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EFFECT OF FEEDING SOME FORAGE SHRUBS ON GOATS PERFORMANCE AND RUMEN FERMENTATION IN DRY SEASON

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ABSTRACT

The present study was performed to investigate the effect of feeding leaves and stems of *Acacia saligna, Leucaena leucocephala* and *Moringa oleifera* fodder on nutrients digestibility, nitrogen utilization, rumen fermentation and milk production of goats. Thirty lactating does (weight ranged from 30–33 kg), aged 2-4 years old and from 2nd to 3th lactation season were randomly allocated into three similar groups (10 animals each). Each doe was given 300 gm barley grains per day as energy supplement, while, the shrubs were given *ad libitum*. The first group fed fresh *Acacia saligna*, the second group fed fresh *Leucaena leucocephala* and the third group fed fresh *Moringa oleifera ad libitum*.

The lactating trial was extended for 75 days where goats were fed individually and fresh water was available at all times. Nutrients digestibility coefficients and dietary nitrogen utilization of experimental feeds were evaluated using four adult bucks. Rumen fermentation kinetics as well as some rumen parameters were monitored on three fistulated adult does.

Results indicated that *M. oleifera* and *L. leucocephala* fodder had the (P<0.05) highest in crude protein. Mostly digestibility of different nutrients of goats fed either *M. oleifera* or *L. leucocephala* rations were (P<0.05) higher than those fed *acacia saligna* one. But nutritive value, nitrogen utilization, and dry matter intake were (P<0.05) improved with goats fed *L. leucocephal* and *M. oleifera* in comparison with *acacia saligna*. Milk production, protein and fat percentage were (P<0.05) better for goats fed *M. oleifera* and *L. leucocephala* diet than those fed *Acacia saligna* diet. Ammonia-N, volatile fatty acids concentrations, rumen volume, microbial protein synthesis and total bacteria counts were (P<0.05) highest with *M. oleifera* and *L. leucocephal* groups compared with *A. saligna* group. Blood glucose and serum total protein were decreased in goats fed *A. saligna*. Thus, it could be concluded that *M. oleifera* and *L. leucocephal* fodder are suitable for feeding goats without any adverse effect on their growth performance.

***Keywords**: Acacia saligna; Leucaena leucocephala; Moringa oleifera; milk production; rumen fermentation; goats.*

INTODUCTION

Animal production faces conflicting demands to produce large quantity of high-quality food at low prices. Nutritional solutions now become more important to resolve these demands. This can achieved by taking the full advantage of alternative feed resources, such as tropical or subtropical plants, in goat diets. Furthermore, one of the ways to reduce cost of animal production in developing countries and therefore making protein available to people at cheaper prices is by using agricultural by-products and tropical plants to feed livestock (Asar *et al*., 2010). Availability of conventional feed resources is declining as livestock populations increase especially in arid and semi-arid areas of Egypt. Fodder trees and shrubs are indispensable sources of animal feed in Egypt, particularly in areas with dry to semi-dry Mediterranean climate. This because they

can alleviate the feed shortages or even fill up the feed gaps in the summer. They are spontaneous species and essential components of natural communities. In addition, they cover large areas and constitute the grazing lands for all domestic animals, mainly goats. Productivity and nutritive value are widely vary among species and provenances. In general, they have low protein content, high fiber and ash and low to moderate digestibility. Their feeding value however does not always relate to their chemical composition due to the presence of anti-nutritional factors in most species such as tannins, alkaloids, saponins, etc., which limit nutrient utilization and reduce animal performance (Hassan, 2012).

The use of fodder trees and shrubs to solve the attendant problems of low productivity of small ruminant has received research attention in recent years (El Shaer, 2010) because fodder trees are an important source of supplementary protein, vitamins and minerals in developing countries (Cheema *et al*., 2011). Acacia is a perennial legume shrub that yield green forage year round and are considered as a palatable pasture shrub rich in protein (El Shaer, 2010). *Leucaena leucocephala* is a nutritious, leguminous tree found throughout the tropics, subtropics and arid region for ruminants and can be an excellent source of Ca, P, and other nutrients (Helal *et al*., 2013). The leaves of *L. leucocephala* have been widely used in Egypt (Yousuf et al., 2007) as valuable forage supplement to ruminants consuming low-protein diets. *Moringa oleifera*, a non-leguminous multi-purpose tree, is one of the fastest growing trees in the world, with high crude protein in the leaves > 20 % and negligible contents of anti-nutritive compounds (Makkar and Becker 1996). Its leaves and green fresh pods are used as vegetables by humans and are rich in carotene and ascorbic acid with a profile of amino acids, vitamins A, B and C, Ca, Fe and P (Makkar and Becker 1996). There has been an increasing interest in the use of Moringa as a protein source for livestock (Asaolu *et al*., 2011).

Egypt, as one of the developing countries, face shortage of animal meat, due to poor production of animals, which led to high cost of livestock and livestock products as well. So, the purpose of this study is to evaluate the nutritional effect of feeding goats with *A. saligna, L. leucocephala* and *M. oleifera*, as plant protein sources on the growth performance, digestibility coefficients, nitrogen utilization and milk production.

