Scientific Paper

Dehydration of the foliage, under sunlight and shade, of three forage protein plants

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Abstract

The objective of the study was to evaluate the influence of the drying method (under sunlight and shade) of the foliage of *Morus alba* (mulberry), *Boehmeria nivea* (ramie) and *Tithonia diversifolia* (Mexican sunflower), on the dehydration dynamics and meal quality. The water loss, under sunlight and shade, of the edible biomass of each species, was determined. The yield and bromatological quality were quantified in the dehydrated foliage. A completely randomized design was used, with two treatments and seven replicas each. The foliage dehydration was reached after five days with both drying methods, in the three species. The yield in meal was higher in mulberry, than in ramie and Mexican sunflower (186,4; 131,5 and 81,2 g /kg GM, respectively); however, in each species it had a similar value with both drying forms. In mulberry and ramie, although the dehydration method did not affect the CP content of the meal, under shade the highest values of DM (88,2 %), ADF (33,8 %) and cellulose (26,8 %) were detected in the former, as well as the value of ADF (39,8 %), cellulose (25,8 %) and lignin (9,2 %) in the latter. In Mexican sunflower, the drying under sunlight produced a higher CP content (27,1 %); while DM (89,6 %), ADF (34,1 %) and cellulose (25,7 %) were higher with drying under shade. It is concluded that both drying types constitute an alternative to dehydrate the edible biomass of the three species, with little affectation of the bromatological indicators.

Keywords: *Boehmeria nivea*, drying, meal, *Morus alba*, *Tithonia diversifolia*.

Introduction

In tropical countries, the rainy season brings about an increase of biomass production of forage plants. This production is so high that the animals cannot consume all the available feedstuff; nevertheless, the surplus that is generated can be preserved and offered in the dry season (González-García and Martín-Martín, 2015).

The studies in Cuba focus more on the use of locally available forage resources, which contribute decisively to the establishment of adequate sustainable production systems (Milera-Rodríguez, 2010). Different authors indicate that the edible biomass produced by some shrub and tree forage plants can be used as meal (Castrejón-Pineda *et al.*, 2016).

The high production of plant biomass in the tropic and the existence of many species with high feeding potential for herbivore animals encourage the conservation of these resources and their nutritional evaluation. This practice contributes to decrease the unexpected events that occur because of pests and long droughts, which affect plant availability and growth (Moreno and Sueiro, 2009).

Foliage dehydration, when having an optimum relation between yield and quality of the edible biomass, to be turned later into meal, guarantees preserving a feedstuff of good quality and, subsequently, of high nutritional value. In addition, it allows to decrease the weight and volume with regards to that of the fresh feed, for which it facilitates storage and transportation.

On the other hand, this conservation process contributes to optimize the use of local resources of the agroecosystems, and to increase self-sufficiency in the generation of the raw materials that can be incorporated in the diets of the animals from different species. Likewise, it allows to store and preserve feedstuffs for the dry season (Cattani, 2011).

The preservation of the exceeding foliage in the form of meal is attractive for tropical countries with low technological resources. In them different plant species have been evaluated which have been incorporated to the animal diets as meal, mainly in pigs and rabbits (Leyva *et al.*, 2012).

In this sense, mulberry (*Morus alba*), ramie (*Boehmeria nivea* (L.) Gaud.) and Mexican sunflower (*Tithonia diversifolia*) are plants with high production of edible biomass and of high nutritional value. Due to these characteristics, their surplus can be preserved as meal and have been included as protein plants in diets of different animal species (Ruíz *et al.*, 2014). In Cuba, the dehydration kinetics during drying under sunlight has been studied, but there is little information about the dehydration kinetics under shade, which allows foliage to reach high dry matter content in little time of exposure. That is why the objective of this research was to study the influence of drying form (under sunlight or shade) of the foliage of *M. alba*, *B. nivea* and *T. diversifolia*, on the dehydration dynamics and meal quality.

Materials and Methods

Location of the experiments. The experiments were conducted at the Pastures and Forages Research Station Indio Hatuey of the Perico municipality, Matanzas province, Cuba (22° 50' 12.26" N, 81° 02' 25.99" W), at 19 m.a.s.l..

Characterization of the soil and used plant material. The area from which the plant material was taken to conduct the experiment had 300 m^2; while the characteristic soil where the three species were planted is Ferralitic Red (Hernández-Jiménez *et al.*, 2015)2015. The management of the plantation did not include irrigation or fertilization and the harvest of the forage that would be dehydrated was performed at the end of the rainy season.

