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SHORT NOTE [NOTA CORTA]

EFFECT OF DRY ROASTING ON COMPOSITION, DIGESTIBILITY AND DEGRADABILITY OF FIBER FRACTIONS OF MESQUITE PODS (*PROSOPIS LAEVIGATA*) AS FEED SUPPLEMENT IN GOATS

[EFECTO DEL TOSTADO EN SECO EN LA COMPOSICIÓN, DIGESTIBILIDAD Y DEGRADABILIDAD DE LAS FRACCIONES DE FIBRA DE LA VAINA DE MESQUITE (*PROSOPIS LAEVIGATA*) COMO SUPLEMENTO EN CABRAS]

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SUMMARY

Two studies were performed to analyze the roasting effects (150º C/45 min) in the composition, *in vivo* digestibility and *in situ* degradability of fiber fractions (NDF and ADF) of mesquite pods. In the first test, eight Nubian goats (37.6±3.4 kg), fistulated and cannulated of rumen were used, in two periods with four goats/treatment, each. Roasted pods (150ºC/45 min) (RMP) and Raw pods (RP) were milled in a 2 mm sieve, and placed into porous bags; two bags were used as sample, one of them without sample for each degradation time and for each animal. Tested degradation times were 1, 3, 6, 9, 12, 24, 48 and 72 hours. A cross-over design was used, with two periods, considering the treatments (raw or roasted pods), periods and interactions in question. The kinetics of degradation for the fibrous fractions were valued with a non-lineal model (Deg= a + b* (1 – e(-c*t)) and the effective degradation (E.Deg) (a + b* [c/c + kp*]), being kp the fractional rate of passage (kp 0.6/hr). During the second experiment, *in vivo* digestibility of the fiber fractions was studied, using ten male goats (32.68 ± 4.5 kg) for two periods of twenty-two days each, including fifteen days for adaptation and seven days for sampling in a metabolic cage. The food administered and rejected in addition to excrements were weighed and measured and the NDF and ADF contents were analyzed. With this information the digestibility coefficient was calculated (Cdig). The experimental rations were control (CTR); raw mesquite pods (RP) = 80% CTR+ 20% of RP; Roasted mesquite pods (RMP) = 80% CTR+20% RMP. Roasting process modified the mesquite pods composition (P< 0.05), increasing the content of crude protein (CP), ADF, crude protein linked to NDF and ADF (CP-NDF and CP-ADF) as well as ashes. The treatment did not modify (P>0.05) both, NDF and ADF degradation. Nevertheless, soluble fraction decreased (P<0.05), whereas slow degradation fraction (b) and degradation fractional rate (c) increased, resulting in a major E.Deg (P<0.05). Roasting caused an increment (P<0.05) in ADF slow degradation fraction (b), which caused a minor D effect (P<0.05). A 20 % inclusion of RP or RMP did not affected (P>0.05) the consumption (g/d) of NDF and ADF. Nevertheless, ADF consumption (g/kg of $PV^{0.75}$ per day) was higher in the RMP. Otherwise, the RP or RMP inclusion increased the NDF and ADF digestible content (% of DM), without Cdig modification. In conclusion, roasted mesquite pods can modify their nutrimental content, as it can modify the NDF kinetic degradation increasing the fractional degradation rate and the effective degradation, thus, RP or RMP inclusion in the rations improved the Cdig of the ADF.

Key words: *Degradability, digestibility, fiber fractions, mesquite, roasted, goats.*

INTRODUCTION

Nearly 70% of the goat population in México is found in arid or semiarid zones, in extensive production systems, depending on pasture, which restrain the production, considering that the low raining levels determine the food quantity and quality available (Iruegas et al., 1999). The goat is a seasonal animal, presenting its births and production season during dry periods, when poor forage production occurs, leading to important production losses (Pacheco-López, et al. 2007). Mesquite pods (*Prosopis laevigata*) are an alternative as alimentary supplement during dry periods due to their nutritional content (12 to 18% of CP), and its excellent adaptation capabilities to arid or semiarid zones (Pacheco-López, et al. 2007). Nevertheless, as a leguminous plant, it may have a high content of degradable proteins that could lead to nitrogen losses (Yu et al 2002). Otherwise, it also presents a high content of anti-nutritional factors (such as lectins, protease inhibitors and tannins) that may affect food degradation and digestion (Yu et al, 2002; Huyler and Kincaid, 1999). Heat treatments, such as roasting, can diminish the degradability of proteins and other nutrients, even the heat labile anti-nutritional factors (Alegría-Ríos et al., 2007; Andrade-Montemayor. 2005; Yu et al., 2002), and for this reason, the objective of this study was to analyze the dry roasting effects of mesquite pods on the fiber fractions degradability and digestibility.

