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Original

Wet extrusion and chemical treatment of maralfalfa grass (*Pennisetum* sp)

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ABSTRACT

Objectives. Test the effect of wet extrusion and the application of two alkaline compounds on the *in vitro* digestibility of dry matter (IVDDM) and neutral detergent fiber (IVDNDF) of maralfalfa grass. **Materials and methods.** 48 samples of 51 days of regrowth were chopped and assigned to eight treatments: raw, chopped, and dehydrated grass (CTRL); raw, chopped, and extruded grass (EXTR); EXTR treated with 0.45, 0.90, and 1.35% of lime ($Ca(OH)_2$) or urea for 21 days in micro-silos under aerobic conditions (EXTR0.45Ca, EXTR0.90Ca, EXTR1.35Ca, EXTR0.45U, EXTR0.90U, and EXTR1.35U, respectively). The content of dry matter (DM), nitrogen (N), calcium (Ca), neutral detergent fiber (NDF), acid detergent lignin (ADL) and the *in vitro* digestibility of dry matter (IVDDM) and NDF (IVDNDF) were determined for each sample. **Results.** The EXTR presented lower N content, higher NDF content, and higher IVDNDF than the CTRL. On the other hand, the EXTR1.35Ca treatment showed the highest Ca concentration and the highest IVDDM and IVDNDF, while the EXTR0.90U treatment presented the highest N concentration and an IVDNDF statistically similar to that of the EXTR1.35Ca. **Conclusions.** The wet extrusion of maralfalfa grass alone increases IVDNDF; however, IVDDM and IVDNDF are maximized when treated with 1.35% of $Ca(OH)_2$.

Keywords: Bagasse; biomass; calcium; delignification; digestibility; *In vitro*; nitrogen (*Fuente: AGROVOC*).

RESUMEN

Objetivos. Evaluar el papel de la extrusión húmeda y la aplicación de dos compuestos alcalinos sobre la digestibilidad *in vitro* de materia seca (DIVMS) y fibra en detergente neutro (DIVFDN). **Materiales y métodos.** Se picaron 48 muestras de 51 días de rebrote y se asignaron a ocho tratamientos: pasto fresco, picado y deshidratado (CTRL); pasto crudo, picado y extruido (EXTR); EXTR tratado con 0.45, 0.90 y 1.35% de cal ($Ca(OH)_2$) o urea durante 21 días en microsilos bajo condiciones aeróbicas (EXTR0.45Ca, EXTR0.90Ca, EXTR1.35Ca, EXTR0.45U, EXTR0.90U y EXTR1.35U, respectivamente). El contenido de materia seca (MS), nitrógeno (N), Calcio (Ca), Fibra Detergente Neutra (FDN), Lignina Detergente Ácida (LDA) y la DIVMS y DIVFDN fueron determinadas en cada muestra. **Resultados.** El EXTR presentó menor contenido de N, mayor contenido de FDN y mayor

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DIVFDN que CTRL. Por otro lado, el tratamiento con EXTR1.35Ca presentó la mayor concentración de Ca y la mayor DIVMS y DIVFDN, mientras que el tratamiento con EXTR0.90U presentó la mayor concentración de N y una DIVFDN estadísticamente similar a la de EXTR1.35Ca. **Conclusiones.** La extrusión húmeda solo de pasto maralfalfa aumenta el IVDNDF, sin embargo, la DIVMS y DIVFDN se maximizan cuando se tratan con 1.35% de $Ca(OH)_2$.

Palabras clave: Bagazo; biomasa; calcio; deslignificación; digestibilidad; *In vitro*; nitrógeno (*Fuente: AGROVOC*).

INTRODUCTION

Maralfalfa grass (*Pennisetum* sp) is a tropical grass characterized by a low content of crude protein and non-structural carbohydrates, but it is high in structural carbohydrates and lignin (1). The latter is a polymeric structure of phenylpropanoid units that combine through ether and ester bonds to cellulose and hemicellulose (2) being able to limit the microbial fermentation or enzymatic hydrolysis of these carbohydrates, reducing their digestibility and the contribution of fermentable energy (3,4,5). In order to make up for this energy deficiency in animal production systems based on tropical grasses, the use of food supplements with a high content of non-structural carbohydrates is common, unfortunately, it has negative effects such as reduction in structural carbohydrates fermentability (6,7,8); increased probability of feeding problems such as ruminal acidosis and laminitis (9,10), which in turn affect animal welfare, animal yield and production costs; and the use of raw materials of high nutritional value for human consumption such as corn generates significant competition for said foods between humans and animal species, a use that has been criticized for decades (11). Additionally, the incorporation of these raw materials increases production costs and dependence on international markets since countries like Colombia are net importers of said foods (12). This makes this strategy counterproductive and unsustainable over time.

