Scientific Paper

Characterization of five promising protein shrubs for the Cuban animal husbandry

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Abstract

Objective: To characterize five protein plants and approach their effect on animal productivity and health.

Materials and Methods: The available literature related to the agronomy, agroecology and application in production and animal health of the species *Moringa oleifera* Lam., *Tithonia diversifolia* Hemsl., A. Gray, *Morus alba* L., *Trichanthera gigantea* H. & B. and *Cratylia argentea* Desv., was consulted, in order to analyze the results obtained in conventional agriculture and animal husbandry systems at international level and in Cuba.

Results: There is variability in the management, processing and conservation conditions of the forage of *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea*. Their crude protein contents oscillate between 13 and 33 %. They are sown in densities between 555 and 1 000 000 plants/ha. The yield varies from 3 to 35 t DM/ha/year, and they are abundant during the dry season. With these species between 5 and 7 kg milk/animal/day can be obtained and the animal weight gain can exceed 500 g/animal/day.

Conclusions: Due to their adaptation to the agricultural conditions of Cuba, biomass availability throughout the year and nutritional value, *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* constitute forage resources of quality, with potentialities to supplement the animals and improve their health; besides protecting the soil and decreasing the methane emission to the environment.

Keywords: *C. argentea*, *M. alba*, *M. oleifera*, *T. gigantea*, *T. diversifolia*

Introduction

The animal husbandry that is supported on pastures is associated with the destruction and degradation of ecosystems, loss of water, soil biodiversity and increase of climate change effects (Schultze-Kraft *et al*., 2018). In Cuba, the areas for animal feeding are covered, to a larger extent, by natural pastures and, in lower proportion, by cultivated pastures, whose productivity and nutritional quality depend on the establishment, management, rehabilitation, soil fertility, season, use of fertilizers, irrigation, stocking rate and grazing level. The affectation in these factors limits biomass availability, which along with the impossibility of accessing concentrate products, affects animal husbandry and forces farmers to search for feeding alternatives in their locality.

In Cuba, at present recovering the livestock that existed in the 1980's, situation limited by the still prevailing feeding deficiency, is attempted. In the face of this problem, the Pastures and Forages Research Institute, the Institute of Animal Science and the Pastures and Forages Research Station Indio Hatuey are in favor of the utilization of forage shrubs as feeding complement. These plants increase the protein and mineral content in the ration, increase dry matter consumption (Savón-Valdés *et al*., 2017) and influence positively health (Puerto-Abreu *et al*., 2014; Jiwuba *et al*., 2017) and animal productivity (Babiker *et al*., 2017). They stand better a deficient agricultural management, prevent soil erosion and degradation; besides improving soil fertility, by increasing the content of organic matter, calcium, potassium, magnesium and decreasing the salt content (Mattar *et al*., 2018; Navas-Panadero *et al*., 2020). They also contribute to recover the macrofauna and microfauna, associated to agricultural ecosystems (Navas-Panadero, 2019) and can be used for phytoremediation of soils contaminated with heavy metals (Zeng *et al*., 2020).

In Cuba, the main criterion of selection of protein species depends on the farmers and their previous experiences, which are not always satisfactory due to erroneous practices. For such reason, educational and training campaigns about the benefits of these plants are developed. Today, it is frequent

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to find *Moringa oleifera* Lam, *Tithonia diversifolia* Hemsl., A. Gray and/or *Morus alba* L., in the diet of Cuban livestock (Savón-Valdés *et al*., 2017). Recently, the possibility of producing *Trichanthera gigantea* H. & B. and *Cratylia argentea* Desv. is studied, in order to increase the availability of shrubs with feeding purposes. Due to the importance of this species, the objective of this work was to characterize five protein plants and approach their effect on animal productivity and health.

Materials and Methods

Two hundred works were consulted, available in the library of the Pastures and Forages Research Institute, Scholar Google and ResearchGate, which approach the agronomy, agroecology and application in the animal feeding of the species *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea*, in order to analyze the results obtained in the conventional agriculture and animal husbandry systems at international level and in Cuba.