MATERIAL AND METHODS

Study area localization

The experiment was performed at the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP, CENID- National center of research in animal physiology) located in Ajuchitlán, Colón, Queretaro, Mexico, and at the animal nutrition Laboratories of Veterinary, School of Natural Sciences Faculty of the Autonomous University of Queretaro, Campus Juriquilla, Queretaro, Mexico.

In situ tests

Design, consumption rates and ration

Tests were performed in two periods, with 15 days for adaptation and 72 hours for sampling each. 4 Nubian goats, rumen fistulated and cannulated, were used in each period, with an average weight of 37.6$\pm$3.4 kg. A crossed design in two periods with two treatments (raw and roasted) was used (Steel and Torrie, 1986), analyzing the effects of treatment, period and their interaction.

The offered portion was composed of: sorghum grains 37.5%, soybean meal 6.1%, alfalfa hay 24.2%, corn stubble 20%, molasses 11.1%, minerals and vitamins premix 1.1%. Presenting a 94% organic matter (OM), 15.9 % of crude protein (CP), 9.7% acid detergent fiber (ADF), 18.2% neutral detergent fiber (NDF), 5.4% CP linked to ADF (CP-ADF); 8.9% of CP linked to NDF (CP-NDF) and 6.1% ashes.

Pods and ration preparation

Roasting: Pod roasting (RMP) was conducted according to Yu et al. (2002). The raw pods (RP) were extended on to trays and introduced into a dry oven with forced air at 150º C /45 min.

Desiccation and milling

The RMP as the RP desiccation was performed under a 60 ºC temperature for 48 hrs, to determine its dry matter content (DM), and later were milled in a Willey mill with a 2 mm sieve.

In situ degradability

In situ degradability tests were performed according to methodology recommended by Mehrez and Ørskov (1979). Three g of milled RMP or RP were introduced into nylon porous bags (10 x 5 cm), with a 50 µm pore size (Ankom Technology™).

Degradation times were from 0 to 1, 3, 6, 9, 12, 24, 48 and 72 hrs. Two bags and a blank were introduced per time and per animal. Bags removed at its corresponding time were washed and frozen at -20ºC for their posterior analysis.

Laboratory Analysis

Once the samples were defrosted, they were washed three times with distilled water during 15 min each cycle, following with drying in a forced air oven to 60 ºC for 48 hrs. In the original RMP and RP (Without degradation) as well as in the residual of each bag after degradation, dry material content (DM) and CP (AOAC; 1984) were determined in addition to NDF and ADF (Van-Soest et al., 1991) and PC-NDF and PC-ADF, according to Licitra et al. (1996).

Degradation kinetics

Degradation kinetics was determined according to the non-lineal model described by Ørskov and MacDonald (1979) ($a+b\ (1-e^{(-c*t)})$) that estimate soluble fraction (**a**), one potentially degradable fraction (**b)** and a degradation fractional rate **(c)** through time (**t**). From this model the potential degradation (a+b) and the effective degradation (a+b (c/c+kp)) was calculated, in which applied a fractional rate of passage (kp) of 0.06/h (Sauvant et al., 2003).

Statistic model of degradability analysis

The statistic model used was:
$Yijk= \mu + Ti + Pj+ \varepsilon ijk$
Where:

Yijk = observation of the i-number treatment (RP and RMP) in the j-number period (1, 2) with the k-number of experimental error.
µ = general average
Ti= i-number treatment (RP, RMP)
Pj= j-number period
(TxC)ij= ij-number treatment x period interaction.
Eijk= ijk,-number experimental error.

The means comparison was calculated by LSD (minimal significant differences), and a T of Student test was used to compare degradation kinetics values. (Steel and Torrie, 1986).

In vivo digestibility tests

10 Nubian male goats were used, with an average weight of 32.68±4.5 kg, remaining in metabolic cages, which a trough, drinking trough and a urine recovery system. The methodology used in this test was according to the recommendations by Huntington and Givens (1995).

The experimental period was carried on for 44 days, divided into two periods of 22 days each, and consisting in 15 days for ration adaptation and 7 days for sampling, establishing a daily and individual control of food consumption and feces and urine production.

The experimental feeds were: Control (CTR) (feed described at *in situ* tests), RP feed: 80% CTR + 20 % RP; RMP feed: 80% CTR + 20% RMP. The food was offered in a restricted form (43g/kg of $PV^{0.75}$) once a day (07:30 hrs). Every day, the offered and rejected food was weighted, so the produced feces, along with samples were taken and frozen at -20ºC for posterior analysis.

