Ghanaian Journal of Animal Science
Journal of the Ghana Society of Animal Production
GJAS, Volume 17, Number 1, 2026

Effect of Moringa and Leucaena Leaf Meals Supplementation on Yield and Quality of Milk Produced by Sanga Cows

Deku[1,*], G., Antwi[1], C., Karikari[1], P. K., Okai[1], D. B. and Omojola[2], A.B.
[1]*Department of Animal Science,*
Kwame Nkrumah University of Science and Technology, Kumasi
[2]*Department of Animal Science, University of Ibadan, Ibadan Nigeria*
**Corresponding author's email Address: gyaw.deku@gmail.com*
https://dx.doi.org/10.4314/gjansci.v17i1.13

ABSTRACT
Moringa oleifera and Leucaena leucocaephala are browse plants that are locally available throughout the year in the tropics and their leaves which are high in protein can be used to supplement feed for cattle. Hence, the study was set up to ascertain the effects of Moringa and Leucaena supplementation on milk yield and composition of milk of lactating cows. Four Sanga cows with an average weight of 340.27 kg were used in a 4x4 Latin Square design experiment over a four-period feeding trial where each period lasted for 10 days. Forages were sampled with a quadrant at each period of the experiment for dry matter composition analysis whilst the experimental diets were supplemented and studied. Milk yield, supplementary feed intake, nutrient composition of milk, biochemical and haematological indices of the blood and serum of the cows are parameters that were measured. Analysis of variance (ANOVA) related to Latin square design was used to separate the treatment means at a significance level of 5% using Minitab version 18 (2017). The results of the study showed that milk yield recorded for the lactating Sanga cows between the treatments ranged from 2218.5g/day/cow to 2423.38g/day/cow and were close to significance (p= 0.06). The levels of glucose in the blood of lactating cows were between 4.10 and 4.438 mmol/L whilst red blood cell count ranged from 5.742 to 6.388 10^6/µL. It was observed that supplementing lactating cows with feed made of wheat bran, moringa and leucaena leaf meals did not result in high cholesterol levels in the cows' serum.

Keywords: *Leaf meals, Nutrient intake, milk yield/feed intake ratio, blood and serum profile*

INTRODUCTION
Milk yield of cows in smallholder cattle farms is low and is partly due to poor feeding management in these farms (Coffie *et al*., 2015). Inadequate nutrition impacts negative effect on the growth and viability of the dairy industry (Wanapat *et al*., 1999; Njarui *et al*., 2009). Smallholder cattle farmers who usually have limited land are mostly found to practice extensive system of raising cattle hence, the cattle are made to travel a longer distance to graze. The animals are mostly underfed especially in the dry seasons and consequently produce less quantity of milk (Manu *et al*., 2014). Forages become scarce during this period and the little which is available declines in protein content (Oppong – Anane *et al*., 2000; Wanapat *et al*., 1999). Supplementing the feed of the animals with concentrate is ideal to make up for the nutritional losses but feeding concentrates as supplement to "dairy" cattle is expensive (Karikari *et al*., 2008) and due to the high cost, most smallholder cattle farmers do not give supplements to their lactating cows (Adjorlolo *et al.*, 2019). Nevertheless, Ayuk *et al*. (2002) reported that tree legumes such as leucaena have the potential to be fed to

ruminants as a feed supplement. Leaves of shrubs such as *Moringa oleifera* and *Leucaena leucocaephala* have also been fed to animals as protein supplement (Melese, 2011; Sodamade *et al*., 2013). These legumes and shrubs are locally available in Ghana, are high in protein and most are available all year round. The crude protein contents of Moringa and Leucaena leaves are about 22%, and 26% respectively (Meena *et al*., 2013). Another benefit of feeding *Moringa oleifera* to cattle is increased weight gain and milk production. For instance, studies have revealed that 32% and 43-65% increment could be achieved in weight gain and milk production respectively when *Moringa oleifera* is fed to cattle (Wanapat *et al*., 1999; Meena *et al*., 2013). It also improved feed digestibility and overall animal health (Melese, 2011; Sodamade *et. al*., 2013). Though leucaena contains mimosine (up to 12% DM in young shoots), which is detrimental to non-ruminants, it is broken down in the rumen of ruminants to DHP (3, 4 and 2, 3 dihydroxy-pyridine). Feeding dairy cows on cut-and-carry Leucaena foliage allows a substantial increase (14%) in milk yield, milk fat and protein content in milk (Melese, 2011; Sodamade *et. al*., 2013). Though Leucaena contains tannins (30mg/g), the level is below the quantity that could adversely affect the nutritive value (Ayuk *et al*., 2002) of the plant that could not serve the purpose of supplementing cattle feed.

The present study was set up to evaluate the effect of feed supplementation with *Moringa oleifera* and *Leucaena leucocaephala* on milk composition and milk yield of local breed of dairy cows in Ghana. The study also sought to assess the influence of *Moringa oleifera* and *Leucaena leucocaephala* on the serum biochemical and haematological parameters of the lactating cows.

MATERIALS AND METHODS

Experimental Site

The on – farm study was carried out at Onwe located on a GPS coordinate of 06^{0}40.798'N and 001^{0}26.851' W in the Ejisu/Juaben Municipality (now divided into two distinct Municipalities) of the Ashanti Region of Ghana. The Region is at 06^{o} 43' N, 01^{o} 36' W of the equator at an altitude of 290 m above mid-sea level. The study area is a semi-deciduous forest ecological zone and the rainfall for the area is bimodal. The rainy season is from April to July and September to November and the main dry season starts from December to March (Coffie *et al*., 2015). The mean annual rainfall is 1300 mm and the average daily temperature is 27^{o}C. (https://en.wikipedia.org/wiki/Ejisu-Juabe n_Municipal_District).

Preparation of Leaf Meals

The Moringa leaves used for the study were harvested from a Moringa farm established at the Dairy/Beef Cattle Research Station, KNUST, Kumasi. The Leucaena leaves were harvested at Aprade Junction and around KNUST Senior High School, Kumasi. Leaves of these browse plants were air dried for three weeks. After removing any remaining twigs (from the dried leaves) the leaves were milled in a cormmercially operated mill. The Moringa leaf meal (MoLM) and the Leucaena leaf meal (LeLM) were used to compound the experimental diets indicated in Table 1 and the chemical composition of MoLM and LeLM are presented in Table 2.

