THE KELP *Macrocystis pyrifera* AS NUTRITIONAL SUPPLEMENT FOR GOATS

El Alga Marina *Macrocystis pyrifera* como Sumplemento Alimenticio para Cabras

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ABSTRACT

The present study was aimed to evaluate *Macrocystis pyrifera* (MP) meal as a nutritional supplement for goats. There is an increasing interest to look at nutritional alternatives to guarantee a continuous supply of good quality forage for goats, in many communities around the world. Given its abundance and chemical composition, the algae *M. pyrifera* is an important potential resource as animal feed. Three diets with 10, 20, and 30% of MP meal concentrations and a control diet, with no algae, were evaluated. Four rumen cannulated goats, housed individually in metabolism cages, were used. The experimental design was a 4 x 4 Latin-Square. Feed and water intake, excreted urine and faeces, were measured. Digestibility *in vivo*, dry matter (DM) disappearance, and the metabolic variables of pH and ammoniacal nitrogen in the rumen, were determined. There was no significant difference in the feed intake but there was in water intake and urine excreted. No significant difference in digestibility *in vivo* among diets (P>0.05) was found. A significant difference (P<0.05) for degradability *in situ* was found for the algae diets containing 10 and 30% MP concentrations at 96 hours of sampling (78.3 and 82.2%). The raw algae *in situ* digestibility was 77%. A potential degradability of 87.3% was obtained with 30% MP diet. The highest effective degradation was obtained at an estimated rate of 0.02 h^{-1}. Ruminal pH was higher (P<0.05) in all MP treatments (10% MP: 6.83, 20% MP: 6.85, 30% MP: 6.91). As suggested by the results, *M. pyrifera* represents a good unconventional feeding as a nutritional supplement for goats.

Key words: Marine algae, digestibility, goats, nonconventional feed, *Macrocystis.*

RESUMEN

El objetivo de este trabajo fue evaluar *Macrocystis pyrifera* (MP) como suplemento alimenticio para cabras. Hay un interés creciente en buscar alternativas alimenticias para garantizar el suministro continuo de forraje de buena calidad para cabras en muchas comunidades del mundo. Dada su abundancia y composición química, el alga *M. pyrifera* es un recurso potencial importante como pienso para ganado. Se evaluaron tres dietas con concentraciones de 10, 20, y 30% de harina de MP, y una dieta control, sin las algas. Se utilizaron cuatro cabras canuladas dispuestas individualmente en jaulas metabólicas. El diseño experimental fue un Cuadrado Latino 4 x 4. El alimento y agua consumidos, la orina y las heces excretadas fueron medidas. Se determinaron la digestibilidad *in vivo*, la desaparición *in situ* de la materia seca y las variables metabólicas pH y nitrógeno amoniacal en rumen. No se encontró diferencia significativa en el alimento consumido, ni en la digestibilidad *in vivo* entre las dietas (P>0,05), pero si hubo diferencia significativa en el consumo de agua y la orina excretada (P<0,05). Se encontró diferencia significativa (P<0,05) para la digestibilidad *in situ* en las dietas que contenían el 10 y 30% del alga a la hora 96 del muestreo (78,3 y el 82,2%). La digestibilidad *in situ* del alga fue de 77%. Se obtuvo una degradabilidad potencial de 87,3% con la dieta que contiene 30% de MP. La mayor degradación efectiva se obtuvo a una tasa estimada de 0,02 h^{-1}. El pH ruminal fue más alto (P<0,05) en todos los tratamientos con MP (10% de MP: 6,83, 20% de MP: 6,85, 30% de MP: 6,91). Los resultados obtenidos sugieren que *M. pyrifera* representa un buen suplemento nutricional no convencional para cabras.

Palabras clave: Alga marina, digestibilidad, cabras, alimento no convencional, *Macrocystis*.

