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Effect of Incorporation of Neem Leaves (*Azadirachta indica*) on Feed Intake, Water Intake, Digestibility, Rumen Fermentation Parameter, Blood Biochemicals and Nutrient Utilisation in Camel (*Camelus dromedarious*)

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ABSTRACT

In order to evaluate replacement of conventional roughage ration with fresh neem (*Azadirachta indica*) leaves; Twelve male camels of similar age and body weight were randomly divided into 3 treatment groups (T1, T2 and T3) of 4 each and fed for a period of 13 weeks. T1 control group was fed with groundnut straw and guar straw in 1:1. Whereas, in T2 group basal roughage was replaced with 10% neem leaves and in T3 group basal roughage was replaced with 20% neem leaves (on dry basis). In this study, no significant effect was observed due to replacement of roughage with neem leaves on intake of dry matter, nutrients and water; digestibility of dry matter and organic nutrients; DCP and TDN; rumen fermentation pattern and blood-biochemical indices. However, significant effect of neem leaves incorporation was observed on crude protein intake and egg per gram (EPG) in faeces of animals fed neem leaves. Digestibility of EE and ADF decreased significantly (P=0.05) when neem leaves were fed at higher levels. Nutritive ratio was also observed to be significantly decrease (P=0.05) at higher levels. On the basis of results, it could be concluded that when crop residue-based diet was replaced with neem leaves at lower level of 10% resulted better results in terms of dry matter, crude protein and nutritive ratio which could sustain maintenance as ferment ability of diet, decreased at higher level of inclusion. In addition, supplementation of neem leaves could help to be also used as natural and low-cost anti-parasitic feed supplement which is abundantly available.

KEYWORDS: Camel, Digestibility, Neem leaves, Rumen fermentation parameters, Nutrient utilization

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INTRODUCTION

Neem (*Azadirachta indica*) is a non-leguminous multi-purpose tree and it belongs to the family "Meliaceae". In India it is commonly called as "Indian lilac", "Margosa", "Divine tree", "Wonder tree", "Heal all", "Materia Medica", "Free tree of India", Nature's drug store", "Village Pharmacy" and "Panacea for all diseases" (Ogbuewu et al., 2011). Fruits, seeds, oil, leaves, roots, bark and almost every part of the tree is bitter and contain compounds with proven antiviral, antiretroviral, anti-inflammatory, anti-ulcer and antifungal, antibacterial, antiseptic, antipyretic and anti-diabetic properties (Gowda and Sastry, 2000). Studies on neem in animal production are mostly focused on its medicinal uses; mostly as an anti-helminthic agent (Chandrawathani et al., 2006; Tiwary and Pandey, 2010). Neem leaves have been used as an alternate protein supplement in ruminant diets due to low fibre and high crude protein content (Adjorlolo et al., 2016). Neem leaves incorporation into ruminant feeds will help to increase the utility of the plant and also will be helpful to alleviate the severe feed inadequacy experienced in the dry tropics during the lean season. Neem leaves contain large amounts of tannins and saponins. In ruminants, condensed tannins and saponins may be used to improve rumen ecology (Suchitra et al., 2008). In camel feeding there is a need to evaluate neem leaves as potential feed resource as replacement of roughages for their maintenance and

assess its quality as well to ascertain its use.

