Chemical composition of *Tithonia diversifolia* (Hemsl.) A. Gray (Asteraceae) and diversity of uses in rural areas

Composición química de *Tithonia diversifolia* (Hemsl.) A. Gray (Asteraceae) y diversidad de usos en el medio rural

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**Abstract**

The objective of this study was to evaluate the nutritional quality of *Tithonia diversifolia*, a shrub species in the Asteraceae family and the diversity of uses in rural areas. A bibliographic review was conducted in Mexico and other countries in Central America, South America, Africa and Asia. Bromatological analyses of edible material (leaves and petiole) were performed to determine dry matter (DM), fat, ash, crude fiber, crude protein (CP), and nitrogen-free extract (NFE). Fiber fractions were determined: neutral detergent fiber (FDN), acid detergent fiber (ADF), hemicellulose, cellulose and lignin, from two locations in Jalisco state and one from Colima. Herbarium specimens were reviewed for knowing geographical distribution and rural uses. Results indicate that even without being legume, CP percentages are high with values of 18.42 to 31.54% with high dry matter content up to 98.92%, fiber values (30.81 to 34.08%) for NDF and (22.48 to 31.69%) for ADF. The bibliographic review highlights its forage use, for ruminants and monogastrics, in beekeeping for its content of nectar and pollen, such as medicinal, ornamental and green manure for its contribution of nutrients, mainly phosphorus. *T. diversifolia* is a good option for its nutritional and diversity of uses are demonstrated as an alternative in semi-intensive animal production systems in both tropical and temperate areas.

**Beekeeping, Crude protein, Dry matter, Fiber fractions, Medicinal use**

**Resumen**

El objetivo de este estudio fue evaluar la calidad nutritiva de *Tithonia diversifolia*, especie arbustiva de la familia Asteraceae y la diversidad de usos en áreas rurales. Se realizó una revisión bibliográfica en México y otros países de Centroamérica, Sudamérica, África y Asia. Se realizaron análisis bromatológicos de material comestible (hojas y pecíolo), para determinar materia seca (MS), grasa, cenizas, proteína cruda (PC), fibra cruda (FC) y extracto libre de nitrógeno (ELN). Se determinó fracciones de fibra: fibra detergente neutro (FDN), fibra detergente acido (FDA), hemicelulosa, celulosa y lignina de plantas, procedentes de dos localidades del estado de Jalisco y una del estado de Colima. Asimismo, se revisaron ejemplares de herbáceos para conocer su distribución geográfica y los usos en el medio rural. Los resultados indican que aunque no es leguminosa los porcentajes de PC son altos con valores de 18.42 a 31.54%, con alto contenido de materia seca hasta de 98.92%, valores de fibra de (30.81 a 34.08%) para (FDN) y (22.48 a 31.69%) para (ADF). La literatura resalta su uso forrajero, para ruminantes y monogástricos, en la apicultura por su contenido de néctar y polen, como medicinal, ornamental y abono verde por su aporte de nutrientes, principalmente fósforo. *T. diversifolia* es una buena opción, ya que se demuestra su valor nutritivo y la diversidad de usos, como una alternativa en sistemas semi-intensivos de producción animal, tanto en zonas tropicales como zonas templadas.

**Apicultura, Fracciones de fibra, Materia seca, Proteína cruda, Uso medicinal**

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Introduction

Tropical livestock based their diet on pastures; these have an extraordinary capacity to produce biomass (Palma, 2005), however, the marked seasonality that exists in most of the country, causes a strong forage deficit in the dry season, especially for extensive livestock farming, which during eight months of drought, consumes the foliage and fruits of forage trees and shrubs, present in the pastures, a valuable resource, as it is the only source of fresh and good quality food during the dry season. Among the species mostly used for animal feeding, legumes stand out, predominating among them, different types of Acacia sp., Leucaena spp., Gliricidia sepium, Calliandra spp. and Caesalpinia spp., which are characterized by their high protein content, up to 30% in foliage and up to 24% in fruits (Román et al., 2004; Palma, 2005; Román et al., 2013; Palma et al., 2019). On the other hand, in most tropical countries there is a great diversity of plant species, which can contribute to animal feeding (Valenciaga et al., 2018; Herrera et al., 2020) and reduce production costs in the livestock activity, including Tithonia diversifolia, a shrubby plant of the family (Asteraceae), which grows both in tropical and temperate climates.

The types of habitat where it is distributed include: oak forests, tropical evergreen forests, deciduous forests, secondary vegetation, along the roads, as well as in cultivated fields, its altitudinal range goes from sea level to 2500 m. Likewise, in the review of the material of herbarium specimens, collected in the state of Jalisco, they report it in areas near Puerto Vallarta, collected in a tropical deciduous forest and secondary vegetation, associated with Ficus, Enterolobium, Hura, Gliricidia, Hyptis, Solanum, Tridax and Cosmos among other species.