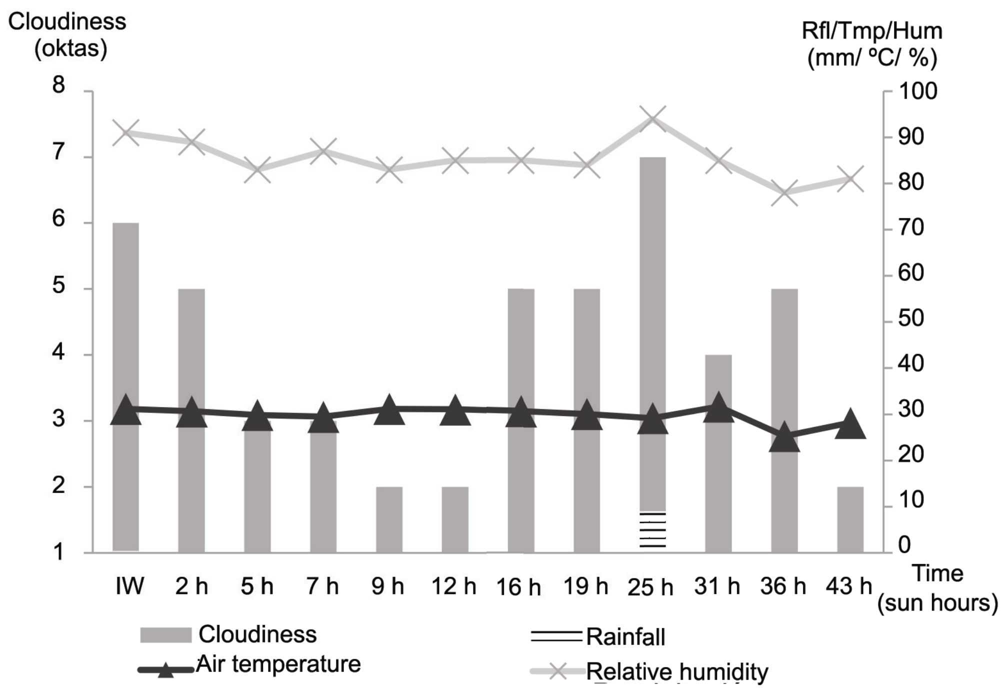
Design and treatments. The cutting age of the foliage in each species was established according to the recommendations made by Elizondo and Boschini (2002), García *et al.* (2007) and Verdecia *et al.* (2011).

The dehydration of the foliage was evaluated under two conditions: sunlight and shade (table 1), with seven replicas for each drying form (treatment) per species.

Table 1. Treatments used in the research.

Species	Age (days)	Drying form
Morus alba	60	Sun
		Shade
Boehmeria nivea	40	Sun
		Shade
Tithonia diversifolia	60	Sun
		Shade

Climate conditions in the experimental stage. The climate elements during the experimental period were provided by the Meteorological Station of the EEPF Indio Hatuey, located less than 200 m away from the experimental area. Figure 1 shows the summary of the climate data recorded by the Station during the days in which the foliage was dehydrated and at the time of weighing (fig. 1).



Rfl: rainfall, Tmp: temperature, Hum: humidity, IW: initial weight, h: hours.

Figure 1. Data of the climate elements during the exposure of foliage to drying.

Dehydration method. For dehydration under sunlight the samples were placed on an asphalted surface, from 9:00 a.m. to 4:00 p.m.; from this hour and throughout the night they were left under roof in a closed place. A quantity of 1,03 ± 0,03 kg of forage (fresh stems of 0,75 m with their leaves) was deposited in woven nylon bags (table 2).

Table 2. Initial weight of the edible biomass of the three species dehydrated under sun and under shade.

Species	Drying		
	Sun	Shade	SE ±
M. alba	1,05	1,05	0,0011
B. nivea	1,03	1,04	0,015
T. diversifolia	1,02	1,02	0,0022

In the case of the dehydration under shade the samples were deposited in an open and roofed shed, only protected with cyclone fence in the laterals, on a steel rod grid at a height from the soil of 1,2 m.

The sacs with the samples of all the experiments were weighed at 11:00 a.m., 1:00 p.m. and 3:00 p.m., and in the case of the samples exposed to sunlight, they were turned after being weighed, which was daily done until reaching constant weight. After reaching it in the samples during two days that dehydrated biomass was ground and stored as meal in glass flasks with screw tops, in the chemical analysis laboratory, until the quantification of the indicators.

