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The effects of treatment of *Prosopis juliflora* leaves and pods with bentonite and wood ash on feed intake, milk production and composition in dairy goats

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Abstract
The high tannin content in *Prosopis juliflora* leaves and pods (LP) has hindered its efficient usage as a leguminous tree forage despite its high nutritive value. Goats are capable of using it but in a limited quantity despite being capable of meeting their nutritional requirements. An experiment was conducted to determine the impact of natural binders on intake, milk production, composition, and mineral content of dairy goats when used to treat *P. juliflora* LP. Twelve lactating dairy goats of the Toggenburg breed and their crosses weighing 35±2 kg were used in the experiment. They were placed in four treatments in a randomized completely block design (RCBD) with the breed being the blocking factor. They were housed individually with three goats in each treatment. A digestibility trial was initially conducted to decide on the ratio of *P. juliflora* (LP) that was more digestible for the goats. Feed leftovers were collected every morning to determine intake, and were also milked in the morning and evening to determine milk production. At the end of the experiment, milk samples from every treatment were analyzed to determine milk composition and mineral content. The results showed that treatment not only improved intake but also milk production, composition, and mineral content.

Keywords: Bentonite, *in-vitro* digestibility, natural binders, tannins, wood ash

Introduction
Goats are found in almost all households. The poor man's cow has been credited for its ability to survive in almost all climatic conditions, better resist diseases, and its high feed conversion efficiency. Their high feed conversion capacity coupled with presence of proline in their saliva that act as an initial defence against tannins on consumption, enables them to utilize tannins better than cattle and sheep [18]. *Prosopis juliflora*, a leguminous tree forage that does excellently in arid and semi-arid areas including those receiving rainfall as low as 100mm per annum can be utilized by goats [9]. However, their inclusion in the diet is limited to 30% due to its high antinutritional factors and effect on teeth [16].
This study focused on contributing to enhanced usage of the forage by reduction of the ant nutritional factors, particularly tannins using wood ash and bentonite as binders. These binders are highly effective in tannin reduction and enhancement of feed intake and digestibility. Apart from that, they have no adverse effect on the environment unlike synthetic binders like polyethylene glycol (PEG) and polyvinylpyrrolidone (PVP) whose intensity in affecting the environment is barely known. Moreover, they are locally available and affordable, and has been used since time immemorial in softening vegetables. Bentonite has been reported to be as effective as PEG, and it is also applied at a lower quantity of 20 g/kg [11]. More than 90% of Kenyans rely on either charcoal or wood for cooking, and 6-10% of this is converted to wood ash [1, 3]. According to [13], wood ash can reduce 75% and 96% of tannins in *A. nilotica* and *D. cineraria* fruits respectively.
An experiment was carried out to determine the effect of the treatment of *P. juliflora* LP with wood ash, bentonite, and synergistically on feed intake, milk production, and milk quality of the Toggenburg dairy goats. It aimed at enhancing the usage, adoption, and appreciation of *P. juliflora* as an alternative protein source. According to [2], *P. juliflora* can meet the nutritional requirements of lactating dairy goats of 17% crude protein.

2. Materials and Methods

2.1 Study site

The study was carried out at Tatton Agriculture Park (TAP) of Egerton University's main campus which is situated in Njoro sub-county, Nakuru County, Kenya. It is at 0° 23 S, 35° 55 N with an altitude of 2,238 m above sea level. The latitudes and longitudes are 0.369734°S and 35.932779°E respectively. The average annual rainfall ranges from 900-1,200 mm with average daily temperatures of 17 °C - 22 °C [8].

2.2 Collection and Preparation of feeding materials

Mature leaves and pods used in this study were sourced from Marigat Sub-County, Baringo County, which is 0° 20'N and 35° 37'E. The collection was carried out during the dry months of December and January. Marigat is approximately 20 Km from both Lake Baringo and Bogoria Kenya, and lies 1,080 m above sea level. It receives rainfall of 700-950 mm per year with peaks in April/May and July/August but usually erratic [5]. The collected leaves and pods were transported to Egerton University where they were assorted by removing green pods and spoilt and mouldy leaves and pods. They were then spread out for efficient drying. Bentonite was mixed with the feed at the rate of 20 g/kg, and wood ash collected mixed thoroughly, sieved to remove foreign particles, and used at 400 g/L of water while avoiding kerosene-tainted wood ash.

2.3 Experimental animals and design

Toggenburg dairy goat breeds and their crosses used in this study were sourced from TAP. Twelve lactating and healthy ones weighing 35±2 kg were used. There were eight pure Toggenburg breeds and four crosses. The goats were arranged in a randomized completely block design (RCBD) with a cross in each treatment. They were housed individually with feed troughs, watering cans, and salt licks. They were given fourteen days' adaptation period before data collection commenced.