Another alternative to solve the energy deficiency, as it happens with the maralfalfa grass due to the high content of lignin, is to solubilize the bonds between this and the structural carbohydrates by means of chemical, microbiological or physical methods and their combinations. Extrusion stands out among the physical methods. It is a quick procedure that, by applying pressure, temperature, and shear strength, seeks to partially break these bonds, improving the digestibility of cell walls (13). Recently (14) it was showed that the extrusion of kikuyo grass (Cenchrus clandestinus (Hochst ex Chiov)) increased *in vitro* digestibility of neutral detergent fiber (IVNDFD) by more than 36% and in maralfalfa grass this increase was of more than 20% (15). In other foods such as wheat bran, the combination of various thermo-mechanical and thermo-mechanical-chemical pretreatments such as twin screw extrusion has been used with chemical treatments such as the application of urea and calcium hydroxide ($Ca(OH)_2$) (16), however, there are no known records of this combination in tropical grasses such as maralfalfa grass. The concentration of these alkalis has ranged between 0.3 (17) and 6.0% (18) depending on the material to be treated. In any case, it is necessary to take into account that the use of urea increases the non-protein nitrogen content in the final product by up to 7 times (19) and in the case of lime, the ash and Ca content is increased up to 13 times (20), which can generate imbalances. Therefore, it is necessary to use relatively low concentrations of this alkalis to avoid these problems. That is way the objective of this work was to evaluate the effect of the extrusion of maralfalfa grass as well as the treatment of the extruded bagasse with urea or $Ca(OH)_2$ on the IVNDFD.

MATERIALS AND METHODS

Localization. In a property at the municipality of Támesis (Antioquia - Colombia) located at 2200 meters above sea level, 48 samples of approximately 10 kg of maralfalfa grass with 51 days of regrowth were collected. Each sample was chopped into 2 cm pieces in a grass-chopper and were randomly distributed in eight treatments (six samples/treatment).

Experimental treatments. The eight treatments were: raw and chopped grass (control: CTRL) that was dehydrated at 60oC for 24 h; grass bagasse obtained after processing the raw CTRL in a conical single screw extruder with a processing capacity of approximately 60 kg of green matter/h (220 V motor; 5.0 HP; 1300 rpm) with 1.0 mm output (EXTR); EXTR sample subjected to chemical delignification for 21 days with $Ca(OH)_2$ at 0.45, 0.90, and 1.35% of dry matter (EXTR0.45Ca, EXTR0.90Ca, EXTR1.35Ca, respectively) or urea at 0.45, 0.90, and 1.35% of dry matter (EXTR0.45U, EXTR0.90U and EXTR1.35U, respectively). The CTRL samples and bagasse obtained after the extrusion of the samples were dehydrated at 60ºC for 24 h in a forced air oven previously the apply the chemical treatments.

For the chemical treatments, 225, 450 or 675 mg of $Ca(OH)_2$ or urea were added to 12.5 ml of water, respectively, and mixed thoroughly. Subsequently, they were mixed manually with 50 g of the dried maralfalfa grass samples (14.4% of dry matter) in 1 L plastic bottles (micro-silos) with a screw cap in order to obtain a material with 29.2% of water added on dry basis. The micro-silos were kept under aerobic conditions (with atmospheric air) and under shade for 21 days after which all the samples were dehydrated again at 60oC for 24 h and were subjected to the corresponding analyzes.

Chemycal and physical analysis. In all the samples, the dry matter (DM), nitrogen (N) and calcium (Ca) content was determined using the procedures described by the AOAC for forages (21); the neutral detergent fiber (NDF) and acid detergent lignin (ADL) contents were determined based on the procedures of Van Soest et al. (22), and the *in vitro* digestibility of dry matter (IVDMD) and NDF (IVNDFD) were determined by an enzymatic pepsin-cellulase technique described by Barchiesi et al. (23). All analyzes were carried out in the Laboratory of Chemical and Bromatological Analysis of the Universidad Nacional de Colombia at Medellín.