The search was focused on the period 2016-2020, although works from the last 30 years were included, because *C. argentea* and *T. gigantea* have been less studied with regards to the other species analyzed in this study.

General characteristics. *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* show morphological characteristics that propitiate their identification. However, their recognition is a challenge for animal husbandry farmers with little agricultural experience. For such reason, a brief description of their morphology is offered here.

M. oleifera reaches up to 12 m of height, has a stem of approximately 50 cm, thick roots, compound, pinnate leaves, with small leaflets. Its branching levels depend on the pruning. It can have up to three flowering peaks in one year; the flowers are small and are arranged in racemose inflorescences. The fruit is a capsule 0,2-1,0 m long and has, generally, between 10 and 25 oily seeds (Yang *et al*., 2015; Ledea-Rodríguez *et al*., 2018).

T. diversifolia grows between 2 and 5 m of height, has alternate, serrated, petiolated, lobulated and sometimes glabrous leaves. It shows inflorescences in capitulum of yellow or orange color, similar to those of sunflower. The seeds are small and with generally reduced viability, although they can be used for the crop establishment Gallego-Castro *et al*., 2017; Rodríguez *et al*., 2019; Santos-Gally *et al*., 2019).

M. alba reaches 25 m of height, although when linked to animal husbandry it does not usually exceed 3 m. It has high variability in the morphology of the leaves, which are alternate, petiolated, of light green color and with prominent veins. The branches are gray, the flowers are small and are arranged in racemose inflorescences. The fruits are 2-6 m long, can be white, red, purple or black in color and contain small yellow or brown seeds (Martín *et al*., 2017; Sánchez-Salcedo *et al*., 2017).

T. gigantea grows up to 12 m of height, with crown of 6 m diameter, highly branched and with pronounced nodes. It has petiolated, large, opposite, serrated, hairy leaves, of dark green color on the face and lighter on the back. It produces inflorescences 5-15 cm long, with bell-shaped flowers of ochre yellow color and pubescent anthers that surpass the corolla. The fruit is a small and round capsule, with 30-40 white seeds that have low viability (Cuenca-Angamarca, 2018).

C. argentea is a shrub of 3-6 m of height, which produces between 8 and 17 basal stems. The leaves are papyraceous, pubescent or glabrous. The flowers are arranged in 30-cm inflorescences, of lilac or white color, with asynchronous development. The fruit is a dehiscent and flattened pod, 20 cm long and 2 cm wide. The seeds are circular of 1,5 cm diameter and dark yellow or brown (Arango *et al*., 2016).

Associated to morphology, there are other traits that participate in the selection of one or another species, the ignorance of which leads to undesired results. In spite of drought, *M. oleifera* and *C. argentea* maintain abundant foliage (Yang *et al*., 2015; Mattar *et al*., 2020), which constitutes an advantage for the production systems that lack irrigation and receive minimum rainfall. *M. oleifera* can grow up to 4 m of height in one year (Yang *et al*., 2015); while *C. argentea* during the first year of establishment has slow growth (Aquino *et al*., 2020), proven by the fact that during its first five months of growth it does not exceed 81 cm of height(Rincón, 2005). *M. oleifera* and *T. diversifolia* regrow rapidly with regards to other protein shrubs such as *M. alba* (Savón-Valdés *et al*., 2017), trait that is advantageous for ranchers, especially in the dry season.

These five plants stand acid and poor soils, although only *T. diversifolia* is favorably developed on phosphorus-deficient substrates. However, a soil with good nutrient availability favors its growth (Rivera *et al*., 2018).

Being a legume, *C. argentea* contributes to nitrogen fixation and *T. gigantea* is excellent for the places that show abundant rainfall (Arango *et al*., 2016). Meanwhile, *M. oleifera* does not stand flooding and is considered a highly nutrient-extracting species (Yang *et al*., 2015). From these plants, the lower lignification in *T. diversifolia* stems favors its cutting, processing and animal intake; besides, the experience of national farmers place it as the most rustic and most widely used protein plant.