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INTRODUCTION

An insufficient yearly supply of good-quality feeding forage is common throughout tropical and subtropical regions, particularly in semiarid areas around the world, where native pastures and browse from trees constitute the main forages and, in most cases, the sole components of livestock nutrition [26]. Therefore, there is an increasing interest in the use of unconventional resources to guarantee continuous supplies of good quality forage. Among these resources the kelp *Macrocystis pyrifera* (Linnaeus) C. Agardh is considered a potential resource for animal feeding, given its considerable abundance along the coasts of North and South America, South Africa, Australia and New Zeland, its high regeneration rate after harvest, and its good chemical composition [3].

Studies concerning the digestibility of seaweeds are scarce [9], but it is crucial to have information about this particular issue, prior to the inclusion of this alga in animal feeding. Arieli et al. [2] test the value of *Ulva lactuca* Linnaeus as supplement for ram lambs *Ovis aries* Six five months old rams, with an average body weight of 40 kg were used for four weeks; the experimental diet included 20% of *Ulva*. Digestibility energy measurements (9.1 MJ kg^{-1} DM), organic matter (OM) effective degradability (650 g kg^{-1}), nitrogen effective degradability in the rumen (497 g kg^{-1}), rumen ammonia concentration (311 mg L^{-1}) and excretion of nitrogen in urine (0.91), they all indicated that *Ulva* could be categorized as a low-energy high-nitrogen foodstuff.

Hansen et al. [9] performed a feeding study with 12 north Ronaldsay sheep (23 kg average weight), for five days. Each sheep was fed *ad libitum* with *Laminaria digitata* (L.) Lamouroux and *L. hyperborea* (Gunnerus); dry matter degradation (71.7%) and organic matter digestibility (79.6%) were measured. These authors concluded that such seaweeds can be used as an alternative feeding source. Marin [13] used 20 sheep (20 kg average weight) for 90 days to evaluate the effect of a diet with 25% of the *Sargassum* algae on productive parameters of sheep. No differences were found neither in feed intake (991 g d^{-1}, 992 g d^{-1}), weight increase (870 g $week^{-1}$, 900 g $week^{-1}$) nor feed conversion (7.9; 7.7) between the control diet and the diet with *Sargassum;* but in water consumption (3.8 L d^{-1}, 4.4 L d^{-1}) there were.

Particularly for goats *Capra hircus*, Ventura and Castanon [24] pointed out that *U. lactuca* represents medium-quality forage for goats, with a high protein content. They evaluated in adult male Canarian goats that the effective rumen degradation was 335 g OM and 96 g CP kg^{-1} DM, and the *in vitro* digestion was 512 g OM and 147 g CP kg^{-1} DM. Casas et al. [5] evaluated the nutritive value of *Sargassum* algae as fed for goats; they worked with 20 female Nubian goats (43 weeks old), for 60 days. After dividing them in two groups of 10, one was fed with a control diet and the other with a supplemented diet with 25% of *Sargassum;* there were no significant differences between both diets neither in weight increase (8.6 kg, 9 kg), feed intake (1.30 kg d^{-1}, 1.6 kg d^{-1}), nor feed conversion rate (11.1; 12.6), but only in water consumption (3.8 L d^{-1}, 5.1 L d^{-1}). According to these authors, a diet with 25% of the *Sargassum* algae is efficient as an alternative feedstuff for goats.

Regarding to *M. pyrifera* algae, there is only one study which determined the dry matter disappearance in the rumen of 85% at a lapse of 96 h, with an estimated 0.03 degradability rate, in bovine *Bos taurus - indicus* livestock. Four cross-breeded fistulated zebu bulls, weighing around 600 kg and aging five years old, were used [8].

The present study was conducted to assess the nutritive value of *Macrocystis pyrifera* meal to feed goats, trough the determination of the *in vivo* and *in situ* digestibility of dry matter of the diets, as well as ruminal parameters in goats fed with this kelp.

MATERIALS AND METHODS

Collection of *Macrocystis pyrifera*

The MP *algae* were harvested by a custom made vessel ship called “El Sargacero”, from beds located off Ensenada, B. C., Mexico. The kelp (MP) was spread on a cement surface and sun-dried for three days, turning them periodically to make this process more efficient. Then the algae were ground in a harmer mill (Herza model L).