Studies carried out in Colombia demonstrate the forage potential of this species and its nutritional quality, which without being legume, has high levels of crude protein that range from 14.84 to 28.75%, due to its nutritional value and diversity in its chemical composition (Ríos and Salazar, 1995; Ríos, 1999; Mahecha and Rosales 2005; Mahecha et al., 2007; Gallego-Castro et al., 2017; Rivera et al., 2018), as well as other research carried out in Cuba by (Galindo et al., 2018, Valenciaga et al., 2018) make this species a viable option to be used in agricultural production systems.

Galindo et al. (2018), reported that its use in the animal diet reduces the production of methanogens and protozoa and has beneficial effects on the microbial ecology of the rumen. Lescano-Más et al. (2016) stated that in young cattle it contributes to reducing the parasite. Furthermore, this species presents desirable characteristics that make it attractive to be incorporated into silvopastoral systems; including having a large root volume, and a special ability to recover the scarce nutrients present in the soil (Pérez et al., 2009), has a wide range of adaptation and distribution in tropical and temperate zones, a characteristic that in some parts of the world, consider it as an invasive species in different ecosystems, mainly in Africa and China (Sun et al., 2007; Muoghalu, 2008; Ajao and Moteetee, 2017), it tolerates conditions of acidity and low fertility, it is resistant to poor soils and it can withstand pruning at ground level, it is tolerant to burning and has a rapid growth, it is not demanding of inputs or handling for its cultivation (Mahecha and Rosales, 2005; Pérez et al., 2009).

In Colombia they evaluated the production of dry matter with plants obtained through asexual and sexual means; planting 36 plants per plot of (20 m²), with a density of 1.8 m², with weed control and fertilization, obtaining productions of 13, 17 and 19 t / DM / ha, by establishing the cultivation by stakes, plants produced by seed sexual in in vitro conditions and plants obtained by sexual seed, managed in seedlings (Gallego-Castro et al., 2015).
Herrera et al. (2020), studied the distribution of this species in relation to climate change and its chemical composition, considering precipitation, temperature and distribution, highlighting that the correlation between climatic factors and chemical composition was variable, with the highest coefficients (r) for phosphorus, with maximum temperature (0.64) and average temperature (0.63), OM and ashes with minimum temperature (0.62 and -0.62), respectively; cellulose with the maximum temperature, total rainfall and the number of days with rain, with values of: (-0.62, -0.69 and -0.73), respectively, and nitrogen (N) with rainfall and its distribution (- 0.81 and -0.82, respectively). Being for the other components, low and not significant correlations; reaching the conclusion that climate factors act individually and / or interrelated, which is relevant to know, for the management of the plant in climate change scenarios.

*Tithonia diversifolia* is a species native to Mexico and Central America. However, in our country, it has not been used intensively as a forage species in livestock production systems, nor in the diversity of uses it presents, so the objective of this study is:

**Objective**

Evaluate the nutritional quality of *Tithonia diversifolia* from three different locations, as well as rescue the experiences of other countries on its multiple uses, to enter silvopastoral systems.

**Materials and methods**

The study began with a bibliographic review, as well as a consultation in the herbarium of the Institute of Botany, of the University of Guadalajara, to know its distribution based on reviewed specimens. The plant was collected in three different locations: one in the municipality of Cuauhtémoc, in the state of Colima, present in weed vegetation, another in El Tuito, municipality of Cabo Corrientes, used as an ornamental and the other collected in the Botanical Garden of the University Center of Biological and Agricultural Sciences. The climates present are:

Warm subhumid with rains in summer Aw1, with rainfall of 1200 mm and mean annual temperature of 24 °C for Cuauhtémoc, and semi-warm subhumid with rains in summer for the site of El Tuito A (C) w1, with 1100 mm of rainfall per year and average annual temperatures between 22 and 26 °C., the same climate as Las Agujas in the municipality of Zapopan, Jalisco, although with lower temperature ranges from 20 to 24 °C. Later, made revisions in the herbaria of the Universidad Nacional Autónoma de México (MEXU) and the Instituto Politécnico Nacional (IPN), to know its geographical distribution, altitude ranges, types of vegetation where it occurs and the uses attributed to it in rural areas.

From the last two sites, a previous evaluation of vegetative propagation was carried out with stakes of lengths between ranges for T<sub>1</sub> (20 to 25 cm), T<sub>2</sub> (26 to 32 cm), and T<sub>3</sub> (33 to 40 cm), With variable diameters between the different lengths. Subsequently, they were subjected to water stress to measure survival.