MATERIALS AND METHODS

Experimental shrubs collection

This experiment was conducted at the livestock unit of the City of Scientific Research and Technological Applications, New Borg El-Arab and Animal Production Research Institute, Agricultural Research Centre from 1st August to 15th October, 2013. The plants (*A. saligna, L. leucocephala* and *Moringa oleifera*) were harvested around the experimental site; the leaves and stems of the three shrubs were separately pooled together and air-dried to constant moisture levels, and thereafter bagged for experimental procedures.

Animals, diets and laboratory analyses

Thirty lactating Zaraibi does were used in this experiment. They were 2-4 years old, weighing 30-33 kg and from 2nd to 3th lactation seasons. The animals were divided into equal three groups (10 animals each) according to age, initial live weight and number of kids and randomly assigned to the three experimental rations using a randomized complete block design (Steele and Torrie, 1980). Before the start of the experiment, all does were kept for 7 days for adaption, during which all animals were treated with Ivomec® injections against external and internal parasites. All goats were ear tagged and tethered individually at suitable distance from each other, where barley was given at rate 300 gm/head/day as energy supplement, while, the three shrubs were offered *ad libitum*. The first group was fed fresh *Acacia saligna* (leaves & stems), the second group was fed fresh *Leucaena leucocephala*, and the third group was fed *Moringa oleifera*, for 75 days. Milk yield was individually recorded for two successive days, thus milk samples were collected 4 times twice daily in the 75 days through the collection period from all goats according to Galatov (1994). Milk

samples were chemically analyzed for total solid (TS), protein, fat and ash according to AOAC (2005), while lactose was calculated by difference.

Digestibility trial and ruminal parameters

At the last week of the feeding trial, three bucks weighing approximately 30.5 ± 2kg BW, were housed individually in metabolism cages, built to allow the quantitative collection of hard feces, feed refusals and urine, for the next seven days for digestibility estimation. Sub samples (20% of feces and urine) were taken once daily and frozen until analyses. Chemical analyses of diets, feces and urine were applied according to AOAC (2005). Values of the total digestible nutrients (TDN) were calculated according to the classic formula of Maynard *et al*. (1978) on a dry matter basis (DM). Cell wall was analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and nitrogen bound to neutral detergent fibre (NDF-N) using Tecator Fibretic system. Hemicellulose and cellulose were determined by difference according to Van Soest (1991). Nitrogen free NDF (NDFn) is estimated as: NDFn = NDF – NDFICP (Neutral detergent insoluble crude protein) (NDICP) which derived by determining CP of the insoluble residue of the NDF extraction. Non- fibrous carbohydrate (NFC) was calculated by difference: NFC = 100 − (% NDF + % CP + % EE + % Ash), according to NRC (2001). Extractable total phenols and total tannins in feeds offered were determined as described by Makkar and Goodchild (1996).

Samples of rumen liquor were taken at 0,1, 3 and 6 h post feeding from three fistulated adult goats with approximately 30.5±0.5kg BW for each treatment, to be immediately analyzed for pH using Orion 680 digital pH meter. The rumen fluid samples were preserved for ammonia nitrogen (NH_3-N) determination according to Preston (1995). Concentration of total volatile fatty acid (VFA's) was estimated by using steam methods (Warner, 1964). Total bacteria count was carried out according to Difco (1984). Rumen volume was determined by the colorimetric method using Cr-EDTA before and after 3 and 6 hrs of feeding according to El-Shazly *et al*. (1976). The microbial protein synthesized (g MP/day) in the rumen of goats fed the experimental diets was calculated using the model equation developed by Borhami *et al.* (1992):

g MP / day = mole VFA produced / day × 2 × 13.48 × 10.5 × 6.25 / 100

where one mole VFA yield about 2 mole ATP (Walker, 1965), one mole ATP produce 13.48 Y_{ATP} (g DM microbial cell); Borhami *et al.* (1979), N % of dry microbial cell = 10.5 (Hungate, 1965). Microbial counts as bacteria and protozoa of ruminal fluid were determined using a counting cell (Hawskley, UK) as described by Demeyer (1981).

Nylon bags technique (Mehrez and Ørskov, 1977) was used to determine degradability of DM and CP for different shrubs degradability. Two polyester bags (7 X 15 cm) with pore size of 45 µm were used for each incubation time. Approximately 6 g of air-dried shrubs (ground to 2 mm) were placed in each bag. All bags were incubated in the rumen of each goat, then they were withdrawn after 3, 6, 12, 24, 48, 72 and 96h, rinsed in tap water until the water became clear, then they were squeezed gently. Microorganisms attached to the residual sample were eliminated by freezing at - 20°C (Kamel *et al*., 1995). Zero-time washing losses (a) were determined by washing 2 bags in running water for 15 min. The degradation kinetics of DM and CP were estimated (in each bag) by fitting the disappearance values to the equation $P = a + b (1- e^{-Ct})$ as proposed by Ørskov and McDonald (1979), where P represents the disappearance after time t. Least-squares estimated of soluble fractions are defined as the rapidly degraded fraction (a), slowly degraded fraction (b) and the rate of degradation (c). The effective degradability (ED) for tested rations were estimated from the equation of McDonald (1981), where ED = a + bc/ (c + k), k is the out flow rate.