Experimental design

The diets utilized were: control diet (0% MP), 10, 20 and 30% of *M. pyrifera* meal (10% MP, 20% MP and 30% MP). The study was conducted at the city of La Paz, Baja California Sur, Mexico. The weather in this region is typically warm and semiarid, with a 187.6 mm annual precipitation, a 40-60% average humidity and a 28°C average temperature [6].

The following analyses were carried out to the kelp meal and diets: Dry Matter (DM), ash, crude protein (CP) and ether extract (Soxhlet apparatus, Lab-line Instruments Inc. U.S.A.), determined in accordance to the A.O.A.C. [1] methods (Methods: 934.01, 942.05, 955.04 y 920.39, respectively). A conversion factor of 6.25 was used to calculate CP content. Neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, hemicellulose and lignine were analyzed according to the Van Soest method described by Tejada [22], and gross energy by Calorimetric Bomb (Parr Instrument Bomb, Mod. 6300, U.S.A).

Samples of MP meal for mineral analysis were subjected to acid digestion and analyzed through atomic absorption spectrophotometry (Brand GBC, Mod. Avanta PM, Australia) following the procedures described by A.O.A.C. [1].

Four male Nubian goats (mean weight = 42 ± 1.7 kg, 3 years old) fitted with ruminal cannulae (Plastisol 1”; Bar Diamond) were randomly distributed in a replicated 4 x 4 Latin-square design [20] and were kept in metabolic cages. Data were examined by Analysis of Variance and Tukey’s test for a

multiple comparisons of means, with a significance level of P<0,05 [20]. All animals were treated with anthelmintics. The experimental protocol was approved by the Scientific Committee of the Universidad Autónoma de Baja California Sur.

Feed (0.600 kg of diet) was provided twice a day at 08:00 and 18:00 hours. Water intake was provided *ad libitum*. Each one of the four experimental periods comprised 19 days; 14 days for diet-adaptation period, and 5 days for total feces and urine collection. Feed intake (the difference between feed offered and feed refusal) and water intake were recorded daily. In addition, DM, CP and NDF digestibility (total fecal collection) [19] were determined. Water intake was measured with a glass calibrated cylinder. Total faeces and urine were collected daily from each cage and measured, the first were weighed with a balance; the urine was collected in a bottle and measured with a glass calibrated cylinder.

The DM digestibility coefficient of each diet was estimated using the following formula:

$$DC = \frac{FI - FO}{FI} \times 100$$

Where: DC = digestibility coefficient (%); FI= feed intake (DM basis) and FO= faecal output (DM basis).

Rumen degradability of dry matter for each diet and that for the kelp meal was determined *in situ* using a nylon bag technique. The nylon bags (12 x 8 cm; pore size = 60 µ) were filled with 5 g for each diet and suspended in the rumen of each goat. The bags were incubated for 3; 6; 9; 12; 24; 30; 36; 48; 72 and 96 hours. Nylon bags with kelp meal (5 g) were incubated during 72 hours. Zero time disappearance was obtained by suspending the nylon bags in a NaCl 0.15 N solution, at 37°C for 5 minutes. Upon removal from the rumen, bags were washed five times during 1 min in a mechanical agitator until obtaining a clear and transparent rising liquid and afterwards, dried at 60°C [10, 21] before determining DM disappearance, which was calculated as follows:

$$DM\ (\%) = \frac{((WB + WBI) - (WB + WAI))}{SW} \times 100$$

Where: DM (%)= dry matter disappearance; WB= bag weight; WBI= sample weight prior to incubation; WAI= sample weight after incubation; SW= sample weight.

Data for the *in situ* digestibility of DM were fitted to the non-linear equation: $P = a + b\ (1 - e^{-ct})$ [14] using the Neway Excel program, where: P = disappearance at time *t*; (a + b)= potential degradability; *c* = rate of degradation. The effective degradation was estimated at different degradation rates (fraction h^{-1}): 0.02; 0.05 and 0.08.