The edible material was collected in the three aforementioned sites and consisted of leaves and petioles, 500 g of fresh material, which were transported in a cooler, so that the bromatological analyzes could be carried out in the bromatology laboratory to determine dry matter (DM) and crude protein (CP), which are the most relevant parameters in forage species, in addition to forage production and acceptability in consumption by the animal species, using the technique proposed by the Association of Official Analytical Chemists (AOAC, 1990). Likewise, fiber fractions were analyzed: neutral detergent fiber (NDF), Acid detergent fiber (ADF), cellulose, hemicellulose and lignin, by the method of (Van Soest and Wine, 1967).
Results and Discussion

Vegetative propagation

In the evaluation of vegetative propagation, it was observed that the best values of the variables evaluated were those from El Tuito. Likewise, the highest number of species with regrowths were for treatments 1 and 2 (Table 1), which after submitting them to a 4-month drought period, were the only treatments, which of 10 plants evaluated at least 4 of them managed to survive, not the T2 ones (lengths of 33 to 40 cm), of which none of them survived, probably due to a greater demand for water. In this regard, in other studies, it is highlighted that this species can be propagated sexually (by seed) or by cuttings; recommending vegetative reproduction (Pérez et al., 2009). These authors and (Hartmann and Kester 1995, cited by Pérez et al., 2009) indicated that propagation by cuttings produces a more efficient rooting; if the cutting and planting conditions are optimal, thus allowing greater survival and favoring their ability to produce biomass. Ríos and Salazar (1995) achieved productions of 82, 57 and 42 tons per ha, at densities of 2600, 1800 and 760 plants / ha, with 110 days after sowing and with irrigation application. Also, Mauricio et al. (2017) highlighted reproduction by cuttings, recommending a length of 20 to 40 cm, buried vertically and at a shallow depth, the minimum and maximum length of the treatments suggested in this study.

| Treatment | Diam. (mm) | Sprouts | L (cm) | Survival |
|-----------|------------|---------|--------|----------|
| AT1       | 17.77      | 3.42    | 11.62  | 4        |
| BT1       | 19.57      | 4.83    | 10.64  | 9        |
| AT2       | 17.85      | 2.63    | 12.13  | 5        |
| BT2       | 18.82      | 4.14    | 9.76   | 6        |
| AT3       | 20.32      | 4.00    | 20.38  | 0        |
| BT3       | 19.28      | 3.83    | 8.77   | 0        |

Table 1 Behavior of the shoots of the *Tithonia diversifolia* cuttings, from Las Agujas (A) and El Tuito (B), Jalisco.

It is a forage plant, with high levels of protein and high digestibility, contributing in an important way to animal nutrition, both for ruminants and monogastrics, it is also used in the supplementation of poultry feed, to take advantage of its carotene content and give color to egg yolk and chicken meat (Ríos, 1999). Therefore, this study presents its chemical composition that makes it attractive in animal production.

Chemical composition

Regarding its nutritional quality, it can be observed that it presents high levels of protein (18.42 to 31.54%), compared to legume species, which are characterized by their high protein content: *Tithonia diversifolia* has higher values than many tree species of this family and the results obtained in this study, for the materials from Cuauhtémoc, Colima and El Tuito are higher than those reported by other authors among them (Rosales, 1996; Navarro and Rodriguez, 1990 and Oliva, 1999), the latter, who in turn found high levels of calcium (2.3%) in this species, despite growing in acid soils. *Tithonia diversifolia*, presents high dry matter contents of 98.44%, except the material from Las Agujas, Zapopan that presents 21.96%.

The contents of the evaluated parameters are also higher than that reported by Gallego-Castro et al., (2017), for dry matter, who report values of 12.45 to 12.90% and of crude protein, values of 12.76 to 14.10%. It must be considered that these differences are probably due to soil conditions, environmental characteristics and part of the analyzed plant, since in this study the edible material consisted of leaves and petioles, in contrast to the aforementioned authors, who analyzed leaves and tender stems. Regarding the ash content, the values were similar in both studies (15.50 to 16.19%), with the exception of the material obtained in the municipality of Cuauhtémoc, Colima with a value of 18%. Ponce, (2019), reported DM contents of 90% and CP of 16.09% after 30 days of regrowth. The nutritional quality of arboreal or shrub species such as *Tithonia*, accumulate as much nitrogen as legumes, in addition to presenting high phosphorus contents.

For their part, Pérez et al. (2009), indicated that the nutritional quality depends on the phenological stage of the plant; which generally ranges from 14.8 to 28.5% after flowering and advanced growth; dry matter content 14.1 to 23.2% in advanced growth and after flowering and nitrogen-free extract from 1.91 to 2.4% for advanced growth and after flowering, respectively (Navarro and Rodriguez, 1990), lower values in all parameters, compared with those that occurred in each of the sites of the present study.
Also the values reported by Téllez and Mendoza (2014), indicated crude protein contents of 19.5%, however, it should be noted that these authors evaluated the entire plant and although they do not indicate its phenological stage, the value was slightly higher in plants from Las Agujas, Zapopan, but inferior to those mentioned in Cuauhtémoc and El Tuito. Medina et al. (2009), who carried out a study in Trujillo, Venezuela evaluated morphostructural variables and biomass quality, in plants in the initial growth stage with protein contents of 21.3 to 23.7%; Values similar to this study for the Cuauhtémoc and Zapopan sites, but lower than those reported for plants from El Tuito (Table 2).