Analytical determinations

The samples of offered food, rejected food and feces, were dried in an air forced oven at 60ºCfor 48 hrs. Later were milled in a Willey mill with 2 mm sieve.

The analytical determinations were: DM, CP, OM and ashes according to AOAC (1984), and ADF, NDF and hemicelluloses, according to Licitra et al. (1996).

Statistic design, calculations and determinations

A cross-over statistical design was used (Steel and Torrie, 1986) consisting in 2 periods of animal sampling; each animal receiving a different diet for every period. For the ANOVA the treatment effect, the period and the treatment*period interactions were considered, based on the following model:

$$Yijk=\mu +Ti+Pj+ (TxP)ij + \varepsilon ijk$$

Yijk= Observation of the i-number treatment (Control, RP, RMP) in the ij-number period with the ijk-number experimental error.
μ = general average
Ti= the i- number tratment (Control, RP,RMP)
Pj= The j-number period (1,2)
(TxP)ij= the ij-number T and P interaction
Eijk= the ijk-number experimental error.

Minimum significant differences (LSD) was the average test used and the significant levels were NS= P> 0.05; *=P < 0.05, **=P < 0.01, ***= P< 0.001.

Digestibility Rate

The apparent digestibility rate of the DM, CP, NDF, ADF, Hemicelluloses, CP-NDF and CP-ADF, were determined by the following formula:

Nutrient Cdig (%) ((ingested nutrient g – excreted nutrient g)/nutrient ingested g) x 100

RESULTS AND DISCUSSION

RP and RMP composition

Roasting effect of mesquite pods in the nutrient composition is shown Table 1, noticing an increase (P< 0.05) on the DM, ADF, CP-NDF and ashes content. Consequently, decreases on the OM and NDF content (P<0.05) were recorded, without affecting (P>0.05) the hemicelluloses and CP-ADF content. Heat treatments such as roasting, present various effects on the nutrient composition. One effect is the modification of protein and starch structure, which modify their ruminal solubility and degradability. This also modifies the degradable amount in the rumen as well as the digested at the intestine (Goelema et al., 1998; Yu et al., 2002; Andrade-Montemayor, 2005). Moreover, Sauvant et al. (2003) observed that roasting the *L. angustifolium* increases the DM, CP, NDF and ADF content in a similar way as the observed in this work. Other authors like Mass et al. (1999) and Huyler and Kincaid (1999) indicated that heat treatment increases the content of protein linked to the cell wall existing the formation of complexes between fiber carbohydrates and the protein.

Roasting effects in fiber fractions degradability and degradation kinetics

In table 2 and 3, degradability of the NDF and ADF roasting effect is presented. Notice that treatment did not modified (P>0.05) the fiber fraction degradability. Nevertheless, NDF of the RP and RMP degradation was about the 68.8 and 73.0% each, within the first hour and 76.4% within the 72 hours respectively. Otherwise, the ADF degradation started with 32.78 vs. 27.36% at the RP vs. RMP in each case and ended within 67.9 vs. 72.67% each.

The NDF and ADF degradation kinetics are presented in tables 4 and 5. Again, notice that in NDF of RMP, the soluble fraction (a) and fast degradation % content diminished (P<0.05), but increased the slow degradation fraction (b) (P<0.05) and the fractional rate of degradation (c); resulting in a similar degradation potential (P>0.05), but major effective degradation (P<0.05) (65,9 *vs*. 78.42%). Otherwise, in ADF the heat treatment did not modified (P>0.05) fast degradation fraction content (a), fractional degradation rate (c) and potential degradation (a+b); nevertheless, slow degradation fraction content (b) increased (P<0.05) in the RMP (54.87 vs. 89.38).

Table 1. Nutrient composition in Mesquite pods (*Prosopis laevigata*) and roast effect (%).

	RP[1]	**RMP[1]**	**Sig[3]**	**SEM±[4]**
DM	91.71	95.45	**	2.64
OM	94.10	93.72	***	0.95
CP	11.74	12.25	**	0.36
NDF	26.45	25.93	***	0.36
ADF	16.91	18.21	*	0.91
Hemicellulose	9.54	7.72	NS	1.28
CP-NDF (%DM)	4.77	4.96	**	0.13
CP-ADF (%DM)	3.26	4.51	NS	0.88
CP-NDF(%CP)	40.63	40.48	***	0.10
CP-ADF(%CP)	27.76	36.81	NS	6.39
ASHES	5.90	6.23	**	0.20

[1] Raw Pods; [2] Roasted Mesquite Pods; [3] Significant level: NS (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001); [4] Standard error of the mean.