Experimental Cows, Design and Feeding Trial

Four lactating Sanga cows with an average weight of 340.27 kg were used for a feeding trial over a four period in a 4x4 Latin Square Design experiment. Each period lasted for ten days. The lactating cows in each of the treatments were housed individually under a shed and were given between 500 – 1000 g of formulated diet daily during the adjustment period of eight (8) days. After the adjustment period, each lactating Sanga cow was randomly assigned to one of the four treatments shown in Table 1. Each cow was fed 2 kg/day of the experimental diets shown in Table 1 for 10 days (period). The supplements were given at 10:00 h (ie. after milking) and cows that were unable to consume all the supplement had access to the remaining supplement when they returned from grazing at 18:00 h. Water was provided to all the experimental cows *ad libitum*.

Sampling of forages

The forages on the grazing fields were sampled by throwing a 1 m x 1 m quadrant at each period of the experiment. The forages found within the

quadrant were identified, harvested at about 30 cm or lower from the top of the forages, weighed, chopped and sampled for dry matter content determination. The remaining forages were air dried for three weeks, before being blended into powder with a laboratory mill (Wiley Mill, UK) using a 1 mm screen for further analysis.

Sampling of blood for haematological and biochemical tests

Blood samples were taken from the jugular vein of the Sanga lactating cows at the end of the experiment. The samples were collected in two vacutainers, an Ethylenediamine tetra – acetic acid (EDTA) coated vacutainer sample for the analysis of haematological parameters and serum vacutainer sample for biochemical indices. The collected blood samples were transported on ice to the Medical Laboratory of the KNUST Hospital, Kumasi for the analyses.

Parameters measured

Milk yield

Milk from each lactating cow in a treatment was collected, weighed daily with a top pan balance

Table 1: Formula, ingredients and chemical composition of the experimental diets (± SE)

	Dietary Treatments				
Ingredient (%)	**Treatment 1**	**Treatment 2**	**Treatment 3**	**Treatment 4**	
Moringa leaf meal	0.0	50.0	25.0	0.0	
Leucaena leaf meal	0.0	0.0	25.0	50.0	
Wheat bran	99.0	49.0	49.0	49.0	
Common salt	1.0	1.0	1.0	1.0	
Total	100	100	100	100	
Chemical composition (%)					P-value
Dry Matter	85.15±0.56	86.23±0.63	85.00±0.79	87.35±0.74	0.38
Crude Protein	15.54±0.11^{b}	20.36±0.44^{a}	20.24±0.36^{a}	19.11±0.38^{a}	< 0.001
Crude Fibre	13.14±0.58	14.11±0.81	13.79±0.36	13.95±0.23	0.61
Ether Extract	3.34±0.41^{b}	4.65±0.11^{ab}	5.17±0.41^{a}	4.21±0.28^{ab}	0.004
Ash	6.72±0.41^{b}	13.05±0.46^{a}	11.92±0.49^{a}	11.56±0.27^{a}	< 0.001
NFE	61.26±0.55^{a}	47.83±0.91^{b}	48.90±1.38^{b}	51.18±0.40^{b}	< 0.001
Energy (ME)* (MJ/kg)	1.21±0.01^{a}	1.13±0.01^{c}	1.16±0.01^{b}	1.15±0.01^{bc}	< 0.001
Detergent Fibre (%)					
NDF	40.31±1.32^{a}	30.10±1.00^{b}	30.89±0.65^{b}	32.20±0.69^{b}	< 0.001
ADF	12.17±0.47^{b}	13.59±0.87^{ab}	13.67±0.06^{ab}	14.40±0.21^{a}	< 0.001
Hemicellulose	28.14±0.94^{a}	16.51±0.57^{b}	17.22±0.63^{b}	17.80±0.56^{b}	< 0.001

Means that do not share the same superscript in a row are significantly different (P< 0.05)
**Calculated; SE = Standard Error*

Table 2: Proximate and Detergent Fibre Composition (± SE) of feed ingredients and forages

% Dry Matter Basis	MoLM	LeLM	Wheat Bran	Forage	P-value
Dry Matter	90.25±0.18^{ab}	90.58±0.46^{ab}	86.15±0.63^{c}	92.79±0.67^{a}	< 0.001
Crude Protein	23.89±0.43^{a}	18.46±0.53^{b}	15.44±0.70^{c}	7.80±0.30^{d}	< 0.001
Crude Fibre	14.53±0.74^{bc}	16.09±0.54^{b}	11.51±0.81^{c}	37.98±2.15^{a}	< 0.001
Ether Extract	4.52±0.24^{a}	4.57±0.63^{a}	3.64±0.31^{ab}	1.85±0.49^{b}	< 0.001
Ash	12.60±0.63^{a}	12.48±0.37^{a}	4.98±0.30^{c}	7.29±0.18^{b}	< 0.001
NFE	44.46±1.06^{c}	48.40±1.12^{bc}	64.43±1.47^{a}	45.08±1.66^{c}	< 0.001
Energy (ME)* (MJ/kg)	1.12±0.01^{b}	1.12±0.01^{b}	1.26±0.01^{a}	0.97±0.02^{c}	< 0.001
Detergent Fibre (%)					
NDF (%)	21.81±1.11^{d}	27.67±0.58^{c}	39.33±0.83^{b}	57.44±1.33^{a}	< 0.001
ADF (%)	13.74±0.19^{c}	16.94±0.48^{b}	11.75±0.35^{c}	32.30±0.94^{a}	< 0.001
Hemicellulose (%)	8.07±1.03^{b}	10.73±0.59^{b}	27.57±0.57^{a}	25.14±1.13^{a}	< 0.001

Means that do not share common letters in the same row are significantly (p<0.00) different; SE = Standard Error
**Calculated*

(SF - 400) and recorded as the partial milk yeild. The daily milk yield was then estimated using the fomula S=M+0.6596M as reported by Ahamefule *et al*. (2007). Where S is the daily milk yield and the M in the equation is the milk yield recorded in the morning.

Milk composition

Milk composition test was carried out at the end of the experiment. The parameters measured were protein, fat, solid not fat, total solids, density and lactose content using Lactoscan Milk Analyser (Milkotronic Limited, Bulgaria) at the Dairy Science Laboratory, KNUST Dairy/Beef Cattle Research Station, Boadi. The energy content of the milk was calculated using the formula, Cal /100g of milk = (% protein × 4) + (% fat × 9) + (% lactose × 4) as described by Salman *et al*. (2014).

Supplement intake

The supplement intake was measured by subtracting the quantity of leftover feed from the quantity of feed given to each of the cows on daily basis.

Chemical composition of the leaf meals and the supplementary diets

Proximate analysis was conducted on the leaf meals and the supplementary diets using the standard procedures of the Association of Official Analytical Chemists (AOAC, 1990). The ADF and NDF contents of the browse plants used for supplementary diet formulation were determined using the Ankom technique as described by Ankom Technology (2017a) and Ankom Technology (2017b) respectively with the tests conducted in triplicates.