Ruminal content samples of 150 mL were collected at 0; 3; 6; 9 and 12 h, through the ruminal cannulae, for five days. One portion of the ruminal content was filtered by squeezing out of eight layers of gauze and the pH of the filtrate was recorded immediately using a potentiometer (Orion Mod. 701A, U.S.A.) with a Corning electrode [1]. Ammoniacal nitrogen was determined by the Destilation method [1]. Data were analyzed in triplicates. Ruminal pH and ammoniacal nitrogen data were analyzed as repeated measures [11, 12] using the Statistical Analysis System program [17].

RESULTS AND DISCUSSION

Chemical Proximal Analysis of Diets

The ashes, the nitrogen-free extract and proteins were the main components of MP meal; the minerals found in highest concentrations were Na and K. The variations of the evaluated fractions on each diet are due mainly to the addition of the algae at different concentrations; they are independent to the variations of the ether and crude protein extracts, because these quantities are influenced by the tallow and the urea, which were included to obtain isocaloric and isoproteic diets, respectively. The ashes concentration increased as the kelp concentration was higher, due to their high content of ashes. On the other hand, the concentration of crude fiber decreased because of the substitution of the alfalfa (TABLE I).

In vivo Digestibility of DM

No significant difference was found in feed intake among all experimental diets (P>0.05) (TABLE II). There was a significant difference in water intake and urine excretion between the control diet and the diets with 20% MP and 30% MP (P<0,05). A progressive increase in water intake (r^2= 0.80) and urine excretion (r^2= 0.60) (TABLE III) was observed as the concentration of kelp added in the diets increased, a positive correlation (r^2 =0.73) was found between water intake and urine excretion. This was attributed mainly to the high content of mineral salts, mostly sodium (48.4 mg g^{-1}) and potassium (93.4 mg g^{-1}), while normal requirements for adult goats are 0.06-1.0 mg g^{-1} and 1.8-2.5 mg g^{-1}, respectively. This is in accordance with Marín [13] and Casas et al. [4] who used the algae *Sargassum* on diets for lambs and goats, respectively. Ruminants are capable of tolerating a high consumption of minerals in their diets, increasing water intake to regulate the osmotic balance in the intestinal tract [23].

In vivo digestibility of DM (P>0.05) showed no significant differences among control diet and diets with MP (TABLE II). The values were greater than those obtained by Marín [13], who used 10, 20 and 30% of the *Sargassum* algae in diets for lambs and found values of digestibility of 70.1 - 73.4%, as well as the ones obtained by Casas et al. [4], who used diets containing *Sargassum* in concentrations of 23, 26 and 29% supplied to goats, and obtained digestibility values of 71.2 – 70.0%. The greater digestibility obtained with MP meal is attributed to its higher alginates concentration (32%) a polysaccharide in contrast with the concentration of alginates of *Sargassum* (14%), and also for the high concentrations of NDF (20%) and ADF (13%).

TABLE I

INGREDIENTS AND CHEMICAL COMPOSITION (g 100 g^{-1} DM) OF DIETS USED / COMPOSICIÓN E INGREDIENTES DE LAS DIETAS USADAS (g 100 g-1 DM).

Ingredients	0% MP	10% MP	20% MP	30% MP
Dehydrated alfalfa	50.40	54.35	49.25	34.90
Corn	32.50	26.10	19.42	23.17
Kelp[1]	0.00	10.00	20.00	30.00
Soybean	14.80	6.75	8.40	9.54
Urea	0.30	0.30	0.20	0.30
Tallow	2.00	2.77	2.88	2.33
Total	100.00	100.00	100.00	100.00
Chemical composition:				
Moisture	7.02	6.79	7.19	6.89
Crude protein	19.55	19.20	19.55	19.35
Ether extract	4.69	5.36	3.90	4.05
Ash	10.93	17.17	18.56	20.35
Energy (Mcal kg^{-1})	4.01	3.76	3.88	3.58
NDF (%)	26.77	26.84	24.28	28.75
ADF (%)	21.25	21.65	19.74	14.65
Lignine (%)	5.65	5.62	5.12	4.82

