 3.3. Daily dry matter, organic matter, neutral detergent fibre and acid detergent fibre intakes of the diets were similar (P>0.05) across dietary treatments. In all dietary treatments, goats had different (P<0.05) crude protein intake values. The crude protein intake values ranged from 17 to 48 g/goat/day, with 200 g dietary treatment having the highest.

Dry matter, organic matter, neutral detergent fibre and acid detergent fibre intakes of the diets per metabolic weight were similar (P>0.05) across dietary treatments. Goats on 200 g dietary treatment had the highest (P<0.05) crude protein intake per metabolic weight compared to those on other dietary treatments. However, goats on 50 g level of supplementation had the least (P<0.05) intake value (2.03 g/kgW$^{-0.75}$) per metabolic weight. Goats had similar (P>0.05) dry matter and organic matter digestibility values across the treatments, ranging from 0.57 to 0.68 for dry matter digestibility and 0.52 to 0.71 for organic matter digestibility. Goats on diets supplemented with 150 and 200 g had higher (P<0.05) crude protein, acid detergent fibre and neutral detergent fibre digestibility values than those on diets supplemented with 50 and 100 g. Goats on 100, 150 and 200 g of supplementation had similar (P>0.05) live weight change, which were higher (P<0.05) than those on 50 g.

Daily dietary intake, digestibility and live weight gain were optimized at supplementation levels of 148, 154 and 161 g/goat/day, respectively (Table 3.08 and Figure 3.3).

Table 3.07 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Agripes*

	Treatment				
Variable	50 g	100 g	150 g	200 g	SE
Intake (g/goat/day)					
DM	241	333	351	336	25.63
OM	217	299	314	299	23.24
CP	17^{d}	30^{c}	40^{b}	48^{a}	0.84
NDF	138	187	193	179	9.15
ADF	85	117	122	116	15.27
Intake (g/kgW $^{-0.75}$)					
DM	28.83	36.47	36.60	35.22	2.110
OM	25.96	32.75	32.74	31.34	1.920
CP	2.03^{d}	3.29^{c}	4.17^{b}	5.03^{a}	0.080
NDF	16.51	20.48	20.13	18.76	1.280
ADF	10.17	12.81	12.72	12.16	0.760
Digestibility (decimal)					
DM	0.57	0.65	0.68	0.64	0.020
OM	0.52	0.66	0.71	0.61	0.030
CP	0.63^{b}	0.65^{b}	0.68^{a}	0.71^{a}	0.004
NDF	0.41^{b}	0.43^{b}	0.47^{a}	0.48^{a}	0.003
ADF	0.29^{b}	0.31^{b}	0.34^{a}	0.36^{a}	0.003
Live weight changes					
Initial (kg)	16.93	18.63	19.83	19.67	0.724
Final (kg)	16.97	19.07	20.37	20.23	0.743
Weight gain (g/goat/day)	8^{b}	88^{a}	108^{a}	112^{a}	7.817

DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; CP: Crude protein.

[a, b, c d] Means with different superscripts within a row are significantly different at 5 % level (P<0.05).

SE: Standard error

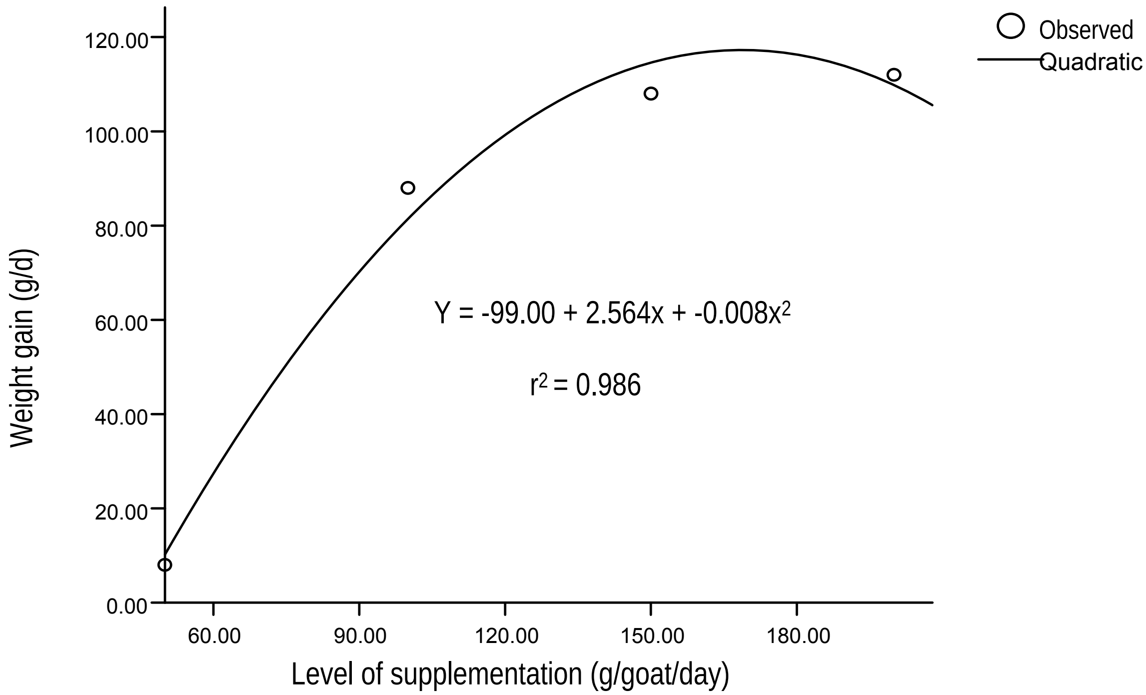

Fig. 3.3 Effect of *Agripes* supplementation level on live weight change in indigenous Pedi goats fed *ad libitum* buffalo grass hay

Table 3.08 Levels of supplementation of *Agripes* for optimum dietary DM intake (g/goat/day), DM digestibility (decimal) and live weight change (g/goat/day) in Pedi goats on a basal diet of buffalo grass