MATERIALS AND METHODS

Studies were conducted at ICAR-National Research Centre on Camel, Bikaner for a period 13 weeks in which twelve male camels (4-5 year.) were divided randomly into three groups of 4 each. Effect of neem leaves was evaluated on feed Intake, digestibility of nutrients, rumen fermentation pattern, and blood biochemicals. Feeding trial was followed by digestibility trial to access nutrient intake. Control group T1 was fed with basal roughage containing crop residues of Groundnut (*Arachis hypogaea*) straw and guar (*Cyamopsis tetragonoloba*) straw as roughages in equal proportions. Whereas, the basal roughage was replaced with 10% neem leaves in T2 and 20% neem leaves in T3 group wherein, neem leaves were offered as in fresh green form. During the entire period of experiment feeds offered (*ad libitum*), residues, and water was recorded to determine daily consumption. Haemato-biochemical parameters and rumen fermentation pattern was also studied. Body weights of all animals were also monitored at fortnightly intervals to ascertain live weight change. The proximate analysis of feed and faeces were performed by procedures of AOAC (2005) and Fiber fractions estimated by the method described by Van Soest et al. (1991). Estimation of calcium and phosphorus of feed was done in ICP-OES (ICAP-7600). Total polyphenols and polyphenol fractions were analyzed by the methods described by Hagerman et al. (2000). Rumen liquor was collected and evaluated for rumen pH, total volatile fatty acids, total nitrogen, ammonia nitrogen, NPN and total protozoal count were estimated at laboratory with the help of standard procedures and Faecal egg count estimated by McMaster technique. After completion of the work data generated from the study were analyzed as per standard statistical procedures given by Snedechor and Cochran (2004) using SPSS (version 20.0) software.

RESULTS AND DISCUSSION

The chemical composition and phytochemical estimation of different feed ingredients are show in Table 1. The dry matter (DM %) content of Groundnut (*Arachis hypogaea*) straw, Guar (*Cyamopsis tetragonoloba*) straw and Neem (*Azadirachta indica*) leaves were 89.34, 90.66 and 33.72, respectively. Crude protein (CP %) was highest in Neem leaves 15.0 as compared to both Guar straw and Groundnut straw which was 7.32 and 8.62, respectively. Calcium (g) and phosphorus (g) content of Neem leaves were 1.41 and 0.22, respectively. Neem leaves had high total polyphenols (TP), non-tannin polyphenols (NTP), total tannin (TT), condensed tannin (CT) and hydrolysable tannin (HT) tannin compared to both Groundnut straw and Guar straw. Whereas, Groundnut straw had high amount of saponins. Observations on the chemical composition revealed that values of DM, OM and CP of Neem leaves obtained in the present study were nearly similar to values reported earlier (Meena, 2006) and EE (Khanum et al., 2007), calcium and phosphorus (Obikaonu et al., 2012; Singh et al., 2014); whereas, lower value of calcium and phosphorus in Neem leaves have also been observed (Singh et al., 2014). Contrary to the results of the present study higher value of CP has been observed (Obikaonu et al., 2012; Singh et al., 2014; Fasae et al. (2018). Fasae et al. (2018) reported higher value of NDF. The possible reason of variability in chemical composition

Table 1. Chemical and phytochemical composition of feed stuff (% DM)

Feed stuff	Groundnut straw	Guar Straw	Neem leaves
DM	89.3	90.6	33.7
OM	92.5	90.1	91.2
CP	8.62	7.32	15.0
EE	1.76	1.77	2.94
TA	7.47	9.89	8.80
NDF	41.8	47.3	36.3
ADF	29.5	35.4	29.5
HC	12.2	11.9	6.76
ADL	10.3	5.35	8.88
TP	1.37	0.67	3.89
NTP	0.53	0.41	1.00
TT	0.84	0.26	2.89
CT	0.32	0.05	0.80
HT	0.52	0.21	2.09
Saponin	3.11	2.87	1.53

DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract, TA:Total ash, NDF:Neutral detergent fiber, ADF: Acid detergent fiber, HC: Hemicellulose, ADL: Acid detergent lignin, TP: Total phenolics, NTP: Non total phenolics, TT: Total tannin, CT: Condensed tannins, HT:Hydrolysable tannin

of neem leaves could be due to environmental conditions like temperature, leaves maturation stages, seasons, water availability and soil nutrients which affect chemical composition. The results of phytochemical value of Neem leaves similar to values reported by Otache and Agbajor (2017) whereas, lower value of phytochemical analysis in neem leaves have also been observed (Atangwho et al., 2009; Ogunsipe et al, 2020). The possible reason of variability in phytochemical composition of neem leaves might be due to leaves maturation (age) stages and plant strain.