[1]Chemical composition of the meal of *Macrocystis pyrifera* (% on DM basis): Moisture: 7.66 ± 0.23, Ash: 38.60 ± 0.28, Proteins: 12.77 ± 0.12, Lipids: 0.22 ± 0.01, Gross energy (Mcal Kg^{-1}): 2.04 ± 0.73, NDF (Neutro detergent fiber): 19.90 ± 1.00, ADF (Acid detergent fiber): 12.60 ± 0.91, Hemicellulose: 7.30 ± 0.50, Cellulose: 8.60 ± 0.08, Lignin: 3.60 ± 0.20, Na: 48.4 mg g^{-1}, K: 93.4 mg g^{-1}, Ca: 15.4 mg g^{-1} , Mg 12.9 mg g^{-1}, Fe: 117. 3 mg kg^{-1}, Zn: 12.24 mg kg^{-1}, Mn: 10.5 mg kg^{-1}, Cu: 1.77 mg kg^{-1}.
10% MP: diet with 10% of *M. pyrifera* meal (MP), 20% MP: diet with 20% of MP, 30% MP: diet with 30% of MP and 0% MP: control diet.

TABLE II

FEED INTAKE AND *IN VIVO* DIGESTIBILITY OF THE DIETS/ ALIMENTO CONSUMIDO Y DIGESTIBILIDAD *IN VIVO* DE LAS DIETAS.

	Control	10% MP	20% MP	30% MP
Feed intake of dry matter (kg)	1.18^{a} ± 0.02	1.2^{a} ± 0.00	1.17^{a} ± 0.05	1.17^{a} ± 0.05
*IVDMD (%)	83.2^{a} ± 0.36	82.4^{a} ± 0.72	82.4^{a} ±1.58	83.6^{a} ± 0.39
Nitrogen digestibility (%)	90.12^{a} ± 0.28	90.82^{a} ± 0.21	88.75^{b} ± 0.54	87.39^{c} ± 0.59
NDF digestibility (%)	80.6^{b} ± 0.46	74.4^{c} ± 1.3	74.2^{c} ± 1.24	83.5^{a} ± 0.31

Means of 4 determinations.
Same letters at the same row indicate that there was not any significant statistical difference (P>0.05).
*IVDMS: *In vivo* digestibility of dry matter. 10% MP: Diet with kelp 10%; 20% MP: Diet with kelp 20%; 30% MP: Diet with kelp 30%.

TABLE III

WATER INTAKE AND URINE EXCRETION, DURING THE FOUR SAMPLING PERIODS/ CONSUMO DE AGUA Y ORINA EXCRETADA, DURANTE LOS CUATRO PERIODOS DE MUESTREO.

Diet	Water intake (L day^{-1})	Urine excretion (L day^{-1})
Control	5.6865 ± 1.30^{a}	1.787 ± 1.17^{a}
10% MP	7.3105 ± 1.33^{ab}	2.557 ± 1.01^{ab}
20% MP	8.1665 ± 0.89^{b}	3.155 ± 0.56^{b}
30% MP	9.1955 ± 0.72^{b}	3.384 ± 0.80^{b}

Means of 4 determinations.
Same letters at the same column indicate that there was not any significant statistical difference (P>0.05).
10% MP: Diet with kelp 10%; 20% MP: Diet with kelp 20%; 30% MP: Diet with kelp 30%.

in situ Digestibility of DM

Results from the *in situ* digestibility of DM showed a significant difference among the several hours of sampling for each diet (P<0.05). At the 96 hour, the diet with a 10% MP concentration was different from the one with 30% (P<0.05). It is important to point out that at 48 hour, there was 76% degradation in the diet with 30% of kelp, which equals 93% of the total of the *in situ* digestibility; in the other diets it reached from 86 to 88% (FIG. 1). The highest value found was 82.2% on the diet with 30% MP. These results are higher than those obtained by Casas et al. [4] who found *in situ* digestibility values of 71.4%. Their diets had a similar composition to those used in this study, but a *Sargassum* meal was used. Marín [13] in studies performed on ovines, obtained an *in situ* digestibility value of 66.3% with 30% of *Sargassum*. The greater values of *in situ* digestibility found in this work with regards to the ones got by Marin [13] and Casas et al. [4] are attributed to the difference in concentration of alginates in the algae previously mentioned. The values for the same variable, but using alfalfa (80.8%) or corn (79.4%), were similar to those obtained in this study.