Factor	Formula	Optimal level (g/goat/day)	r^2	P
Intake	$Y = 108.00 + 3.250x + -0.011x^2$	148	0.989	0.104
Digestibility	$Y = 0.368 + 0 .004x + -0.000013x^2$	154	0.990	0.099
Live weight change	$Y = -99.00 + 2.564x + -0.008x^2$	161	0.986	0.117

P: Probability;
r^2: Regression co-efficient

Experiment 3.4 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Black eye*

The results for dietary intake, digestibility and live weight changes of Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Black eye* are presented in Table 3.09 and Figure 3.4. Goats on 100, 150 and 200 g supplementation levels had higher (P<0.05) dry matter and organic matter intake values than those on 50 g. Goats had different (P<0.05) crude protein intakes across the dietary treatments. Goats on the 200 g dietary treatment had higher (P<0.05) crude protein intake values than those on 150, 100 and 50 g dietary treatments. However, goats on 50 g dietary treatment had the lowest (P<0.05) crude protein intakes.

The dry matter intakes per metabolic weight were similar (P>0.05) for goats on diets supplemented with 50, 100 and 150 g. However, goats on 200 g had lower (P<0.05) DM intakes per metabolic weight than those on 50, 100 and 150 g. Organic matter intakes per metabolic weight were similar (P>0.05) across dietary treatments. Goats had different (P<0.05) crude protein intake values per metabolic weight across dietary treatments. The values ranged from 2 to 5 g/kg $W^{-0.75}$. Goats on 50 and 100 g had higher (P<0.05) neutral and acid detergent fibre intake values per metabolic weight than those on 150 and 200 g.

The dry matter, crude protein and neutral detergent fibre digestibility values were similar (P>0.05) across dietary treatments. Goats on diets supplemented with 100, 150 and 200 g had higher (P<0.05) organic matter digestibility values than those on 50 g level of supplementation. Goats on 150 and 200 g of supplementation had similar (P>0.05) acid detergent fibre digestibility values, which were higher (P<0.05) than those on 50 and 100 g. Goats had different (P>0.05) live weight change among treatments. However, goats on 200 g of supplementation had higher (P<0.05) live weight change than those on other treatments.

Daily dietary intake, digestibility and live weight gain were optimized at supplementation levels of 119, 167 and 191 g/goat/day, respectively (Table 3.10 and Figure 3.4).

Table 3.09 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of *Black eye*

	Treatments				
Variable	50 g	100 g	150 g	200 g	SE
Intake (g/goat/day)					
DM	189[b]	219[a]	207[ab]	201[ab]	2.99
OM	174[b]	205[a]	196[a]	192[a]	2.72
CP	16[d]	28[c]	37[b]	46[a]	0.22
NDF	105[ab]	115[a]	101[bc]	90[c]	1.77
ADF	62[ab]	67[a]	58[b]	51[c]	1.06
Intake (g/kg $W^{-0.75}$)					
DM	22.60[ab]	23.75[a]	22.90[ab]	21.00[b]	0.400
OM	20.81	22.23	20.74	20.06	0.370
CP	1.91[d]	3.04[c]	3.91[b]	4.80[a]	0.090
NDF	12.56[a]	12.47[a]	10.69[b]	9.40[c]	0.200
ADF	7.42[a]	7.27[a]	6.14[b]	5.33[b]	0.120
Digestibility (decimal)					
DM	0.56	0.58	0.59	0.58	0.010
OM	0.43[b]	0.51[a]	0.49[a]	0.48[a]	0.008
CP	0.63	0.64	0.66	0.67	0.004
NDF	0.38	0.42	0.44	0.46	0.002
ADF	0.25[c]	0.28[b]	0.30[a]	0.32[a]	0.004
Live weight changes					
Initial (kg)	17.13	19.20	19.77	20.03	0.636
Final (kg)	16.97	19.33	19.97	20.33	0.646
Weight gain (g/goat/day)	-32[d]	26[c]	40[b]	60[a]	6.922

DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; CP: Crude protein.

[a, b, c d] Means with different superscripts within a row are significantly different at 5 % level (P<0.05).

SE: Standard error

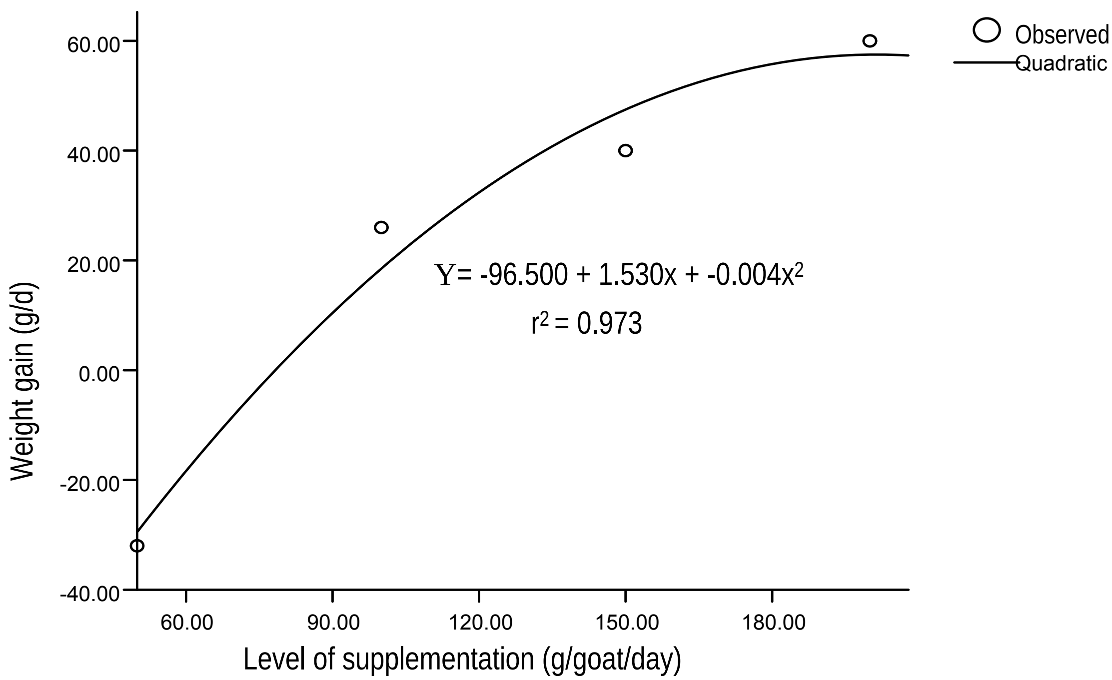

Fig. 3.4 Effect of *Black eye* supplementation on body weight change in indigenous Pedi goats fed *ad libitum* buffalo grass hay