Sampling and analysis of blood serum

Blood samples were collected at the end of the experimental period, from all goats. Blood samples were obtained from the jugular vein of goats in the morning before access to feed and water. Serum was obtained by centrifugation of

blood and then stored at – 20 ºC until analysis. Glucose concentration was determined by the method of Trinder (1969). Serum cholesterol and triglyceride were determined using the colorimetric method of McGowan *et al.* (1983). Serum total protein (TP) was measured as described by the Biuret method according to Henry *et al*. (1974). Albumin (A) concentration was determined according to Doumas *et al*. (1977). Kidney function was evaluated by measuring blood urea using the colorimetric methods of Henry and Todd (1974). Liver function was assessed by measuring the activities of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) by the method of Reitman and Frankel (1957).

Statistical Analysis

One–way analysis of variance was used to test the differences among the experimental groups. Means were separated by Duncan's Multiple Range test (Steele and Torrie, 1980). All statistical analyses were done using Proc ANOVA of statistical analysis system (SAS, 2004).

RESULTS AND DISCUSSION

Chemical composition

The chemical composition of *Acacia saligna*, *Leucaena leucocephala* fodder and *Moringa oleifera* are summarized in Table 1. Crude protein and ether extract content of *Leucaena* were higher (22.13 and 2.17 %, respectively) than other shrubs. On the other hand, fiber fraction contents as neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), nitrogen bound to neutral detergent fiber (NDF-N), total phenols and total tannins of *Acacia* were higher than the other two shrubs.

Digestibility of experimental rations:

Feed fodder intake (g/h/d), nutrients digestibility coefficients (%) and cell wall constituents (%) of goat fed different experimental rations are shown in Table 2. The results indicate that goats consumed *Leucaena leucocephala* or *Moringa oleifera* had ($P<0.05$) higher in DMI than fed *Acacia saligna* ration. The increased DMI from *Leucaena leucocephala* and *Moringa oleifera*, could primarily due to the progressive decrease in fiber fraction and condensed tannin content (CT) of the diets. High dietary fiber generally could reduce feed intake as fiber forms bulk, fill the gut and slows down the rate of passage of ingesta through gastrointestinal tract. In the same trend, CT reduce palatability, digestibility and consequently feed intake due to its astringent property (Mueller-Harvey, 2006). This result was validated by the negative correlation between DM intake and CT and fiber fractions. However, the result of the multiple regression analysis shows that CT intake was the major determinant of feed intake as its effect on feed intake was more pronounced than each of the three fiber fractions intake (Das *et al*., 2011).

Data of Table (2) showed a significant ($P<0.05$) increase in digestion coefficients of DM and OM of *Leucaena leucocephala* group compared with *Moringa oleifera* and *Acacia saligna* groups. While digestion coefficients of CP, CF, NDF, ADF and ADL with *Leucaena leucocephala* and *Moringa oleifera* groups were significantly ($P<0.05$) increased than *Acacia saligna* group. The inclusion of *Acacia saligna* decreased CP digestion coefficient. Binding tannins with dietary protein generated stable protein-tannins complex at rumen pH and reduced the proteolytic activity and protein degradation. When tannin-containing plants are eaten, most binding appears to take place during chewing, but additional binding can occur in the rumen, including binding of proteins from other dietary components (Waghorn and Jones, 1989). Furthermore, tannins can reduce ruminal protein degradability and plant cell wall digestion because they bind with dietary protein and with structural polysaccharides such as cellulose, hemicelluloses and pectin, thereby, slowing their digestion rate. Tannins might also interfere with digestion by binding microbial enzymes (Mc Sweeney *et al*., 2001) and this may explain why *Acacia saligna* supplementation decreased cell walls digestion.

Table 1. Chemical composition and fiber fractions of experimental shrubs (% on DM basis).

Item	*Acacia saligna*	*Leucaena leucocephala*	*Moringa oleifera*
DM	33.76	32.94	31.08
OM	89.83	92.43	93.17
CP	14.88	22.13	17.52
CF	27.45	24.69	22.73
EE	1.76	2.17	1.97
NFE	45.74	43.44	50.95
Ash	10.17	7.57	6.83
NDF	42.75	36.62	28.41
ADF	33.53	29.84	19.55
ADL	10.11	9.28	6.90
NDF-N	7.62	6.48	4.72
NFC	30.44	31.51	45.27
Hemicellulose	9.22	6.78	8.86
Cellulose	23.42	20.56	12.65
Total phenol	13.8	6.39	2.55
Condensed tannin	10.3	2.14	1.75

Table 2: Dry matter forage intake and digestion coefficients of experimental rations fed to goat bucks (mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
Forage intake as DM, g/h/d			
	319.72±45.84 ^{b}	411.89±38.73 ^{a}	403.76±31.88 ^{a}
Digestion coefficients (%).			
DM	52.07±0.52 ^{b}	60.50±0.68 ^{a}	59.30±0.87 ^{a}
OM	54.93±1.26 ^{b}	63.32±0.71 ^{a}	62.39±0.93 ^{a}
CP	47.69±1.16 ^{c}	60.31±0.21 ^{a}	58.44±0.41 ^{b}
CF	44.58±1.65 ^{c}	59.69±0.88 ^{a}	57.64±0.44 ^{b}
NDF	55.62±0.65 ^{b}	59.55±0.58 ^{a}	59.22±0.84 ^{a}
ADF	53.81±1.06 ^{b}	56.79±0.88 ^{a}	56.44±0.72 ^{a}
ADL	38.93±1.93 ^{b}	46.88±1.22 ^{a}	46.19±1.17 ^{a}

^{abc} Means within rows with different superscripts are significantly different (P<0.05).