Calculations and statistical analyses. The dehydration curve was elaborated with the values of the daily average weight of the seven replicas of each treatment. The weighing to estimate the weight loss of the samples were carried out every 2 h, during the time the biomass was exposed to dehydration until reaching constant weight.

The calculations were made with the equations detailed below. For quantifying the weight losses this equation was used:

$$\% \text{ WL} = \frac{(\text{Wi-Wf}) \text{ x } 100}{\text{W}}$$

Where:

% WL: percentage of weight loss.

Wi: initial weight of edible biomass.

Wf: final weight of the edible biomass

The moisture (M) of the sample, expressed in percentage, was calculated by the following equation:

$$\text{M } \% = \frac{(\text{W1-W2}) \text{ x } 100}{\text{W}}$$

Where:

W1: weight, in kilograms, of the woven nylon sac with the sample.

W2: weight, in kilograms, of the woven nylon sac with the dehydrated sample.

W: weight, in kilograms, of the sample.

To the dehydrated and ground biomass (meal) the quality was determined through proximal chemical analysis, which included dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF), cellulose, lignin and ash, according to the regulations of international AOAC (2005).

Statistical processing. To evaluate the weight loss during the dehydration kinetics a comparison of means was made with variance analysis, through Duncan's test for $p \leq 0,05$.

The weight difference of the dry biomass with each drying form, the yield and the bromatological quality in each species, were evaluated through the Student's t-test.

Results and Discussion

Influence of drying form on the dehydration dynamics of the foliage of *M. alba, B. nivea* and *T. diversifolia*

The final weight of the foliage exposed to the dehydration process under sunlight and shade is shown in table 3. No significant differences were found in any of the three species in the final dry weight between the two dehydration forms.

Table 3. Final weight (kg) of the dehydrated edible biomass under sunlight and shade.

Species	Drying		
	Sun	Shade	SE ±
M. alba	0,29	0,30	0,0007
B. nivea	0,21	1,04	0,0049
T. diversifolia	0,16	0,17	0,0005

With both drying forms adequate foliage dehydration was achieved, and the results coincide with those obtained by López *et al.* (2012), who reported DM ranges for mulberry, ramie and Mexican sunflower of 26-29; 12,0-14,7 and 14,3-19,1 %, respectively. These species show low to moderate dry matter contents. In addition, as their CP exceeds that of tropical grasses, the foliage of these plants is commonly used for feeding monogastric animals and ruminants.

The dehydration under shade shows advantages with regards to drying under sunlight, especially under the climate conditions of Cuba which are very variable, and where the high temperatures are between 25 and 34 ºC in the rainy season (INSMET, 2016). This is the propitious period to preserve foliage, because the forage production is abundant. A part of the biomass which is not used in that season for directly feeding the animals remains as surplus, and can be preserved as meal or silage to be offered in the dry season (Ramos-Trejo *et al*., 2013).

These climate conditions favorable for the growth of forage (higher quantity of light hours and intensity of solar radiation) are adequate for the process of dehydration under sun. Nevertheless, the high relative humidity, high cloudiness and higher rainfall frequency also coincide (fig. 1), which attempt against good direct exposure to sunlight constantly and stably, as required by this type of drying.

Plant biomass production is seasonal; for such reason, an alternative is sought to preserve the foliage as meal in an economic way, and use it in animal husbandry to reduce productive costs. It is necessary to emphasize that the forages of this study are characterized by an edible biomass production of 78-80 % in the rainy season with regards to the total value of the year (González *et al*., 2013).

Martín *et al*. (2007) reported that one hectare of mulberry produces the equivalent to 6 t of concentrate feed at a cost of 290,00 CUC *vs.* 1 200,00 CUC, at least, which would be the cost of that amount of concentrate feed.

On the other hand, Canul-Ku *et al*. (2013) indicated that the use of mulberry foliage represented saving 29,0; 38,6 and 54,1 % per doe in the cost of commercial concentrate, for the treatments with restriction to 200, 160 and 120 g day^{-1}, respectively.

Hence an alternative is sought, like drying under roof shade for dehydration, which overcomes the climate problems.

The material to be dehydrated was harvested in October, and, as it usually occurs in Cuba, the climate changed rapidly, from sunny days, adequate for dehydration, to cloudy days with rainfall traces, accompanied by high cloudiness and relative humidity (fig. 1), which attempts against the water loss rate in the biomass exposed to drying.