Table 3.10 Levels of supplementation of *Black eye* for optimum dietary DM intake (g/goat/day), DM digestibility (decimal) and live weight change (g/goat/day) in Pedi goats on a basal diet of buffalo grass

Factor	Formula	Optimal level (g/goat/day)	r^2	P
Intake	$Y=159.00 + 0.948x + -0.004x^2$	119	0.754	0.496
Digestibility	$Y = 0.522 + 0.001x + -0.000003x^2$	167	0.989	0.103
Live weight change	$Y= -96.500 + 1.530x + -0.004x^2$	191	0.973	0.163

P: Probability;
r^2: Regression co-efficient

Experiment 3.5 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts of cowpea cultivars

The results of the dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts (levels for optimum intake) of cowpea cultivars are presented in Table 3.11. Goats on diets supplemented with *Pan 311* and *Red caloona* had higher (P<0.05) dietary DM, organic matter, neutral detergent fibre and acid detergent fibre intakes than those on diets supplemented with *Agripes* and *Black eye*. Goats on *Agripes* and *Black eye* supplemented diets had similar (P>0.05) dietary DM, OM, NDF and ADF intakes. Similarly, goats on *Pan 311* and *Red caloona* supplemented diets had similar (P>0.05) dietary DM, OM, NDF and ADF intakes. Similar trends were observed when intakes of DM, OM, NDF and ADF were calculated per metabolic body weight. Goats on diets supplemented with *Pan 311* had higher (P<0.05) protein intake values per metabolic weight than those supplemented with *Red caloona*, *Agripes* and *Black eye*. *Red caloona* and *Agripes* had similar (P>0.05) values of crude protein intakes per metabolic weight. However, *Black eye* had the least (P<0.05) value on crude protein intake per metabolic weight.

Dry matter digestibility values were similar (P>0.05) across the dietary treatments. Goats on diets supplemented with *Pan 311* and *Red caloona* had higher (P<0.05) organic matter digestibility values than those supplemented with *Agripes* and *Black eye*. There were no significant differences (P>0.05) in organic matter digestibility values for diets supplemented with *Agripes* and *Black eye*. *Pan 311* and *Red caloona* had similar (P>0.05) crude protein digestibility values. However, *Red caloona* and *Agripes* had higher (P<0.05) crude protein digestibility values than *Black eye*. *Pan 311* had higher (P<0.05) neutral detergent fibre and acid detergent fibre digestibilities than the other cultivars. However, *Agripes* and *Black eye* had similar (P>0.05) neutral detergent fibre and acid detergent fibre digestibilities. Goats on *Red caloona*, *Agripes* and *Black eye* had similar (P>0.05) live weight change. However, goats on *Pan 311* had higher (P<0.05) live gains than those on *Black eye*.

Table 3.11 Dietary intake, digestibility and live weight changes in Pedi goats on *ad libitum* buffalo grass hay supplemented with different amounts (levels for optimum intake) of cowpea cultivars

	Treatments				
Variable	*Pan 311* (161 g/goat/day)	*Red caloona* (159 g/goat/day)	*Agripes* (148 g/goat/day)	*Black eye* (119 g/goat/day)	S.E
Intake (g/goat/day)					
DM	501[a]	510[a]	323[b]	321[b]	12.59
OM	448[a]	459[a]	288[b]	280[b]	11.42
CP	48[a]	42[b]	43[b]	38[c]	0.77
NDF	271[a]	284[a]	180[b]	186[b]	7.51
ADF	171[a]	173[a]	113[b]	102[b]	4.50
Intake (g/kg $W^{-0.75}$)					
DM	53.9[a]	55.4[a]	35.2[b]	37.3[b]	2.85
OM	48.2[a]	51.9[a]	31.4[b]	32.6[b]	2.57
CP	5.17[a]	4.57[a]	4.69[ab]	4.42[b]	0.27
NDF	29.2[a]	30.9[a]	19.6[b]	21.6[b]	1.59
ADF	18.4[a]	18.8[a]	12.3[b]	11.9[b]	0.98
Digestibility (decimal)					
DM	0.67	0.70	0.66	0.65	0.017
OM	0.78[a]	0.78[a]	0.65[b]	0.64[b]	0.014
CP	0.74[a]	0.71[ab]	0.70[b]	0.66[c]	0.008
NDF	0.51[a]	0.45[b]	0.42[c]	0.40[c]	0.008
ADF	0.36[a]	0.34[b]	0.32[bc]	0.30[c]	0.006
Live weight changes					
Initial (kg)	18.50	18.37	18.50	17.07	1.407
Final (kg)	19.53	19.27	19.20	17.63	1.465
Weight gain (g/goat/day)	206[a]	180[ab]	140[ab]	112[b]	22.85

DM: Dry matter; OM: Organic matter; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; CP: Crude protein.

[a, b, c d] Means with different superscripts within a row are significantly different at 5 % level (P<0.05).