Statistical analysis. The results were subjected to an analysis of orthogonal contrasts using the SAS statistical package PROC GLM (24) in which CTRL vs. EXTR, CTRL vs. CHEMICAL (the treatments with urea and $Ca(OH)_2$), and EXTR vs. CHEMICAL treatments were compared. On the other hand, the CHEMICAL treatments were analyzed in a nested design using the SAS statistical package PROC GLM (24) under the following linear model:

$$Y_{ijk} = \mu + T_i + N(T_i) + e_{ijk}$$

Y_{ijk} is the response variable; μ is the experimental mean; T_i is the effect of the chemical compound; $N(T_i)$ is the effect of the application level nested in the chemical compound; and e_{ijk} is the experimental error. The comparison of means were carried out using the LSMEANS statement.

Finally, a regression analysis was done between the $Ca(OH)_2$ and Urea concentration and the Ca and N concentration in the samples treated.

RESULTS

Treatment with raw grass (CTRL) presented high content of NDF and ADL but low content of N (Table 1). The Ca content, by other hand, was normal to this grass (25). According to the records in Table 1, it can be established that, except for some specific results (ADL and Ca in Contrast 1; and DM, NDF and ADL in Contrast 4), the comparisons were significant for the chemical components analyzed. Extrusion (EXTR) allowed obtaining a bagasse with higher DM and NDF contents compared CTRL but lower than N, without evidence of change in ADL and Ca.

Table 1. Chemical composition of raw maralfalfa grass (*Pennisetum* sp), bagasse product of extrusion, and extruded bagasse subjected to chemical delignification

Treatments		Chemical fraction % of DM				
		DM[1]	N	NDF	ADL	Ca
CTRL		14.4	1.45	72.8	7.35	0.37
EXTR		91.3	1.07	81.9	7.15	0.28
CHEMICAL		80.2	1.81	77.3	6.12	1.18
$Ca(OH)_2$		80.2	1.22	77.01	6.00	2.09
Urea		80.2	2.40	77.5	6.22	0.26
SEM[2]		2.19	0.02	2.41	0.37	0.03
Orthogonal contrasts[3]	1	0.001	0.001	0.001	0.574	0.383
	2	0.001	0.001	0.001	0.001	0.001
	3	0.001	0.001	0.001	0.001	0.001
	4	0.999	0.001	0.304	0.283	0.001

[1]DM = Dry matter; N = Nitrogen; NDF = Neutral detergent fiber; ADL = acid detergent lignin; Ca = calcium.
[2]SEM = standard error of the mean
[3]Probability of the significance of orthogonal contrasts. The effects tested were 1) CTRL vs. EXTR; 2) CTRL vs. CHEMICALS; 3) EXTR vs. CHEMICALS; 4) $Ca(OH)_2$ vs. urea were evaluated.

The comparison between the CTRL treatment and the CHEMICALS (orthogonal contrast number 2) showed that there were a difference in the five chemical fractions. Except in the ADL, the content of the other fractions was higher in the samples from the chemical treatments. The application of $Ca(OH)_2$ and urea on the extruded bagasse reduced the content of DM, NDF, and ADL; however, this was not the case for N and Ca (Table 1). According to the result of the analysis of orthogonal contrast number 4, no differences were found in the average content of DM, NDF and ADL, but there were a difference on N and Ca. Finally, the contrast between urea and $Ca(OH)_2$ showed that the inclusion of urea increased the content of N, while the application of $Ca(OH)_2$ increased the content of Ca. Also there were an increase of 69.2% in the content of N and 76.2% in Ca in the bagasse that received chemical treatments compared to the bagasse generated only by extrusion.

Table 2 shows the results of the chemical composition analysis of the bagasse of extruded grass subjected to the application of the chemical treatments.

Table 2. Chemical composition of bagasse from extruded maralfalfa grass (*Pennisetum* sp) subjected to different chemical treatments.