The metabolisable energy in the ingredients, the four experimental diets and the forage were all estimated by the method proposed by MAFF (1975) ie.: ME (MJ/kg DM) = (0.012 x Crude Protein) + (0.031 x Ether Extract) + (0.005 x Crude Fibre) + (0.014 x Nitrogen Free Extract).

Haematological and serum biochemical indices

The haematological parameters were measured by the methods outlined by Rastogi (2008) and Cheesebrough (2004) and the serum biochemical indices were measured according to the methods described by Cheesebrough (2005) and Singh (2003).

Statistical Analysis

The analysis of variance (ANOVA) related to Latin Square Design was used to analyze the

data at significance level of 5% using Minitab version 18 (2017). Means were differentiated using Bonferroni pair comparison.

RESULTS

Forages grazed by the Sanga cows

Table 3 shows a list of the forage grazed by the lactating cows during the experimental period. *Panicum maxima* (Guinea grass) and *Centrosema pubescens* (Centro) were reported to be available on all the fields that the lactating cows grazed during the study. The other forages were only found on some of the grazing fields during some of the periods of the trial. For instance, *Commelina spp* and shrubs (eg. *Ficus exasperata*) on grazing fields used in periods 1- 3, *Mimosa spp* was on the fields used during periods 1 and 2, *Chromolaena odorata* also found on fields during periods 2 and 3 and *Pennisetum purpureum* on fields in the third and fourth periods. Rice plants, rice straws and *Sporobolus pyramidalis* were also found in the field where the cows grazed during period 2 of the study.

Proximate Composition and Detergent Fibre of Feed Ingredients

The dry matter percentage in Moringa leaf meal (MoLM) and Leucaena leaf meal (LeLM) were similar while the forage samples recorded the highest dry matter percentage of 92.79% (Table 2). Mean crude protein value in MoLM (23.89%) was significantly ($p < 0.05$) higher than the crude protein obtained for LeLM. However, LeLM was nominally higher in crude fibre than the MoLM. The highest fibre content was recorded in the forages while wheat bran had the lowest. Ether extract in the forage was similar to that of wheat bran but lower than the figure for MoLM and LeLM. Ash composition for MoLM and LeLM were similar. Additionally, MoLM, LeLM and the forages also had comparable nitrogen free extract (NFE) values. The neutral detergent fibre (NDF) for LeLM (Table 2) was significantly ($p < 0.05$) higher than the NDF in MoLM. But the NDF value in MoLM was also lower than the mean NDF for wheat bran and the forages consumed by the lactating cows. Moringa leaf meal and wheat bran had significantly ($p < 0.05$) lower acid detergent fibre (ADF) than leucaena leaf meal and the forages consumed. Moringa leaf meal had lower ($P< 0.001$) hemicellulose than the forage samples and the wheat bran but was similar to that of leucaena leaf meal.

Proximate Composition and Detergent Fibre of Experimental Diets

All the values for the proximate composition parameters measured on the experimental diets showed significant differences ($p< 0.05$) except for dry matter and crude fibre composition (Table 1).

The crude protein content of experimental diet one (T1) was 15.54% and it was lower than the crude protein in the other three dietary treatments. There was no significant difference in the crude fibre content between the four dietary

Table 3: Forages grazed by lactating Sanga cows during the various periods of the experiment

SN.	Forages	Period 1	Period 2	Period 3	Period 4
1.	Guinea grass	x	x	x	x
2.	Centrosema	x	x	x	x
3.	Mimosa	x	x		
4.	Commelina	x	x	x	
5.	Shrubs*	x	x	x	
6.	*Chromolaena odorata*		x	x	
7.	Rice plant and straw		x		
8.	*Sporobolus pyramidalis*		x		
9.	*Pennisetum purpureum* (Elephant grass)			x	x

**Shrubs include: Ficus exasperata; SN = Serial Number*

treatments. Ether extract for experimental diet 3 was significantly ($p < 0.05$) higher than that of experimental diet 1. However, the mean ether extract values for experimental diets 2, 3 and 4 were similar. Ash composition of experimental diets 2 to 4 were similar. Nitrogen free extract (NFE) content of feed for Treatment 1 was significantly higher. The NFE in diets 2 to 4 were similar. All the values for the three fibre components studied in the work were significantly ($p < 0.05$) different. Neutral detergent fibre (NDF) of experimental feeds (Table 1) in treatments 2 to 4 were comparable but significantly ($p < 0.05$) lower than NDF in experimental diet 1. Acid detergent fibre (ADF) values for the supplementary feed unlike the NDF values were similar for all the feed used except for experimental diet 4. The hemicellulose values for the supplementary feed 1 was higher than that of treatments 2 to 4.

Effect of Supplementary Diet on Feed and Nutrients Intake

The supplementary feed intake observed in Table 4 shows that the inclusion of MoLM showed significant ($p < 0.05$) decrease in feed intake by the cows in the respective treatment groups. Lactating cows in the control (T1) group (ie. without any of the browse plants) had an intake which was similar to the intake of cows in treatment 4 (ie. with leucaena leaf meal only) whilst the group which had supplementary feed that contained MoLM only (T2) had the least feed intake. However, there was no significant difference ($p>0.05$) in the nutrient and energy intake between the treatment groups.

Effect of Experimental diet on Milk yield and composition

Milk yield to supplementary feed intake ratio (1.30 to 3.46) did not show significant variation among the means in the treatment groups. It was observed that milk yield (2218.5g/day/cow to 2423.38g/day/cow) recorded for the lactating Sanga cows (Table 5) were close to significance ($p = 0.06$) with treatment 2 (Moringa only) recording the highest whilst cows in treatment 1 gave the least yield. There was no significant difference ($P < 0.05$) in the means of the values for composition of milk among the four treatments. Treatment means for milk density, conductivity and freezing point (Table 5) were statistically similar ($P > 0.05$).

Effects of experimental diets on haematological profile of lactating Sanga cows

The red blood cell count (5.742 to 6.388 x 10^6/µL) and haemoglobin values which ranged from 17.917±0.74 to 21.333±1.20 g/dL were observed to be approaching significance (Table 6). While lactating cows in treatment 2 recorded the highest value for haemoglobin and red blood cell count, cows in treatment 1 had the least value for haemoglobin and red blood cell count.