SE: Standard error

3.4 Discussion

Buffalo grass contained low crude protein content of 3.3 g/kg DM. This value is similar to the ones reported by Aganga *et al.* (1999), Giacomini *et al.* (2006) and Motubatse *et al.* (2008). All cowpea cultivars had over 15 % crude protein content. However, *Black eye* hay had higher protein content than the other cowpea cultivars. These values are similar to the ones reported by Savadogo *et al.* (2000), Baloyi *et al.* (2001), Chakeredza *et al.* (2002) and Rivas-Vegas *et al.* (2006). All the cowpea cultivars contained traces of condensed tannins but the total amounts varied between the cultivars. *Pan 311* contained highest amounts of condensed tannins while *Red caloona* contained the lowest amounts of condensed tannins (Table 3.02). Baloyi *et al.* (2001) also indicated that some cowpea cultivars contained high proportions of protein–binding tannins. No traces of tannins were found in buffalo grass hay. This is similar to the findings of Motubatse *et al.* (2008). It can be concluded that cowpea cultivars used in the present experiment have high crude protein contents and thus often great potential as protein supplements for goats and sheep fed low quality roughages.

Goats responded positively to different levels of supplementation with all the cowpea cultivars. However, intake, digestibility and live weight gains of goats were optimized at different cowpea supplementation levels. Generally, live weight changes were optimized at higher supplementation levels than intake and digestibility when compared within the same cultivar. Thus, it would be advisable to use supplementation levels for optimal live weight gains when doing dose-response type of trials because changes in live weight are better indications of the feeding values of forages (McDonald *et al.,* 2002). Estimated optimal live weight gain of goats on *Pan 311* was the highest followed by *Red caloona*, *Agripes* and *Black eye* (Table 3.12). No such analysis of cowpeas for goats was found in the literature.

When supplementation levels for optimal intakes of each cowpea cultivar were used in Experiment 3.5, goats responded positively to all the treatments. Diet dry matter intakes ranged between 35.2 g/kg $W^{-0.75}$ for *Agripes* to 55.4 g/kg $W^{-0.75}$ for *Red caloona*. Diet organic matter digestibility ranged from 0.64 for *Black eye* to

0.78 for *Red caloona* and *Pan 311*. Daily live weight change ranged from 112 g/goat/day for *Black eye* to 206 g/goat/day for *Pan 311*. Generally, goats on *Pan 311* responded best (206 g live weight gain/goat/day) followed by those on *Red caloona* (180 g live weight gain/goat/day), *Agripes* (140 g live weight gain/goat/day) and then *Black eye* (112 g live weight gain/goat/day) (Table 3.11). These intake, digestibility and live weight gain values in goats are within the ranges reported elsewhere in the literature (Mandal *et al*., 2005; Mupangwa *et al*., 2000; NRC, 1981) on goats and on sheep.

Table 3.12 Cowpea supplementation levels for optimal responses (intake, digestibility and live weight gain) in goats fed *ad libitum* buffalo grass.

Variable	*Pan 311*	*Red caloona*	*Agripes*	*Black eye*
Intake				
Optimum intake (g/goat/day)	515	408	348	215
Supplementation level (g/goat/day)	161	159	148	119
Digestibility				
Optimum digestibility (decimal)	0.676	0.676	0.675	0.605
Supplementation level (g/goat/day)	147	167	154	167
Live weight				
Optimum live weight change (g/goat/day)	202	162	106	50
Supplementation level (g/goat/day)	212	210	161	191

Pan 311 had lower protein content compared to *Agripes* and *Black eye* and yet animals on *Pan 311* exhibited better intake, digestibility and live weight gain responses. Normally, animals on supplements with higher protein contents exhibit better intake, digestibility and live weight gain responses (Scollan *et al.,* 2001). *Pan*

311 had the highest amount of condensed tannins. Feeds high in condensed tannins tend to have low digestibility and intake values (Goromela *et al.,* 1997; Makkar, 2003). This is because condensed tannins tend to bind with proteins and other nutrients, thus rendering them indigestible (Cooper and Owen-Smith, 1985; Frutos *et al*., 2002; Makkar, 2003). Thus, lower intake and digestibility values would have been expected from *Pan 311* as compared to *Red caloona*, *Agripes* and *Black eye*. More research should be done to determine the reasons for high responses in animals on *Pan 311* as compared to those on *Red caloona, Agripes* and *Black eye*.

3.5 Conclusion

All the cowpea cultivars contained more than 15 % crude protein. Therefore, they can be used as protein supplements for goats on low quality roughages. *Pan 311* had higher feeding values than the other cultivars. However, *Pan 311* contained the highest amounts of condensed tannins. These high amounts of condensed tannins in *Pan 311* did not exert negative effects on its intake and digestibility. This contradiction requires further studies.

Intake, digestibility and live weight gains were optimized at different cowpea supplementation levels. Generally, live weight gains were optimized at higher supplementation levels than intake and digestibility when compared within the same cultivar. Thus, it is recommended that supplementation levels for optimal live weight gains be used when doing dose-response type of trials.

CHAPTER FOUR

INTAKE AND RELATIVE PALATABILITY INDICES OF PEDI GOATS AND DORPER SHEEP OFFERED *AD LIBITUM* BUFFALO GRASS HAY AND FOUR COWPEA CULTIVARS GROWN IN LIMPOPO PROVINCE

4.1 Introduction

Goats and sheep select diets based on their palatability values (Marten, 1978). Palatability is a complex phenomenon determined by animal, plant and environmental variables. The palatability and intake of forages are determined by their ability to provide stimuli to the oropharyngeal senses of the animal, for example, taste, odour and texture (Kaitho *et al.,* 1996). Evidence exists that sheep and goats possess different degrees of sensitivity to palatability factors when a choice of feed is offered (Marten, 1978). Therefore, optimal intake of nutrients by grazing animals could be more easily achieved if there is a good understanding of their dietary habits and preferences. Thus, the objective of this study was to determine intake and relative palatability indices of Pedi goats and Dorper sheep offered *ad libitum* buffalo grass hay and four cowpea hay cultivars.

4.2 Materials and methods

The feeds used in this experiment were *Pan 311*, *Red caloona*, *Black eye* and *Agripes* harvested at vegetative stage. Buffalo grass hay and cowpea hays were cut and dried as described in Section 3.2.2.