Some studies have shown that the intake of *M. oleifera*, *T. diversifolia* and *M. alba* reduces the production of rumen methane (Savón-Valdés *et al*., 2017), which is an indication of efficiency in energy utilization and affects, to a lower extent, the environment. Practical experiences prove that, when the optimum harvest time of *T. diversifolia* passes, its biomass decreases and it turns bitter, which influences its palatability and forces to supply it with other products for livestock to accept it.

Agronomic requirements, propagation and yield. The agricultural management in protein plants is usually sufficient, and although they can be developed with minimum attentions, a supply of stable water stimulates leaf development, and the use of fertilizers and manures favor their growth (González-Crespo and Crespo-López, 2016), thus, learning to balance management is a priority for farmers. Table 1 shows some generalities of the agrotechnical procedure of *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea*.

The planting density of *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* is between 555 and 1 000 000 plants/ha; lower densities are related to seed production (Gallego-Castro *et al*., 2017; Padilla *et al*., 2017). The advantages of higher planting densities, in the case of *T. diversifolia* and *C. argentea,* are that higher dry matter content is obtained per cutting (Londoño *et al*., 2019). Nevertheless, these same cultivation conditions in *M. oleifera,* besides generating large seed expenses, cause higher repopulation rate due to the high competition that is generated among plants and that provokes lower stem diameter, height, rooting and vigor (Sosa-Rodríguez *et al*., 2017).

Protein plants are sown by gamic and agamic seeds, and each method has its requirements, advantages and disadvantages. The establishment of crops by gamic seeds depends on their availability, which is influenced by the flowering and fructification frequency of each species and/or variety. This is a process that takes between six months and one year, although in young plantations it is usually limited, which leads to this production time to be doubled. In the case of *T. gigantea* and *T. diversifolia*, their gamic seeds are not usually a recommended option for cultivation at large scale, due to their low viability (0-20 %) (Gallego-Castro *et al*., 2017; Cuenca-Angamarca, 2018). Nevertheless, results in Cuba, focused on the germination of *T. diversifolia*, show that it reaches up to 54,9 % (Rodríguez *et al*., 2019). Yet, Cuban farmers use the asexual propagation of *T. diversifolia* due to its good results.

High temperatures and humidity during storage of gamic seeds causes great losses of viability and vigor. These conditions are frequent in the storehouses of animal husbandry farms, for which it is recommended to establish the plantations with young seeds or conduct previously germination tests to prevent unnecessary material expenses. Particularly, in *M. alba* attention should be paid to the management of its seeds, because as they are very small they must be planted on the surface, which increases the probability that they are washed off with strong rains or inadequate irrigation.

Planting by agamic seeds or stakes has been applied in these five protein plants, although the establishment of *M. oleifera* is usually done through gamic seeds. The effectiveness in stake regrowth depends on the position in which they are placed (horizontal or vertical), their length, diameter, number of nodes and age of the mother plant (Rossner *et al*., 2019); besides, they cannot be stored because their viability is affected (Gallego-Castro *et al*., 2017). As minimum requisites to guarantee a high establishment percentage it is recommended that the stakes have at least two nodes and diameter not lower than 1 cm or higher than 6 cm (Ledea-Rodríguez *et al*., 2018). Vegetatively reproduced plants have a shallow and weak root system (Santos-Gally *et al*., 2019), which in the Cuban system makes plantations more susceptible to cyclones and prevents them from having access to water and nutrients that are found in the deepest strata of soil. It should be taken into consideration that the populations from vegetative origin are genetically identical to the mother plant, with the positive and negative implications it involves.

The availability of gamic and agamic seeds constitutes the main factor that limits the planting of protein plants. At present, there are national projects that seek to increase the production of both seed types; nevertheless, the real quantities of seed production areas are insufficient to cover the demand animal husbandry has.

Tree biomass depends on the planting density, season, cutting frequency and height and soil fertility (López-Herrera and Briceño-Arguedas,

Table 1. Propagation, agronomic management and biomass production of five protein shrubs.

