Online Journal of Animal and Feed Research

Volume 6, Issue 2: 38-44; Mar 30, 2016

ISSN 2228-7701

MINERALS DISAPPEARANCE RATE OF LEAVES OF SOME ACACIA TREES AFTER DIGESTION IN GOATS' RUMEN USING NYLON BAGS TECHNIQUE

Nabaa Kamal AL SHAFEI[1] and Abdelfattah NOUR[2]

[1]*Department of Biochemistry, Faculty of Veterinary Medicine, University of Bahri, Sudan*

[2]*Department of Basic Medical Sciences, College of Veterinary Medicine, Purdue University, USA*

Email: nabaak@yahoo.com

ORIGINAL ARTICLE
pii: S222877011600007-6
Received 01 Mar. 2016
Revised 19 Mar. 2016
Accepted 24 Mar. 2015

ABSTRACT: The browse plants, including acacia species, provide excellent forage with high nutritive value for ruminants especially in dry areas of Africa. In this study, some minerals (P, K, Na, Mg, Ca, Mn, Cu and Zn) were determined in leaves of browse plants (*Acacia albida, Acacia nubica, Acacia sieberiana, Balanites aegyptiaca and Ziziphus spina- christi)* collected from different areas of Sudan before and after digestion of the sample in goat's rumen by using nylon bag technique. Nylon bags containing the samples were inserted through the rumen fistula into the goat's rumen, and were incubated for 6, 12, 24, 48, and 72 hrs. After incubation periods, it was found that there were a high loss of minerals and this is attributed to the rumen digestion and solubility of minerals in rumen liquor. The results indicate that the time of incubation and the type of mineral likely had a significant effect on the loss of minerals in the rumen. It can be observed from these figures that the disappearance rates (slope of the curves) vary across mineral types and species of acacia trees. Disappearance rates suggest that the rumen microorganisms have a significant role in the digestion of minerals and their disappearance rates are due to the solubility of minerals in the rumen liquor and the loss of minerals due to utilization of microorganisms to a certain amount for their maintenance.

Keywords: Acacia Trees, Browse Plants, Minerals, Rumen, Nylon Bag Technique, Disappearance Rates.

INTRODUCTION

The growing patterns, leaf longevity and growing dynamics that characterize plants species (González et al., 2010) provide habitat to wildlife (González and Cantu, 2001). Further, leaf longevity has an impact on the vegetation biomass (Zhang et al., 2016). Forage plants provide small ruminants and other livestock with good quality forage which is high in protein, fiber, vitamins and essential fatty oils for (Moya et al., 2002). Although ruminants in the tropics naturally graze growing forages which are poor in quality and have low digestibility (Minson, 1980), acacia trees provide browse that is important for goats and camels nutrition. Browse and shrubs can provide supplemental feeds for ruminants grazing tropical pastures, and provide very much needed nutrients and minerals (Minson, 1980). Edible browse tree parts serve as an insurance against seasonal feed shortages. In that regards, acacia trees and shrubs are important for sustaining livestock productivity in arid and semi-arid zones (Backlund, 1991). The main feature of browse plants is their high crude protein and mineral contents, with higher calcium and potassium content than other minerals (Backlund and Belskog, 1991). Because quantity and quality of grasses decrease in the dry season, livestock growth, development, and animals' productivity suffer (Darrag, 1995). Brows plants, which are well adapted to water stress by means of their morpho-physiological traits, thrive under drought conditions (Fardous et al., 2011) and provide valuable feeds for browsing animals. In the semi-arid rangeland of Sudan where this study was conducted, free grazing of rangelands sustains traditional livestock production. The contributions of browse acacia trees to livestock nutrition needs to be investigated The objective of this study was to determine the minerals composition of some acacia browse plants collected from different areas of Sudan before and after the digestion in the goat rumen using nylon bags technique for different periods of time.

MATERIAL AND METHODS

Animals

Three female Nilotic goats approximately 20 kilograms of weight and 2 years of age, were used in this experiment. All goats were apparently healthy. The animals were housed separately under hygienic conditions in clean rooms, with adequate light and good ventilation. All animals were fed with Berseem (*Medicago sativa*). The rumen fistula was made as described by Alshafie and Nour (2016). Animals were kept for two weeks before experiment for acclimatization. The experimental period was two weeks.

Collection of feed material (Acacia leaves)

In this study, leaves were obtained from *Acacia albida, Acacia nubica, Acacia sieberianae, Balanites aegyptiaca and Ziziphus spina- christi* acacia trees growing in different parts of the Sudan. The leave samples were carefully cleaned and freed from stones, dirt, and other materials; they were then numbered and carefully stored in polythene bags. The leaves were analyzed for their chemical composition as described by Alshafie and Nour (2016)

Nylon bags

To ensure that rumen fluid can easily enter the bag and mix with sample, the size of the bags was selected to be large enough relative to sample used and small enough so it can easily be withdrawn through the rumen fistula. The mesh size of these bags allows entry of rumen microbes and exit of accumulated gases. On the other hand, mesh size ensures that the losses of solid particles will be minimal.

Analytical methods

Preparation of the samples for minerals analysis

Approximately, three grams of each test sample were weighed and placed into pre-weighed empty, clean and dry crucibles. All the crucibles were numbered and were then transferred to an oven and the temperature was adjusted to 100°C. The samples were left in the oven for 24 hrs and then the crucibles were weighed several times until a constant weight was reached. The dry

To cite this paper: Al shafei N. K and Nour A. 2016. Minerals disappearance rate of leaves of some acacia trees after digestion in goats' rumen using nylon bags technique. *Online J. Anim. Feed Res*., 6(2): 38-44.