The *in situ* digestibility obtained for the kelp meal was 77% at hour 72, which differs from the values reported by Gojón et al. [8] on bovines (85.4%). This is due to the fact that they measured the algae digestibility after 96 h. Gojón et al. [8] mentioned that the crude protein of this seaweed is not degraded in the rumen, and that *in vitro* protein degradability results (90%) suggest that these proteins may function as bypass proteins to be digested in the abomasums. If this is considered then the MP digestibility in ruminants is bigger than 77%.

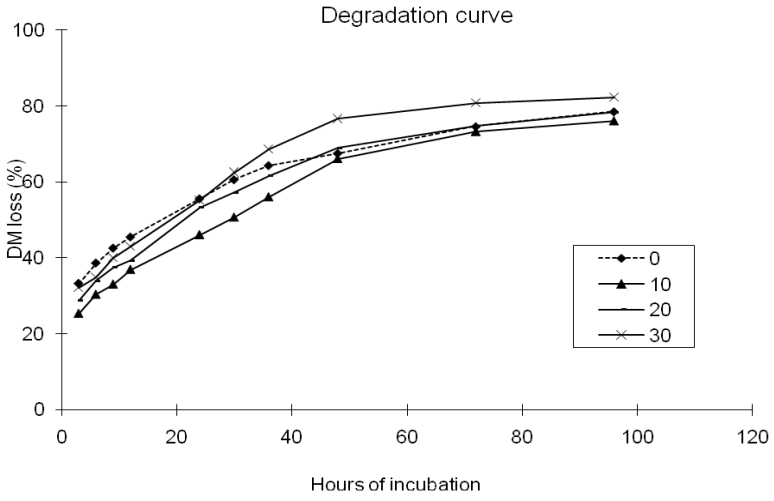
Kinetics of *in situ* Disappearance of DM

The soluble fraction (a) increased on diets with kelp, but there were no differences (P>0.05) with the control diet that is bigger (TABLE IV). The value obtained for the soluble fraction (a) on the control diet is related to its high content of carbohydrates, whose fractions have the characteristic of having a fast degradation for sugars and an intermediate one for starches, pectins and beta-glucans. The diets with 10, 20 and 30% of the alga had a progressive increase of the fraction (a) as the concentration of the alga was higher. This is related to the content of ashes specifically with sodium, since according to Gojón et al. [8], the minerals of *M. pyrifera* disappear from the nylon bag up to 81% at time zero by diffusion.

The addition of the MP meal to the diets increased the potentially digestible fraction (b) of DM, as compared to the control diet (P<0.05). This is an indicator of how the feed containing kelp can be used better by the rumen microorganisms, in the volatile fatty acids production and in the microbial protein, which are related to its insoluble degradability in water.

The digestion rate or ruminal disappearance of 0.03; 0.02; 0.03 and 0.03 % h^{-1} for each one of the diets (P>0.05) (TABLE IV) showed higher ranges than those obtained by Galina et al. [7] who found values of 59.1% at the 0.05 % h^{-1} digestion rate, when the effects of slow-intake urea supplementation were evaluated on goat kids pasturing natural Mexican rangeland. Values are also higher than those found when using nine shrubs (15.5 – 54.7%) from Northeast Mexico on sheep [15].

No significant difference was found between the values obtained for potential degradability, with a range between 82.4 and 87.3% (P>0.05) (TABLE IV). This reflects the low percentage of the indigestible fraction on each diet. The highest effective degradation was obtained at a 0.02 h^{-1} rate (TABLE IV), because the flow is slower than at 0.05 and 0.08 h^{-1}. This allows the feed to remain longer time in the rumen and hence to



10% MP: diet with 10% of *M. pyrifera* meal (MP), 20% MP: diet with 20% of MP, 30% MP: diet with 30% of MP and 0% MP: control diet.