There was no significant difference in the parameters for blood platelet profile of lactating Sanga cows except for platelet large cell concen-

Table 4: Supplementary feed and nutrient intake and milk yield/ feed intake ratio (± SE)

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4	P-value
Total intake (g/cow/day)	1739.53±121^a	1166.46±218^b	1443.30±171^{ab}	1542.95±190^a	0.001
Dry Matter (g)	1481.21±103	1005.84±188	1226.81±145	1347.77±166	0.17
Protein (g)	230.11±16.0	204.79±38.3	248.31±29.4	257.42±31.7	0.60
Fat (g)	49.47±3.43	46.77±8.75	63.43±7.50	56.74±7.00	0.32
Ash (g)	99.54±6.90	131.26±24.6	146.24±17.3	155.80±19.2	0.15
Energy* (ME) MJ	17.92±1.24	11.37±2.13	14.23±1.68	15.50±1.91	0.08
Yield / supplement intake ratio	1.30±0.18	3.46±1.50	1.88±0.45	1.80±0.40	0.116

*Means that do not share the same superscript on the same row are significantly different ($P < 0.05$); SE = Standard Error; *Calculated*

Table 5: Mean Milk yield and composition of milk produced by lactating Sanga cows (± SE)

	Treatment 1	Treatment 2	Treatment 3	Treatment 4	P Value
Milk Yield/day (g)	2218.50±281	2423.38±278	2342.88±302	2328.63±290	0.06
Fat (%)	4.357±0.20	4.457±0.17	4.498±0.23	4.551±0.29	0.61
Protein (%)	2.886±0.03	2.843±0.03	2.86±0.02	2.851±0.02	0.09
SNF (%)	7.88±0.09	7.765±0.07	7.813±0.07	7.791±0.06	0.10
Total Solids (%)	12.236±0.17	12.223±0.15	12.311±0.22	12.341±0.27	0.81
Lactose (%)	4.339±0.05	4.276±0.04	4.302±0.04	4.29±0.03	0.09
Milk Density (kg/m^3)	1027.27±0.45	1026.74±0.38	1026.89±0.38	1026.76±0.41	0.61
Milk fat yield (g)	95.08±11.4	106.51±11.5	103.92±13.9	104.68±15	0.82
Conductivity (mS/cm)	3.95±0.14	3.823±0.11	3.804±0.09	3.816±0.11	0.20
Freezing Point (°C)	-0.5042±0.006	-0.4968±0.005	-0.5003±0.004	-0.4989±0.004	0.13
Milk Energy* (Cal/100g)	68.11±1.64	68.59±1.40	69.13±2.02	69.52±2.52	0.96

*SE = Standard Error; *Calculated*

tration (P-LCC) which showed a variation ($p < 0.05$) between the treatment groups (Table 6). Lactating cows on the feed made with wheat bran, *Leucaena leucocaephala* and salt (T4) had the lowest value and the feed with wheat bran and equal proportions of *Leucaena leucocaephala* and Moringa (T3) had the highest value followed by the feed with wheat bran, moringa and salt (T2).

White blood cell values did not vary significantly among the treatments. The values for the major components of the white blood cells (ie. neutrophil, lymphocyte, monocyte, eosinophil, basophil) as shown in Table 6 followed the same trend exhibited by the white blood cells.

Effects of browse plants on serum biochemical indices of lactating Sanga cows

The levels of glucose in the blood of the lactating cows in the various treatments (Table 7) were between 4.10 and 4.438 mmol/L and the differences in their means were observed to be approaching significance ($p=0.06$). However, there was a significant difference ($p < 0.05$) in the means for albumin and alkaline phosphatase between the lactating Sanga cows in the treatment groups. All the mean values for globulin, total protein, ALT and total bilirubin between the groups did not show significant differences ($p > 0.05$) but the values increased nominally from T1 to T3 and dropped in T4. While AST and direct bilirubin will rise and fall from one treatment to the other, indirect bilirubin rose from T1 to T2 and dropped further in T4. However, Gamma – GT increased nominally from T1 to T4.

Though creatinine and urea values (Table 7) did not show significant differences between the treatments, creatinine value for lactating cows in T3 was nominally higher and the urea value for T1 was nominally lower.

The lipid profile results as presented in Table 7 did not show any significant differences for any of the lipid tests conducted between groups. The nominal mean values for the lipid profile showed that the highest value for cholesterol and triaglycerides were all recorded in T3 followed by T1, T2, and T4 respectively.

DISCUSSION

Forages grazed by Sanga cows

The most common forage consumed by the lactating Sanga cows were *Panicum maxima* and *Centrosema pubescens*. The *Panicum maxima* and *Centrosema pubescens* forages were also reported by Coffie *et al*. (2015) to be grazed by lactating cows. The presence of both grasses and

leguminous forages means the lactating cows probably grazed balanced forages on the grazing fields throughout the study. However, the 7.8% crude protein of the forage, which is similar to the 7.5% (for confined N'dama calves) is lower than the 12.37% (for grazing N'dama calves) Deku and Karikari (2018) earlier reported. The availability of *Panicum maxima* (guinea grass) during the four phases of the study agrees with the observation of Obese *et al*. (2013) that *Panicum maxima* is one of the commonest grass species. The rice plant and straw in some of the fields suggests that either the field on which they were found was an abandoned rice field or it was rice field that had been left to fallow. The cows also grazed on fields that had Mimosa and *Chromolaena odorata* which also point to the fact that weeds were gradually taking over those fields.

Proximate composition of experimental feeds and feed materials

The crude protein (7.8%) in the forages consumed by the lactating cows was similar to the 7.0 % CP required to support microbial activity in the rumen of the lactating cows (Ahamefule *et al*., 2002). The low crude protein in the forage therefore supports the call for supplementing the

Table 6: Blood haematological profile of lactating Sanga cows (± SE)