Scienceline/Journal homepages: www.science-line.com; www.ojafr.ir

samples weights were calculated and recorded. Crucibles and their contents of the dry matter were transferred to a muffle furnace set at 250ºC. The temperature was then increased by 25ºC gradually until it reached 450ºC. The samples were left over night to ash. The crucibles and their contents were left to cool at room temperature.

Material extraction was done by adding 10 ml of 25% HCL to the dry ash. The extract was then dried on a sand bath, and then the contents were boiled and filtered into 50-ml volumetric flask using 1% HCL. The final volume was made up to 50 ml with 1% HCL solution. 20 ml of each treated sample were then pipetted into a clean acid washed dry plastic vials, the vials were closed, and saved for mineral analysis. Calcium (Ca), Magnesium (Mg), Cupper (Cu), Zinc (Zn) and Manganese (Mn) were determined by the atomic absorption spectrophotometer, while the flame photometer (FP 410 Corning) was used to estimate the Sodium (Na) and Potassium (K) levels in the samples. Phosphorus (P) concentration was determined calorimetrically as described by Parkinson and Allen (1975).

Preparation of the sample for incubation

Prior to the use, the nylon bags were thoroughly washed under tap water, dried to a constant weight at 105° C in a hot air oven and weighed. Four grams of each sample were placed in the bag.

Incubation of the bags in the rumen

Minerals disappearance rate of acacia leaves were determined using the nylon bags technique described by Alshafie and Nour (2016). Briefly, the nylon bag containing four grams of the browse leave samples were administered into the rumen directly through the fistula, and were incubated for 6, 12, 24, 48 and 72 hrs. Each sample was replicated 3 times in one of three goats used. At the end of the incubation period, the bags were washed cleaned, and dried as described by Alshafie and Nour (2016). The losses were determined by calculating the mean of the three replications.

Statistical analysis

Data were subjected to standard methods of statistical analysis that was performed using windows-based Statistical Package for Social Sciences (SPSS) Version 17.0. Descriptive statistic (percentages, means and standard deviation) was used to evaluate the minerals disappearance rates in leaves of acacia trees.

RESULTS

Minerals composition of the browse plants studied is given in table 1. The content of phosphorus in the browse samples analyzed was within the range of 0.09- 0.21 %. Some browse species, including *Ziziphusspina Christi*, had high phosphorus content. These include *Z. spina-christi* and *A.siebriana*. On the other hand, *Balaneties. Aegyptiaca* had low phosphorus content. The content of calcium in the browse samples analyzed ranged between 4.05- 10.92%. *Balanites aegyptiaca* had the highest calcium content, while, *A. albida* leaves has the lowest calcium content. On the other hand, the content of magnesium in browse samples analyzed ranges between 0.80- 1.92%. The browse species with the high magnesium content was *Z. spina-Christi*, while *A. seibriana* and *A. albida* contained low amount (Table 2). Sodium content in the browse samples ranged between 12.23-17.06%. Generally, all samples had high sodium content. The potassium content in the browse samples analyzed ranged from 0.29% to 2.49%. *A. albida* had the lowest value, while *Balanites aegyptiaca* had the highest potassium in their leaves. Samples content of zinc was between 0.30 to 1.22%. The browse species with the high zinc content was *A.seibriana*, while *Balanites aegyptiaca* contained low amount. The content of copper in the samples analyzed was within the range of 0.049-0.079%. The acacia trees with the highest copper content was *Balanites aegyptiaca*, and the sample that contained the lowest amount of copper was *A. albeda*. Manganese content in the acacia leaves analyzed was within the range of 0.0135 to 0.0487%. Generally, all samples were low in manganese (Table1).

Tables 2 through 7 and figures 1 through 5 present the concentration of minerals after the incubation of the samples in the rumen. There is a marked loss in the mineral concentration of the samples analyzed after incubation in the rumen of goats compared to that of un-incubated samples. The difference between mineral levels of the incubated samples and un-incubated ones is clear as shown in the tables. It can be said that from figures 1 through 5 that showed the pattern of the change in the concentration of Mg, Ca, Na, Cu, Mn and Zn of different browse plants incubated in the rumen of goat; and that all the curves showed regular loss of minerals. In all samples, the loss of element increased with increasing incubation time.

Table 1 - Percentages of phosphorus, potassium, magnesium, calcium, manganese, copper and zinc of leaves of some Acacia browse trees in Western Sudan.

Botanical name	P%	K%	Na%	Mg%	Ca%	Mn%	Cu%	Zn%
Acacia albida	0.18	0.29	14.01	0.80	4.05	0.0135	0.049	1.02
Acacia nubica	0.14	1.03	12.73	1.02	5.35	0.0312	0.057	0.42
Acacia seiberiana	0.19	1.06	13.32	0.80	5.95	0.0214	0.069	1.22
Balanites aegyptiaca	0.09	2.49	17.00	1.70	10.92%	0.0484	0.079	0.30
Ziziphusspina christi	0.21	1.22	17.06	1.92	8.92	0.0217	0.057	0.37

Table 2 - The mean values ± SD of Mg^{+2} % in different acacia plants incubated in the rumen of goats for different periods of time by using nylon bag technique.