Regarding the content of fiber fractions, there were low values (30.81, 33.30 and 34.08%), with respect to (NDF), and (22.48, 25.74 and 31.69%), for (ADF), which indicates that it presents high digestibility of dry matter; that suggests a better animal behavior in its consumption (Table 2); These values are lower than those reported in Colombia in the Upper Tropics for NDF from 50.21 to 53.81 and ADF from 48.18 to 48.87% (Gallego-Castro, et al., 2017). On the other hand, Ponce (2019) indicated content of neutral detergent fiber (NDF) of 67.24% and acid detergent fiber (ADF) of 45.84%, high values where the digestibility of the dry matter would be from low to regular, limiting consumption from the animal. Téllez and Mendoza, (2014), reported NDF contents of 58.8% and for ADF of 42.2% with an in vitro digestibility of dry matter (DIVMS) of 57.6%. For their part, Medina et al. (2009), indicated similar values, to those presented in this study, for fiber fractions: with contents of 33.27% for (NDF) and 27.37% for (ADF) and a high DIVMS of 68.9 to 73.4%.

### Diversity of uses

*Tithonia diversifolia* has multiple uses in most countries of origin and where it has been introduced, including its use as green manure, due to its rapid growth, high capacity to fix nitrogen and accumulation of phosphorus, with beneficial effects on poor soils (Scraser et al., 2019). In Kenya it is used as a source of nitrogen, phosphorus and potassium in maize and rice crops (Jama et al., 2000), also for the control of termites (Aduoye et al., 1997).

Another alternative for use is as an insecticide since its insecticidal properties have been demonstrated to combat the leaf defoliator ant (Pantoja-Pulido et al., 2017). Due to the beauty of its yellow or orange flowers and its prolonged flowering, it is cultivated in several countries in Central America, South America, Asia and Africa, for ornamental purposes. Within the bibliographic review, we can cite very varied uses (Table 3), from ornamental, medicinal, forage and also due to its high content of pollen and nectar for the production of honey, contributing in an important way to the beekeeping industry. It is a soil improver due to its high nutrient content (nitrogen, phosphorus and potassium) and its rapid decomposition, which makes it available for other crops, improving the recycling of nutrients from these elements.

### Chemical composition of leaves and petioles of *Tithonia diversifolia*

| Determination           | Cuauhtémoc, Colima | El Tuito, Jalisco | Zapopan, Jalisco |
|-------------------------|--------------------|------------------|------------------|
| Dry matter              | 98.44              | 98.92            | 21.96            |
| Crude protein           | 21.64              | 31.54            | 18.43            |
| Etherial Extract        | 3.12               | 2.73             | 2.60             |
| Ashes                   | 18.00              | 15.70            | 17.60            |
| Fiber                   | 27.07              | 26.30            | 10.31            |
| NFE                     | 28.61              | 22.65            | 50.98            |
| NDF                     | 30.81              | 34.08            | 33.30            |
| ADF                     | 22.48              | 25.74            | 31.69            |
| Lignin                  | 16.23              | 19.39            | 23.67            |
| Cellulose               | 6.25               | 6.35             | 8.02             |
| Hemicellulose           | 8.33               | 8.34             | 1.61             |
| NFE= nitrogen-free extract | 8.33               | 8.34             | 1.61             |

Table 2 Chemical composition of leaves and petioles of *Tithonia diversifolia*, based on dry matter in (%)

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| Country       | Activity                                                                                                            | Benefits                                                                                     |
|--------------|--------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Colombia     | Attraction of beneficial insects                                                                                 | Attracts pollinators and beneficial insects for pollination                                  |
| Africa       | It is used by farmers for pest control                                                                           | Reduces pest population                                                                    |
| Guatemala    | In the treatment of eczema and skin lashing in pets.                                                              | Helps in wound healing, eczema management                                                  |
| Venezuela    | To decrease abortions and cannibalism in conejas                                                                   | Prevents cannibalism, promotes healthy growth                                               |
| Mexico       | Living and windbreaker fences                                                                                     | Protects and conserves water sources, prevents wind erosion, acts as a windbreak            |
| Kenya        | Green fertilizer and soil improver                                                                                | Incorporates biomass for rapid decomposition in rice and maize crops, add nitrogen to soil |
| Costa Rica   | Tithonia diversifolia was found to have high levels of N, P and K                                                 | Replenishes nutrients, promotes plant growth                                                |
| Philippines  | Used to recover grass-invaded soils                                                                                | Restores degraded soils                                                                      |

Table 3 Different uses of *Tithonia diversifolia*, reported in the literature

In many countries its main use is as forage and medicinal, for various ailments, so its two main uses are described in more detail:

Forage use

*Tithonia diversifolia* has been used as animal feed in several countries such as Cuba and Colombia, mainly in CIPAV and in the University of Sao Joao del Rei-Brazil (UFSJ), highlighting its nutritional quality that varies depending on the phenolic stage of the plant, its forage production based on dry matter of 5.6 to 8.1 t / ha / year and on fresh basis was obtained from 24.7 to 41.3 t / ha / year (Mauricio et al. 2017). It is a species with good biomass production capacity and rapid recovery after cutting, which depends on the sowing density, soil characteristics and the vegetative state. Due to its high protein value, it is used in both ruminants and monogastrics; This species is used for cutting and hauling: for sheep, cattle, pigs, rabbits and buffalo; as well as in grazing together with grasses in the herbaceous stratum, in the food diet, it is generally used pre-dried or ground in the form of flour and feed (Pérez, et al., 2009).