Haematological profile	Treatment 1	Treatment 2	Treatment 3	Treatment 4	P - value
Red Blood Cell (10^6/µL)	5.742±0.22	6.388±0.26	5.772±0.14	6.177±0.25	0.07
Haemoglobin (g/dL)	17.917±0.74	21.333±1.20	18.6±0.95	19.733±1.35	0.06
Haematocrit (%)	28.633±1.73	31.95±1.70	27.767±1.11	30.567±1.63	0.132
MCV (µm^3)	49.567±1.27	49.8±1.00	48±1.02	49.267±0.97	0.316
MCHC (g/dL)	63.433±2.38	66.95±1.63	66.9±1.96	64.133±1.42	0.205
RDW – CV (%)	13.233±0.07	13.3±0.22	13.267±0.23	13.233±0.21	0.984
RDW – SD (µm^3)	27.433±0.58	27.45±0.52	26.733±0.56	27.3±0.44	0.288
Blood platelet profile					
PLT (10^3/µL)	436.667±45.4	469.833±45.0	429.833±32.6	394±57.6	0.42
PCT (%)	0.325±0.03	0.358±0.03	0.332±0.03	0.297±0.04	0.30
MPV (µm^3)	7.483±0.11	7.75±0.19	7.717±0.15	7.583±0.11	0.33
PDW (µm^3)	9.2±0.54	10.3±0.64	9.933±0.53	9.5±0.37	0.25
P-LCC (10^3/µL)	52.667±4.04^c	59.833±6.02^b	63.333±6.96^a	47.167±5.55^d	0.01
P-LCR (%)	12.5±0.65	13.65±1.45	14.7±1.08	12.467±0.84	0.22
Profile of white blood cells (10^3/µL)					
White Blood Cell	351.957±19.9	387.5±20.5	356.67±21.5	383.075±22.5	0.31
Neutrophil	196.492±24.8	240.14±25.9	206.918±26.6	236.97±24.6	0.34
Lymphoctes	144.345±7.41	131.095±9.01	131.933±8.58	129.685±7.24	0.40
Monocyte	4.363±0.23	3.875±0.49	6.17±1.26	4.625±0.41	0.19
Eosinophil	4.423±1.24	9.867±3.39	8.735±2.94	9.133±2.66	0.31
Basophil	1.678±0.08	1.563±0.05	1.578±0.07	1.668±0.05	0.50

± SE = Standard Error MCV: Mean Corpuscular volume, MCHC: Mean Corpuscular Haemoglobin Concentration, RDW – CV: red blood cell distribution width – complete volume, RDW – SD: red blood cell distribution width – standard deviation, PLT: Platelet PCT: Plateletcrit MPV: Mean platelet volume, PDW: Platelet Distribution Wilt, P-LCC: Platelet Large Cell Concentration, P-LCR: Platelet Large Cell Ratio

Table 7: Biochemical indices of (blood) serum for lactating Sanga cows (± SE)

Liver Function	Treatment 1	Treatment 2	Treatment 3	Treatment 4	P-value
Glucose (mmol/L)	4.188±0.11	4.175±0.07	4.1±0.08	4.438±0.14	0.06
Albumin (g/l)	20.956±2.81^{b}	21.32±2.12^{b}	26.826±2.55^{a}	22.183±2.37^{b}	0.04
Globulin (g/l)	36.398±6.42	39.701±5.09	41.613±4.37	35.954±5.32	0.31
Total Protein (g/l)	57.353±9.11	61.024±7.08	68.443±6.59	58.14±7.63	0.15
Alkaline phos (U/I)	171±25.7^{b}	171.5±18.2^{b}	231.5±30.4^{a}	175.625±21.5^{b}	0.04
ALT(U/I)	28.463±4.25	29.729±3.63	34.913±3.93	29.988±4.15	0.12
AST (U/I)	69.038±7.78	58.596±2.63	79.188±7.90	66.825±8.61	0.10
Direct Bil (µmol/l)	2.037±0.28	1.667±0.06	2.343±0.51	2.144±0.31	0.34
Total Bil (µmol/l)	0.995±0.20	1.004±0.12	1.1±0.12	0.875±0.12	0.17
Indirect Bil (µmol/l)	-1.041±0.38	-0.664±0.10	-1.245±0.56	-1.3±0.37	0.34
Gamma - GT (U/I)	19.7±2.50	20.329±1.89	21.2±3.52	23.05±4.79	0.65
Renal function					
Creatinine (µmol/l)	105.175±7.50	107.988±6.79	120.962±10.3	110.85±10.3	0.15
Urea (mmol/l)	8.094±0.75	9.877±0.81	9.815±0.80	9.479±0.80	0.17
Lipid profile					
Cholesterol (mmol/l)	2.885±0.41	2.861±0.40	3.299±0.42	2.783±0.38	0.33
Triglycerides (mmol/l)	0.255±0.04	0.23±0.01	0.28±0.03	0.246±0.03	0.59

Means with same superscript in the same row are significantly different (P< 0.05); SE = Standard Error; Bil: Bilirubin, ALT: Alanine Transaminase, AST: Aspartate Aminotransferase, Gamma – GT: Gamma – Glutamyl Transferase

diets of lactating cows (Karikari *et al.,* 2008; Moore *et al*., 1999; Susanti and Marhaeniyanto, 2007). The supplements given to the lactating Sanga cows had crude protein values of 15.54, 20.36, 20.24 and 19.11% for Treatments 1 to four respectively. The crude protein in the supplement used in Treatment 1 was significantly lower than the crude protein in Treatments 2 to four because it was made of wheat bran and salt only without any of the leaf meals. However, the crude fibre levels were similar for the feeds used in the four treatments. It is unclear why ether extract (5.17%) for the feed used in Treatment 3 (mixture of Leucaena and Moringa) had a higher value compared to that of wheat bran only and those containing wheat bran and moringa; and wheat bran and Leucaena. The ash content of the feed used in Treatment 1 (6.72%) was very low compared to the 11.56 to 13.05 obtained for T2 to T4 and it could affect the health of the lactating cows and the calves. However, the addition of salt, Moringa and *Leucaena leucocephala* leaf meals increased the ash content significantly. The percentage increase seems too high but it could be attributed to a possible synergetic effect in the compounded supplementary feed.

The fibre content of 37.98% in the present forage was close to the 34.79% observed in forage fed to confined N'dama calves and higher than 25.73% crude fibre in forages grazed by N'dama calves in a previous report by Deku and Karikari (2018). The 23.89% crude protein content recorded for Moringa leaf meal was similar to the 23.51% reported by Nouman *et al*. (2014) but lower than the 251g/kg DM and 29.6% reported by Makkar and Becker (1996) and Ogunbosoye *et. al*. (2015) respectively. The ash content for Leucaena (12.48%) was higher than the 11.4% reported by Ayssiwede *et al*. (2010). The crude protein for *Leucaena leucocephala* leaf meal of 18.46% was below the 24.9% obtained by Ayssiwede *et al*. (2010) and 25 – 44% reported by Aletor and Omodara (1994). Variations in the composition of materials could be due inter alia to the processing of the materials. However, the

crude protein for both the Moringa and Leucaena fell within the range of 17.1% to 31.2% for browse plants (Fadiyimu *et al*., 2011).

Detergent fibre composition of feed and feed materials

The compounded supplementary feeds containing equal proportions of the leaf meals did not show significant ($p > 0.05$) differences in ADF, NDF and hemicellulose values from the feeds compounded with either of the leaf meals. The NDF and hemicellulose for the supplementary feed, Treatment 1 (wheat bran only) were significantly ($p < 0.05$) higher but the ADF was similar to those of the other three treatments. Though the feed used in T1 was significantly higher in NDF, ADF and hemicellulose than the three other feeds, they were all within the 30-75% NDF range (Van Soest, 1994) and 17 – 61% ADF range (Topps, 1992; Budi and Wina, 1995).