Dry matter, organic matter, water intake and digestibility of organic nutrients were observed to be similar among the treatments (Table 2). However, higher DMI and OMI were observed in T2 followed by T3 and T1 group which reflect that palatability of the diet was not affected even at level of 20% inclusion in the diet of camel. Findings of present investigation revealed that DMI and OMI are in accordance with the Dida et al. (2019) with graded levels of neem leaves in the diet of goat. Similar results were reported by Raghuvansi et al. (2007) and Misra et al. (2000) in sheep. Whereas, higher OMI in camel and sheep were reported by Nagpal et al. (2002) and Karim (2017), respectively.

The results of CP intake revealed significant ($P \leq 0.01$) effect of Neem leaves incorporation at different levels in feed on CPI in different treatment. The significantly highest CPI was observed in T3 group followed by T2 and T1 group. The findings of present investigation regarding CPI on supplementation of neem leaves feed was observed to be in accordance with the Dida et al. (2019); they recorded the highly significant ($P \leq 0.001$) impacts on crude protein intake value due to Neem leaves inclusion in diet of goats. Similar results were also reported by Karim (2017) in sheep.

Water intake was observed to be similar among treatments however, numerically higher water intake was found in Neem leaves included groups due to toxic substances of Neem leaves required more water for their excretion from body. Non-significant effect was observed on average body weight with incorporation of neem leaves in camel diet during entire experiment. Whereas, during the trial the body weight of animal was maintained. The findings of experiment regarding average live weight change are in agreement with the results of Meena (2006), Paengkoum (2010), Dida et al. (2019) and Ajeigbe et al. (2021). Intake of DM was maintained throughout the feeding trial and this response might be associated with increment in body weight and consequent increase in intake to satisfy nutrient requirement of the animals.

Rumen fermentation parameters (Table 2) revealed that there was non-significant difference among all treatments except total protozoa count. There was significantly ($P \leq 0.05$) lower in T3 as compared to T1 and T2. The findings of present investigation regarding rumen parameters are in accordance with the Raghuvansi et al. (2007), Yang et al. (2009) and Paengkoum (2010). Blood Biochemical parameters (Table 3) revealed that there was non-significant difference among all treatments with incorporation of Neem leaves in camel diet. The present experiment is in accordance with Raghuvansi et al. (2007), Karim (2017) and Garba and Ibrahim (2019).

The digestibility of various nutrients presented in Table 4. The results of statistical analysis of variance data revealed non-significant effect on digestibility of nutrients with incorporation of Neem leaves in camel diet during experiment. However, EE and ADF were significantly ($P \leq 0.05$) higher in T1 group then T3 group and comparable to T2 group. The results of DCP and TDN were non-significant in all groups. However, significantly ($P \leq 0.05$) higher value of NR observed in control group then treatment groups. The DM, OM and NDF digestibility in present experiment is in accordance with Raghuvansi et al. (2007), Yang et al. (2009) and Paengkoum (2010). Similarly, Yang et al. (2009) and Adelusi et al. (2019) also reported no significant difference on digestibility of CP and DM, respectively. The findings of NDF digestibility in present experiment was in accordance with Dida et al. (2019). On contrary, Dida et al. (2019) observed significant effect on digestibility of DM,