Table 2. Roast effect of the Mesquite pods (*Prosopis laevigata*)[1] in the NDF degradability.

	0	**1**	**3**	**6**	**9**	**12**	**24**	**48**	**72**	**SEM±**	**Sig[1]**
RP	52.48a	68.88b	73.68b	77.64b	75.19b	77.27b	71.34b	73.14b	76.35b	4.9	*
SEM±	6.13	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84		
RMP	46.59a	73.02b	77.27b	78.48b	65.30b	72.12b	70.64b	74.78b	76.48b	4.8	*
SEM±	4.84	4.84	4.84	5.18	4.84	4.84	4.84	4.84	4.84		
Sig[1]	ns	ns	Ns	ns	ns	ns	ns	ns	ns		

[1]Raw Pods; [2] Roasted Mesquite Pods; [3] Significant level: NS (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001); [4] Standard error of the mean. a,b,c, differences within lines(P<0.05).

Table 3. Roast effect of ADF mesquite pods (*Prosopis laevigata*)[1].

	0	**1**	**3**	**6**	**9**	**12**	**24**	**48**	**72**	**SEM±[4]**	**Sig[3]**
RP[1]	32.78a	36.94a	40.21ab	51.05ab	60.43b	52.64ab	53.07b	60.16b	67.99b	8.2	*
SEM±	9.60	7.59	7.59	7.59	7.59	7.59	8.76	9.60	8.11		
RMP[2]	27.36a	40.20a	38.21ab	50.16ab	55.17b	51.43ab	62.52b	60.93b	72.67b	7.8	*
SEM±	7.59	7.59	7.59	8.11	8.11	7.59	7.59	7.59	8.76		
Sig[3]	ns	ns	Ns	ns	ns	ns	Ns	ns	ns		

[1] Raw Pods; [2] Roasted Mesquite Pods; [3] Significant level: NS (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001); [4] Standard error of the mean. a,b,c, differences within lines(P<0.05).

Table 4. Kinetic parameters of NDF degradation of mesquite raw and roasted pods (*Prosopis laevigata*).

Treatment	A	b	c	Potential Deg. [1]	Effective Deg.[2]	R^2	SEM±
RP	53.62	27.21	0.52	80.83	65.98	75.64	5.19
RMP	46.96	33.51	0.94	80.44	78.42	78.87	6.47
Sig[2]	***	***	***	Ns	**		

In which a= Soluble fraction and fase degradation (%), b = Potentially degradable fraction, c = degradation fraction rate. [1.] Potential Degradation = a + b; [2] NS = non-differences (P>0.05);** Differences (P<0.01); *** Differences within columns(P<0.001).
[2] Effective Deg.= a+b(c/c+kp), in which kp: fractional rate of passage (0.06/hr)
RP: Raw Pods; RMP: Roasted Pods.

Table 5. Kinetic parameters of ADF degradation in mesquite raw and roasted pods (*Prosopis laevigata*).

Treatment	A	b	C	Potential Deg. [1]	Effective Deg.[2]	R^2	SEM±
RP	34.96	60.71	0.05	95.67	89.38	73.33	11.20
RMP	31.96	68.83	0.03	100.76	54.87	68.72	13.90
	Ns	**	ns	Ns	**		

In which a= Soluble fraction and fase degradation (%), b = Potentially degradable fraction, c = degradation fraction rate. [1.] Potential Degradation = a + b; NS = non-differences (P>0.05);** Differences (P<0.01); *** Differences within columns (P<0.001).
[2] Effective Degradation.= a+b(c/c+kp), in which kp: fractional rate of passage (0.06/hr)
RP: Raw Pods; RMP: Roasted Pods.

Roasting may allow complex formations among fiber carbohydrates and proteins and diminishing the rumen fiber degradability (Huyler and Kincaid, 1999). Therefore, the protein structure is modified and diminishes its rumen degradability, making N less available to ruminal microorganisms which may affect the ruminal degradation process (Andrade-Montemayor, 2005; Yu et al., 2002). For that reason, could affect the soluble and fast availability fractions in NDF and ADF. This is indicated with a fast degradation that stops within the first hours, obtaining a degradability percentage that ranges from a 78% in the NDF of RMP, and 65% in the NDF of RP, and in ADF a 54% in the RMP to 89% in RP. The degradability values are superior to those obtained by other investigators, who obtained a cell wall potential degradability (a+b) of 39 to 42% and an effective degradability of 17 to 27% in mesquite pods (*Prosopis glandulosa*) (Ramírez et al., 2000). This could be affected by anti-nutritional factors, however the heat treatments may affect or can diminish the content or activity of these factors (Alegría-Ríos et al., 2007).