Botanical name	Incubation period in hours				
	0	12	48	72	Means± SD
Acacia albida	0.80	0.60	0.40	0.20	0.5 ±0.26
Acacia nubica	1.02	0.50	0.45	0.30	0.57 ±0.31
Acacia seiberiana	0.80	0.80	0.60	0.20	0.6 ±0.28
Balanites aegyptiaca	1.70	0.60	0.42	0.30	0.76 ±0.64
Ziziphusspina christi	1.92	0.70	0.50	0.40	0.88 ±0.70

To cite this paper: Al shafei N. K and Nour A. 2016. Minerals disappearance rate of leaves of some acacia trees after digestion in goats' rumen using nylon bags technique. *Online J. Anim. Feed Res*., 6(2): 38-44.
Scienceline/Journal homepages: www.science-line.com; www.ojafr.ir

Table 3 - The mean values ± SD of Ca^{+2} % in different plants incubated in the rumen of goats for different periods of time by using nylon bag technique.

Botanical name	Incubation period in hours				
	0	12	48	72	Means ± SD
Acaciaalbida	4.05	1.90	1.70	1.00	2.16 ±1.32
Acacianubica	5.35	1.50	1.30	1.10	2.31 ± 2.03
Acacia seiberiana	5.95	1.70	1.20	0.80	2.41 ±2.39
Balanites aegyptiaca	10.95	1.80	1.60	0.50	3.71 ±4.68
Ziziphus spinachristi	8.92	1.90	1.70	0.60	3.28 ±3.80

Comparison between different incubation times are given as Mean ± SD

Table 4 - The mean values ± SD of Na^{+} % in different plants incubated in the rumen of goats for different periods of time by using nylon bag technique.

Botanical name	Incubation period in hours				
	0	12	48	72	Means ± SD
Acacia albida	14.01	13.75	11.00	10.25	12.25 ±1.91
Acacia nubica	12.73	12.50	11.25	9.75	11.56 ±1.37
Acacia seiberiana	13.32	12.75	10.25	8.25	11.14 ±2.34
Balanites aegyptiaca	17.00	15.50	11.50	9.25	13.31 ±3.57
Ziziphus spinachristi	17.06	16.25	12.50	10.50	14.08 ±3.10

Comparison between different incubation times are given as Mean ± SD

Table 5 - The mean values ± SD of Cu^{+2} % in different plants incubated in the rumen of goats for different periods of time by using nylon bag technique.

Botanical name	Incubation period in hours				
	0	12	48	72	Means ±SD
Acacia albida	0.049	0.04	0.03	0.01	0.03 ±0.012
Acacia nubica	0.057	0.05	0.04	.02	0.04 ±0.02
Acacia seiberiana	0.069	0.06	0.05	0.015	0.05 ±0.02
Balanites aegyptiaca	0.079	0.07	0.04	0.025	0.05 ±0.03
Ziziphus spinachristi	0.057	0.05	0.04	0.01	0.04 ±0.02

Comparison between different incubation times are given as Mean ± SD

Table 6 - The mean values ± SD of Zn^{+2}% in different plants incubated in the rumen of goats for different periods of time by using nylon bag technique.

Botanical name	Incubation period in hours				
	0	12	48	72	Means ±SD
Acacia albida	1.02	0.280	0.240	0.180	0.430 ±0.395
Acacia nubica	0.42	0.202	0.165	0.110	0.224 ±0.136
Acacia seiberiana	1.22	0.250	0.182	0.110	0.441 ±0.523
Balanites aegyptiaca	0.30	0.265	0.110	0.075	0.188 ±0.1115
Ziziphus spina Christi	0.37	0.3	0.125	0.100	0.224 ±0.132

Comparison between different incubation times are given as Mean ± SD

Table 7 - The mean values ± SD of Mn^{+2} % in different plants incubated in the rumen of goats for different periods of time by using nylon bag technique.

Botanical name	Incubation period in hours				
	0	12	48	72	Means ± SD
Acacia albida	0.0135	0.011	0.0062	0.0061	0.0092 ±0.0037
Acacia nubica	0.0312	0.030	0.0053	0.0019	0.0171 ±0.0157
Acacia seiberianae	0.0214	0.019	0.0079	0.0028	0.01280 ±0.0089
Balanites aegyptiaca	0.0484	0.010	0.0062	0.0061	0.0177 ±0.0206
Ziziphus spina christi	0.0217	0.019	0.0086	0.0030	0.0131 ±0.0088

Comparison between different incubation times are given as Mean ± SD

To cite this paper: Al shafei N. K and Nour A. 2016. Minerals disappearance rate of leaves of some acacia trees after digestion in goats' rumen using nylon bags technique. *Online J. Anim. Feed Res.*, 6(2): 38-44.
Scienceline/Journal homepages: www.science-line.com; www.ojafr.ir