2.4 Experimental diets and feeding

Rhodes grass hay sourced from a local supplier was used as the basal diet. They were ground to pass through a 4 mm sieve. The goats were also provided with a mineral supplement in form of a salt lick and water *ad-libitum.* The four diets were decided upon after an *in-vitro* digestibility trial that was carried out earlier on *P. juliflora* leaves and pods, where 75% leaves mixed with 25% pods were found to be the most digestible. This was used as the supplement at 30% of the diet in all the treatments. The dietary treatments were as follows: -

T_1) - Rhodes grass hay (*ad-libitum*) plus 75:25 ratios of *P. juliflora* LP (control)

T_2- Rhodes grass hay (*ad-libitum*) plus wood ash treated 7_5:25 ratios of *P. juliflora* LP

T_3- Rhodes grass hay (*ad-libitum*) plus bentonite treated 75:25 ratios of *P. juliflora* LP

T_4- Rhodes grass hay (*ad-libitum*) plus 75:25 ratios of *P. juliflora* LP treated with a 50:50 ratio combination of wood ash and Bentonite

2.5 Data collection

Data collection was carried out for eight weeks with a 14-day adaptation period. The supplements and the treatments were mixed thoroughly and left overnight before being fed in the morning just after milking. They were given two hours with the supplement before the basal diet, given *ad-libitum*, was introduced. The goats were milked daily in the morning at 07:00 am and in the evening 04:00 pm, and the milk produced recorded. Feed refusals were collected just before milking and introduction of fresh feeds, then weighed and recorded. The animal handling procedures were approved and certified by the Ethical Clearance Committee, Egerton University, and permitted by the National Commission for Science and Innovation (NACOSTI), Kenya.

2.6 Milk analysis

During the last week of data collection, milk samples were retrieved from goats in all treatments and analyzed for fats, solids, proteins, lactose, salts, freezing point, and density using an Ultra scan milk analyzer.

2.7 Determination of minerals

Calcium, phosphorus, zinc, and iron content in milk of the four treatments were determined using the Atomic Absorption Spectrometer 3300 as was used by Perkin-Elmer, Massachusetts, USA. The milk samples were prepared according to [6] by precipitation of casein using trichloroacetic acid (TCA). The four minerals were decided upon based on the results of [4] who categorizes minerals in goat milk with their solubility. According to these authors, zinc has 14% solubility while iron is 38% soluble. In the category of major minerals, calcium and phosphorus have the lower solubility compared to other major minerals at 32% and 38% respectively.

3. Results

Dairy goats fed diets with untreated *P. juliflora* leaves and pods (control) performed worse than those fed with treated *P. juliflora* leaves and pods (Table 1). In terms of dry matter intake, there was no significant difference (p>0.05) between T_1, T_3 and T_4, while there was no difference between T_4, T_3, and T_2. However, T_1 and T_2 were different. There was no difference in milk production in all the treatments except for the control.

Table 1: Average daily dry matter intake and milk production of dairy goats fed Rhodes grass hay and supplemented with treated and untreated *Prosopis juliflora* leaves and pods

Treatments	Total DMI (kg)	Milk Production (ml)
Control (T_1)	1.90^{b}	108.02^{b}
Wood ash treated (T_2)	2.01^{a}	137.67^{a}
Bentonite treated (T_3)	1.96^{ab}	124.26^{a}
Wood ash and Bentonite treated (T_4)	1.94^{ab}	123.89^{a}
SEM	0.01	2.07
p-value	0.0021	<.0001

^{a,b} Means within a column with different superscripts differ significantly at p<0.05., DMI=dry matter intake

Milk sourced from dairy goats fed diets with untreated *P. juliflora* leaves and pods (T_1) was low in all parameters (Table 2). Wood ash (T_2) and bentonite treated (T_3) had similar fat contents, solids, density, and salts while solids, freezing points, proteins, and lactose contents were similar in all treatments except T_1. T_1 and 50:50 wood ash and bentonite (T_4) had similar amounts of salts.

Table 2: Comparison of various parameters of milk composition of the treatments

Parameters	T_1	T_2	T_3	T_4	SEM	*p*-value
Fats (%)	2.30^{c}	5.20^{b}	6.15^{b}	8.70^{a}	0.33	0.0001
SNF (%)	6.45^{b}	9.55^{a}	9.60^{a}	8.35^{a}	0.37	0.0009
Density (g/l)	1021.98^{c}	1032.02^{a}	1032.55^{a}	1026.65^{b}	0.4	0.0001
Freezing point (°C)	0.41^{b}	0.65^{a}	0.66^{a}	0.59^{a}	0.03	0.0007
Protein (%)	2.40^{b}	3.60^{a}	3.65^{a}	3.30^{a}	0.14	0.0009
Lactose (%)	3.60^{b}	5.40^{a}	5.45^{a}	4.70^{a}	0.21	0.0009
Salts (%)	0.45^{b}	0.75^{a}	0.70^{a}	0.48^{b}	0.03	0.0002

$^{a, b, c}$ Means within a row with different superscripts differ significantly at $p<0.05$; SNF=Solids-Non-Fat

Treatment 3 had the highest amounts of iron, while other treatments had equal amounts (Table 3). Treatment 3 and 4 had similar and highest amounts of calcium while T_1 had the lowest. T_2 had the highest amount of zinc whereas the rest of the treatments had comparable amounts. Treatment 2 also had the highest similar amounts of phosphorus with T_1 while T_3 and T_4 had equal amounts.