In Colombia it is part of the intensive silvopastoral systems (SSPI), many of which have been carried out by CIPAV, together with forage grasses and some other tree species, including *Leucaena leucocephala* and *Guazuma ulmifolia*.

Mahecha et al., (2007), pointed out the advantages in the use of *Tithonia diversifolia* foliage as a forage supplement for dairy cows, with no significant difference between the use of concentrates and different inclusions of the foliage of this species of up to 35%. In forage banks with a density of 12,500 plants / ha, productions of 107.6 t / ha / year of green forage and 24.6 t / ha / year of DM were obtained (Tellez and Mendoza, 2014).

In many countries its main use is as forage and medicinal, for various ailments, so its two main uses are described in more detail:
Medicinal use

*Tithonia diversifolia* is valued by many cultures, for its medicinal properties. It is a species used in traditional medicine, due to its multiple properties, due to the presence of secondary metabolites such as antimicrobial and anti-inflammatory (Sousa *et al*., 2019) to combat malaria (Afolayan *et al*., 2016), indicating that the extracted extracts with dichloromethane and methanol 1: 1 of *Tithonia diversifolia* and *Lawsonia inermis* were more effective against the *Plasmodium* parasite parasite than the aqueous extracts, used in traditional medicine; *T. diversifolia* has also been highlighted for its use against diabetes (Sari *et al*., 2018) and cancer (DiGiacomo *et al*., 2015).

Antioxidant properties are attributed to it; González-Sierra *et al*., 2019, indicated that the roots have a higher antioxidant capacity with 1.10 mg; followed by the leaves with 1.08 mg and finally the stems with 0.50 mg of ascorbic acid / mg of extract. They also reported phenol, flavonoid, coumarin, quinine and terpenoid content. It is important to point out that the concentration of these metabolites varies according to the phenological stage of the plant, the time of year, the characteristics of the soil, the region where the sample is obtained and environmental conditions of the area; noting that both the nutrient content in the soil, mainly Ca and P, as well as climatic conditions, seem to affect the presence of volatile constituents, mainly the content of sesquiterpenes in the leaf (Sampaio and Da Costa, 2018). *T. diversifolia* has shown variability in the content of secondary metabolites (Rivera *et al*., 2018), hence the difference in the results and the versatility of the plant, to adapt to different environments.

The oxidant activity can be associated with the content of phenols and flavonoids, which is explained by the redox properties of phenolic compounds (Gutiérrez-Sierra *et al*., 2019). The antioxidant activity, in general, is given by its ability to sequester free radicals, iron chelator, as well as the inhibition of oxidase enzymes. These metabolites are capable of avoiding or attenuating oxidative stress, due to reactive oxygen species (ROS), which prevents the oxidation of important biomolecules (proteins, nucleic acids, lipids and sugars).

This is associated with the appearance of diseases such as: cancer, Alzheimer’s, aging, cataracts, diabetes, hypertension, cardiovascular diseases, among others (Valco *et al*., 2007; Sies, 2010; Dzialo *et al*., 2016). The extracts of the roots and leaves of *T. diversifolia* presented the highest concentrations of phenols and flavonoids (González-Sierra *et al*., 2019), (Table 4).

| Disease Type                | Part of the plant used | Countries           | Bibliographic reference |
|-----------------------------|------------------------|---------------------|-------------------------|
| Bruises, abscesses          | Stems and leaves       | Venezuela           | Frei, *et al*., 1998    |
| Viper bite                  | Leaves as an antidote  | Kenya               | Owuor *et al*., 2005    |
| Liver problems              | The leaves in cooking  | Colombia            | Rios, 1999              |
| Malaria remedy              | Macerated leaves like  | Guatemala           | Nash, 1976, cit. Rios, 1999 |
|                            | ámica                  |                     |                         |
| Hits                        | Macerated leaves       | Cuba                | Rios, 1999              |
|                            | like ébano              |                     |                         |
| Spasms and cold             | Cooking leaves         | Colombia            | Rios, 1999              |
|                            |                        |                     |                         |
| Malaria                     | Mexico and Nigeria     | Heinrich, 2000;     |
|                            |                        | Ajayesha *et al*., 2006 |
| Dermatological problems     | Toasted leaves         | India               | Heinrich, 2000; Frei, *et al*., 1998 |
| wounds                      |                        |                     |                         |

Table 4 Use in traditional medicine of *Tithonia diversifolia* and parts used

The information collected in the herbarium specimens indicates a wide geographical distribution, as well as different habitats, where it occurs, including home gardens and coffee plantations, the altitudinal ranges include from those close to sea level to altitudes of 2000 m, generally in cloud forest and the main uses are as ornamental and medicinal, only in two states its use as forage is reported (Table 5).
Table 5 Types of habitat, altitude and uses in rural areas of Tithonia diversifolia

### Conclusion

The results indicate that due to its high nutritional quality, its wide distribution and its diversity of uses, *T. diversifolia* is a viable option to be used in semi-intensive animal production systems, both in tropical and temperate zones.