When analyzing these data, it was observed that they are far from the recommendations by other authors to dry the material (Muciño-Castillo, 2014), that is, choosing sunny days with low relative humidity. During the evaluation rainfall of 74,5 mm occurred in five days.

The practical advantages of drying under roof is the fact that there is no risk of the feedstuff being lost or deteriorated due to unexpected rain, or need of extra labor to put away the foliage and afterwards to expose it to sunlight again, which can delay the drying period and increase the losses in the quality of the material with which the work is done (Guevara-Pérez, 2010).

When exposing the foliage that is dehydrated in a protected premise, its transfer to put it under shelter is not necessary, which implies not having an additional facility or destining a man for that activity. Likewise, no fuel is required to generate the heat that helps to evaporate the water contained in such material. When the farmer dehydrates the material he/she does not need to be aware of climate and thus can perform other activities during that time. Once the biomass is drying, it is not gathered again until it is dry to be stored.

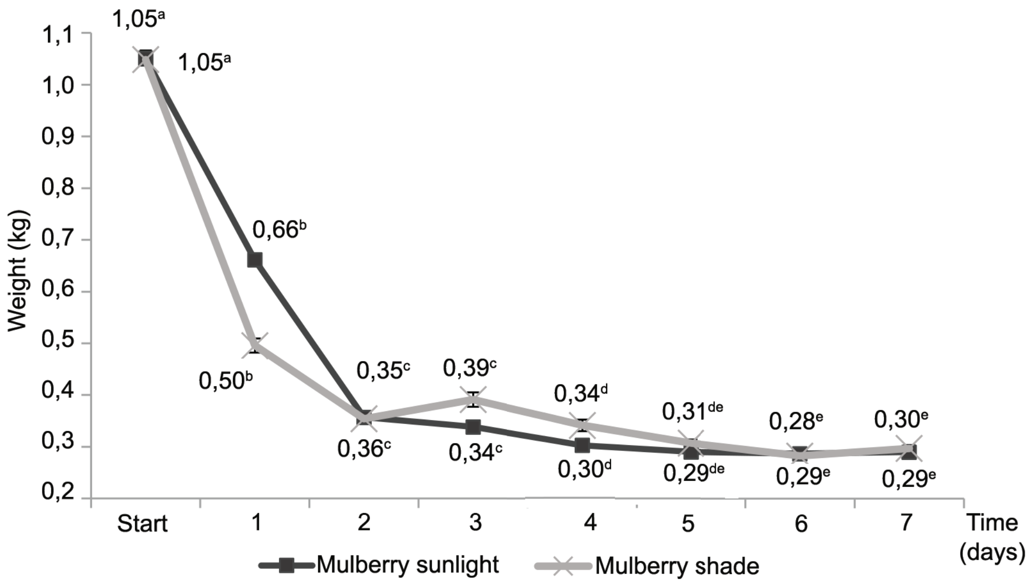
The structure of the shed where the foliage was dehydrated allowed the passage of air, which contributed to water loss and benefitted the drying process; this coincides with the report by Pineda-Castro *et al*. (2009), who stated that, from the climate variables, temperature and air speed were the ones that showed higher influence on the dehydration of the mulberry forage.

The biomass dehydration kinetics showed a similar performance in the three species. Figures 2, 3 and 4 show a drastic water loss in the first and second days, which is in correspondence with approximately 70-90 % of the moisture that was eliminated throughout the dehydration process. Nevertheless, until the fifth day no constant weight of the sample was reached, coinciding with the report by Silveira-Prado and Franco-Franco (2006).

Under those conditions, the moisture losses of the edible biomass in the forage of each species were 72,4; 79,8 and 84,3 %; similarly, in literature contents between 74 and 90 % are reported (López, 2012).