Table 2. Effect of neem leaves on intake and rumen fermentation pattern of camel

Parameter	T1	T2	T3	SEM	P-value
DMI (kg/day)	6.55	6.68	6.83	0.080	0.275
DMI (kg/100 kg BW)	1.48	1.56	1.53	0.022	0.604
DMI (g/kg $W^{0.75}$)	67.8	70.6	70.3	0.868	0.560
OMI (kg/day)	5.99	6.23	6.23	0.080	0.219
OMI (kg/100 kg BW)	1.35	1.45	1.40	0.028	0.370
OMI (g/kg $W^{0.75}$)	62.0	65.8	64.2	1.121	0.312
CPI* (kg/day)	0.52^{a}	0.58^{b}	0.63^{c}	0.032	0.001
CPI* (kg/100 kg BW)	0.12^{a}	0.14^{b}	0.14^{b}	0.007	0.001
CPI* (g/kg $W^{0.75}$)	5.40^{a}	6.14^{b}	6.51^{b}	0.325	0.001
Water intake (L/day)	22.06	24.61	27.00	1.428	0.555
Water intake (L/100 kg BW)	4.90	5.58	6.08	0.340	0.384
Water intake (L/kg $W^{0.75}$)	2.25	2.55	2.79	0.153	0.399
Water intake (L/kg DM)	3.43	3.97	3.94	0.172	0.625
Av. BW (kg)	452.5	439.9	449.4	3.801	0.361
Weight change (kg)	0.20	0.17	0.20	0.010	0.968
Rumen pH	7.39	7.86	7.80	0.148	0.242
Rumen N (mg/dl)	113.0	136.0	112.0	7.839	0.553
Rumen NH_3 N (mg/dl)	5.01	7.70	6.53	0.779	0.089
TCA precipitable - N (mg/dl)	56.0	59.5	51.3	2.367	0.950
TVFA (mmol/dl)	9.16	8.01	8.68	0.333	0.509
Total protozoa count(10^3/ml)	3.004^{b}	2.208^{b}	1.894^{a}	0.331	0.005

Means with different superscripts in a row differ significantly, $P \leq 0.05$

Table 3. Effect of neem leaves incorporation on blood biochemical attributes of camel

Attributes	T1	T2	T3	SEM	P-value
Haemoglobin (g%)	12.7	12.6	12.6	0.017	0.995
Glucose(mg/dl)	76.3	80.3	74.6	1.678	0.256
BUN(mg/dl)	15.3	18.5	17.3	0.941	0.377
Total protein (g/dl)	4.18	4.71	4.04	0.206	0.797
Calcium(mg/dl)	10.3	10.3	8.62	0.568	0.235
Phosphorus(mg/dl)	3.54	4.13	3.54	0.197	0.320

CP and ADF on the inclusion of Neem leaves with concentrates mixture in the diet of goat. The possible reason for variability in the reduction in digestibility of CP has been attributed to the negative effects of the phenolic compounds through formation of indigestible complexes with proteins as suggested by Singh and Bhat (2001). The lack of effect on digestibility of CP was probably due to moderate levels of tannin in the diet as suggested by Patra et al. (2003). The possible reason of reduction in digestibility of ADF is the anti-protozoal activity of Neem, that causes reduction in the number of rumen protozoa. The mean value of total faecal egg count of T1, T2 and T3 were 833, 450 and 216, respectively. Result indicate that Neem leaves effectively decreased parasitic faecal eggs count in T2 and T3 groups reflecting it could be used as a natural anti parasitic feed supplement.

Replacing Neem leaves did not significantly affect the average nutrient and digestible nutrient intake except crude protein intake and digestibility of ether extract and ADF. No significant differences were found in blood attributes and ruminal parameter whereas, total protozoal counts were decrease.

Table 4. Effect of neem leaves incorporation on digestibility of nutrients (%)

Parameter	T1	T2	T3	SEM	P-value
DM	66.1	62.0	57.8	2.393	0.223
OM	69.5	65.7	61.6	2.284	0.164
CP	69.7	68.4	66.5	0.917	0.802
EE	80.3^{b}	69.4^{ab}	63.7^{a}	5.186	0.027
NDF	47.9	39.4	36.0	3.108	0.363
ADF	38.2^{b}	36.2^{ab}	25.7^{a}	4.013	0.038
TCHO	69.3	65.3	61.0	2.402	0.152
DCP (%)	5.54	6.01	6.26	0.211	0.260
TDN (%)	65.3	61.6	57.7	2.179	0.144
Nutritive Ratio	10.7^{b}	9.24^{a}	8.24^{a}	0.735	0.001
Feacal egg count	833^{b}	450^{ab}	216^{a}	179.764	0.015

Means with different superscripts in a row differ significantly, $P \leq 0.05$

Faecal egg counts were significantly decreased; that indicate Neem leaves effectively decreased parasitic faecal eggs count in treatments groups reflecting, it could be used as a natural anti parasitic feed supplement.