Five indigenous goats (16 ± 4 kg) and five Dorper sheep (17 ± 1 kg) were used in this experiment. Animals were housed in individual pens with individual feeders. Five feed troughs were placed in each pen for each animal. Five feeds used in this experiment were buffalo grass hay and the four cowpea hay cultivars. Each animal was offered all the feeds simultaneously. The animals underwent a 20-day period of adaptation to confinement feeding. The collection period was for five days. Each animal was initially offered 300 g of grass hay in addition to 200 g of each cowpea hay. The amount for each feed was adjusted daily so that a 10 to 15 % refusal was maintained (Kaitho *et al.,* 1996). The order of placement of feeds in the troughs was changed daily to avoid habit reflex. Water was provided *ad libitum* using a rubber bucket. The feeds offered and refusals were weighed and recorded daily and dry matter determined for each animal.

The following parameters were used:

TI = average daily intake of grass hay.

Ti = average daily intake of other feeds where i = 2, 3, 4, or 5 were representing *Pan 311*, *Red caloona*, *Agripes* and *Black eye*, respectively.

AI = quantity of buffalo grass hay offered.

Ai = quantity of the other feeds offered as listed above.

Relative palatability indices (Ri) which were describing palatability of individual feeds in relation to grass hay were calculated as follows:

RI = (TI/ AI) / (TI/ AI) for buffalo grass hay

Ri = (Ti/ Ai) / (TI/AI), where i = 2, 3, 4, or 5 were representing *Pan 311*, *Red caloona*, *Agripes* and *Black eye*, respectively.

RI and Ri were calculated for each feed daily for the period of data collection. A 2 (animal species) x 5 (diets) factorial arrangement in a completely randomized design (SAS, 2004) was used and each treatment had five replicates. Analysis of variance was used to compare effects of feed type and animal species on intake and relative palatability indices. Correlation analysis was used to establish associations between chemical composition, intake and relative palatability indices.

4.3 Results

The results of the nutrient composition of cowpea cultivars and buffalo grass hay were similar to those reported in Chapter 3, Section 3.3.1.

Intake of feeds by goats and sheep are presented in Table 4.01. Sheep consumed more ($P<0.05$) feeds than goats. Goats ate similar ($P>0.05$) amounts of buffalo grass hay, *Pan 311* and *Red caloona*. However, they ate lower ($P<0.05$) amounts of *Black eye* and *Agripes* than those of *Pan 311* and *Red caloona* hays. *Black eye* and *Agripes* were consumed in similar ($P>0.05$) amounts by goats. Sheep ate less ($P<0.05$) of *Black eye* and *Agripes* than buffalo grass and *Pan 311*. However, they consumed similar ($P>0.05$) amounts of buffalo grass and *Pan 311*. Sheep consumed similar (P>0.05) amounts of *Red caloona*, *Black eye* and *Agripes*. There was a significant interaction between animal and feed type.

The relative palatability indices of the feeds offered to sheep and goats are presented in Table 4.01. Sheep had similar (P>0.05) palatability indices for buffalo grass, *Pan 311*, *Red caloona*, *Black eye* and *Agripes*. However, sheep had lower (P<0.05) palatability indices than goats. Goats had similar (P>0.05) palatability indices for buffalo grass, *Black eye* and *Agripes*. They also had similar (P>0.05) palatability indices for *Red caloona* and *Black eye*. However, goats preferred more (P<0.05) of *Pan 311* and *Red caloona* than buffalo grass, *Black eye* and *Agripes*.

Palatability indices were positively and significantly (P<0.05) predicted from dry matter intakes of goats (r^2 = 0.998) and sheep (r^2 = 0.994) (Tables 4.02 and 4.03, respectively). However, there were poor relationships between nutrients of the forages and their intake and palatability indices by goats and sheep.

4.4 Discussion

All four cowpea forages had high protein contents (ranging from 195 to 260 g/kg DM), making them a valuable source of protein for livestock. The high intake and palatability indices of the cowpea cultivars by both goats and sheep suggest that these forages have potential for use as ruminant animal feeds.

Poor relationships were observed between chemical composition and both palatability indices and intake of the forages by goats and sheep. Indeed, forages of high crude protein contents gave lower palatability indices and intake values in both goats and sheep. Similarly, forages high in condensed tannins gave higher intake and palatability indices where lower values were expected (McNeil *et al.,* 1998). These findings are similar to those of Kaitho *et al.* (1997) and Irvins (1955) who observed poor relationships between palatability and chemical constituents of forages. However, Martz *et al.* (1967) and Heady (1964) observed that chemical composition of forages influenced their intake and palatability values.

Table 4.01 Feed intakes (g/day/animal) and relative palatability indices of Pedi goats and Dorper sheep fed *ad libitum* cowpea cultivars and buffalo grass hay

	DM Intake		Palatability indices	
Feeds	Goats	Sheep	Goats	Sheep
Buffalo grass	127^{ab}	184^{a}	1.0^{c}	1.0
Pan 311	166^{a}	164^{ab}	2.1^{a}	1.4
Red caloona	145^{a}	141^{bc}	1.8^{ab}	1.2
Black eye	101^{b}	114^{c}	1.2^{bc}	0.9
Agripes	88^{b}	125^{c}	1.1^{c}	1.0
SE	8.56	8.56	0.13	0.13
Total	627	728	7.2	5.52
Feed type	**		**	
Animal species	**		* *	
Animal x Feed type	**		**	
Animal weight	NS		NS	
S.E	8.56		0.13	

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

** Significant at P<0.05

S.E: Standard error

NS: Non-significant (P>0.05)

Table 4.02 Regression equations predicting intake and palatability from crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), polyphenols, condensed tannins and palatability indices of four cowpea hays and buffalo grass hay fed to Pedi goats