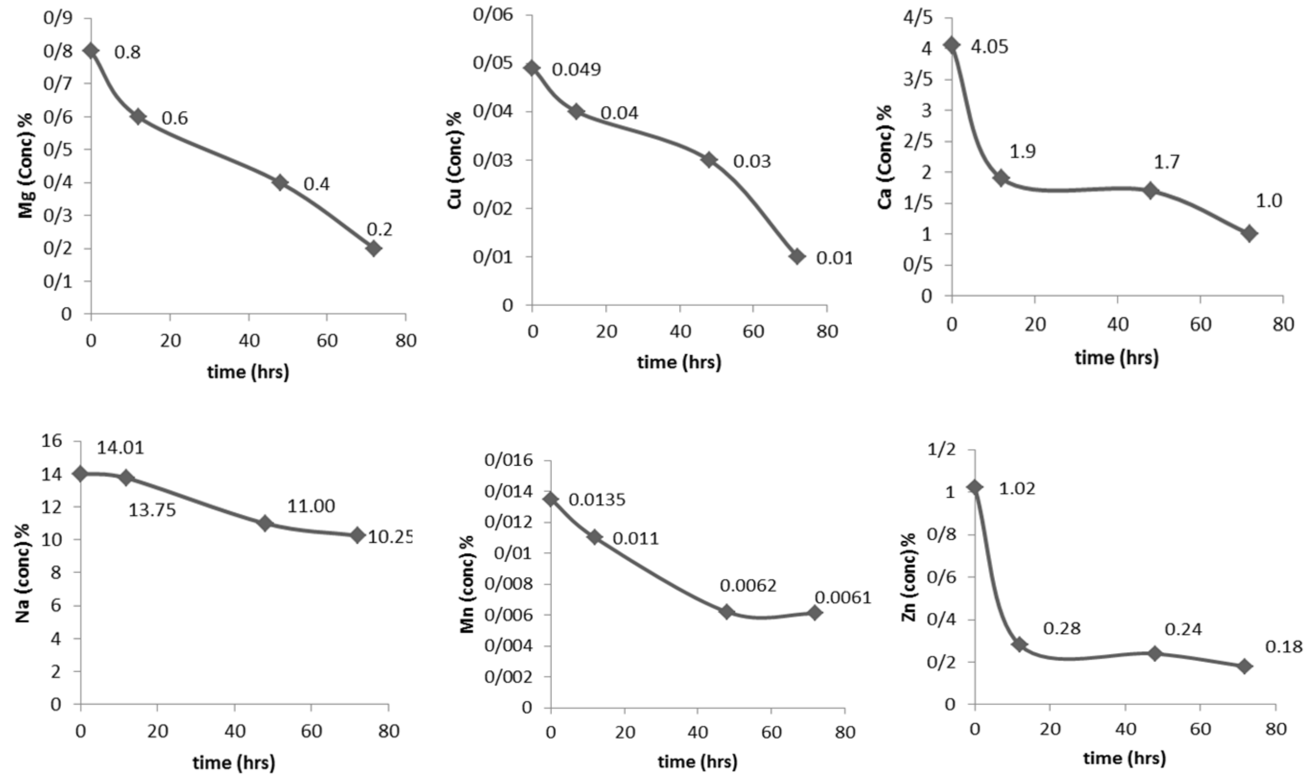

Figure 1. Minerals disappearance rates of *Acacia albida* after incubation in the rumen for 0, 20, 40, 60, and 80 hrs.

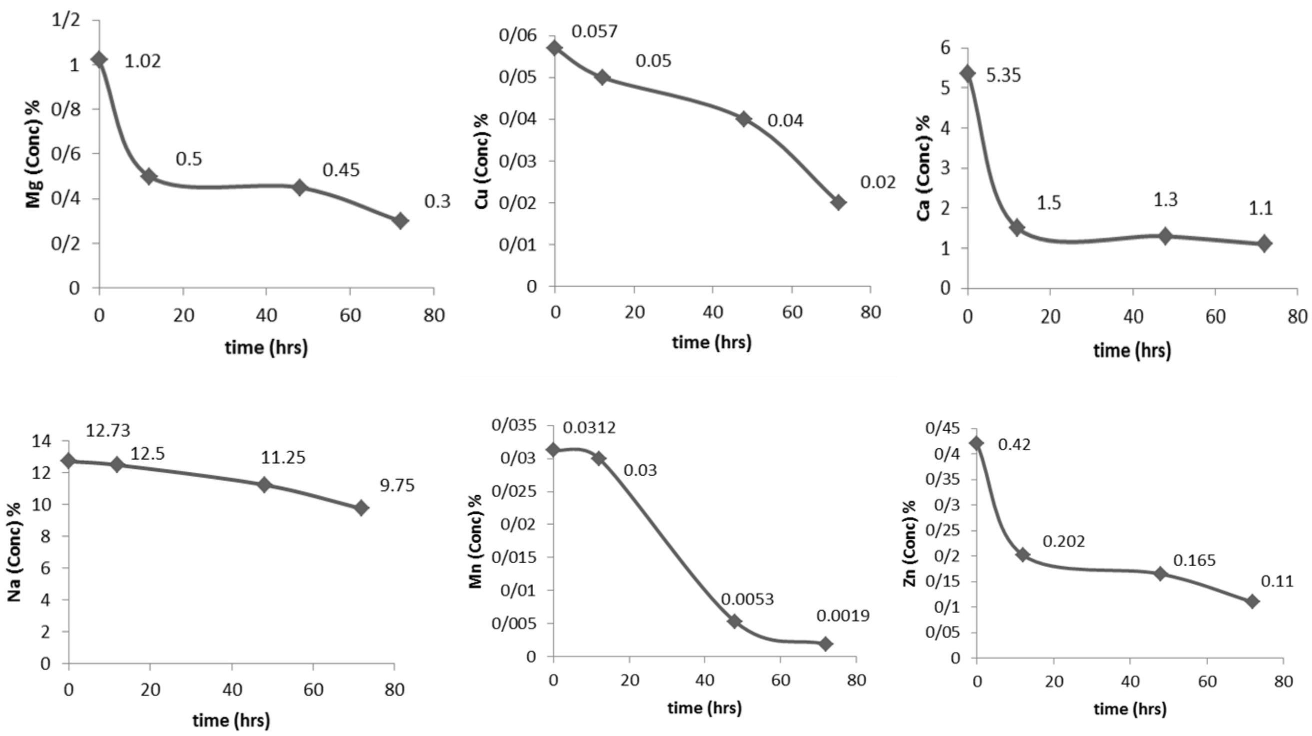

Figure 2. Minerals disappearance rates of *Acacia nubica* after incubation in the rumen for 0, 20, 40, 60 and 80 hrs