Treatments (% of DM)[1]	Chemical fraction % of DM				
	DM[2]	N	NDF	ADL	Ca
EXTR0.45Ca	79.9	1.15d	78.7a	5.60b	1.42c
EXTR0.90Ca	80.0	1.15d	77.5a	6.50a	2.10b
EXTR1.35Ca	80.0	1.38d	74.8b	5.92b	2.77a
EXTR0.45U	79.9	1.88c	80.2a	6.23a	0.28d
EXTR0.90U	80.2	2.52b	75.8b	6.13b	0.26d
EXTR1.35U	80.5	2.80a[3]	76.7b	6.32a	0.27d
SEM[4]	2.49	0.02	1.83	0.12	0.04
P[5]	0.907	0.001	0.001	0.002	0.001

[1]EXTR0.45Ca = grass bagasse treated with 0.45% of $Ca(OH)_2$; [1]EXTR0.90Ca = grass bagasse treated with 0.90% of $Ca(OH)_2$; [1]EXTR1.35Ca = grass bagasse treated with 1.35% of $Ca(OH)_2$; EXTR0.45U = grass bagasse treated with 0.45% of urea; EXTR0.90U = grass bagasse treated with 0.90% of urea; EXTR1.35U = grass bagasse treated with 1.35% of urea
[2]DM = Dry matter; N = Nitrogen; NDF = Neutral detergent fiber; ADL = acid detergent lignin; Ca = calcium
[3] Means within a column with similar letter are not different according to the LSMEANS test
[3]SEM = standard error of the mean
[4]Probability of significance

Of the chemical fractions analyzed, DM was the only one that did not present a difference associated with the treatments. The independent analysis of each chemical fraction shows that the content of N increased as the level of urea incorporated increased, but there was no difference with the addition of $Ca(OH)_2$. The Ca content increased with the increase in the inclusion level of $Ca(OH)_2$ but there was no difference between samples from the addition of urea.

Although the analysis of orthogonal contrasts did not show differences between the treatments with urea and $Ca(OH)_2$ in terms of the content of NDF and ADL (Table 1), the analysis of the nested design used to evaluate the chemical treatments, shows differences in these chemical fractions. Thus, the NDF level was lower, and not different, in the treatments with the highest $Ca(OH)_2$ concentration and with the medium and high urea concentration; in turn, the highest contents, although not different, occurred with the lowest level of urea application and with the first two levels of $Ca(OH)_2$. The content of ADL was lower with the treatments with the lowest and highest levels of application of $Ca(OH)_2$ and with the treatments with medium and high application of urea.

Table 2 also identifies that the N content increased linearly with the application of urea ($y = 1.19 + 1.29X$; $r^2 = 0.92$; $p<0.001$) but there was no incidence of $Ca(OH)_2$. The N content went from 1.07% in the crude bagasse (EXTR) (Table 1) to 2.80% in the bagasse treated with 1.35% urea, this is 2.6 times higher. Because the urea treatment reduced the NDF content (Table 2), the content of the other components increases, including N, so its concentration was exacerbated by the contribution of N made by the applied urea. Unlike the latter, the application of $Ca(OH)_2$ does not translate into changes in the N content. The application of urea had no effect on the Ca content of the samples, the situation was different with the application of $Ca(OH)_2$; it increased linearly with the increase in its application to such an extent that with the 1.35% $Ca(OH)_2$ treatment this increase was 9.9 times greater than in raw bagasse going from 0.28 (EXTR) (Table 1) to 2.77% ($y = 0.42 + 1.81x$; $r^2 = 0.93$; $p<0.001$). Again, as with urea, there was a decrease in the NDF content due to the delignifing effect of this hydroxide, which generated the recomposition of the other chemical components of the bagasse and an increase in the Ca content.

Although the bagasse obtained by extrusion (EXTR) had a higher NDF content than the grass from the CTRL treatment and there was no difference in the ADL (Table 1), the results of Table 3 show that there was no difference in the IVDMD but that the IVNDFD increased by 33.0%.

Table 3. *In vitro* dry matter digestibility (IVDMD) and neutral detergent fiber (IVNDFD) of raw maralfalfa grass (*Pennisetum* sp), bagasse product of extrusion, and extruded bagasse subjected to chemical treatment.

Treatment		IVDMD	IVNDFD
CTRL		42.9	30.3
EXTRUDED		42.8	40.3
CHEMICAL		48.8	43.4
$Ca(OH)_2$		50.7	44.9
Urea		46.9	41.9
SEM[1]		4.55	5.63
Orthogonal contrasts[2]	1	0.949	0.001
	2	0.001	0.001
	3	0.001	0.006
	4	0.001	0.001

[1]SEM = standard error of the mean
[2]Probability of the significance of orthogonal contrasts. The effects using 1) CTRL vs. EXTR; 2) CTRL vs. CHEMICALS; 3) EXTR vs. CHEMICALS; 4) $Ca(OH)_2$ vs. urea were evaluated.