Factor	Y-variable	Formulae	R^2	Probability
CP	Intake	324.49x + -8.60	0.431	0.344
NDF	Intake	181.77x + -1.26	0.004	0.935
ADF	Intake	112.178x + 0.04	0.002	0.951
Polyphenols	Intake	60.692x + 846.15	0.009	0.904
Condensed tannins	Intake	1114.38x + 25.54	0.257	0.493
Intake	Palatability	9.561x + 74.84	0.998	0.001
CP	Palatability	4.22x + -0.120	0.432	0.341
NDF	Palatability	1.862x + -0.007	0.001	0.973
ADF	Palatability	1.239x + 0.010	0.008	0.913
Polyphenols	Palatability	1.031x + 6.731	0.003	0.943
Condensed tannins	Palatability	15.344x 0.173	0.273	0.477

r^2 : Regression coefficient

Table 4.03 Regression equations predicting intake and palatability from crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), polyphenols, condensed tannins and palatability indices of four cowpea hays and buffalo grass hay fed to Dorper sheep

Factor	Y-variable	Formulae	R^2	Probability
CP	Intake	221.27x + -3.674	0.224	0.526
NDF	Intake	195.30x + -1.328	0.013	0.885
ADF	Intake	135.59x + 0.014	0.001	0.997
Polyphenols	Intake	250.00x + -1500	0.083	0.712
Condensed tannins	Intake	875.413x + 57.87	0.451	0.328
Intake	Palatability	26.169x + 97.627	0.994	0.003
CP	Palatability	2.116x + -0.043	0.290	0.461
NDF	Palatability	1.630x + -0.011	0.009	0.904
ADF	Palatability	1.091x + 0.001	0.001	0.979
Polyphenols	Palatability	2.148x + -13.46	0.064	0.747
Condensed tannins	Palatability	8.256+ 0.388	0.385	0.380

r^2 : Regression coefficient

In the present study, high (r^2=0.998) and significant (P=0.001) relationships were observed between intake and palatability indices of the forages by goats and sheep. These observations are in line with the assertions made by Arnold (1970), Kaitho *et al.* (1997) and Marten (1970) that palatability influences voluntary intake in ruminant animals. However, results from studies examining the relationships between palatability and intake of forages in ruminants are unequivocal. In some studies no relationship was observed between preferences for a forage and intake (Bums *et al.,* 1987; Minson and Bray, 1986), whereas in others, palatability was assumed to be responsible for observed differences in intake (Doyle, 1988; Greenhalgh and Reid, 1979; Weston and Davis, 1986).

It was observed in the present study that goats and sheep possess different degrees of sensitivity to intake and palatability factors when a choice of feed is offered. Sheep had significantly higher voluntary feed intake values than goats while palatability indices of goats were higher than those of sheep. Based on palatability indices, the goats were able to rank the different cowpea cultivars. This may suggest that goats should be selected in preference to sheep when assessing palatability indices of cowpea hays or any other similar legumes. This is similar to the findings of Marten (1970) and Arnold (1970), but contrary to the findings of Mokoboki (2007) who found that goats and sheep possessed the same degree of palatability when offered leaves of acacia species.

4.5 Conclusion

Results of this study indicate that all cowpea cultivars are good sources of protein for Dorper sheep and Pedi goats. They can provide valuable protein when fed as supplements to goats and sheep on low quality basal diets. However, *Pan 311* had higher intake and palatability indices in both goats and sheep. Sheep had higher voluntary feed intake values than goats. However, palatability indices the goats were higher than those of sheep. Based on palatability indices, the goats were able to rank the different cowpea cultivars better than sheep. This may indicate that goats are better suited for assessing palatability indices of cowpea hays and other similar legumes. Forage intakes and palatability indices by goats and sheep were poorly predicted from their nutrient composition. However, forage intakes accurately predicted their palatability indices by goats and sheep.

CHAPTER FIVE

ENZYMATIC *IN VITRO* DIGESTIBILITY OF COWPEA CULTIVARS AND BUFFALO GRASS HAY GROWN IN LIMPOPO PROVINCE OF SOUTH AFRICA

5.1 Introduction

Factors that determine the feeding value of feedstuffs are very complex. All available information, both quantitative and qualitative must be used in making judgements on the feeding values of a particular plant species (Dzowela *et al.,* 1995). The highest level of efficiency of animal production can be achieved only by reaching the highest possible level of nutrient intake (Blaxter, 1962). Forage intake by ruminants involves interactions between the forage itself, the microbes in the gastro-intestinal tract and the animal (Blaxter *et al.,* 1961; McDonald *et al.,* 2002). Thus, forage intake is a function of the forage rate of degradation by ruminal microbes, the rumen capacity, the forage digestibility and passage rate through the gut (McDonald *et al*., 2002). These factors are important when considering the forage feeding value. Conventional *in vivo* digestibility and voluntary intake of a forage are consistently used to enable one to make an accurate and reliable assessment of forage feeding values in the majority of situations. However, *in vivo* digestibility and voluntary intake experiments with animals are laborious, time consuming, expensive and require large feed quantities (Karsli and Russell, 2002). A simple and inexpensive technique to estimate *in vivo* digestibility and voluntary intake quickly and accurately is a necessity. In commercial agriculture, chemical analysis is usually used to determine the forage quality, and their nutrient contents are then matched with requirements for different physiological stages of the livestock to develop feeding systems and rations (Chessworth, 1992). The *in vitro* digestibility technique (Tilley and Terry, 1963) is widely cited as the laboratory procedure of choice which ensures the most precise and accurate estimation of *in vivo* digestibility of forages (Abdouli and Attia, 2006; Melaku *et al.,* 2003; Tessema and Baars, 2004). The main objective of this experiment was to determine *in vitro* digestibility of four cowpea cultivars and buffalo grass grown in Limpopo province.

5.2 Materials and methods

5.2.1 Feeds and experimental design

The feeds used in this experiment were *Pan 311*, *Red caloona*, *Black eye* and *Agripes* harvested at vegetative stage. Buffalo grass hay and cowpea hays were cut and dried as described in Section 3.2.2. The forages were assigned as treatments, with three replications, in a completely randomized design.