The NDF and ADF values for *Leucaena leucocephala* leaf meal were significantly ($p < 0.05$) higher than that of *Moringa oleifera* leaf meal and this could be due to the method of preparation of the materials and maturity of the leaves (Van Soest, 1994; Oba and Allen 1999). The NDF and ADF values obtained for Moringa leaf meal were lower than the 11.40% for NDF and 8.49 % for ADF reported by Moyo *et al*. (2011) and the present ether extract value was also below the 5.95 – 18.58% range earlier reported (Ogunbosoye *et al*., 2015).

Supplementary feed intake

An intake of 1739.53 g out of 2000 g of the supplementary feed allowed in Treatment 1 implies that the feed was highly accepted by the cows. However, the addition of leaf meals reduced the intake of the supplementary feeds. The intake of feed (1542.95g) in Treatment 1 was similar to the intake of feed in Treatment 1 but was significantly ($p < 0.05$) higher than the intake (1166.46 g) of the Treatment 2 feed. This means that using as high as 50% leucaena leaf meal in the supplementary diet of lactating cow does not negatively influence feed intake. Intake of the feed made of equal amounts of *Moringa oleifera* and *Leucaena leucocephala* leaf meals was similar to the one in treatment two. Increasing moringa leaf meal only to 50% inclusion level with wheat bran decreased feed intake significantly ($p < 0.05$). The reduction could be due to poorer palatability of the Moringa leaf meal (Su and Chen, 2020). The significantly ($p < 0.05$) lower intake of the Moringa feed did not have any detrimental effect on milk yield. This could be due to its relatively high crude protein and crude fibre which aided rumen activity for improved nutrient availability.

Effect of browse plant on milk yield and composition

The milk yield of the lactating cows for the 4 treatments was between 2218.5 and 2423.38 g/day/cow and was lower than the 2.7L (2789 g) reported by Karikari *et al*. (2008). It was expected that supplementation with the MoLM and LeLM would have increased milk yield and enhanced composition significantly as reported by Martono *et al*. (2016) but the increase was only close to significance for yield, and for protein and lactose contents. This could be due to the duration of milk collection from the cows, the kind of roughage fed and the energy composition of the consumed feed (Abughazaleh, 2008; Fernandes *et al.*, 2009).

Effects of browse plants on blood haematological profile of lactating Sanga cows

The haematological profile studied included the red blood cells, platelet and white blood cells profiles. The three haematological profiles have been discussed below.

Red blood cells

Red blood cell counts which ranged from 5.742 to 6.388 x 10^6/µL were within the normal limit of 4.9 – 7.5 x 10^6/µL (Wood and Quiroz – Rocha, 2010), 5 – 10 x 10^6/µL (Kraft and Durr, 2005) and 5.1- 7.6 x 10^6/µL (George *et al*., 2010). This indicates that the lactating cattle were in good health (Roland *et al*., 2014). However, the MCHC values were higher than the normal limits of 36 – 39 g/dl (George *et al*., 2010). The high MCHC value (Table 6) could be due to hemolysis (Gaven *et al*., 2010).

Haemoglobin

Haemoglobin (HGB) test results (17.92 – 21.3 g/dL) were above the 8.4 -12.0; 9-14; 8.5- 12.2 g/dL reported by Wood and Quiroz – Rocha (2010); Kraft and Durr (2005) and George *et al.*

(2010) respectively. The high haemoglobin values suggest that the lactating Sanga cows might have had some health challenge (Roland *et al*., 2014). The haematocrit value for treatment 2 and treatment 4 were slightly above the 28.5 – 30.02% reported by Coroin *et al*. (2017) but within the 28 – 38 % reported by Kraft and Durr (2005). The MCV and RDW – CV were also within the normal ranges reported by Wood and Quiroz-Rocha (2010).

Blood platelet profile

Platelet count values (Table 6) were within the normal physiological range of 160 – 650 × 10^3/µL (Wood and Quiroz-Rocha, 2010) and the MPV values of 7.43 – 7.75 were close to the upper limit of the 4.5 – 7.5 µm^3 reported by George *et al*. (2010). This showed that all the lactating cows had high supply of iron and enough of the platelets were produced and their loss was not at a faster rate and so they did not stand the chance of suffering thrombosis (Roland *et al*., 2014).

Profile of white blood cells

White blood cells figures (351.96 – 387.5 x 10^3/µL) were higher than the 7.8 – 15.1 x 10^9/L reported by Coroian *et al*. (2017). Though WBC decreases with age and lactating cows record lower WBC counts than their non-lactating counterparts, the high values recorded in this study may be due to tick infection (Roland *et al*., 2014).

Effects of browse plants on biochemical indices of serum

The biochemical indices considered were liver, renal functions and lipid profile of the lactating Sanga cows and are discussed below.

Liver function

The glucose values of 4.10 to 4.438 mmol/L obtained from the lactating Sanga cows in this study was within the range of 3.33 – 6.11 mmol/L reported by Tietz (1995). The present result suggests that the lactating cows could obtain enough glucose for the functioning of the mammary gland (Davis and Bauman, 1974) and milk and lactose secretion (Ahrne *et. al*., 1983).

Though Treatment 3 (T3) had significantly ($p < 0.05$) higher serum albumin, the result for all four treaments in this study were below the 29.2 – 36.9 g/L, 30.0 – 35.5g/L and 35 – 50 g/L recorded in earlier works by Coroian *et al*. (2017), Pampori (2003) and Singh (2003) respectively. It is possible that the higher nutritional demand for milk synthesis could have led to the low albumin levels in the lactating Sanga cows. However, a mixture of equal levels of moringa and leucaena mixed with wheat bran appeared to have sustained the albumin level to a significant ($p < 0.05$) level in the lactating cows as observed in Treatment 3 (T3).

Renal functions

The values of 8.09 to 9.88 mmol/L observed in this study for urea was higher than the 1.07 – 1.47 mmol/L (19.18 – 26.4 mg/dL) and 3.6 to 8.9 mmol/L in the serum of lactating cows previously reported by Coroian *et al*. (2017) and Merck Veterinary Manual (2010) respectively. The creatitine values observed in this study were within the normal range of 44 – 194mmol/L (Merck Veterinary Manual, 2010). The creatinine and urea values which did not show significant ($p > 0.05$) differences indicated that the moringa and leuceana leaf meals used in this study had similar effects on the kidney functions of the lactating cows.