### References

Adoyo, F., Mukalama, B.J., and Enloya, Musa. 1997. Using *Tithonia* concoctions for termite control in Busia District, Kenya. ILEIA Newsletter pp 24-25.

Ajaio, A.A. y Moteteet, A.N. 2017. *Tithonia diversifolia* (Hemsl.) A. Gray (Astheraceae Heliantheae), an invasive plant of significant ethnopharmacological importance: A review. South African Journal of Botany 113: 396-403. https://doi.org/10.1016/j.sajb.2017.09.017 (Accessed 7 November 2020).

Ajaiyeoba, E.O., Abiodun, O.O., Falade, M.O., Ogbole, N.O., Ashidi, J.S., Hapi, C.T. y Aquinboye, D.O. 2006. *In vitro* cytotoxicity study of 20 plants used in nigerian antimalarial ethnomedicine. Phytomedicine. 13 (4): 295-298.

Alfoyan, I.D.F., Adegbolagun, M.O., Irungu, B., Kangethe, L., Orwa, J. y Anumudu, I.Ch. 2016. Antimalaria actions of *Lawsonia inermis*, *Tithonia diversifolias and Chromolaena odorata in combination*. Journal of Ethnopharmacology. 191:188-194. https://www.sciencedirect.com/science/article/abs/pii/S0378874116304056

Association of Official Analytical Chemists (AOAC). 1990. Official methods of analysis (15TH ed.). Association of Official Analytical Chemists. Washington, D.C., E.E.U.U. pp 70.

Di Giacomo, C., Vanella, L., Sorrenti, V., Santangelo, R., Barbagallo, I., Calabrese, G., et al. (2015) Effects of *Tithonia diversifolia* (Hemsl.) A. Gray Extract on Adipocyte Differentiation of Human Mesenchymal Stem Cells. PLoS ONE 10(4): e0122320. https://doi.org/10.1371/journal.pone.0122320

Dzialo, M., Mierziaik, J., Korzun, U., Preisner, M., Szopa, J. & Kulma, A. 2016. The potential of plant phenolics in prevention and therapy of skin disorders. Int. J. Mol. Sci. 17 (2):160. DOI: https://doi.org/10.3390/ijms17020160 (Consultado 13 de noviembre del 2020).

Frei, B., Baltisberger, M., Sticher, O. y Heinrich, M. 1998. Medical ethnobotany of the Zapotecos of the Isthmus Sierra (Oaxaca-Mexico): documentation and assessment of indigenous uses. J. Ethnopharmacol. 62: 149-165.

Galindo, B. J. L., La O León, O., Ruiz, V. T., González, V.A. y Narvaez, C. W. 2018. Efecto de diferentes materiales vegetales de *Tithonia diversifolia* (Hemsl.) Gray en la producción de metanógenos y protozoos del rumen. UNESUM-Ciencias. Revista Científica Multidisciplinaria 2(3): 1-10.

Gallego-Castro, L. A., Mahecha, L.L. y Angulo, A.J. 2015. Crecimiento y desarrollo de Tithonia diversifolia Hemsl. A. Gray, en condiciones de Trópico Alto. 53-57. 3° Congreso Nacional de Sistemas Silvopastoriles – VIII Congreso Internacional de Sistemas Agroforestales. Del 7 al 9 de mayo del 2015. Iguazu, Misiones, Argentina 734 p.
Gallego-Castro, L. A., Mahecha, L.L. y Angulo, A.J. 2017. Calidad nutricional de *Tithonia diversifolia* (Hemsl.) A. Gray, bajo tres sistemas de siembra en el Trópico Alto. Agron. Mesoam. 28 (1): 213-222.

George, T. S., P.J. Gregory, J.S. Robinson, R.J. Buressh and B.A. Jama. 2001. *Tithonia diversifolia* variations in leaf nutrient concentration and implications for biomass transfer. Agroforestry Systems. 52 (3): 199-205.

Heinrich, M. 2000. Ethnobotaniy and its role in drug development. Phytother. Res. 14: 479-488.

Herrera, R.S., Verdecia, D.M. y Ramírez, J.L. 2020. Chemical composition, secondary and primary metabolites of *Tithonia diversifolia* related to climate. Cuban Journal of Agricultural Science 54 (3): 1-9.

Jama, B., Palm, C.A., Buressh, R.J., Niang, A., Gachengo, C., Nziguhuba y Amadalo, B. 2000.*Tithonia diversifolia* as a green manure for soil fertility improvement in western Kenya. Agroforestry Systems 49: 201-221.