Indicator	*M. oleifera*	*T. diversifolia*	*M. alba*	*T. gigantea*	*C. argentea*
Propagation	Seeds and stakes	Stakes	Seeds and stakes	Stakes	Seeds and stakes
Planting distance for seed production, m	3 x 2,5 and 3 x 3	0,7 x 1	3x3; 4x4	Not performed	3 x 3
Distance for forage production, m	0,1-0,1 to 1 x 1	0,5 x 0,5 to 1 x 1	0,5 x 0,5 to 1 x 1	0,5 x 0,5 to 1 x 1	0,5 x 0,5 to 1,5 x 1,5
Establishment cutting	5 - 6 months	6 months	6 months - 1 year	6 months	6 months
Cutting height seed, m	1,5-2,0	0,15-0,25	0,15-0,25	Not performed	Not performed
Cutting height forage, m	0,2-0,7	0,1-0,7	0.05-0.5 m	1-1,5 m	0,25-0,9
Cutting frequency, days	35-45[¥] and 60[¥¥]	30-60[¥] and 60-90[¥¥]	35-60[¥] and 60-75[¥¥]	50, 60 and 90[¥¥¥]	45, 56, 60, 75, 84, 90, 112 and 120[¥¥¥]
Yield, t FM/ha/year	30-100	27-100	50-60	32-68	31-42
Yield, t DM/ha/year	20-30	13-22	12-35	Not reported	3-12,7
References	Yang *et al.* (2015), Padilla *et al.* (2017)	Gallego-Castro *et al.* (2017), Londoño *et al.* (2019), Rossner *et al.* (2019)	Martín *et al.* (2017) Eshetu *et al.* (2018)	Cuenca-Angamarca (2018), Kien *et al.* (2020)	Arango *et al.* (2016), López-Herrera and Briceño-Arguedas (2016), Navas-Panadero *et al.* (2020)

[¥]Rainy season, [¥¥] dry season, [¥¥¥] there is no distinction between the seasons
FM: fresh matter, DM: dry matter

2016; Padilla *et al.*, 2017). In the management of protein plants, the establishment cut contributes to model the aerial architecture to facilitate their management and increase the production of branches, leaves, fruits and seeds (Eshetu *et al.*, 2018; Kien *et al.*, 2020). Regular pruning favors leaf development, eliminates old branches and limits apical growth, which results in more productive crops that are resistant to weather inclemency. It is frequent to think that lower cutting heights favor obtaining a higher quantity of biomass, and it is not considered that this procedure eventually affects regrowth and survival of the population, especially in the dry seasons.

Nutritional value and chemical composition. The changes in the nutritional value of trees and shrubs are less drastic than in pastures; its modifications depend on the variety, cutting date, physiological state, planting region and season, agricultural management, processing and conservation techniques (López-Herrera and Briceño-Arguedas, 2016; Navas-Panadero, 2019). For such reason, the use of equal quantities of these species in the animal diet throughout the year might not generate the same benefits.

Table 2 shows the chemical composition of *M. alba*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea*. It should be considered that the results reflected here are merely referential and prove wide variability, according to the conditions under which the data were recorded, for which it is possible that the concentration, appearance and detection of any of the components changes over the duration of the studies and according to the productive systems.

In these plants it is relevant that they contain a level of crude protein (CP) higher than 15 %, which allows them to supply the nutritional requirements of rumen microorganisms. However, only for *M. oleifera*, *T. diversifolia* and *C. argentea,* more than 30 % CP has been reported (Arango *et al*., 2016; Savón-Valdés *et al*., 2017; Rivera *et al*., 2018). In these shrubs, the level of neutral detergent fiber (NDF) is not usually high, for which they stimulate rumination and prevent acidosis (Van Soest *et al*., 1991). Nevertheless, up to 70 % NDF has been reported for *C. argentea* (Roa-Vega *et al*., 2017).

The good contributions of micro- and macronutrients constitute one of the characteristics that contribute to the high demand these species

Table 2. Chemical composition of the forage of five protein shrubs.