To cite this paper: Al shafei N. K and Nour A. 2016. Minerals disappearance rate of leaves of some acacia trees after digestion in goats' rumen using nylon bags technique. *Online J. Anim. Feed Res*., 6(2): 38-44.
Scienceline/Journal homepages: www.science-line.com; www.ojafr.ir

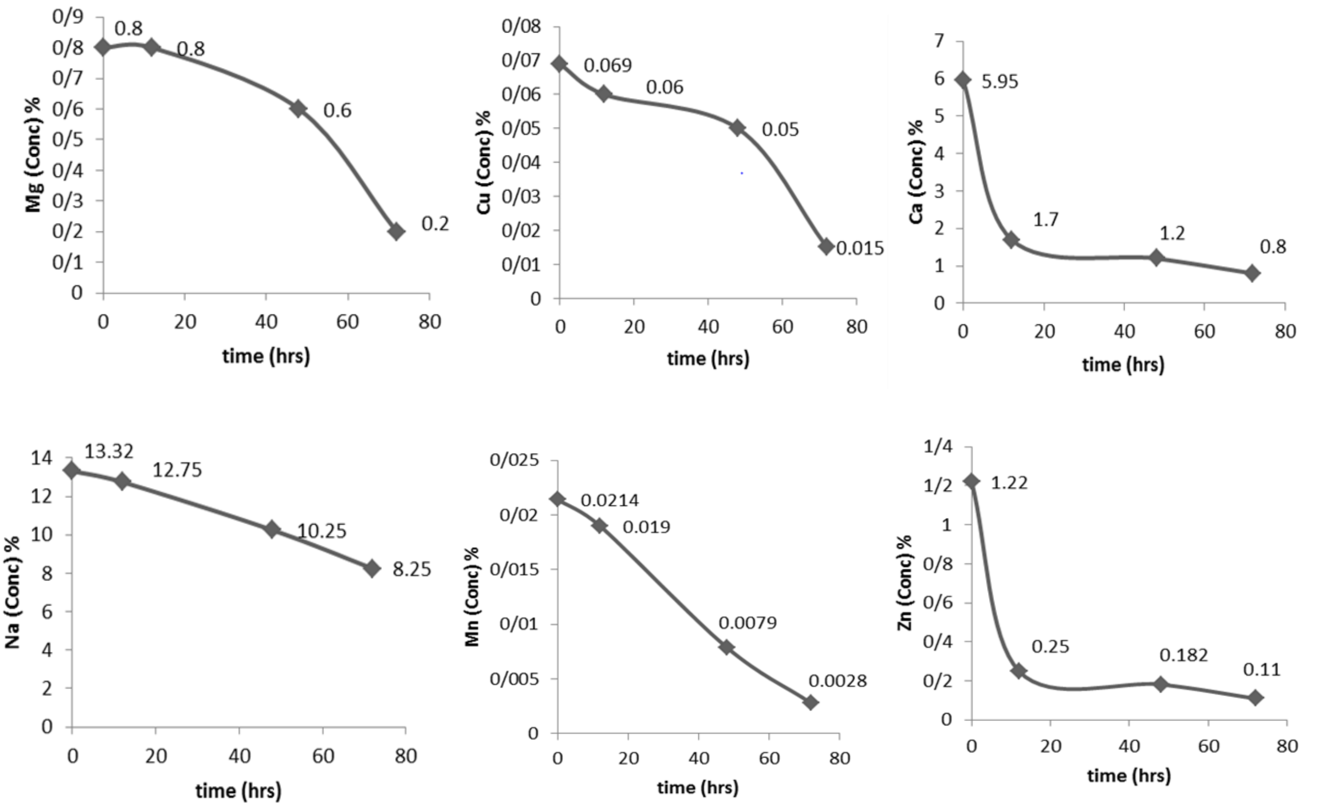

Figure 3. Minerals disappearance rates of *Acacia sieberiana* after incubation in the rumen for 0, 20, 40, 60, and 80 hrs.