Lescano-Más, Y., Soca-Pérez, M., Roque-López, E., Ojeda-García, F., Machado-García, R. y Fontes-Marrero, D. 2016. Forraje de *Tithonia diversifolia* para el control de estroncifílidos gastrointestinales en bovinos jóvenes. Pastos y Forrajes 39 (2): 133-138.

Mabou-Tagne, A., Marino, F. y Cosentino, M. 2018. *Tithonia diversifolia* (Hemsl.) A. Gray as a medicinal plant: A comprehensive review of its ethnopharmacology phytochemistry, pharmacotoxicology and clinical relevance. Journal of Ethnopharmacology. 220 (18): 94,116.

Mahecha, L. y Rosales M. 2005. Valor nutricional del follaje del botón de oro *Tithonia diversifolia* (Hemsl.) Gray en la producción animal en el trópico. Livestock Research for Rural Development. 17 (9): 1. Disponible en: http://www.cipav.org.co/lrrd/lrrd17/9/mathe171 00.htm.

Mahecha, L., Escobar, J.P., Suárez, J.F y Restrepo, L.F. 2007. *Tithonia diversifolia* (Hemsl.) Gray (botón de oro) como suplemento forrajero de vacas F1 (Holstein por Cebú). Livestock Research for Rural Development. Volume 19, Article #16. Retrieved November 12, 2020, from http://www.lrrd.org/lrrd19/2/mathe19016.htm.

Malama, C. M. 2001. Evaluating the agronomic potential of *Tithonia diversifolia* prunings in the acid soils of Northern of Zambia. Seventh Eastern and Southern Africa Regional Maize Conference. pp 372-376.

Mauricio, R.M., Calsavara, H.F.L., Ribeiro, R.S., Pereira, G.R.L., de Freitas, S.D., Paciuollo, S.D., Barahona, R., Rivera, E.J., Chará, J. y Murguiotiu, E. 2017. Feed Ruminants using *Tithonia diversifolia* as Forage. Journal of Dairy, Veterinay & Animal Research. 5 (4): 00146. DOI: 10.15406/jdvar.2017.05.00146.

Medina, M.G., Garcia, E.D., González, E.M., Cova, J.L. y Moratinos, P. 2009. Variables morfo-estructurales y de la calidad de la biomasa de *Tithonia diversifolia* en la etapa inicial de crecimiento. Zootecnia Tropical 27 (2): http://ve.scielo.org/scielo.php?pid=S0798-72692009000200003&script=sci_arttext (Consultate November 12, 2020).

Muoghalu, J.I. 2008. Growth, reproduction and resource allocation of *Tithonia diversifolia* and *Tithonia rotundifolia*. Weed Research. An International Journal of Weed Biology, Ecology and Vegetation Management. https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-3180.2007.00613.x (Consultate November 12, 2020).

Navarro, F. y Rodríguez, E.F. 1990. Estudio de algunos aspectos bromatológicos del Mirasol (*Tithonia diversifolia* Hemsl y Gray) como posible alternativa de alimentación animal. Tesis Licenciatura. Universidad del Tolima. Ibagué, Tolima.

Olivares, E. 1999. Nutrientes y metales en *Tithonia diversifolia* (Hemsl.) Gray (Asteraceae).

Owuor, B.O., Mulemi, B.A. y Kokwaro, J.O. 2005. Indigenous snake bite remedies of the Luo of western Kenya. J. Ethnobiology 25 (1): 129-141.
Palma, J.M. 2005. Árboles en la ganadería tropical. Avances en la Investigación Agropecuaria. 9 (1): 1-9

Palma, J.M., Zorrilla, J.M. y Nahel, J. 2019. Incorporation of tree species with agricultural and agroindustrial waste in the generation of resilient livestock systems. Cuban Journal of Agricultural Science. http://cjascience.com/index.php/CJAS/article/view/863 (Consulte November 10, 2020).

Pantoja-Pulido, K.D., Colmenares, D. A.J., Isaza, M. J.H. 2017. New caffeic acid derivative from *Tithonia diversifolia* (Hemsl.) A. Gray butanolic extract and its antioxidant activity. Food and Chemical Toxicology 109 (2): 1079-1085.

Pérez, A., Montej, I., Iglesias, J.M., López, O., Martín, G.J., García, D.E., Milián, I. y Hernández, A. 2009. *Tithonia diversifolia* (Hemsl.) A. Gray. Pastos y Forrajes. 32 (1): http://scielo.sld.cu/scielo.php?script=sci_arttext &pid=S0864-03942009000100001

Ponce, Z.J.L. 2019. Composición química, degradabilidad y cinética ruminal in situ del botón de oro (*Tithonia diversifolia*) en diferentes períodos de corte. Tesis de Licenciatura. Universidad Estatal de Quevedo, Quevedo, Los Ríos, Ecuador. 55 p.

Ríos, K.C.I. y Salazar, A. 1995. Botón de oro (*Tithonia diversifolia* (Hemsl.) Gray) una fuente proteica alternativa para el trópico. Vol. 6 No. 3 Livestock Research for Rumiant for rural development.