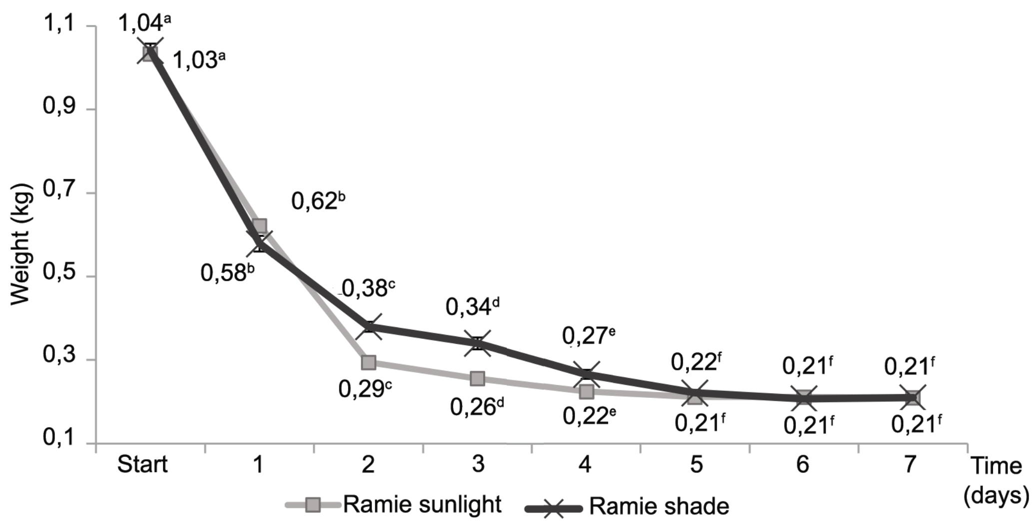
The dry matter and stability in the moisture content reached by the foliage of the species were adequate for the meal to preserve its quality. This has been reported by Itzá-Ortiz *et al.* (2010).

In the case of the dehydration curve of mulberry (fig. 2), it coincides with the one reported by Martín *et al*. (2007).



Different letters within each drying form differ at p < 0,05.

Figure. 2. Dehydration dynamics of the *M. alba* foliage.

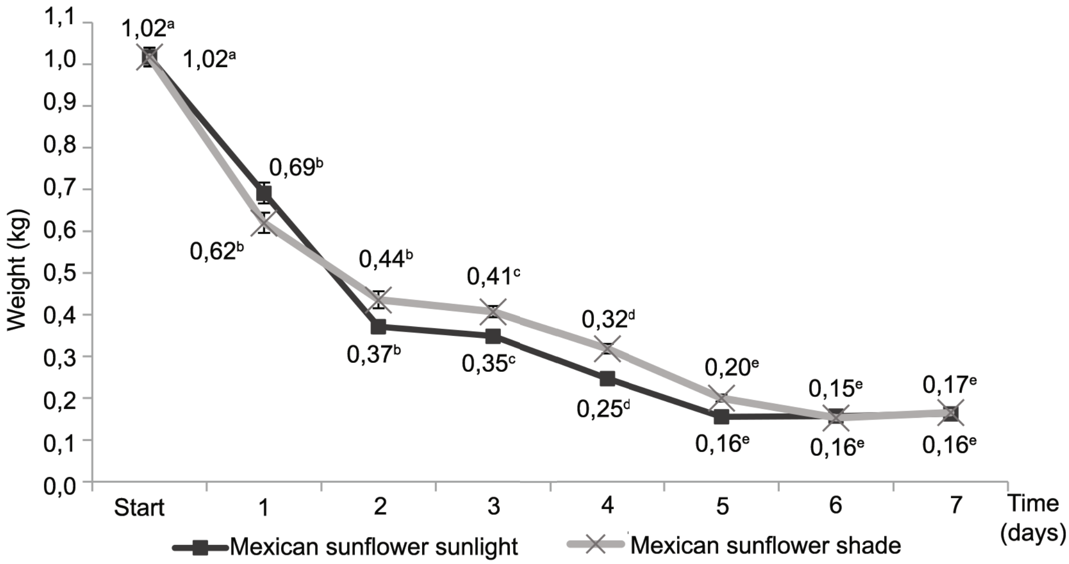


Different letters within each drying form differ at p < 0,05.

Figure 3. Dehydration dynamics of the *B. nivea* foliage.

In the studies conducted by Meza *et al*. (2014) the drying time was lower, because only the leaves were dehydrated; while in this study, the increase of time to achieve dehydration was due to the fact that the dried biomass contained leaves and fresh stems. In addition, as it was stated above, during the dehydration period rainfall occurred, which, undoubtedly, influenced the duration of the drying process.

The leaves alone show a higher drying rate when they are bound to the stem; for such reason, the dehydration of biomass in the second case requires more time. A possible explanation of this phenomenon is that when drying the edible foliage (leaves and fresh stems), part of the water of the leaves when they wilt can be accumulated in the fresh stems and be added to the water they contain; which occurs because the leaf surface:volume ratio



Different letters within each drying form differ at p < 0,05.

Figure 4. Dehydration dynamics of the *T. diversifolia* foliage.

of the leaves is higher than in the stems (Jahn-B. *et al.*, 2003).