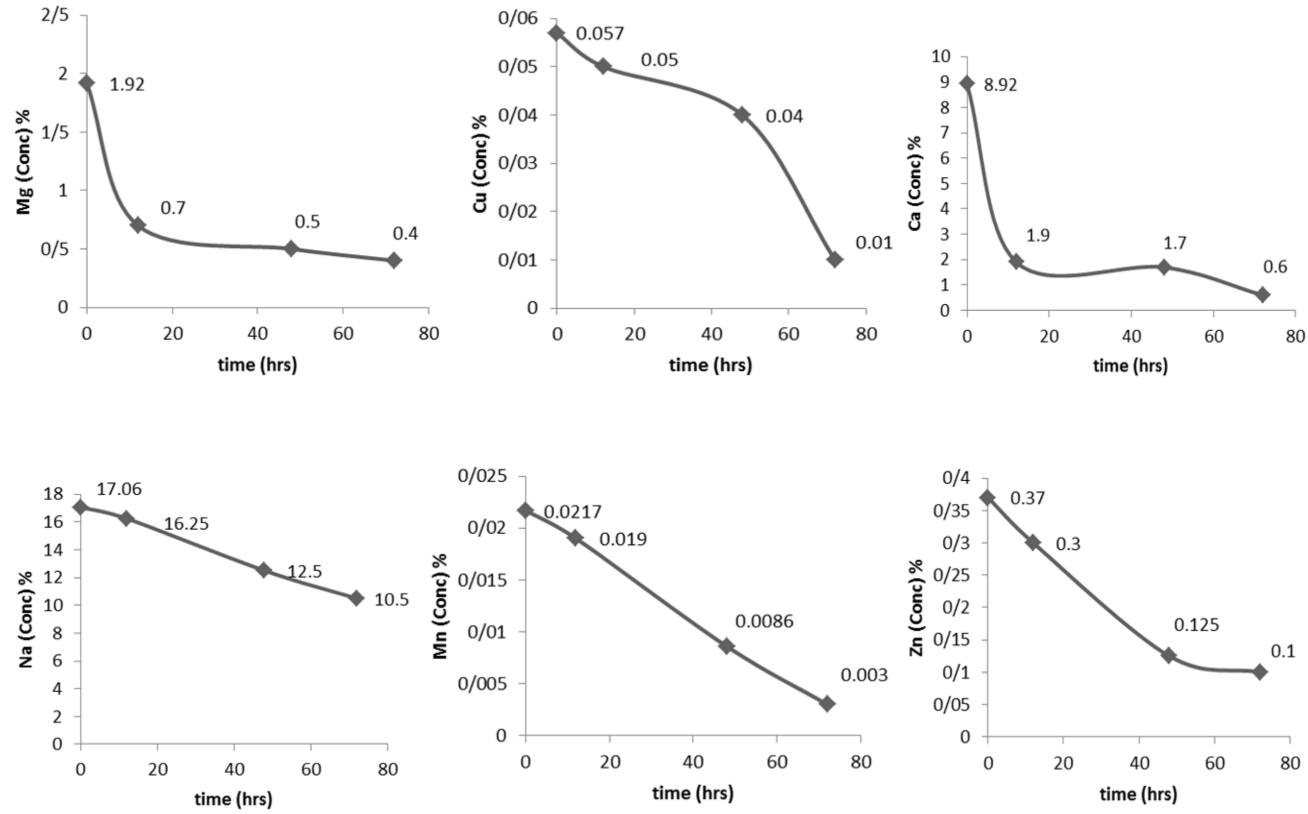

Figure 4. Minerals disappearance rates of Z. spina-christi after incubation in the rumen for 0, 20, 40, 60, and 80 hrs.

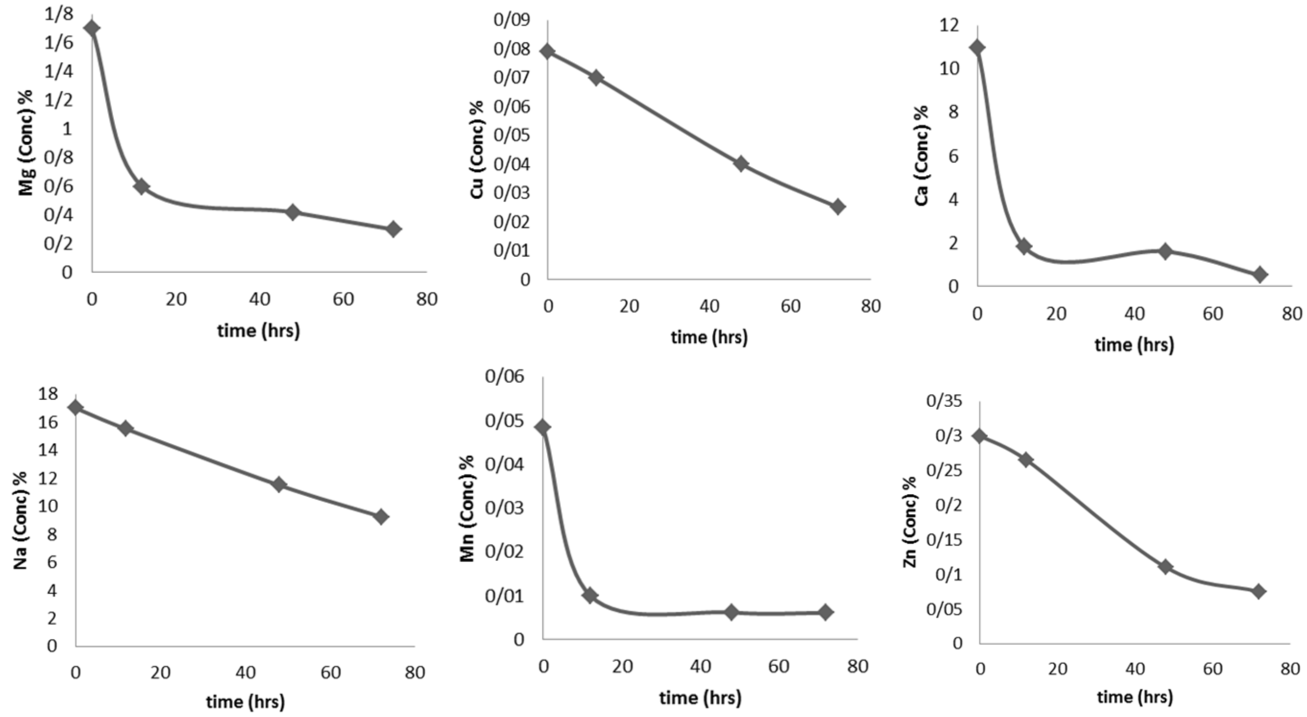

Figure 5. Minerals disappearance rates of Balanites aegyptiaca after incubation in the rumen of goat for 0, 20, 40, 60, and 80 hrs.