5.2.2 Determination of *in vitro* enzymatic digestibility

In vitro enzymatic digestibility was determined using the method of Michalet-Doreau and Aufrère (1988) and Tilley and Terry (1963) for the four cowpea cultivars and buffalo grass hay. Three grammes of the sample were accurately weighed into a 50 ml plastic centrifuge tube with a screw cap in duplicate. Thirty milliliters of 0.1 NHCL containing 0.2 % (w/v) pepsin was added and incubated in a water bath of 39 °C for 48 hours. The tube was shaken at least three times a day. The sample was then filtered back into crucibles and then transferred back to the centrifuge tubes with quantitatively minimum amounts of sodium acetate buffer containing 2.5 % (w/v) cellulase. The volume in the tubes was made up to 30 ml with acetic acid cellulase buffer. The tubes were then incubated in the water bath at 39 °C for 48 hours. The tubes were shaken twice a day. At the end of the incubation period, the contents of the tubes were filtered through dried and pre-weighed sintered glass. The residues were washed with distilled hot water. The residues were then placed in an oven to be dried overnight at 105 °C. The dried residues were analyzed for dry matter, organic matter, crude protein, neutral detergent fibre and acid detergent fibre.

5.2.3 Chemical analysis of the forages

Forages were analyzed for DM, CP, OM, NDF, ADF and ash as described in Chapter 3, Section 3.3.1.

5.2.4 Statistical analysis

Analysis of variance was used to test the effect of cowpea and buffalo grass hays on their *in vitro* enzymatic digestibility using General Linear Model (GLM) procedures of SAS (2004) as in a completely randomized design. Duncan multiple range test was used to separate the means (SAS, 2004).

5.3 Results and discussion

The forages contained similar nutrients as discussed in Chapter 3, Section 3.4.

The results of the enzymatic *in vitro* digestibility of cowpea and buffalo grass hays are presented in Table 5.01. Buffalo grass had lower (P<0.05) *in vitro* dry matter, organic matter, crude protein, neutral detergent fibre and acid detergent fibre digestibility values than those of cowpea hays. However, cowpea cultivars had similar (P>0.05) *in vitro* dry matter and organic matter digestibility values. *Pan 311*, *Red caloona* and *Agripes* had similar (P>0.05) *in vitro* neutral and acid detergent fibre digestibility values. *In vitro* dry matter, crude protein and organic matter digestibility values of cowpea cultivars are within the ranges reported by Kiflewahid and Mosimanyana (1989). Neutral and acid detergent digestibility values reported in the present study are similar to those reported by Hoffman *et al*. (2003) who found that *in vitro* neutral and acid detergent fibre digestibility values of leguminous hays ranged from 35 to 40 %. *Black eye* and buffalo grass hays did not differ (P>0.05) from each other on acid detergent fibre digestibility. *In vitro* dry matter, organic matter and crude protein digestibility values of buffalo grass hay are similar to those reported by Aregheore *et al.* (2006). The authors found that buffalo grass hay had 49.6 % *in vitro* dry matter, 47.4 % organic matter and 52.9 % crude protein digestibility values. *In vitro* NDF digestibility of buffalo grass hay in the present study is also within the range reported by Hoffman *et al.* (2003) in grasses. The authors found that *in vitro* NDF digestibility of grasses ranged between 21.7 and 31.1 %.

In vitro digestibility values of the cowpea cultivars found in the present study are quite high and hence the legumes should be able to supply enough nutrients, particularly proteins, to the animals when given as supplements.

Table 5.01 The *in vitro* enzymatic digestibility (decimal) of cowpea hay cultivars and buffalo grass hay

Nutrient	*Pan 311*	*Red caloona*	*Agripes*	*Black eye*	Buffalo grass	SE
DM	0.74^{a}	0.75^{a}	0.70^{a}	0.71^{a}	0.55^{b}	0.025
OM	0.72^{a}	0.74^{a}	0.71^{a}	0.69^{a}	0.56^{b}	0.020
CP	0.70^{a}	0.70^{a}	0.69^{a}	0.64^{b}	0.55^{c}	0.006
NDF	0.39^{a}	0.40^{a}	0.37^{a}	0.33^{ab}	0.26^{b}	0.028
ADF	0.25^{a}	0.25^{a}	0.26^{a}	0.22^{b}	0.19^{b}	0.009

$^{a, b, c}$ Means in the same row not sharing a common superscript are significantly different ($P<0.05$)

SE: Standard error

CHAPTER SIX

RELATIONSHIPS BETWEEN FEED CHEMICAL COMPOSITION, INTAKE, DIGESTIBILITY, PALATABILITY INDICES AND GROWTH OF PEDI GOATS ON *AD LIBITUM* BUFFALO GRASS HAY SUPPLEMENTED WITH COWPEA HAYS

6.1 Introduction and statistical analysis

The objective of this study was to determine the degree of association between chemical composition, *in vivo* digestibility, *in vitro* digestibility, growth, intake and palatability indices of the forages of cowpea cultivars by indigenous Pedi goats. The data used for the above variables came from Chapters 4 and 5 of this dissertation. Correlation analysis was used to establish associations between feed chemical composition, digestibilities, palatability indices, intake and growth of Pedi goats.

6.2 Results and discussion

The correlation co-efficients between chemical composition parameters and *in vitro* digestibility were generally low (Tables 6.01). Indeed, forages of different chemical composition gave similar *in vitro* enzymatic digestibility. These results show that chemical contents of the cowpea cultivars and buffalo grass have poor capacity to predict forage *in vitro* digestibilities. For example, the digestibility of cellulose carbohydrates was so variable that the acid and neutral detergent fibres were not well related to the *in vitro* enzymatic digestibilities of the forages. This may be due to the different environmental factors promoting lignification as opposed to cell content (Van Soest, 1996). The studies reported by Barber *et al.* (1984), Givens *et al.* (1988) and Ng'ambi (1995), also, indicated that chemical measurements of forages provided no indication of forage digestibility. However, Van Soest (1980) showed that acid and neutral detergent fibres were negatively and significantly correlated to *in vitro* digestibility of forages. The explanation was that NDF and ADF are analytical products having nutritional characteristics that describe those forage components that have low solubility in specific systems and are relatively less digestible than starch. Similarly, Linn and Kuehn (1993) found that high acid and neutral detergent fibre contents reduced digestibility of plants and could be used to predict net energy contents of feeds in ruminant animals.