Effect of the drying form of the foliage on the yield and bromatological quality of the meal

The yield in meal, obtained from the green foliage, was quantified (table 4). The mulberry forage produced 1,4 times more meal per kilogram of green matter than ramie, and 2,3 times more than Mexican sunflower. These differences in production among the three species had been reported by López *et al.* (2012).

Table 4. Yield in meal from the fresh forage of the three species.

Species	g DM/kg fresh forage			
	Sun	SE ±	Shade	SE ±
M. alba	183,9	12,70	188,9	13,26
B. nivea	126,9	8,20	136,1	11,04
T. diversifolia	82,7	7,09	79,7	2,48

No significant differences were found for the yield in meal between both drying forms of each forage species (table 4). This proved that it is possible to use the two variants under local conditions, like the existing ones in Cuban animal husbandry farms. Nevertheless, dehydrating under shade guarantees that drying is not affected if unexpected rainfall occurs.

Table 5 shows the results of the proximal chemical analysis of the meal for each one of the species. There were significant differences in DM ($p < 0{,}001$) for mulberry and Mexican sunflower between the two drying forms, although they are not important from the practical point of view, because they did not exceed the percentage unit. Itzá *et al.* (2010) reported similar values to the ones in this work for the meal from mulberry leaves, with 89,5 and 17,1 % for the DM and CP, respectively. The CP differed ($p < 0{,}05$) only in the case of Mexican sunflower.

The contents of crude fiber, neutral detergent fiber and acid detergent fiber of the forages did not differ from the ones reported by Naranjo and Cuartas (2011), who classified *M. alba*, *B. nivea* and *T. diversifolia* as protein forage plants. These plants have a protein content between 14 and 29 % (Retamal-Contreras, 2006), which depends, among other factors, on the age of the forage of each species. For such reason, the adequate utilization of these forages in animal feeding increases the protein of the diet and live weight gain, in monogastric species as well as ruminants (Leyva-Cambar *et al.*, 2012).

The values of ADF and cellulose in the three species, as well as lignin in ramie, were higher when the forage was dehydrated under shade. The other evaluated indicators did not differ between both drying forms in any of the species.

According to Periche *et al.* (2015), the ADF and lignin are susceptible of changing due to the effect

Table 5. Proximal chemical analysis (%) of the meals obtained with each species and drying form.

Plant	Drying form	DM	CP	NDF	ADF	Cellulose	Lignin	Ash
M. alba	Sun	87,3	14,2	46,0	33,1	25,5	5,9	9,4
	Shade	88,2	14,5	47,6	33,8	26,8	6,0	9,9
	SE ±	0,3***	0,79	2,14	1,71***	1,31***	1,21	0,68
B. nivea	Sun	89,8	15,8	45,7	37,3	25,5	8,3	19,6
	Shade	88,0	16,7	46,9	39,8	25,8	9,2	18,6
	SE ±	3,99	0,60	4,1	1,93***	2,06*	0,94**	1,14
T. diversifolia	Sun	88,6	27,1	49,8	31,7	22,4	8,7	18,1
	Shade	89,6	23,3	52,5	34,1	25,7	8,2	17,5
	SE ±	0,48***	0,95*	3,67	1,87**	1,3**	1,67	0,93

DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber.
* $p < 0,05$; ** $p < 0,01$; *** $p < 0,001$.

of temperature and humidity during the drying process, because the endogenous enzymatic degradation increases with temperature (Noda, 2006).

These forages, fresh as well as preserved as meal, can be used for feeding rabbits and pigs, in partial substitution of concentrate feeds based on imported raw materials, such as soybean, torula yeast, fish meals, among others (Fernández *et al.*, 2012).

In that sense, low-resource farmers can use the meal from these plants in the elaboration of homemade concentrate feeds, with satisfactory productive results (Diz, 2013).

As explained above, the advantage of preserving the feed as meal is that it allows its inclusion in the different feedstuffs that are supplied to the animals. In addition, one of the most important benefits that is ascribed to this conservation form is allowing the storage of the feedstuff for long periods of time, with little change in its nutritional value (Gallego-Castro *et al.*, 2014).

Conclusions

The choice of drying under shade, before the conservation process, combined the advantages of performing an economical dehydration and solving the problem of climate instability.

The two drying forms allowed to obtain a dry matter percentage higher than 87 %, from the dehydration of the forage of the three species after five days.

The drying form of the foliage did not affect the yield in meal, or the crude protein content in *M. alba* and *B. nivea*; while in *T. diversifolia* the latter was lower when dehydration occurred under shade.

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Received: May 7, 2017

Accepted: February 23, 2018