Lipid profile

The cholesterol values of 2.783 to 3.299 mmol/L observed in this study were lower than the 110.6- 128.8 mg/dL earlier reported (Coroian *et al.*, 2017) but higher than the earlier report of 2.47 mmoL (Damptey *et al.,* 2014). However, it was within the normal range of 1.6 – 5.0 mmol/L (Merck Veterinary Manual, 2010). This suggests effective use of energy as the lactating cows require high amount of energy to synthesise milk. Supplementing lactating cows with feed made of wheat bran, moringa and leucaena leaf meals did not result in high cholesterol levels in the cows' serum. The triglyceride levels of 0.23 to 0.28 mmol/L were similar to the 0.25 mmol/L reported for Sanga cattle by Adjorlolo *et al*. (2019).

CONCLUSION

Using 50% of leucaena leaf meal in T3 had an intake which was similar to the feed without leaf meal, even though the use of 50% moringa leaf meal led to a significant decrease in feed intake it did not have negative effect on milk yield.

The supplementary feed intake of the Leucaena leaf meal diet was higher than that of Moringa leaf meal. The effect of this variation in feed intake on milk yield was close to significance but the nutritional quality of the milk were similar. The Mean corpuscular haemoglobin concentration and haemoglobin levels in the lactating Sanga cows were negatively affected but the liver enzyme concentration showed that there was no detrimental effect on the liver of the lactating Sanga cows used.

REFERENCES

Abughazaleh, A.A. (2008). Effect of fish oil and sunflower oil supplementation on milk conjugated linoleic acid content for grazing dairy cows. Animal Feed Science and Technology, 141:220-232.

Adjorlolo L., Obese, F. Y. and Tecku, P. (2019). Blood metabolite concentration, milk yield, resumption of ovarian activity and conception in grazing dual purpose cows supplemented with concentrate during the postpartum period. Veterinary medicine and science, 5:103-111.

Ahamefule, F.O., Ahamefule, F.O., Ukweni, I.A. and Umunnakwe, D. U. (2007). Performance of weaner rabbits fed diets containing raw and processed pigeon pea seed meal (*Cajanus cajan*). Journal of Animal and Veterinary Advances., 6(6):797-801.

Ahamefule, F.O., Ibeawuchi, J.A. and Oche, .J.E. (2002). An assessment of the nutritive value of browse plants in Makurdi, Nigeria. Nigerian Agricultural Journal 33:128-135.

Ahrne, L., Bjork, L. and Claesson, O. (1983). Glucose levels in bovine colostrum. Journal of Dairy Research, 50: 97-100.

Aletor, V.A. and Omodara, O.A. (1994). Studies of some leguminous browse plants with particular reference to their proximate, mineral and some endogenous anti-nutritional constituents. Animal Feed Science Technology, 46: 343-348.

Ankom Technology (2017a). Acid Detergent Fiber in Feeds- Filter Bag Technique (for A2000 and A2000I). https://www.ankom.com/sites/default/files/document-files/method_12_ADF_A2000.

Ankom Technology (2017b). Neutral Detergent Fiber in Feeds- Filter Bag Technique (for A2000 and A2000I). https://www.ankom.com/sites/default/files/document-files/method_13_ADF_A2000.pdf

AOAC (1990). Official Methods of Analysis. In: AOAC (15th edition), Arlington, Virginia, USA. pp: 1298.

Ayssiwede, S. B., Dieng, A. Chrysostome, C., Ossebi, W., Hornick, J. L. and Missohou, A. (2010). Digestibility and metabolic utilization and nutritional value of *Leucaena leucocephala* (Lam) leaves meal incorporated in the diets of indigenous Senegal chickens. International Journal of Poultry Science 9(8):767-776.

Ayuk, A., Iyayi, E. A. and Okon, B. I. (2002). Proximate composition and tannin content of some multipurpose tree leaves. Global Journal of Agricultural Sciences, 1(2): 77-82.

Budi, T. and Wina, E. (1995). Chemical Evaluation of Shrub Legumes. Indonesian Agricultural Research and Development Journal 33:128-135.

Cheesebrough, M. (2004). District laboratory practice in tropical countries, Part 2. Cambridge University Press, Cambridge.

Cheesebrough, M. (2005). District laboratory practice in tropical countries, Part 1, 2nd edition. Cambridge University Press, Cambridge.

Coffie, I., Annor, S. Y., Kagya-Agyemang, J. K., and Bonsu, F. R. K. (2015). Effect of breed and non-genetic factors on milk yield of dual-purpose cattle in Ashanti Region, Ghana. Livestock Research for Rural Development. http://www.lrrd.org/lrrd27/7/coff27134.htm

Coroian, C.O., Mireşan, V., Coroian, A., Răducu, C., Andronie L., Marchiş Z., Terheş S. and Muntean M-V. (2017). Biochemical and hematological blood parameters at different stages of lactation in Cows. Bulletin UASVM Animal Science and biotechnologies 74(1):31-36.

Damptey, J. K., Obese, F. Y, Aboagye, G. S, Ayim-Akonor. M and Ayizanga .R.A.

(2014). Blood metabolite concentrations and postpartum resumption of ovarian cyclicity in Sanga cows. South African Journal of Animal Science 44: 10-17.

Davis, C. L. and Bauman, D. E., (1974). General metabolism associated with the synthesis of milk. *In.:* Larson, B. L. and Smith, V. R. (eds). Lactation: A comprehensive treatise. 2: 3--30. Academic Press New York and London.

Deku, G. and Karikari, P.K. (2018). Response of early weaned N'dama calves to different feeding management systems. Ghanaian Journal of Animal Science 9(2):64-72.

Fadiyimu, A. A., Fajemisin, N. A. and Alokan. J. A. (2011). Chemical composition of selected browse plants and their acceptability by West African Dwarf Sheep. Livestock Research for Rural Development 23 (12).

Fernandes, A.R.M., Sampaio, A.A.M. and Henrique, W. (2009). Composição química e perfil de ácidos graxos da carne de bovinos de diferentes condições sexuais recebendo silagem de milho e concentrado ou cana-de-açúcar e concentrado contendo grão de girassol. Revista Brasileira de Zootecnia, 38:705-712.

Gaven. M, Malikovich. A.Y, Sergeevich. P. (2010). Resonance one-body Scattering on a Junction. Nanosystem: Physics, Chemistry and Mathematics 1 (1):108-147.

George, J.W., Snipes, J. and Lane, V.M. (2010). Comparison of bovine hematology reference intervals from 1957 to 2006. Veterinary Clinical Pathology Journal 39:138–148. 592-598.