Table 3: Iron, calcium, zinc, and phosphorus contents of the treatments

Parameters	T_1	T_2	T_3	T_4	SEM	*p*-value
Iron	13.85^{b}	18.08^{a}	12.12^{b}	11.15^{b}	0.7	0.0005
Calcium	0.32^{c}	2.30^{a}	1.98^{b}	2.16^{ab}	0.05	0.0001
Zinc	0.08^{b}	0.08^{b}	0.15^{a}	0.09^{b}	0.01	0.0015
Phosphorus	2.60^{ab}	2.45^{b}	2.86^{a}	2.38^{b}	0.07	0.0055

$^{a, b}$ Means within a row with different superscripts differ significantly at $p<0.05$

4. Discussion

The results indicate that treatment with tannin binders enhanced feed intake. As much as there was no difference between T_3 and T_4 with the control, there was a difference between T_2 and the control, and no difference between T_2, T_3, and T_4. This makes wood ash more effective in enhancing feed intake as compared to other forms of treatment when used at 400 g/l. This is in agreement with the findings of [7] that the more the amount of wood ash used, the better the results. This can be attributed to the fact that wood ash is alkaline and can be used to inhibit ant nutritional factors such as toxins in tannins in diets [21].

Tannins not only interfere with the digestibility of feeds but also limit their palatability hence intake. Wood ash has been used in the treatment of sorghum grain, millet, vegetables, and the leaves of leguminous tree forages like *Acacia cyanophylla.* T_1 might have performed the same as T_3 and T_4 because the ratio of leaves and pods in the diet can also be used to minimize the effect of tannins. According to [14], mixtures can be applied to thwart the harmful effects of tannins. [20] Also discovered that leaves of calliandra were affected when mixed with its leaves or pods. An *in-vitro* digestibility study that was conducted by [19] prior to this experiment also showed that wood ash at 400 g/l of water was more digestible than bentonite, and the ratio combination of leaves and pods also affected their digestibility.

Milk production was higher in all the treatments except the control. This could be because the ratio combination does not have as much effect on tannins as treatment with either wood ash, bentonite, or wood ash and bentonite at a 50:50 ratio combination. [10] Carried out research to determine the effect of quebracho tannin extract, a source of condensed tannins, on milk production in dairy cows among other factors, and found out that at high inclusion level, it had detrimental effects on not only milk production, but also diet digestibility, and general performance of the animals. This study shows the effects tannins have on milk production, with the treated diets generally performing better than the untreated control. In addition to that, with high tannin diets, there is reduced voluntary intake and animals tend to spend more time and energy ruminating due to the astringent factor that is formed as a result of the complexes formed with tannins and salivary proteins [15].

The results also show that the composition of milk sourced from goats in the treated diets was higher in all the parameters that were determined (fats, solids, density, freezing point, proteins, lactose, and salts) than in the control. According to [17], high tannin content in the diet reduce the productive efficiency of goats. In their study, high tannin content decreased the concentration of milk fat. This is also in agreement with the findings of [22] that investigated the effect of condensed tannins present in *Lotus corniculatus* on the lactation performance of ewes.

[18] Investigated the impact of condensed tannins on milk composition in angora goats and found out that they not only interfere with lactose content, lowering them, but also decrease the level of solids, solid-not fats and somatic cell count in milk. Tannins generally interfere with protein degradation in the rumen and increase rumen and intestinal protein by-pass by forming tannin-protein complexes which make the protein component of the feed unavailable to the animal [14]. This can explain the lower protein component in milk. It can also explain the low freezing point, density, salts, and mineral contents (iron, calcium, zinc, and phosphorus) in the control. The density of the milk derived from the control diet was below the minimum and average in goats of 27 and 30 respectively. The high calcium content in a wood ash-treated diet can be attributed to the fact that calcium is the major mineral component in wood ash. According to [21], the higher the calcium content in the diet, the lower the phosphorus content hence phosphorus deficiency in livestock. This can explain the lower phosphorus content in milk derived from goats-fed wood ash treated diets compared to bentonite treated.

5. Conclusion

It was concluded that lactating dairy goats fed diets supplemented with treated *P. juliflora* leaves and pods (75:25) performed better in terms of dry matter intake, milk production, as well as milk composition. Treatment with wood ash at the rate of 400 g/l had a higher positive impact on feed intake. Treatment with either wood ash, bentonite, or wood ash and bentonite (50:50) positively affected milk production, composition, and milk mineral content. Therefore, treatment with natural, and readily available binders (wood ash and bentonite) is effective in enhancing the performance of lactating dairy goats.

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7. Conflict of Interest

Authors agreed to lack of conflict of interest and came to an agreement to publish the paper.

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