Nutritive values and nitrogen utilization:

The nutritive values as TDN and DCP (%) of *Leucaena leucocephala* and *Moringa oleifera* groups were significantly (P<0.05) higher than *Acacia saligna* group, may be due to higher values of their digestibilities of various nutrients. Dietary shrubs had significant effect on nitrogen intake (NI) and N-utilization among the experimental groups. The highest values of NI and NA (19.39 and 11.69 g/h/d) were noticed with *Leucaena leucocephala* group compared with *Moringa oleifera* and *Acacia saligna* groups, but NB of *Leucaena leucocephala* and *Moringa oleifera* groups were significantly (P<0.05) higher than *Acacia saligna* group. The goats fed *Acacia saligna* at the current study tended to less N balance. This was explained by Degen *et al*. (1997), as probably due to the presence of CT, the high proportion of acid detergent insoluble nitrogen,

which not easily digested by intestinal enzymes, and high urinary N that in turn might attributed possibly to an imbalance of high N relative to a low energy in the rumen. Tannins consistently reduce the digestibility of protein in forages (Barry *et al*., 2001) and these data fit these general hypothesis. The relatively poorer utilization of N in the *Acacia saligna* could instead be a consequence of a post-ruminal inhibition of digestion and or metabolism.

Rumen fermentation:

Ruminal fermentation activity of goat fed different shrubs rations are presented in Table 4. Rumen liquor pH values were insignificantly different among groups. While NH_3-N concentration was ($P<0.05$) higher with goats fed *Leucaena leucocephala* and *Moringa oleifera* compared with that of *Acacia saligna* groups, which may be due to reduced proteolytic activity in the rumen with *Acacia* leaves fed to animals. Also, Min *et al*. (2002) reported a similar action of Lotus corniculatus, as a CT tannin rich plant, in the form of a markedly reduced rumen proteolytic activity and rumen ammonia concentration in sheep. Bermingham *et al*. (2001) found a decrease of ammonia nitrogen concentration in the rumen of sheep fed sainfoin which contained 38 g CT/kg DM. Thus, tannins usually reduce the amount of ammonia N produced in the rumen, which improves the assimilation of feed amino acidic N by ruminants (Patra and Saxena, 2009). This decrease in ammonia concentration, which usually accompanied with reduction in the production of isoacids, which consequence a decrease in degradation of feed proteins (Alexander *et al*., 2008). However, rumen ammonia concentrations are probably related to a reduction in protozoa numbers (Newbold *et al*., 1997), which plays a major role in ruminal feed protein degradation (Jouany, 1996). The impairment of protein metabolism in the rumen may be due to two additive mechanisms (Newbold *et al*., 2004). The first is reduction of protein degradation to peptides thus plant extracts such clove bud to reduce concentrations of large peptides without affecting ammonia concentrations suggesting reduced peptidolityc activity (Busquet *et al*., 2005), and the second mechanism is specific inhibition of microbes such as the "hyper ammonia-producing bacteria" and their deaminase activity (Newbold *et al*., 2004). Moss *et al*. (2000) showed that propionate formation could considered as a competitive pathway for CH_4 production. Moreover, Szumacher-Strabel and Cieslak (2012) noted that limitation of methanogenesis might be due to transformation of readily digestible carbohydrates, such as starch, to propionic acid, which may impact hydrogen transfer and, as a consequence, limit processing rate. Indeed propionic acid can be formed by pyruvate conversion to propionate via the succinate pathway or by converting pyruvate to lactate and then propionate via the lactate-acrylate pathway. Total VFA's concentration was higher ($P<0.05$) with goats fed *Moringa oleifera* compared with *Leucaena leucocephala* and *Acacia saligna* groups. In similar trend, rumen volumes and microbial protein synthesis were greater ($P<0.05$) with goats fed *Leucaena leucocephala* and *Moringa oleifera* than goats fed *Acacia saligna*.Formation of VFA's, including propionic acid, in the rumen depends on the substrates available in the rumen and, therefore, the microbes involved (Szumacher-Strabel and Cieslak, 2012). Molar proportion (%) of propionic and butyric acids in (Table 4) were insignificantly different among groups. However, goats fed *Leucaena leucocephala* and *Moringa oleifera* showed higher acetic acid content than *Acacia saligna* group. The lower production of TVFA for Acacia group could be due to lower solubility of nitrogen and reduced availability of substrates viz. amino acids for production of VFAs. Getachew *et al*. (2008) reported lower VFA production by adding CT in batch culture of mixed rumen microorganisms. The variability in VFA and its molar proportion with different tannin sources may be due to the variations in the type and concentration of tannins presented in the tested materials.