DISCUSSION

Fate of minerals in the rumen of goat using the nylon bags technique

For optimal rumen function, the process of rumination is essential for maintenance of adequate salivation and optimal pH for cellulose fermenting microorganisms. The fermentation process typically yields higher volatile fatty acids comprising mainly of acetate. Acetate and other volatile fatty acids (VFAs). VFAs provide energy for maintenance, growth, reproduction, and production (Lu et al., 2005). Mineral nutrition is essential for the functions of rumen microbes, including production of VFAs the animal needs. Plants provide variable amounts of minerals for the rumen microbes and their host. For proper mineral nutrition of ruminants which rely solely on plants for their nutritional needs, mineral composition of feeds such as browse leaves needs to be quantified and their disappearance rates in the rumen needs to be assessed.

High concentrations of minerals in browse acacias leaves investigated in this study provide mineral supplements in the diets of ruminants. These feeds contained higher levels of Ca, P, Mg and S than the recommended requirements for various physiological and production functions of ruminants. In this study, phosphorus concentration was about 0.09- 0.21% (Table 1), which is similar to the values reported by Elginaid (1997) and within the range of those obtained by Dougall et al. (1964). Gomide (1978) maintained that the level of phosphorus in plants decreases with the age, and moves from the oldest tissues to the newest parts of the plant, such as the leaves. On the other hand, Rodgers (1975) observed that plants in the savannah areas of eastern Africa are deficient in phosphorus, and only browse shrubs provide animals with high phosphorus during the dry season (Wilson and Bredon, 1963). Elginaid (1997) reported similar findings in the central areas of Sudan. Mc Dowell and Conard (1977) found that in more than a thousand Latin American forages, 72.8% of their phosphorus values were 0.3% or less.

The sodium concentration of browse species in this study was found to be high 12.23 - 17.06% (Table1) compared to the values of 0.03-0.07% reported by (Dougall et al., 1964), and also is opposite to that found by (Fadel Elseed, et al., 2002) who argued that that sodium content was very low for all tree species studied and attributed this to the soil conditions. On the other hand, magnesium concentration of the browse species studied lies within the range of 0.80- 1.92% (Table 1) which is near the range of (0.20- 0.76%) for leaves reported by Le Houerou (1980). Since magnesium was found to be immobile in the plant, hence it is found to be higher in old parts of the plant (Gomide, 1978). Calcium concentration of the browse species were in the range of 4.05-10.92% (Table1) which is higher than the range of 0.48- 4.68% recorded by Dougall et al. (1964), and the range obtained by Elginaid (1997), 0.40- 2.80%, and these differences may be due to genetic factors. The concentration of potassium of the browse leaves studied was in the range of 0.29- 2.49% (Table1) which is similar to that obtained by Dougall et al. (1964). Decreased potassium concentration in the leaves was attributed to the movement of potassium to the older parts. to the roots system, and then to the soil (Gomide, 1978).

The trace minerals of the acacia browse plants investigated in this study were low in terms of Cu and Zn and this is in agreement with Le Houerou (1980) who reported that the deficiency in Cu and Zn may occur concurrently in browse species. Under wood (1977) suggested that different plant species had different abilities to absorb and return copper; this is determined by the availability of minerals from the soil, and genetic makeup of the plants. Zn concentration in the investigated samples was low and this is in agreement with (Sauchelli, 1969). The present study reports large variation in Mn concentration of plant samples analyzed (table1). These findings are in agreement with Miller (1972) who has stated that such variation is found even in the plants of the same species. Generally, variation in Mn may be due to genetic factors, nature of the soil nature and its pH. It seems also that the stage of the plant growth may have an effect on this (Under wood, 1977).

Minerals digestion and disappearance rates in the rumen

One of the purposes of the current work is the determination of the rumen mineral digestion and mineral disappearance rates by using nylon bag technique. Two possible explanations are suggested for the disappearances rates of minerals in the rumen. The first explanation is that minerals losses after incubation of samples in the rumen of goats might be due to the

To cite this paper: Al shafei N. K and Nour A. 2016. Minerals disappearance rate of leaves of some acacia trees after digestion in goats' rumen using nylon bags technique. *Online J. Anim. Feed Res*., 6(2): 38-44.
Scienceline/Journal homepages: www.science-line.com; www.ojafr.ir

rumen digestion in which the rumen microorganisms attack various organic complexes. This microbial activity and thus releases minerals making them available for absorption by the animal or for the usage of the microorganisms. The second explanation of the losses might be due to solubility of minerals in rumen liquor. The results obtained in the current study strongly support these two suggestions. It is quite clear from all the figures (1-5). Which illustrate the effect of incubation of various browse plants in the rumen of goats. that the curves show regular and gradual disappearance of all minerals with time of incubation. Some of the minerals, such as calcium, demonstrate a sharp disappearance during the first few hours of incubation opposite to that of sodium whose disappearance rate is gradual. Further these figures indicate that the time of incubation and the type of mineral likely had a significant effect on the loss of minerals in the rumen. It can be observed from these figures that the disappearance rates (slope of the curves) vary across mineral types and species of acacia trees. Disappearance rates suggest that the rumen microorganisms have a significant role in the digestion of minerals and the minerals disappearance rates are due to the solubility of minerals in the rumen liquor and the loss of minerals due to utilization of microorganisms to a certain amount for their maintenance.