FIGURE 1. VARIATION OF THE PERCENTAGE OF *IN SITU* DIGESTIBILITY OF DRY MATTER (%) AT EACH SAMPLING TIME FOR EACH DIET/ VARIACIÓN DEL PORCENTAJE DE DIGESTIBILIDAD *IN SITU* DE LA MATERIA SECA (%) POR HORA DE MUESTREO PARA CADA DIETA.

TABLE IV

KINETICS OF *IN SITU* DISAPPEARANCE OF DRY MATTER FROM EXPERIMENTAL DIETS/ CINETICA DE LA DESAPARICIÓN DE MATERIA SECA *IN SITU* DE LAS DIETAS EXPERIMENTALES.

	Experimental Diets			
	0% MP	10% MP	20% MP	30% MP
Soluble fraction (a) (%)	$29.45^{a} \pm 7.59$	$21.37^{a} \pm 3.76$	$23.30^{a} \pm 6.13$	$24.45^{a} \pm 2.34$
Potentially digestible fraction (b) (%)	$52.92^{b} \pm 5.07$	$64.27^{a} \pm 9.84$	$61.00^{ab} \pm 7.83$	$62.85^{a} \pm 2.21$
Degradation rate or ruminal digestion (c) (Kd h^{-1})	$0.03^{a} \pm 0.01$	$0.02^{a} \pm 0.004$	$0.03^{a} \pm 0.01$	$0.03^{a} \pm 0.005$
Degradability insoluble in water (%)	$69.47^{a} \pm 14.16$	$79.42^{a} \pm 6.67$	$75.02^{a} \pm 5.12$	$77.92^{a} \pm 0.85$
Potential degradability (%)	$82.40^{a} \pm 6.29$	$85.62^{a} \pm 6.67$	$84.30^{a} \pm 5.16$	$87.30^{a} \pm 0.82$
Effective degradation at different degradation rates (fraction h^{-1}):				
0.02	$60.50^{ab} \pm 3.85$	$54.92^{c} \pm 1.54$	$58.42^{bc} \pm 3.55$	$62.87^{a} \pm 2.07$
0.05	$48.92^{a} \pm 4.22$	$41.00^{b} \pm 3.09$	$45.17^{ab} \pm 4.22$	$48.80^{a} \pm 2.36$
0.08	$43.67^{a} \pm 4.61$	$35.27^{b} \pm 3.41$	$39.27^{ab} \pm 4.22$	$42.27^{a} \pm 2.27$

abc, different letters at each row indicate statistical significant difference (P<0,05).
10% K: diet with 10% of *M. pyrifera* meal (MP), 20% MP; diet with 20% of MP, 30% MP; diet with 30% of MP and 0% MP: control diet.

TABLE V

pH VARIATION AMONG TIMES AND DIETS IN THE FOUR SAMPLING PERIODS / VARIACIÓN DEL PH ENTRE HORAS Y DIETAS EN LOS CUATRO PERIODOS DE MUESTREO.

Time	Control	10% MP	20% MP	30% MP
0	$7.03^{aA} \pm 0.19$	$7.11^{aA} \pm 0.08$	$7.08^{aA} \pm 0.059$	$7.08^{aA} \pm 0.033$
3	$6.62^{aD} \pm 0.17$	$6.77^{bD} \pm 0.11$	$6.8^{bD} \pm 0.19$	$6.87^{cD} \pm 0.08$
6	$6.75^{aC} \pm 0.25$	$6.8^{abC} \pm 0.17$	$6.86^{bC} \pm 0.20$	$6.9^{bC} \pm 0.13$
9	$6.8^{aB} \pm 0.25$	$7.00^{bB} \pm 0.13$	$6.88^{abB} \pm 0.17$	$7.01^{bB} \pm 0.11$
12	$6.32^{aE} \pm 0.15$	$6.51^{abE} \pm 0.16$	$6.64^{bE} \pm 0.14$	$6.71^{bE} \pm 0.08$
Mean	$6.7^{A} \pm 0.14$	$6.83^{B} \pm 0.10$	$6.85^{B} \pm 0.15$	$6.91^{B} \pm 0.07$