Roasting effects on feed intake and digestibility

Three rations were tested in this experiment. The control ration (CTR) or base feed, and 2 feeds in which a 20% of the DM of CTR feed was replaced by a 20% of RMP or 20% of RMP. As observed in table 6, the RP or RMP inclusion did not modified the feed nutritional contents, except the NDF content which increases (P<0.05) with RP or RMP inclusion. Nevertheless, these did not affect the NDF consumption (table 7), even that a slight increase was presented (P<0.05) at the ADF consumption (g/kg $PV^{0.75}$). Roasting does not modify the NDF and ADF Cdig (P > 0.05) (Table 8). Therefore the RP or RMP used in the feeds, improves (P<0.05) the digestible NDF and ADF (% DM). Yu et al. (2002) and Andrade-Montemayor (2005) observed that it is advantageous that roasting do not affect the fiber fractions digestibility of many leguminous plants (*L. angustifolium, Vicia faba, Vicia ervilia)* as it was found herein. Therefore, Ramírez et al. (2000) and Guerrero et al. (2007) obtained Cdig and potential and effective degradability of DM and NDF of mesquite pods (*Prosopis laevigata*) values inferior to those shown in this document.

Table 6. Experimental ration composition used at digestibility tests.

	Control	20% RP[1]	20%RMP[2]	Sig[3]	SEM±[4]
DM	87.04	88.26	89.01	NS	0.43
OM	93.87	93.92	93.83	NS	0.39
CP	15.97	16.90	15.26	NS	1.44
NDF	**18.25a**	**19.88b**	**19.85b**	*******	**0.19**
ADF	9.69	11.12	11.45	NS	0.45
CP-NDF(%DM)	8.73	7.93	7.97	NS	0.62
CP-ADF(%DM)	5.39	4.93	5.30	NS	1.07
ASHES	6.13	6.08	6.17	NS	0.39

[1] Ration with raw pods; [2] Ration with roasted Pods; [3] Significant level: NS (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001); [4] Standard error of the mean. a,b,c, differences within lines(P<0.05). Different letters in a line are statistically differences.

Table 7. Nutrients ingested in experimental feeds.

	Control	RP	RMP	SEM±[2]	Sig[1]
		Ingestion (g/day)			
NDF	110.3±4.8	105.9±5.4	116.4±5.4	7.2	NS
ADF	58.7±2.6	59.7±2.9	66.9±2.9	3.8	NS
		Ingestion(g/Kg. $PV^{0.75}$ and day)			
NDF	7.9±0.3	7.9±0.3	8.6±0.3	0.3	NS
ADF	4.2±0.1[a]	4.4±0.2 [a]	4.9±0.2[b]	0.2	*

[1]Ration with raw pods; [2] Ration with roasted Pods; [3] Significant level: NS (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001); [4] Standard error of the mean. a,b,c, differences within lines(P<0.05). Different letters in a line are statistically differences.

Table 8. Digestibility coefficient (%) and digestible nutrient content.

Nutrient	Control	RP[1]	RMP[2]	SEM±[3]	Sig[4]
		digestibility coeficent			
NDF	87.9±0.7	89.8±1.0	89.7±1.0	1.0	NS
ADF	76.1±2.7	80.1±3.8	78.5±3.8	3.8	NS
		digestible nutrient content(%MS)			
NDFN[5]	16.0±0.1[a]	17.8±0.2[b]	17.8±0.2[b]	0.2	***
ADFD[6]	7.3±2.8[a]	8.9±0.4[b]	9.0±0.4[b]	0.4	**

[1] Ration with raw pods; [2] Ration with roasted Pods; [3] Standard error of the mean; [4] Significant level: NS (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001); a,b,c, differences within lines (P<0.05). Different letters in the same line are statistically differences, [5]FDND= Neutral-detergent fiber digestibility; [6]ADFD= Acid-detergent fiber digestibility.

CONCLUSIONS

Mesquite pods roasted allow an increase at the NDF effective degradability, but diminish the ADF effective degradability. Nevertheless, it improves the digestible NDF and ADF content (%DM) with no Cdig modifications. The latter may be caused by the diet fiber fractions major content in the ration with the addition of the RP or RMP.

However, the Cdig and degradability in these studies are good, and this indicates that the mesquite pods can be a food supplement in goats in the semi-desert.

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