CONCLUSION

Observations of the investigation revealed that Neem leaves could be utilized as non-conventional feed resource in the diet of camel. Supplementation of conventional legume straw-based diet of camel with Neem leaves did not have any deleterious effect on feed intake, rumen fermentation pattern and digestibility of nutrients at lower levels however, at higher levels protozoal population decreased reflecting anti-microbial effect at higher levels of inclusion. Parasitic faecal egg counts were also decreased in treatment groups. Thus, Neem leaves can be safely used to replace conventional crop residue-based diet at level of 10 percent to improve intake of feed, dietary protein, digestibility of nutrients, rumen fermentation pattern and also act as natural antiparasitic resource to economized feed cost of camel raised under arid environments.

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REFERENCES

Adelusi, F., Eniola, O., Adedokun, S. and Olunloyo, A. 2019. Digestibility and nitrogen utilization of semi intensively managed West African dwarf sheep fed neem leaf meal concentrate. Ethiopian Journal of Environmental Studies & Management. 12(5):530-538.

Adjorlolo, L.K., Timpong-Jones, E.C., Boadu, S. and Adogla-Bessa, T. 2016. Potential contribution of neem (*Azadirachta indica*) leaves to dry season feeding of ruminants in West Africa. Livestock Research for Rural Development. 28(5): 1-7.

Ajeigbe, O. M., Sangosina, M. I., Ogunseitan, T. O., Lawal, R. A. and Yusuff, K. O. 2021. Effects of Neem Leaves (*Azadirachta Indica*) And Cassava Peels on the Performance of West African Dwarf Goat. Federal Polytechnic Ilaro Journal of Pure and Applied Science. 3(2): 73-79.

AOAC. 2005. Official methods of analysis, Association of Official Analytical Chemists,

Washigton, DC.

Atangwho, I.J., Ebong, P.E., Eyong, E.U., Williams, I.O., Eten, M.U. and Egbung, G.E. 2009. Comparative chemical composition of leaves of some antidiabetic medicinal plants: *Azadirachta indica,* Vernonia amygdalina and Gongronema latifolium. African Journal of Biotechnology. 8(18): 4685-4689.

Chandrawathani, P., Chang K.W., Nurulaini, R., Waller, P.J., Adnan, M., Zaini, C.M., Jamnah, O., Khadijah, S. and Vincent, N. 2006. Daily feeding of fresh Neem leaves (*Azadirachta indica*) for worm control in sheep. Tropical Biomedicine. 23(1):23–30.

Dida, M. F., Challi, D. G. and Gangasahay, K. Y. 2019. Effect of feeding different proportions of pigeon pea (*Cajanus cajan*) and neem (*Azadirachta indica*) leaves on feed intake, digestibility, body weight gain and carcass characteristics of goats. Veterinary and Animal Science. 8:100079.

Gowda, S.K. and Sastry, V.R.B. 2000. Neem (*Azadirachta indica*) seed cake in animal feeding - Scope and limitations. A review. Asian -Australasian Journal of Animal Sciences. 13(5): 1-8.

Fasae, O.A., Aganto, T.O. and Jimoh, H.O. 2018. Nutritional potentialities of neem (*Azadirachta indica*) plant parts as supplementary feed in ruminant production system. Nigerian Journal of Animal Production. 45(3):301-308.

Garba, Y. and Ibrahim, Z. H. 2019. Haematological and biochemical parameters of Kano brown bucks fed graded levels of potash treated neem (*Azadirachta indica*) leaf meal-based diets. Nigerian Journal of Animal Production. 46(1): 196-205.

Hagerman, A. E. 2000. Quantification of tannins in tree foliage: a laboratory manual for the FAO/ IAEA coordinated research project on" The use of nuclear and related techniques to develop simple tannin assays for predicting and improving the safety and efficiency of feeding ruminants on tannin ferrous tree foliage. http://www. iaea.org/programmes/ nafa/d3/crp/pubd31022manual-tannin. pdf.

Karim, A. S. 2017. Evaluation Of Neem Leaves Meal as A Protein Source for Sheep on Low Quality Forage (Doctoral dissertation, University of Ghana).