CONCLUSION

Knowledge of browse plants in terms of availability, utilization and other related information under Sudan condition is still lacking. For proper mineral nutrition of ruminants that rely solely on plants for their nutritional needs, this study quantified mineral composition of browse leaves of acacia trees, and determined their disappearance rates in the rumen. Acacia trees provide important nutrients for livestock in arid areas of the tropics, such as that of Western Sudan. High concentrations of minerals in browse acacia leaves investigated in this study provide important nutrients and minerals for ruminants such as goats and camels. The results indicate that the time of incubation and the type of mineral likely had a significant effect on the loss of minerals in the rumen. It can be observed from these figures that the disappearance rates (slope of the curves) vary across mineral types and species of acacia trees. Disappearance rates suggest that the rumen microorganisms have a significant role in the digestion of minerals. Further, minerals disappearance rates are due to the solubility of minerals in the rumen liquor and the loss of minerals can be due to their utilization.

Competing Interest
The authors declare that there are no significant personnel, professional or financial competing interest that might have influenced the presentation of the results of the study described in this manuscript

REFERENCES

Al shafei NK and Nour A (2016). Nutritive value and dry matter disappearance of Sudanese acacia browse leaves in goat nutrition. World's Veterinary Journal. Volume 6, issue 2, 46-52.

Backlund M and Belskog J (1991). The role of trees and shrubs in livestock production in central Tanzania. A survey of their nutritive value during the dry season. Swedish University of Agricultural Science International Development Centre, Uppsala 24 p.

Darrag A (1995). Range and feeding balance in livestock. Paper presented in the workshop on pastoralism and pasture resource development sector in Kosti.

Dougall HW, Drysdol UM and Glover PE (1964). The chemical composition of Kenya browse and pasture herbage. E. Afr. Wildi. J. 2: 86- 121.

Elginaid EM (1997). Feeding potential of important natural pastures and crop residues in the Butana, Eastern Sudan. Ph. D. Dissertation. University of Gottingen.

Fadel Elseed AMA, Amin AE, Khadiga A, Abdel Ati SJ, Hishinuma M and Hamana K (2002). Nutritive Evaluation of Some Fodder Tree Species during the Dry Season in Central Sudan). Asian-Australasian Journal of Animal Science 15, 844-850.

Fardous AK, Ahmad SG, Khan ZI, Ejaz A and Valeem EE (2011). Assessment of iron, cobalt and manganese in soil and forage: a case studyat a rural livestock farm in Sargodha, Pakistan. *Pak. J. Bot*., 43(3): 1463-1465.

Gomide JA (1978). Mineral composition of grasses and tropical leguminous forage. In: Conard, J.H. and Mc Dowell, L, R. (Eds): Proc. Latin America symposium on mineral Nutrition Research with grazing Ruminants. University of florida, Gainesville. Florida, 32.

González-Rodríguez H, Ramírez-Lozano RG, Cantú-Silva I, Gómez-Meza MV and Uvalle-Sauceda JI (2010). Composición y estructura de la vegetación entres sitos del estado de Nuevo León, México. *Polibotánica*., 29:91-106.

González-Rodríguez H and Cantú-Silva I (2001). Adaptación ala sequía de plantas arbustivas del matorral espinoso tamaulipeco. *CIENCIA UANL*., 4(4):454-461.

Lu CD, Kawas JR and Mahgoub OG (2005). "Fiber Digestion and Utilization in Goats". *Small Ruminant Research*. 60:45–52.

McDowell LR and Conrad JH (1977).Trace mineral nutrition in Latin America (English, Spanish, French) World Animal Review (FAO), (no.24) p. 24-33 / FAO, Rome (Italy). Animal Production and Health Division.

Miller WJ (1972). The use of mineral data presents unusual problems in feed formulation – feed stuffs, 44, 23 – 25.

Mnison DJ (1980). Nutritional differences between tropical and temperate pasture. In: Morley, F.H.N. (Editor). Grazing animals. Elsevier, Amsterdam, Netherlands. 103-157.

Moya-Rodriguez JG, Foroughbakhch R and Ramírez RG (2002). Variación estacional de nutrientes y digestibilidad *in situ* de materia seca, de hojas de arbustivas del noreste de México. *Phyton*., 8:121-127.

Parkinson JA and Allen SE (1975). A Wet Oxidation Procedure Suitable for the Determination of Nitrogen and Mineral Nutrients in Biological Material. *Communications in Soil Science and Plant Analysis*. 6:1-11.

Rodgers WA (1975). Mineral Content of Some Soils, Range Grasses and Wild Animals from Southern Tanzania. East African Agricultural and Forestry Journal. Volume 41, Issue 2.

Sauchelli V (1969). Trace Elements in Agriculture. Van, Nostrand Reinhold Company, New York. pp. 84, 87-88.

Underwood EJ (1977). *Trace* Elements in *Human and Animal Nutrition*, 4thed. Academic press, London and New York.

Wilson JG and Bredon RM (1963). Nutritional value of some common cattle browse and fodder plants of Karamoja, N. Province, Uganda. East African Agricultural and Forestry Journal. 28: 204-208.

Zhang H, Liu D, Dong W, Cai W and Yuan W (2016). Accurate representation of leaf longevity is important for simulating ecosystem carbon cycle, Basic and Applied Ecology. Volume 17, issue 5, 396-407.