Means of 4 determinations.
abc, different letters in the same row indicate statistical significant difference among diets (P<0.05).
ABCDE, different letters in the same column indicate statistical significant difference among times (P<0.05).
10% MP: Diet with kelp 10%; 20% MP: Diet with kelp 20%; 30% MP: Diet with kelp 30%.

suffer higher degradation and digestion, because of the digestibility results from the retention time.

pH and Ammoniacal Nitrogen Determination

The lowest pH value (6.7 ± 0.14) was recorded on the control diet (P<0.05), compared to the diets with kelp meal (TABLE V). Increase in pH values was observed as the proportion of algae increased on the diet (6.9 ± 0.07), hence favoring a neutral pH. This behavior is related to water intake, which will increase with the concentration of mineral salts supplied by the algae on the diets. Because of the concentration of the alga was higher on the diet, the pH was closer to 7. It is noteworthy to mention that the pH values obtained for each diet favored the replication of cellulolitic bacteria and their metabolic functions, since these bacteria prefer a neutral pH to grow and values lower than 6.0 affect them [16, 25]. The behavior of the pH was similar in each diet, having two decreases right after feeding. These decreases are attributed to the fermentation peaks where the wasting products such as volatile fatty acids (VFA's), reduce their value of this variable. Marín [13] found that the pH values reduced right after feeding, corresponding to the highest synthesis of VFA's.

Regarding ammoniacal nitrogen, there was no significant difference among diets at different times of sampling (P>0.05) (TABLE VI), but there was among sampling hours in the diet control and diets with 10 and 30% of MP. Even though ammoniacal nitrogen concentration average was 312.6 mg L^{-1} in the control diet, this was not significant difference with regards to the diets with MP. The values of ammoniacal nitrogen were between 291 and 234 mg L^{-1} on the diets that included the algae. Satter and Slyter [18] stated that a concentration of 50 mg of NH_3-N L^{-1} is enough to support a maximum growth rate of ruminal bacteria and that excessively high levels (800 mg L^{-1}) do not inhibit bacterial growth.

TABLE VI

VARIATION OF AMMONIACAL NITROGEN AMONG TIMES AND DIETS IN THE FOUR SAMPLING PERIODS (mg/L)/ VARIACIÓN DEL NITROGENO AMONIACAL ENTRE HORAS Y DIETAS (Mg/L) EN LOS CUATRO PERIODOS DE MUESTREO.

Time	Control	10% MP	20% MP	30% MP
0	$328.12^{aB} \pm 110.02$	$307.30^{aA} \pm 61.83$	$327.25^{aA} \pm 62.96$	$303.70^{aA} \pm 76.55$
3	$401.2^{bA} \pm 232.26$	$282.10^{bA} \pm 55.27$	$309.75^{bA} \pm 18.40$	$233.10^{bB} \pm 72.77$
6	$297.15^{cD} \pm 152.50$	$195.65^{cB} \pm 24.25$	$267.07^{cA} \pm 60.60$	$204.05^{cB} \pm 87.49$
9	$232.22^{dE} \pm 93.07$	$205.45^{dB} \pm 48.61$	$250.60^{dA} \pm 65.27$	$233.30^{dB} \pm 58.30$
12	$304.50^{eC} \pm 102.32$	$271.60^{eA} \pm 32.04$	$303.62^{eA} \pm 56.24$	$207.55^{eB} \pm 34.83$
Mean	$312.65^{A} \pm 134.76$	$252.42^{A} \pm 31.38$	$291.66^{A} \pm 27.77$	$234.34^{A} \pm 45.90$

Means of 4 determinations.
abcde, different letters in the same row indicate statistical significant difference among diets (P<0.05).
ABCDE, different letters in the same column indicate statistical significant difference among times (P<0.05).
10% MP: Diet with kelp 10%; 20% MP: Diet with kelp 20%; 30% MP: Diet with kelp 30%.

CONCLUSIONS

The results suggest that *M. pyrifera* may be used in a concentration up to 30%, as an unconventional dietary supplement for goats, without affecting the *in vivo* digestibility, *in situ* digestibility and parameters of ruminal fermentation, such as pH and ammoniacal nitrogen.

The highest *in situ* digestibility (82.2%) was found on the 30% MP diet.

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