Khanum, S. A., Yaqoob, T., Sadaf, S., Hussain, M., Jabbar, M. A., Hussain, H. N. and Rehman, S. 2007. Nutritional evaluation of various feedstuffs for livestock production using in vitro gas method. Pakistan Veterinary Journal. 27(3): 129-135.

Meena, H.S. 2006. Comparative utilization of Neem (*Azadirachta indica*) green leaves by Sheep and Goats (Doctoral dissertation, MPUAT, Udaipur).

Nagpal, A.K., Arora, M. and Roy, A.K. 2002. Utilization of guar phalgati and tree leaves based mixed rations in camel calves. Indian Journal of Animal Nutrition. 19(2):144-148.

Obikaonu, H.O., Okoli, I.C., Opara, M.N., Okoro, V.M.O., Ogbuewu, I.P., Etuk, E.B. and Udedibie, A.B.I. 2012. Haematological and serum biochemical indices of starter broilers fed leaf meal of neem (*Azadirachta indica*). Journal of Agricultural Technology. 8(1):71-79.

Ogbuewu, I.P., Odoemenam, V.U., Obikaonu H.O., Opara, M.N., Emenalom O.O., Uchegbu, M.C., Okoli I.C., Esonu B.O. and Iloeje M.U. 2011. The growing importance of neem (*Azadirachta indica*) in agriculture, industry, medicine and environment: A review. Research Journal of Medicinal Plant. 5(3):230-245.

Ogunsipe, M.H., Doloruntola, O., Agbede, J. and Igbasan, F. 2020. Influence of *Azadirachta indica* as phytogenic feed supplement on the growth performance and immunomodulatory response of broiler chickens. Journal of Biology and Nature. 12(1):57-66.

Otache, M.A. and Agbajor, G.K. 2017. Proximate and mineral composition of leaves of *Azadirachta indica.* International Journal of

Current Research in Chemistry and Pharmaceutical Sciences. 4(11):50-54.

Paengkoum, P. 2010. Effects of neem (*Azadirachta indica*) and leucaena (*Leucaena leucocephala*) fodders on digestibility, rumen fermentation and nitrogen balance of goats fed corn silage. Journal of Animal and Veterinary Advances. 9(5): 883-886.

Patra, A. K., Sharma, K., Dutta, N. and Pattanaik, A. K. 2003. Response of gravid does to partial replacement of dietary protein by a leaf meal mixture of *Leucaena leucocephala, Morus alba* and *Azadirachta indica.* Animal Feed Science and Technology. 109(1-4): 171-182.

Raghuvansi, S.K.S., Prasad, R., Mishra, A.S., Chaturvedi, O.H., Tripathi, M.K., Misra, A.K., Saraswat, B.L. and Jakhmola, R.C. 2007. Effect of inclusion of tree leaves in feed on nutrient utilization and rumen fermentation in sheep. Bioresource Technology. 98: 511–517.

Singh, B., Bhat, T. K. and Singh, B. 2001. Exploiting gastrointestinal microbes for livestock and industrial development-Review. Asian-Australasian Journal of Animal Sciences.14(4): 567-586.

Singh, M. K., Singh, S. K. and Sathapathy, S. 2014. Studies on the nutritional evaluation of neem leaves of Pantnagar area. International Journal of Scientific Research. 3(9): 445-47.

Snedecor, G. W. and Cochran, W. C. 2004. Statistical method, 8th Edn. The lowa state University Press, Ames, Lowa, U.S.A.

Suchitra, K. and Wanapat, M. 2008. Study on ruminal degradability of local plants by using nylon bag technique. Livestock Research for Rural Development. 20(Supplement), http://www.lrrd.org/lrrd20/supplement/such1.htm

Tiwary, M. K. and Pandey, A. 2010. Feeding neem (*Azadirachta indica*) products to small ruminants as anthelmentics. Food Science and Technology Letters. 1(1):10.

Van Soest, P.V., Robertson, J. and Lewis, B. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 74:3583-3597.

Yang, W. Z., Laurain, J. and Ametaj, B. N. 2009. Neem oil modulates rumen fermentation properties in a continuous cultures system. Animal Feed Science and Technology. 149(1-2):78-88.