Indicator	*M. oleifera*	*T. diversifolia*	*M. alba*	*T. gigantea*	*C. argentea*
Dry matter	>19 %	>12,4%	>13,4	>18 %	>18 %
Crude protein	15-30 %	13-33%	15-28 %	17-22 %	18-30 %
NDF	42-59 %	17-55%	26-38 %	28-50 %	43-70 %
ADF	15-49 %	19-48,8%	16-37 %	21-41 %	34-48 %
Macronutrients	Ca 1,5 – 3,65 % and P 0,30 %	Ca 0,83-3,14% and P 0,25-0,6%,	Ca 0,7-2,7 % and P 0,14-0,23 %	Ca 0,6-4,5 % and P 0,22-0,43 %	Ca 1,2-1,63 % and P 0,15 %
Vitamins and amino acids (high concentration)	Vitamin A, B, C, E, methionine, lysine and cysteine	Vitamin C	Vitamin B, C and essential amino acids	Methionine	There are no references
Secondary metabolites	Tannins, condensed tannins, saponins and phenols	Coumarin, tannins and phenols	Tannins, alkaloids, saponins, anthocyanidins, triterpenes and coumarins	Tannins, alkaloids, anthocyanidin, triterpenes, saponins, coumarins and steroids	Sterols, phenols and tannins
References	Moyo *et al.* (2011), Savón-Valdés *et al.* (2017), Navas-Panadero (2019)	Gallego-Castro *et al.* (2017), Rivera *et al.* (2018)	Sánchez-Salcedo (2017), Savón-Valdés *et al.* (2017), Tesfay *et al.* (2017a)	Castaño (2012), Balraj *et al.* (2018), Kien *et al.* (2020)	Cobo *et al.* (2002), Rodríguez *et al.* (2015), Arango *et al.* (2016), Roa-Vega *et al.* (2017)

NDF: Neutral detergent fiber, ADF: Acid detergent fiber

have. Particularly, calcium and phosphorus are fundamental for growing or milk-producing animals. *T. diversifolia*, *T. gigantea* and *M. oleifera* can reach 1,5-4,5 % calcium and 0,3-0,6 % phosphorus.

M. oleifera, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* show secondary metabolites, which in large quantities affect the capacity of rumen microorganisms to degrade the organic matter of the feed (Riascos-Vallejos *et al*., 2020), although the level of these compounds in such species is low or moderate, for which it does not affect palatability, intake or digestibility of their forages (Gallego-Castro *et al*., 2017).

Role of protein shrubs in animal production. Protein plants have digestibility and degradability between 48 and 91 % (Eshetu *et al*., 2018; González-Arcia *et al*., 2018; Navas-Panadero, 2019). They are offered fresh, pre-dried, in the form of hay, meal, multi-nutritional blocks and silage (Rodríguez *et al*., 2015; Tesfay *et al*., 2017a; Dong *et al*., 2020; Rodríguez *et al*., 2020), which allows to have conservation and selection alternatives related to season, animal preference and farmers' possibilities. The low availability of easily-fermented carbohydrates in *T. gigantea* hinders its ensiling (Castaño, 2012), for which sugar-rich products or microorganisms with lactic-acid action, or both, should be incorporated, so that the conservation process is facilitated and the silage quality is improved. With this procedure excellent results have been reported in *M. oleifera* and *M. alba* silages (Dong *et al*., 2020; Rodríguez *et al*., 2020).

M. oleifera, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* stand browsing and, thus, allow to establish silvopastoral systems (Arango *et al*., 2016). Their incorporation favors the sustainability of the animal husbandry ecosystem, by improving soil fertility and benefitting the development of pastures, which contributes to the increase of the stocking rate and its productivity (Santos-Gally *et al*., 2019).

In the ration generally between 0,08 and 10 kg of protein plants are included (Savón-Valdés *et al*., 2017; Tesfay *et al*., 2017b), quantity that depends on the other diet components, and which is difficult to control in silvopastoral systems. Their intake benefits the weight gain and milk production, as long as their incorporation satisfies the nutritional needs. In Cuba there is higher availability of pastures than forage from shrubs, for which the current productions do not allow to supplement livestock adequately, negatively affecting animal husbandry.