Ríos, K. C.I. 1999. *Tithonia diversifolia* (Hemsl.) Gray una planta con potencial para la producción sostenible en el trópico. Conferencia Electrónica de la FAO sobre “Agroforestería para la producción animal en Latinoamérica”.

Rivera, J. E., Chará, J., Gómez-Leiva, J.F., Ruiz, T. y Barahona, R. 2018. Variabilidad fenotípica y composición fitoquímica de *Tithonia diversifolia* A. Gray para la producción animal sostenible. Livestock Research for Rural Development. 30 (12). https://www.researchgate.net/profile/Rolando_Barahona_Rosales/publication/329196626_Variabilidad_fenotipica_y_composicion_fitoquimica_de_Tithonia_diversifolia_A_Gray PARA LA PRODUCCION_ANIMAL_SOSTENIBLE (Consulte November 12, 2020).

Román, M.M.L., Mora, S. A; Gallegos, R. A. 2004. Especies arbóreas de la Costa de Jalisco, México, utilizadas como forraje en sistemas silvopastoriles. Scientia Vol. 6 Núm. 1-2 pp 3-12.

Román, M.M.L., Palma, J.M. Mora S.A. Gallegos, R.A. 2006. Arbóreas tropicales nativas productoras de nectá y polen para la apicultura en el estado de Colima, México. Segundo Congreso Latinoamericano de la IUFRO. Octubre 2006, La Serena Chile. Published in: http://www.iufro.org/uploads/media/t1-gallegos-et-al.doc. stand 12/01/06

Román, M.M.L., Martínez, R. L.A., Mora, S.A., Torres, M. P., Gallegos, R. A. y Avendaño, L.A. 2013. *Leucaena lanceolata* S. Watson ssp. lanceolata especie forestal para ser introducida en sistemas silvopastoriles. Rev. Chapingo Serie Ciencias Forestales y del Ambiente. 103-114.

Sampaio, B.L. y Da Costa, F.B. 2018. Influence of abiotic environmental factors on the main constituents of the volatile oils of *Tithonia diversifolia*. Revista Brasileira de Farmacognosia 28: 135-144.

Sari, R.A., Saraswati, R. T. y Yuniwarti, W. E. Y.2018. Antihyperglycemic Activity of Aqueous Extract of Insulin Leaves (*Tithonia diversifolia*) on Hyperglycemic Rats (Rattus norvegicus). Biosaintifika. Journal of Biology & Biology Education. 10 (3): 636-641.

Scrass, M.F., Sinclair, L.F., Farrar, F.J., Pavinato, S.P. y Jones, L. D. 2019. Rhizosphere. 9: 27-33.

Sies, H. 2010. Polyphenols and health: Update and perspectives. Arch. Biochem. Biophys. 501, 2–5. [CrossRef] [PubMed]
Sousa, I.P., Chagas-Paula, Daniela, A., Tiossi, R. F. J., Silva, E. de D. O., Oliveira, S. E., Abreu, M.M., Barbosa de Oliveira, R., Cropanese, S.A.C., Kenupp, B. J., Jacometti, C. N.A. y Batista Da Costa, F. 2019. Essential oils from *Tithonia diversifolia* display potent anti-oedematogenic effects and inhibit acid production by cariogenic bacteria. J. Essent. Oil Res. 31 (1): 43-52. DOI: https://dpoi.org/10.1080/10412905.2018.1500315

Sun, G. W.; Chen, G. y Wang, S. 2007. Characteristics of *Tithonia diversifolia*: an invasive plant in Yunnan, south-west China. 3rd Global Botanic Gardens Congress, Botanica Gardens Conservation International, Wuhan. pp 1-7.

Tellez, S.A. y Mendoza, B. R.A. 2014. Comportamiento productive de *Tithonia diversifolia* en bancos forrajeros, bajo condiciones de suelos de Piedmonte llanero. Tesis de licenciatura Universidad de la Salle. Bogotá, Colombia. 47 p.

Thor, B. S., H. Tiessen and R. J. Buresh. 2002. Short fallows of *Tithonia diversifolia* and *Crotalaria grahamiana* for soil fertility improvement in western Kenya. Agroforestry Systems vol. 55, No. 3 pp 181-194.

Valenciaga, D., Lopez, J.R., Galindo, J., Ruiz, T. y Monteagudo, F. 2018. Cinética de degradación ruminal de materiales vegetales de *Tithonia diversifolia* recolectados en la región oriental de Cuba. Livestock Research for Rural Development. Vol. 30 Art. # 186 Retrieved November 12, 2020, from http://www.lrrd.org/lrrd30/11/daiky30186.html

Valko, M.; Leibfritz, D.; Moncol, J.; Cronin, M.T.; Mazur, M.; Telser, J. 2007. Free radicals and antioxidants in normal physiological functions and human disease. Int. J. Biochem. Cell Biol. 39 (1): 44–84.

Van Soest, P. J y Wine, R. H. 1967. Use of detergents in the analysis of fibrous feed. Determination of plant cell-wall constituyents. J. Assoc. Off. Anal. Chem. pp 50:50.