Condensed tannin contents provided no reliable indication of *in vitro* enzymatic and *in vivo* digestibility of the forages (Table 6.01), thus suggesting that condensed tannin contents have limited potential for predicting the feeding value of forages.

This is similar to the observations of Mashamaite (2004) who found that diet digestibility in rabbits was poorly predicted by condensed tannin contents of leaves of acacia species.

Growth of goats was well predicted by *in vivo* organic matter (r^2=0.885), crude protein (r^2=0.920), acid detergent fibre (r^2=0.993) digestibilities and palatability indices (Table 6.02), indicating that *in vivo* digestibility and palatability indices of the forages have the potential for predicting the growth of goats. Thus, a highly digestible feed will tend to promote higher growth rates of the animals (McDonald *et al.,* 2002). Similarly, a feed high in palatability indices will tend to promote higher intakes and growth rates of the ruminant animals (Kaitho *et al.,* 1997; Mokoboki, 2007). Feed intake (Table 6.03) was poorly predicted from *in vitro* digestibility, suggesting that *in vitro* digestibility of forages has limited potential for predicting the feeding value of forages. This is similar to the findings of Givens *et al.* (1988) and Ng'ambi (1995).

It is concluded that chemical contents of the cowpea cultivars and buffalo grass had poor capacity to predict forage *in vitro* digestibility. Similarly, forage intake and growth rate of Pedi goats were poorly predicted from *in vitro* digestibility of the forages. However, growth of goats was well predicted by forage *in vivo* digestibility and palatability indices.

Table 6.01 Prediction of *in vitro* organic matter (IVOMD), crude protein (IVCPD) and acid detergent fibre (IVADFD) digestibilities (decimal) from chemical composition of the forages (g/kg DM for OM, CP, ADF and condensed tannins)

Factor	Y-variable	Formulae	R^2	Probability
OM	IVDMD	Y= -0.001OM + 1.765	0.276	0.363
OM	IVOMD	Y= -0.001OM + 1.494	0.200	0.450
OM	IVCPD	Y= -0.001OM + -1.135	0.087	0.630
OM	IVADFD	Y= 0.0001OM + 0.352	0.026	0.795
CP	IVDMD	Y= 0.001CP + 0.542	0.767	0.051
CP	IVOMD	Y= 0.001CP + 0.885	0.756	0.055
CP	IVCPD	Y= 0.001CP + 0.315	0.663	0.093
CP	IVADFD	Y= 0.0001CP + 0.189	0.574	0.138
ADF	IVDMD	Y= -0.001ADF + 1.027	0.400	0.252
ADF	IVOMD	Y= -0.001ADF + 0.938	0.289	0.350
ADF	IVCPD	Y= 0.0001ADF + 0.808	0.129	0.554
ADF	IVADFD	Y= 0.0001ADF + 0.266	0.028	0.790
CT	IVDMD	Y= 2.795CT + 0.459	0.512	0.174
CT	IVOMD	Y= 2.322 CT + 0.492	0.451	0.214
CT	IVCPD	Y= 2.226 CT + 0.472	0.515	0.172
CT	IVADFD	Y= 0.901 CT + 0.160	0.420	0.237

r^2: Regression coefficient
CT: Condensed tannins

Table 6.02 Prediction of Pedi goat growth (g/goat/day) from palatability indices and digestibility (decimal) of forages.

Factor	Y-variable	Formulae	r^2	Probability
PALAT	GROWTH	Y= 78.984PALAT + 37.667	0.858	0.074
DMD	GROWTH	Y= 1257.14DMD + -683.79	0.424	0.349
OMD	GROWTH	Y= 502.60OMD+ -198.60	0.885	0.060
CPD	GROWTH	Y= 1210.687CPD+ -691.01	0.920	0.041
ADFD	GROWTH	Y= 1610.00 ADFD+ -371.80	0.993	0.004

r^2 : Regression coefficient
Palat: Palatability

Table 6.03 Prediction of DM intake of forages from *in vitro* dry matter (IVDMD), organic matter (IVOMD), crude protein (IVCPD) and acid detergent fibre (IVADFD) digestibilities (decimal).

Factor	Y-variable	Formulae	r^2	Probability
IVDMD	INTAKE	Y= 75.954IVDMD+72.992	0.038	0.755
IVOMD	INTAKE	Y= 73.197IVOMD+ 75.33	0.027	0.791
IVADFD	INTAKE	Y= 136.077IVADFD+ 36.13	0.076	0.654
IVCPD	INTAKE	Y= 235.54IVCPD+ 70.283	0.046	0.730

r^2: Regression coefficient

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

All the cowpea cultivars contained more than 15 % crude protein. Therefore, they can be used as protein supplements for goats on low quality roughages*. Pan 311* had higher feeding values than the other cultivars. However, *Pan 311* contained the highest amounts of condensed tannins. This contradiction requires further studies.

Intake, digestibility and live weight gains of Pedi goats were optimized at different cowpea supplementation levels. Generally, live weights were optimized at higher supplementation levels. Thus, it is recommended that supplementation levels for optimal live weight gains be used when doing dose-response type of experiments with goats.

Pan 311 had higher intake and palatability indices in both goats and sheep. Sheep had higher voluntary diet intakes than goats. However, palatability indices of goats were higher than those of sheep. Additionally, palatability indices of goats were able to rank the different cowpea cultivars better than those of sheep. This may indicate that goats are better suited than sheep for assessing palatability indices of legume hays.

Chemical contents of the cowpea cultivars and buffalo grass hay had poor capacity to predict forage intake, digestibility and growth of Pedi goats. Similarly, forage intake and growth of Pedi goats were poorly predicted from *in vitro* digestibility of forages. However, growth of goats was well predicted from forage *in vivo* digestibility and palatability indices.

CHAPTER EIGHT

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