Worldwide, the partial or total substitution of industrial concentrate feeds, without taking into consideration the nutritional contribution of one product compared with another, generates little encouraging results (Balraj *et al*., 2018). Hypothetically, if adequate quantities of protein plants are supplied, but the needs of minerals, pastures and water are not satisfied, positive results in the animal yield will not be observed either.

The incorporation of *M. oleifera*, as substitute of alfalfa hay stimulated milk production by 2,63 and 5,34 kg/day for ewes and goats, respectively; as well as the content of fat, lactose, non-fatty solids, vitamin C and antioxidant compounds (Babiker *et al*., 2017). Its inclusion in 2 and 3 kg in cow feeding allowed to obtain 1,8 and 2 kg/day/cow, with regards to the group that did not receive *M. oleifera* (Reyes, 2006). The presence of *T. diversifolia* in a silvopastoral system allowed to increase the stocking rate per hectare of 1,84 and 2,71 and stimulated milk production and quality (15,4 kg/ha/day with 3,39 % protein), results that are higher than those obtained with a conventional system (9,7 kg/ha/day with 3,35 % protein) (Rivera *et al*., 2015). The incorporation of 0,45 kg/day of *M. alba* in the ration of buffaloes allowed to obtain 7,67 kg of milk/day/animal with 5,36 % protein, higher productions than the ones reported for the animals that did not consume *M. alba* (Li *et al*., 2020). The combination of Taiwan grass with fresh forage from *M. alba* and *T. gigantea* allowed to produce 5,8 L of milk/cow/day with 4,89 % of fat matter and 5,4 L milk/cow/day with 4,95 % of fat matter; higher results than the report in animals that only received pasture (Laguna-Gámez, 2018). Another study, also with *T. gigantea*, showed that its inclusion in 30 % increased by 0,35 L of milk/cow/day and by 0,07 % the protein content, although it did not influence the fat content (Cuenca-Angamarca, 2018). The supplementation with 2 and 3 kg of *C. argentea* stimulated the milk production by 5,1 and 5,7 kg/day compared with the intake of sorghum (*Sorghum bicolor* L.), which was 3,9 kg/day (Reyes, 2006). Nevertheless, Laguna-Gámez (2018) observed that fresh *C. argentea* stimulates higher milk production (4,2 %) with regards to ensiled *C. argentea* (3,9 %); however, this last alternative allows to increase the fat content (4,0 %) compared with the forage of such species (3,5 %).

These shrubs also influence the animal body condition. The incorporation of *M. oleifera* as substitute of *Medicago sativa* L. hay stimulated weight gain in lambs and goats, by 320 and 183 g, if it is compared with the record in animals of this category fed with hay, whose increases were 234 and 164 g, respectively (Babiker *et al*., 2017).

Iraola *et al*. (2019) in the fattening of grazing bulls, supplemented with 4 kg of *M. oleifera* silages obtained daily (703 g) and final weight gains (42,2 kg) higher than those recorded in bulls that received 4 kg of forage (daily gain 541 g and final gain 32,5 g).

The incorporation of 30 % *T. diversifolia* to the diet of growing lambs contributed to the weight gain during five weeks. This result surpasses the report by Cadena-Villegas *et al*. (2020), who used a traditional diet based on concentrate feed and *Zea mays* L. silage, with which they reached gains between 10 and 60 g/day, along with a better feed conversion.

In calves supplemented with multi-nutritional blocks of *M. alba* (0,933 kg/day), Cabrera-Núñez *et al*. (2016) achieved higher weight gain than the one obtained in calves that received such blocks without this shrub (0,866 kg/day). In addition, the incorporation of *M. alba* as substitute of concentrate feeds in the ration of lambs increased the weight in a range between 0,64 and 0,76 kg/day, which was related to higher feed conversion (Tesfay *et al*., 2017a).