Table (3). Nutritive values and nitrogen utilization of goats fed experimental rations (mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
Nutritive values (%).			
TDN	52.71±0.78 [b]	61.67±0.63 [a]	60.95±0.44 [a]
DCP	6.35±0.67 [b]	10.83±0.97 [a]	9.84±0.81 [a]
Nitrogen utilization (g/h/d)			
NI	12.42±0.28 [c]	19.39±0.63 [a]	16.12±0.48 [b]
N in faeces	6.50±0.21 [c]	7.70±0.16 [a]	6.70±0.12 [b]
N in urine	4.59±0.14 [c]	7.43±0.26 [a]	5.44±0.17 [b]
NB	1.43±0.16 [b]	4.27±0.36 [a]	3.98±0.22 [a]
NA	5.92±0.17 [c]	11.69±0.12 [a]	9.42±0.10 [b]
NB/NI	10.73±0.37 [c]	22.01±1.73 [a]	24.70±2.51 [a]
NB/NA	22.51±0.55 [c]	36.50±1.41 [b]	42.26±2.69 [a]

[abc] Means within rows with different superscripts are significantly different (P<0.05).

Table 4: Rumen liquor parameters and microbial nitrogen synthesis of goats fed experimental rations (mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
pH	6.26±0.44	6.37±0.15	6.44±0.22
NH_3-N (mg/100 ml)	9.33±0.41 [b]	11.01±0.68 [a]	10.76±0.62 [a]
Total VFA's ml equv/100 ml)	7.94±0.38 [c]	11.54±0.41 [b]	12.82±0.35 [a]
Proportions of total volatile fatty acids (mol/100 mol)			
Acetate	53.51±1.58 [b]	66.41±1.98 [a]	64.37±1.78 [a]
Propionate	23.74±1.12	21.11±2.10	21.32±1.68
Butyrate	11.26±0.89	12.52±0.67	12.33±0.92
A:P	2.25±0.16 [b]	3.15±0.13 [a]	3.02±0.10 [a]
Rumen volume (L)	2.51±0.24 [b]	3.64±0.35 [a]	3.57±0.66 [a]
Rates of outflow (% hr)	6.44±0.37 [a]	5.26±0.17 [b]	5.39±0.27 [b]
Microbial protein synthesis (g/h/d)	53.84±0.27 [b]	68.94±0.57 [a]	69.31±0.46 [a]

[abc] Means within rows with different superscripts are significantly different (P<0.05).

Rumen microbial counts:

Data of rumen microbial counts of ruminal fluid of goats fed rations including *Acacia saligna, Leucaena leucocephala or Moringa oleífera* are presented in Table 5. Total bacteria count was (P<0.05) higher with goats fed *Moringa oleifera* and *Leucaena leucocephala* compared with *Acacia saligna* groups. But total protozoa counts were insignificantly different among groups. Effects of tannins on rumen protozoa and bacteria are variable and mostly depend on type of tannins, their origin and supplementation levels (Patra and Saxena, 2011). Animut *et al*. (2008) demonstrated that increasing levels of tannins (i.e., 50, 101, 151 g/kg DM) in diets reduced protozoa numbers in goat rumens. Wang *et al*. (2009) demonstrated that addition of phlorotannins to rumen bacterial cultures inhibited growth of *Fibrobacter succinogenes* but stimulated

growth of *Streptococcus bovis* and *Prevotella bryantii*. The lack of tannins effect in these studies may be due to inhibitory effects on some bacterial species but stimulatory effect. Moreover, due to the long period of rumen microorganisms exposure to tannins, it could acquire resistance (Patra and Saxena, 2011). Tannin-resistant or -insensitive bacteria have been isolated in recent years from gastrointestinal tract ecosystems (Nelson *et al*., 1998). Tannin-resistant microorganisms in the rumen are thought to prevent detrimental effects on the animal due to tannins in the diet and may be able to confer protection to animals not adapted to a tannin-containing diet (Schneider and Blaut, 2000). The low density of fibre degrading microbes population (cellulolytic bacteria and fungi) may be responsible for the inhibition of fibre degrading enzymes and protease activity. These in turn could also reflected on reducing feed digestibility resulting in low concentration of metabolites in the rumen of goats fed pakar leaves (Singh *et al*., 2011). Tjakradidajaja *et al*. (1999) reported that Feral goats and camel fed on Acacia and *Callindra calothyrsus*, containing high level of tannins, were capable of tolerating tannins in diet due to the presence of high numbers of tannins resistant bacteria like *Streptococcus caprinus* and *Selenomonas ruminantium*.

Degradation kinetics:

Estimates of ruminal degradation values (a, b and c) fitted with rates of DM and CP disappearance of tested shrubs are presented in Table 6. The results illustrated that washing loss fraction "a", degradable fraction "b" rate of degradation "c" and effective degradability "ED" of DM and CP were significant (P<0.05) higher for goats fed *Moringa oleífera* campare with those fed *Leucaena leucocephala* and *Acacia saligna* rations, while rumen undegradable fraction "U" was (P<0.05) lower for those fed *Moringa oleífera* campare with *Leucaena leucocephala* and *Acacia saligna* groups. The metabolites of *Acacia* tannin reduced the *in vitro* digestibility of dry matter, organic matter and crude protein. The degraded products of tannins from *Acacia nilotica* pods in rumen fluid of goats were phloroglucinol, gallic acid, resorcinol and catechin. Phloroglucinol was the major degradation product while, gallate was produced in traces. Goats harbor the tannin degrading bacteria in the rumen microflora without pre-exposure to a tannin-containing diet (Barman and Rai, 2008). The change in rate of degradation in the present study was significantly (P<0.05) associated with the tannin effect, suggesting that the contribution of tannins to decrease the effective degradation was a more result of delay in digestibility than a reduction of the potentially degraded fractions. *In vitro* DM disappearance (IVDMD) for tree leaves has been found to decline with an increase in tannin content (Kumar and Vaithiyanathan, 1990). Chiquette *et al*. (1988) showed by scanning and transmission of electron microscopy that rumen bacteria formed multiple adherent microcolonies on high-tannin leaf and stem surfaces of the plant, but these colonies did not penetrate the plant tissues as effectively as did bacteria associated with low-tannin strains. These bacterial responses to high tannin contributed to the reduction of DM disappearance and tannins may also inactivate the rumen microbial enzymes (Kumar and Singh, 1984). Horigome *et al*. (1988) reported the inhibitory effect of tree leaf tannins on enzyme activities. Inhibition increased with the increase in degree of polymerization and they demonstrated that both the hydrolysable and condensed tannins had a negative influence on IVDMD, but the batter's influence was more pronounced.

Table 5: Rumen microbial counts of ruminal fluid of goats fed *Acacia saligna, Leucaena leucocephala and Moringa oleífera* rations(mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
Bacteria (x 10^{-9} cfu per ml)	5.86±0.53 [b]	7.63±0.66 [a]	7.99±0.41 [a]
Protozoa (x 10^{-5} cfu per ml)	1.89±0.64	1.71±0.48	1.49±0.61

[ab] Means within rows with different superscripts are significantly different (P<0.05).

Table 6. Degradation kinetics of DM and CP (%) for *Acacia saligna*, *Leucaena leucephela* and *Moringa oleifera* fodder (mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
		DM	
a, %	17.63±0.24 [c]	21.91±0.38 [b]	30.12±0.22 [a]
b, %	38.25±1.86 [b]	36.13±0.91 [b]	43.06±0.33 [a]
a+b, %	55.88±0.51 [c]	58.04±0.31 [b]	73.18±0.63 [a]
c, %	0.036±0.007 [b]	0.049±0.006 [a]	0.035±0.003 [b]
U	43.77±0.19 [a]	41.81±0.24 [b]	26.77±0.44 [c]
EDDM 3, %	42.31±0.44 [c]	47.29±0.41 [b]	57.02±0.37 [a]
		CP	
a, %	11.34±0.21 [c]	16.15±0.33 [b]	17.53±0.27 [a]
b, %	39.61±0.39 [c]	40.66±0.26 [b]	46.44±0.59 [a]
a+b, %	50.95±0.31 [c]	56.81±0.44 [b]	63.97±0.24 [a]
c, %	0.041±0.002 [b]	0.043±0.00 4 [b]	0.061±0.006 [a]
U	48.83±0.41 [a]	43.11±0.32 [b]	35.64±0.25 [c]
EDCP 3, %	37.81±0.52 [c]	43.44±0.19 [b]	52.06±0.33 [a]

[abc] Means within column with different superscripts are significantly different (P<0.05).
a = soluble degradable fraction (%) b = degradable fraction (%)
c = rate of degradability (% h^{-1}) U = ruminely undegradable fraction {100-(a+b)}
ED = effective degradability (%).

Lactation trials:

Milk yield and milk composition of lactating goats fed *Acacia saligna*, *Leucaena leucephela* or *Moringa oleífera* rations are presented in Table 7. Milk and fat yields were significantly (P<0.05) increased for goats fed *Leucaena leucephela* and *Moringa oleífera* compared with goats fed *Acacia saligna.* But Protein yield was (P<0.05) lower with goats fed *Acacia saligna* than those fed *Leucaena leucephela* and *Moringa oleífera*. However, milk yield, fat and protein proportion of milk could be reduced if dairy cows fed condensed tannins daily (Grainger *et al*., 2009).

This contrasts with Wang *et al*. (1996) who reported that tannins from Lotus corniculatus fed to lactating ewes increased milk yield, lactose and protein contents. One of the reasons for these effects could be the increase in metabolizable protein supply due to protein binding action of condensed tannins (Patra and Saxena, 2011) because effects of tannins on ruminant productivity depend on the quality and quantity of dietary protein. There were differences in the quality of milk across different shrubs, although Kumagai *et al*. (1993) suggested that milk yield and composition of dairy cows may be influenced by the source of roughage. The present study agrees with the conclusions drawn by Khorasani *et al*. (1996), that dairy cows can maintain similar milk yields, despite the marked differences in the type of end products arising from carbohydrate and protein digestion. Reyes Sanchez *et al*. (2006) found that daily milk production was significantly (P<0.05) higher for cows fed M. oliefera supplement than those fed B. brizan hay only. They added that the improvement of milk production was associated with an increase of fat and protein yields. Mendieta-Aracia (2011) reported that M. oliefera supplement did not affect milk organoleptic characteristics including taste, smell or color. The good influence of moringa leaves on milk production and composition was also reported by Basitan and Emma (2013), who found that cows fed moringa supplemented rations had (P< 0.05) higher milk and fat yields than cows fed moringa free ration.