It is clear that extrusion had a partial effect on *in vitro* digestibility by affecting only IVNDFD; but the chemical treatments increased both IVDMD and IVNDFD when compared with those of the CTRL and EXTR treatment. Together, the chemical treatments generated an average increase of 13.8% in IVDMD compared to raw grass (CTRL) and 14.0% compared to extruded grass; with respect to the IVNDFD this increase was 43.2% and 7.4%, respectively. The comparison of the two alkalizing compounds showed that the effect of $Ca(OH)_2$ was superior to that of urea in 8.1% and 7.2% for IVDMD and IVNDFD, respectively.

When comparing the chemical treatments, it was established that the addition of 1.35% of $Ca(OH)_2$ increased IVDMD and IVNDFD by 24.3% and 54.1%, respectively, compared to CTRL. Treatment with 0.9% urea generated an increase in IVNDFD statistically similar to that of treatment with 1.35% $Ca(OH)_2$ but, unlike this, the increase in IVDMD was only 14.7%.

Table 4. *In vitro* dry matter digestibility (IVDMD) and neutral detergent fiber (IVNDFD) of bagasse product of the extrusion of maralfalfa grass (*Pennisetum* sp) subjected to delignification with three levels of calcium hydroxide ($Ca(OH)_2$) and urea (UREA).

Treatments (Values in% of DM)	IVDMD	IVNDFD
EXTR0.45Ca[1]	47.9b	42.8b
EXTR0.90Ca	51.0b	45.3a
EXTR0.135Ca	53.3a	46.7a
EXTR0.45U	45.2b	41.3b
EXTR0.90U	49.2b	43.4ab
EXTR0.135U	46.5b	41.0b
SEM[2]	5.43	6.66
P[3]	0.001	0.004

[1]EXTR0.45Ca = grass bagasse treated with 0.45% of $Ca(OH)_2$; [1]EXTR0.90Ca = grass bagasse treated with 0.90% of $Ca(OH)_2$; [1]EXTR1.35Ca = grass bagasse treated with 1.35% of $Ca(OH)_2$; EXTR0.45U = grass bagasse treated with 0.45% of urea; EXTR0.90U = grass bagasse treated with 0.90% of urea; EXTR1.35U = grass bagasse treated with 1.35% of urea
[2]SEM = standard error of the mean
[3]Probability of the significance

DISCUSSION

The high content of NDF and ADL but low content of N in the CTRL is typical of this grass for the regrowth age in which it was harvested (1,25,26). Jaimes et al (15) reported an increase in the NDF content in the maralfalfa grass bagasse obtained by extrusion but with a significant reduction in the ADL content. The increase in the NDF content is a consequence of the extraction of nutrients in the grass juice, which allows obtaining a bagasse rich in cell walls (14,15) as well as chemical changes in it (27).

The composition of bagasse treated with chemicals (Table 1), would be a consequence of the hydrolytic effect generated by both ammonia from urea (28) and $Ca(OH)_2$ (29) on the ether and ester bonds of lignin with structural carbohydrates. In general, alkaline treatments (such as urea and $Ca(OH)_2$) have the ability to remove lignin and various uronic acids from hemicellulose, which improves the access of hydrolytic enzymes that attack cellulose and hemicellulose (30). The increase in the N content of the treated biomass, by other hand, does not only depend on the level of urea applied (31) but on the delignification method used (32).

Trach et al (33) reported that in rice husk delignification there was a reduction in NDF content by increasing the application of both urea (2.0 to 4.0%) and $Ca(OH)_2$ (3.0 to 6.0) but there was no effect of urea on the ADL content and it significantly reduced as the $Ca(OH)_2$ concentration increased. These results suggest that the effect of alkaline compounds on cell wall components depends, among other factors, on the type of plant biomass treated and on the concentrations of the delignifying compounds used. In this regard, Behera et al (34) pointed out that the effect of chemical treatments conducive to improving the availability of structural carbohydrates for enzymatic hydrolysis depends on numerous factors among which the type of lignocellulosic biomass; process parameters such as time, temperature, and pressure; as well as the type of delignifying compound used stand out.

The application of $Ca(OH)_2$ linearly increased Ca concentration in bagasse until to 2.77% whit 1.35% of $Ca(OH)_2$ (Table 1). However, it is important to note that this application cannot be considered restrictive for its inclusion in ruminant feeding since it has been reported that high Ca contents in the diet of lactating cows can improve production (35,36). Some time ago it was thought that the Ca-phosphorus (P) relationship could affect the absorption of Ca and P (37), however data reviewed by NASEM (36) suggest that the ratio is not critical.