Karikari, P. K., Asare, K. and Okantah, S. A. (2008). The economic feasibility of concentrate supplementation of lactating sanga cows grazing natural pasture in the dry season. Livestock Research for Rural Development 20(12). http://www.lrrd.org/lrrd20/12/kari20203.htm

Kraft, W. and Durr, U. M. (2005). Klinische Labordiagnostik in der Tiermedizin [Clinical laboratory diagnostics in veterinary medicine], 6th ed. Schattauer, Stuttgart, Germany. :592-598.

MAFF (1975). Ministry of Agriculture, Fisheries and Food. Energy allowance and feeding system for ruminants. Technical Bulletin 33, Ministry of Agriculture, Fisheries and Food, HMSO, London, pp 63 – 67.

Makkar, H.P. and Becker K. (1996). Nutritional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Animal Feed Science and Technology. 63: 211–228.

Manu, I. N., Bime, M.J., Fon, D. E, and Ajaga, N. J. I. (2014). Effect of farmer-grazer conflicts on rural development: A Socio- Economic Analysis. Journal of Agricultural Science 4(3):113-120.

Martono, Y., Riyanto, S. and Rohman, A. (2016). Improvement of method fast and isocratic RP-HPLC analysis of major diterpene glycoside from Stevia rebaudiana leaves. Advances of Science and technology for society: Proceedings of the 1st International Conference on Science and Technology 2015. Doi: 10.1063/1.4958509.

Meena D. V. N., Ariharan V. N. and Nagendra P. P. (2013). Nutritive value and potential uses of *Leucaena leucocephala* as biofuel – A mini review. Research Journal of Pharmaceutical, Biological and Chemical Sciences 4(1): 515.

Melesse, A. (2011). Comparative assessment on chemical compositions and feeding values of leaves of *Moringa stenopetala* and *Moringa oleifera* using *in vitro* gas production method. Ethiopian Journal of Applied Science and Technology. 2(2): 31 – 41

Merck Veterinary Manual, (2010): A Handbook of Diagnosis, Therapy and Disease Prevention and Control for Veterinarians, 10th edition. Kahn CM, Line S (eds), Merck and Co. Inc., New Jersery. pp. 905-908.

Minitab Inc. (2017). 'Minitab Statistical Package, Version 18'.

Moore, J. E., Brant, M. H., Kunkle, W. E. and Hopkins, D. I. (1999). Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. Journal of Animal Science. 2:122-35. doi: 10.2527/1999.77suppl_2122x.

Moyo, B., Masika, P. J., Hugo, A. and Muchenje, V. (2011). Nutritional Characterization of Moringa (*Moringa oleifera* Lam.) leaves. African Journal of Biotechnology. Doi: 10.12925/12933.

Njarui. D. M. G, Gatheru. M, Wambua. J. M, Nguluu. S. N, Mwangi. D. M and Keya. G. A. (2009). Dairy Cattle Value Chain Assessment: Characterization of Milk production in Semi- Arid Kenya. Kenya Arid and Semi- Arid Land Programme (KASAL).

Nouman. W, Basra. S. M. A, Siddiqui. M.T, Yasmee. A, Gull. T, and Cervantes Alcayde. M. A. (2014). Potential of *Moringa oleifera* L. as livestock fodder crop: A Review. Turk. J. Agric. 38(1): 1-14.

Oba M. and Allen. M.S. (1999). Evaluation of the importance of the digestibility of Neutral Detergent Fiber from forage: Effects on dry matter intake and milk yield of dairy cows. Journal of Dairy Science. https://doi.org/10.3168/jds.S0022-0302 (99)75271-9.

Obese F.Y, Achempong. D. A. and Darfour-Oduro. K. A. (2013). Growth and reproductive traits of Friesian x Sanga crossbred cattle in the Accra Plains of Ghana. African Journal of Food, Agriculture, Nutrition and Development. 13(2):7357-7371.

Ogunbosoye, D. O., Tona, G. O. and Otukoya, F. K. (2015). Evaluation of the nutritive value of selected browse plant species in the southern guinea savannah of Nigeria for feeding to ruminant animals. British Journal of Applied Science And Technology 7(4): 386-395.

Oppong-Anane, K., Addae, P. C., Awotwi, E. K. and Oddoye, E. (2000). Behaviour Interactions between West African dwarf nanny goats and their single-born kids during 48 hours post-partum. Applied Animal Behaviour Science 68:281-291.

Pampori (2003) and Pampori, Z.A. (2003). Field cum Laboratory Procedure in Animal Health Care. Daya Publishing House, India. 185 pp

Rastogi, S.C. (2008). Essentials of Animal Physiology, 4th edition. New Age international (P) limited, New Delhi.

Roland, L., Drillich, M. and Iwersen, M. (2014). Hematology as a diagnostic tool in bovine medicine. Journal of Veterinary Diagnostic Investigation 26(5):592-598

Salman, M. S., Ali, S., Jan. M. T., Afridi, M.S. and Malik, M. S. (2014). Comparative studies of various phytonutrients in citrus fruits. Pakistan Journal of Chemistry. Doi:10. 15228/2014.v04.i02. p4.

Singh, S.P. (2003). Practical Manual of Biochemistry, 4th edition. CBS publishers, New Delhi.

Sodamade, A., Bolaji, O. S. and Adeboye, O. O. (2013). Proximate analysis, mineral contents and functional properties of *Moringa oleifera* leaf protein concentrate IOSR Journal of Applied Chemistry 4(6): 47-51.

Su, B. and Chen, X. (2020). Current status and potential of *Moringa oleifera* leaf as an alternative protein source for animal feeds. Frontiers in Veterinary Science, 53.

Susanti, S and Marhaeniyanto, E. (2007). Kecernaan, Retensi Nitrogen dan Hubungannya dengan Produski susu Pada Sapi Perananakan fresian Holestein yang diberi Pakan Pollard dan Bekatul. Journal Protein. 15(2):147-147.

Tietz, N.W. (1995). Clinical Guide to Laboratory Tests, 3rd edition. WB Saunders Co. Philadelphia.

Topps, J.H. (1992). Potential, composition and use of legume shrubs and trees as fodders for livestock in the tropics. The Journal of Agricultural Science 118 (01): 1-8.

Van Soest, P.J. (1994). Nutritional Ecology of the Ruminant (2nd Edition). Cornell University Press, Ithaca, New York.

Wanapat, M., Pimpa, O., Petlum, A., Wchirapakorn, C. and Yuanklang, C. (1999). Participation shceme of smallholder dairy farmers in the Northeast Thailand on improving feeding systems.

Wood, D. and Quiroz-Rocha, G.F. (2010). Normal hematology of cattle. *In*: Schalm's Veterinary Hematology, ed. Weiss DJ, Wardrop KJ, 6th ed., pp. 829–835. Wiley, Ames, IA.