Table 7: Milk yield and milk composition for lactating goats fed *Acacia saligna*, *Leucaena leucephela* and *Moringa oleifera* rations (mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
Milk yield, g/d	725.00±30.65 [b]	875.50±20.49 [a]	890.50±25.77 [a]
Fat, g/d	22.48±0.27 [b]	31.52±0.32 [a]	31.17±0.17 [a]
Protein, g/d	24.36±0.16 [c]	33.71±0.22 [a]	32.24±0.20 [b]
Milk composition (%):			
Total solids	12.98±0.30	13.27±0.11	13.39±0.15
Solids not fat	9.88±0.33	9.67±0.19	9.89±0.23
Fat	3.10±0.10 [b]	3.60±0.16 [a]	3.50±0.11 [a]
Protein	3.36±0.09 [c]	3.85±0.10 [a]	3.62±0.12 [b]
Lactose	5.38±0.25	4.89±0.14	5.42±0.31
Ash	1.14±0.07 [a]	0.93±0.09 [b]	0.85±0.05 [b]

[abc] Means within rows with different superscripts are significantly different (P<0.05).

Blood biochemical constituents:

Data of blood analysis given in Table 8, illustrated that blood glucose was (P<0.05) higher for goats fed *Leucaena leucephela* and *Moringa oleífera* containing diets compared with goats fed *Acacia saligna* diet, while blood urea- N was (P<0.05) lower for goats fed *Acacia saligna* compared with goats fed *Leucaena leucephela* and *Moringa oleífera*. However, total protein, albumin and globulin were (P<0.05) higher for goats fed *Leucaena leucephela* compared with goats fed *Moringa oleífera* and *Acacia saligna*. Moreover, cholesterol, creatinine, AST and ALT were insignificantly different among groups. However, calcium and phosphorus were (P<0.05) higher for goats fed *Moringa oleífera* compared with goats fed *Leucaena leucephela* and *Acacia saligna* rations. The experimental animals, particularly those consuming *Acacia saligna* which contained CT, did not show clinical signs of ill health or signs of tannin toxicity such as brisket oedema, diarrhoea, constipation, anorexia, hard pelleted feces coated with blood and mucous. The linear increase in glucose concentration reflects the increased DM intake with increasing concentrate proportion. Also, this is probably a reflection of the energy status of the diets which obviously would increase with increasing concentrate proportion in the diets. Lower serum glucose level of *Acacia saligna* relative to other treatments could be attributed to higher CT intake, which reduced feed intake and consequently available energy. This conjecture is confirmed by the negative significant correlation between CT intake and serum glucose level. However, the normal range of blood glucose level (1.1 - 3.0 mmol/L) (Žubčić, 2001) tends to suggest that the depressed serum glucose level of goats fed diet containing tanniniferous *Acacia saligna* fodder is not due to hypoglycaemia and tannic acid intoxication. Similar cholesterol levels with all animals indicate the absence of hypocholesterolemia that agree with the findings of Olafadehan (2011a). The insignificantly varied cholesterol values for all goats further confirmed the absence of hepatocellular damage. Increased serum urea-N suggests increased rumen ammonia concentration as the concentrate level increased in the diets. Lower urea N of *Acacia saligna* may be due to the comparatively higher CT intake, which was negatively and significantly correlated to urea N. The serum urea-N levels were within the normal established range 3.5 - 10.7 (mmo/L) for goats (Sirois, 1995). The increased catabolism of amino acids, when proteins of lower biological value are used as feed, has been implicated for high plasma urea N levels (Aderolu *et al*., 2007). The insignificantly affected creatinine values, which were within the normal range of 100 – 200 µmmol/L reported for healthy goats by Sirois (1995), suggest absence of waste or catabolism of muscle tissues, and that the

animals were not surviving at the expense of body reserve (Olafadehan, 2011b).

The significantly lower total protein and albumin of goats fed *Acacia saligna* (Table 8) is an indication of the relatively poor protein quality of the grass and, of course, the level and availability of dietary protein. The results indicate the absence of proteinuria and hypoproteinaemia observed in cattle consuming tannin-rich oak foliage and manifesting tannic acid toxicosis (Garg *et al*., 1992). The superior values obtained with *Acacia saligna* show that the tannins level of *Acacia saligna* is safe and beneficial, and not detrimental, because tannins at low levels are beneficial as they influence some qualities of rumen undegradable protein, thus improve protein availability and utilization. Serum level of AST conventionally used for diagnosing human and domestic animal hepatic damage (Silanikove and Tiomkin, 1992), whereas liver enzymes such as ALT, which is a liver specific hepatocellular enzyme, released by hepatocellular damage, more than gamma glutamyl transpeptidase (GGT), which used to assess liver damage, (Mahgoub *et al*., 2008). The normal ranges for ALT and AST are 7-24 IU/L and 43-132 IU/L (Daramola *et al*., 2005). The fact that none of these blood metabolic profiles in the present study differed from those measured on tannin-free grass (Acacia saligna), and all of them fell within the normal ranges for goats suggest that no damage to the liver occurred. This result, which is in agreement with that of Tabosa *et al*., (2000), contradicts the report that the antinutritional factors in Prosopis julifloral pod diets caused tissue damage in goats.