The IVNDFD (Table 3) in EXTR treatment compared with CTRL, is higher than the 24.5% reported by Jaimes et al. (15) obtained in maralfalfa grass processed in an extruder with a 1.0 mm outlet but lower than the 36.2% found by Jaimes et al. (14) in kikuyu grass extruded with an extruder with a 1.0 mm outlet. The positive effect of extrusion on IVNDFD was also reported by Elgemark (38) who explained it from the combined effects of temperature, pressure, and shear strength generated by extrusion on the physical and chemical structure of the processed biomass. For their part, Heredia et al. (39) indicated that extrusion generates a modification of the crystalline structure of cellulose with the consequent increase in its porosity and increased susceptibility of the fibrous portion of the plant biomass to enzymatic degradation.

The higher response in IVDMD and IVNDFD due to $Ca(OH)_2$ treatments compared with urea treatments, coincides with that reported by Sirohi and Rai (40) who evaluated the effect of various levels of application of urea and $Ca(OH)_2$ on the *in situ* digestibility of wheat husk organic matter and found that for similar additions the digestibility was 5.2% higher with the $Ca(OH)_2$. Various authors have evaluated the incidence of some chemical treatments on the *in vitro* digestibility of fibrous foods, some of these findings are found in the identified literature: Zaman & Owen (41) found that the treatment of barley husk with $Ca(OH)_2$ at 6% of DM increased the *in vitro* digestibility of organic matter in a greater proportion than that obtained with urea (27.5 vs. 23.1%, respectively); Sirohi & Rai (40) also compared the effect of urea and $Ca(OH)_2$ on digestibility in wheat husk and found that $Ca(OH)_2$ at 4% improved IVDMD by 31.2% compared to the control, but with urea at the same concentration this increase was half (15.6%). In other forage materials, higher increases *in vitro* digestibility than those found in the present work have been registered, but it should be noted that applications were made at higher concentrations. Thus, Ramírez et al (42) established that in buffel grass (*Cenchrus ciliaris*) treated with urea at 4.5% of DM there was an increase in IVDMD and IVNDFD of 58.8% and 63.0%, respectively, while Lázaro et al. (43) found increases of 69.4% and 65.6% in IVDMD and IVNDFD, respectively, in sugarcane harvest residues treated with $Ca(OH)_2$ at 9% of DM.

According to the results recorded in Table 2, it can be considered that both the addition of $Ca(OH)_2$ and urea decreased the concentration of NDF. Regarding *in vitro* digestibility, these chemical treatments also had an effect on IVDMD and IVNDFD (Table 4) but with different trends: while the addition of Ca $(OH)_2$ increased IVDMD from 0.45 and 0.9% to 1.35%, urea had no effect on this variable. In the case of IVNDFD a more consistent effect is observed for $Ca(OH)_2$ than for urea.

The results of this work confirm that there is a technological possibility to substantially improve the potential of the fermentable energy inputs of tropical grasses whose NDF and lignin contents are high and limit production with ruminants. Oba and Allen (44) estimated that an increase in a percentage unit in the *in vitro* digestibility of NDF would be reflected in an increase of 0.17 kg/d in the consumption of dry matter from the pasture and of 0.25 kg/d in milk production. Based on these premises and under the assumption that the use of extruded maralfalfa grass treated with $Ca(OH)_2$ as a supplement would generate a substitution effect close to 1.0 when dealing with fibrous materials (45), it can be estimated that the replacement of 1.0 kg of DM of raw maralfalfa grass by 1.0 kg of DM of bagasse of the same grass obtained by extrusion would generate an increase of 0.27 L/Cow/d in milk production. If this replacement is made with 1.0 kg of DM of maralfalfa grass bagasse extruded and treated with 1.35% $Ca(OH)_2$, the increase would be 0.32 L/Cow/d.

In conclusion the wet extrusion process of maralfalfa grass, as used in this experiment, generates a bagasse with a higher NDF content and a higher IVNDFD but with a lower CP content. The treatment of this bagasse with $Ca(OH)_2$ at 1.35% further increases the IVNDFD and also increases the Ca content while reducing that of NDF and ADL. The increase in IVNDFD in this experiment suggests that there is a technological possibility to increase the potential for milk consumption and production in animals fed with tropical grasses such as maralfalfa grass.

Conflicts of interest

The authors declare no conflict of interest

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