Weight gains were also reported in 60-day old sheep when they consume *C. argentea* (Silva *et al*., 2018), as well as in growing calves (68,65 kg), with regards to the ones that did not consume this feedstuff (59,05 kg) (Benavides-Calvache *et al*., 2010). In a study conducted with grazing lambs it was observed that there are no problems of selectivity with the fresh forage of *C. argentea*, because they consumed 1 210 g/day, similar value to the one recorded by Rodríguez *et al*. (2015) in a work with *Leucaena leucocephala* (Lam) de Witt, which was 1 214 g/day.

The supplementation of grazing bulls with *Saccharum officinarum* L. and *C. argentea* allowed to maintain a stocking rate of 5 animals/ha, with live weight gain of 1 t/ha/year (Rincón, 2005). Also the incorporation of 20 % *T. gigantea* in the diet of cattle increased the daily weight gain (0,555 kg) with regards to the animals that only consumed pasture (0,433 kg/day) (Olarte-Díaz, 2018).

Effect on animal health. The incorporation of 15 % *M. oleifera* meal in the ration of goats influences positively their immune system by increasing the mean cell volume, packed cell volume and number of white blood cells (Jiwuba *et al*., 2017). Meanwhile, its content of secondary metabolites affects the development of eggs and the neuromuscular coordination of the larvae from the nematodes that attack the gastrointestinal system of livestock, at the same time they offer resistance to future infections (Puerto-Abreu *et al*., 2014). The forage of *M. alba* in low quantities decreases the caloric stress buffaloes experience in tropical zones (Li *et al*., 2020) and in the form of silage in the diet of Holstein cows, it improves the antioxidant capacity in blood and decreases the presence of pathogenic bacteria of the genus *Tyzzerella* in the intestine (Hao *et al*., 2020). The foliage of *C. argentea* acts as antiparasitic medicine, by decreasing at 42 days the number of nematode eggs in the sheep feces, effect that is associated to its content of secondary metabolites (Silva *et al*., 2018). In addition, grazing cattle supplemented with 3,5 kg of dry matter of *C. argentea* have higher content of blood ureic nitrogen, glycaemia, aspartate aminotransferase, total protein, cholesterol and triglycerides (Roa-Vega *et al*., 2017). The content of secondary metabolites of *T. gigantea* contributes to decreasing the presence of endoparasites, limits the appearance of bloat and is used to cure hernias and expel the placenta in horses (Pérez, 1990).

The biggest incognita and deficiency regarding this alternative of natural medicines is given by the fact that there are no elaborated protocols to incorporate in a stable way these products in animal husbandry for health purposes. Aspects such as the administration method, frequency, supply quantity, conservation alternatives, long-term results and health conditions which they influence, are still to be determined and, thus, constitute future lines of research for the centers focused on animal science.

Final considerations

The adaptation to the Cuban agricultural conditions, biomass availability throughout the year and nutritional value determine that *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* are considered quality forage resources to supplement the animals and improve their health. In turn, these species contribute to the sustainability of the animal husbandry industry, by protecting and increasing the soil quality and decreasing the emission of methane to the environment.

In Cuba, the knowledge acquired about the management and processing techniques of *M. oleifera*, *T. diversifolia* and *M. alba* allow ranchers to be more confident about their utilization, which limits the use of *T. gigantea* and *C. argentea*. Thus, agronomic, physiological, genetic, forage processing and nutrition studies are necessary, which allow to develop technologies for the management of *T. gigantea* and *C. argentea* and for their adequate inclusion in the livestock diet. However, emphasis should be made on the fact that for all these plants there are still difficulties regarding the agrotechnical management, mainly in the cultural attentions that are applied.

For the inclusion in the diet of the protein plants approached here, it must be taken into consideration that the ideal quantities of forage will vary depending on the animal species, its development status and the ration it consumes. It is recommended that each farmer evaluates during one year the effect different quantities of *M. oleifera*, *T. diversifolia*, *M. alba*, *T. gigantea* and *C. argentea* have on the animal productive performance for them to determine the volume of protein feed they have to incorporate to the ration, and thus obtaining maximum productivity.

Conflict of interests

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Authors' contribution

- Yadiana Ontivero Vasallo. Elaborated and wrote the paper.

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