Blood antioxidant enzymes:

Enzymatic antioxidants activity of goats fed *Acacia saligna*, *Leucaena leucephela* and *Moringa oleífera* are presented in Table 9. Thiobarbituric acid-reactive substances (TBARS) was significantly (P<0.05) increased with goats fed *Acacia saligna* compared with goats fed *Leucaena leucephela* and *Moringa oleífera*, but glutathione peroxidase (GPx), glutathione S-transferase (GST), catalase (CAT) and superoxide dismutase (SOD) were significantly (P<0.05) increased with goats fed *Moringa oleífera* compared with goats fed *Leucaena leucephela* and *Acacia saligna*.

Antioxidant enzymes mainly SOD and CAT are the first line defensive against free radicals, which cause oxidative damage in animal tissues. Catalase (CAT) is one of the most important intracellular enzymes in the detoxification of the oxidant hydrogen peroxide. The activity of CAT and SOD enzymes is inhibited with the high level of toxic metabolites (Visavadiya and Narasimhachary, 2008). Glutathione peroxidase (GSH-Px) is the most powerful antioxidant enzyme protects cellular proteins against reactive oxygen species (ROS) in the body (Arivazhagan *et al*., 2000). It was reported that M. oleifera leaves contained flavonoids such as Kaempferol, rhamnetin, isoquercitrin and Kaempferitrin. These polyphenolic compounds could significantly contribute in scavenging free radicals or act as free radical terminator (Satish *et al*., 2013). Oyedemi *et al*. (2010) stated that, moringa can reduce reactive free radicals that might lessen oxidative damage in the tissues through hydrogen peroxide decomposition. While, Choi *et al*. (2010) found that the antioxidant potential of plants stimulate GSH activity in rats. The mode of action of plant antioxidant compounds was explored by Venkatesan *et al*. (2012), who stated that external antioxidants might enhance phagocytic activity and increase stimulation of immune and antioxidant activity. So that, *M. oleifera* is a rich source of antioxidant compounds i.e.; flavonoids, Vit A, B, C and E beside some other trace minerals (Zn, Cu, Se and Fe) which could eliminate the free radical harmful effect, and in turn considered as added value to its nutritional quality in ruminants feeding.

Table 8. Blood serum biochemical components of goats fed *Acacia saligna*, *Leucaena leucephela* and *Moringa oleifera* rations (mean±SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
Glucose (mmol/L)	1.34 ±0.10 [b]	1.98 ±0.13 [a]	2.11 ±0.11 [a]
Cholesterol (mmol/L)	1.75 ±0.46	1.76 ±0.39	1.76 ±0.58
Total protein (g/L)	58.22 ±0.52 [c]	69.90 ±0.48 [a]	65.61 ±0.33 [b]
Albumin (g/L)	28.96 ±0.44 [c]	33.60±0.66 [a]	31.14 ±0.29 [b]
Globulin (g/L)	29.26 ±0.38 [c]	36.30 ±0.32 [a]	34.47 ±0.55 [b]
Urea N (mmol/L)	4.11 ±0.11 [c]	5.36 ±0.16 [a]	4.94 ±0.14 [b]
Creatinine (µmol/L)	108.56 ±0.69	107 ±0.95	109.11 ±1.03
AST (IU/L)	56.64 ±1.21	55.88 ±0.96	55.52 ±0.80
ALT (IU/L)	12.31 ±1.17	11.83 ±0.72	11.33 ±0.92
Calcium (mmol/L)	2.22 ±0.19 [b]	2.36 ±0.16 [b]	3.30 ±0.11 [a]
Phosphorus (mmol/L)	3.67 ±0.10 [c]	4.55 ±0.15 [b]	6.37 ±0.10 [a]

[abc] Means within rows with different superscripts are significantly different (P<0.05).

Table 9: Enzymatic antioxidants activity in serum of lactating goats fed *Acacia saligna*, *Leucaena leucephela* and *Moringa oleifera* rations (mean ± SE).

	Acacia saligna	*Leucaena leucocephala*	*Moringa oleifera*
(TBARS; nmol/ml)	0.54 ± 0.13[a]	0.22 ± 0.010 [b]	17.66±0.17 [c]
(GPx; U/ml)	13.78 ± 0.58 [c]	19.52 ± 0.34 [b]	21.84±0.31 [a]
(GST; µmol/hr/ml)	1.17 ± 0.09 [c]	1.76 ± 0.17 [b]	1.84±0.22 [a]
(CAT; µmol H_2O_2 onsumed/min./ml)	46.16± 0.66 [c]	68.42 ± 1.14 [b]	74.77±0.72 [a]
(SOD; U/ml)	2.32 ± 0.33 [c]	4.16 ± 0.22 [b]	4.87±0.38 [a]

[abc] Means within rows with different superscripts are significantly different (P<0.05).

CONCLUSION

The results of this study indicate that *L. leucocephala* and *Moringa oleifera* can be used by smallholder crop-livestock farmers and agropastoralists in arid and semi-arid areas as they provide a locally available feed that is cheap and high in protein.

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