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Nutritional evaluation of mature seeds of *Enterolobium cyclocarpum* (parota) from diverse ecological zones in western Mexico

Evaluación nutricional de semillas maduras de *Enterolobium cyclocarpum* (parota) de diversas zonas ecológicas del oeste de México

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SUMMARY

There is little information on the agroecological characteristics and chemical composition of some wild forage species in Mexico, which can be proposed as alternatives for forage uses; therefore, the aim of this work was to assess the nutritional properties of *Enterolobium cyclocarpum* (common name: parota) mature seeds collected from several native habitat locations with distinct physiographic and ecological conditions in Jalisco in western Mexico. Physiographic data, coexisting vegetation, environmental conditions, soil type, mineral and organic content of soils from each site were determined. Seed nutritional values (amino acid profile, mineral content and *in vivo* protein degradability) were evaluated by proximate composition. Seed samples from Autlán exhibited the highest crude protein values, ethyl ether extract, histidine, phosphorus, dry matter digestibility and protein efficiency ratio. This site coincides with the highest contents in soil organic carbon, soil organic matter and phosphorus, and appropriate climatic conditions; while seeds with the lowest value of crude protein, dry matter digestibility, and protein efficiency ratio were collected from Puerto Vallarta, La Huerta and Amatitán, which are the locations with inferior soil fertility characteristics.

Key words: ecosystems, mineral content, proximate chemical analyses, digestibility, amino acids.

RESUMEN

Existe poca información relacionada con las características agroecológicas y de composición química de algunas especies forestales silvestres en México con potencial forrajero, que pueden ser alternativas para alimento animal; por ello, el objetivo de este trabajo fue evaluar las propiedades nutricionales de semillas maduras de *Enterolobium cyclocarpum* (parota) colectadas en diversos habitats nativos bajo diferentes condiciones fisiográficas y ecológicas de Jalisco en el occidente de México. En cada sitio se determinó datos fisiográficos, vegetación asociada, condiciones ambientales, tipo de suelo, así como su contenido mineral y orgánico. Se evaluó el contenido nutricional de las semillas mediante el método de composición proximal, perfil de aminoácidos, minerales y degradabilidad de la proteína *in vivo*. Las semillas de Autlán mostraron el mayor valor de proteína cruda, extractos en etil éter, histidina, fósforo, digestibilidad de la materia seca, y relación de eficiencia proteica. Este sitio de muestreo presentó el suelo con mayor contenido de carbono orgánico, materia orgánica y fósforo, así como aceptables condiciones climáticas. Las semillas con el menor valor de proteína cruda, digestibilidad de la materia seca y relación de eficiencia proteica fueron colectadas en los sitios de Puerto Vallarta, La Huerta y Amatitán, los cuales presentaron suelos menos fértiles.

Palabras clave: ecosistemas, contenido mineral, análisis químico proximal, digestibilidad, aminoácidos.

INTRODUCTION

Mexico ranks fourth worldwide in biodiversity and endemism, having thirteen major vegetation types, with a total estimated forest cover of about 144,500,000 hectares (FAO 2010). Mexico has approximately 2,000 of the more than 20,000 leguminous species of the world (Sotelo 1981, Souza and Delgado 1993). Leguminous seeds are impor-

tant protein sources, some essential amino acids, minerals, vitamins, essential fatty acids and fiber (Liu 1997, Sabuola *et al.* 2012). Many legumes have protein content between 20-40 %, or up to 60 % (Lawal and Adebawale 2006). The amino acid profile in legume seeds is normally high in lysine and low in tryptophan and sulfur amino acids. Hence, they need to be used in combination with cereals, or supplemented with free methionine, to prevent developing

sulfur-containing amino acid deficiencies (Yi *et al.* 2010).

Enterolobium cyclocarpum (Jacq.) Griseb. (Leguminosae), known in western Mexico as parota, has been deemed one of the most important legume species in tropical America, as a reserve and potential source of proteins. Leaves and pods have been reported to provide good forage for cattle while pods and seeds are known to be used locally for human consumption (Sotelo 1981, Castro *et al.* 2006). In some rural areas in Mexico where parota trees grow, people sometimes eat roasted seeds and mixed in soups when still green (Bressani and Elias 1980).

It is a long-lived tree, 20 to 30 m tall, with trunks up to 3 m in diameter and foliage kept most of the year. Dark-bright ovoid seeds (10 to 15) are contained in ear-shaped pods (Pennington and Sarukhan 1968), with yield of about 86 kg of pods per tree, containing 15.6 % crude protein (Andrade *et al.* 2008). In a previous publication (Serratos *et al.* 2008) claim that *E. cyclocarpum* seeds had 26.3 % of crude protein (CP), 2.8 % of ether extracts (EE), and 63.1 % of nitrogen free extractives (NFE).

This plant is now present in some other tropical regions in the world and has been the subject of many studies. The wood is employed in housing, furniture, cabinet making and other carpentry applications (Rocha and Lobo 1996).

Enterolobium cyclocarpum, although originally from the Americas, is currently distributed throughout the tropics (deciduous, subdeciduous, evergreen and subevergreen flora) and grows in an approximate area of 29 million hectares worldwide (FAO 2010). In Mexico *E. cyclocarpum* trees are part of the native flora and are distributed along the Gulf of Mexico coastal area and in the Pacific Coast along streams and rivers (Vázquez-Yanes *et al.* 1999, Pennington and Sarukhan 2005), preferably at altitudes of 0-800 meters above sea level (m a.s.l.). It grows best in sandy, sandy-clay and black soils (Vázquez-Yanes *et al.* 1999). In the State of Jalisco, located in central-western Mexico, chosen in this study as the collection area, this species is mainly located in lowland tropical areas, with well differentiated dry and rainy seasons (Aw climate), mostly within the Pacific Ocean watershed (Rzedowski 1991, INE 1994). *Enterolobium cyclocarpum* is also located at higher altitudes, in the center of Jalisco, in fragmented relicts along the foothills of the Sierra Madre Occidental and the Trans-Mexican Volcanic Belt, under more temperate climatic conditions (Sedeur 2010). There is little information on the agronomical characteristics, chemical composition and toxicity of some wild species in Mexico, such as *E. cyclocarpum*, which could be an alternative for substituting import conventional forage. Also, the environment (altitude, temperature, relative humidity, etc.) of different locations plays an important role in determining the quality and quantity of proteins in seeds, it may be relatively more important than how plants are agriculturally grown (Dodd and Pushpamma 1980). The nutritional properties of seeds of this species under study would be different under diverse ecosystems in western Mexico. The

information obtained from this study is expected to improve knowledge on the variability in the chemical composition as well as nutritional and digestibility properties of seeds of this species, in relation to its habitat. This also could be used to increase the information on this legume as an alternative source for the enrichment of foodstuffs with proteins and/or amino acids. Although in this work *E. cyclocarpum* is considered as an alternative for forage, it is important to consider that both pods and seeds have been used for human consumption in certain areas of Mexico since antiquity. Thus, the aim of this study was to assess the nutritional properties of *E. cyclocarpum* mature seeds, originated from native habitat sites with different climatic and soil conditions in the State of Jalisco.

METHODS

Collection sites. Mature seeds of *E. cyclocarpum* were collected, all within the State of Jalisco, in A) four tropical zones: (1) Puerto Vallarta (in the site known as Valle de Banderas), (2) Tomatlán (in the site known as Llano Grande-los Lindos), (3) La Huerta and (4) Autlán; B) one temperate central location: Amatitán (Achío Canyon) (figure 1). The type of vegetation, physiographic and ecological data were duly recorded.

Ecological characteristics of collecting sites. The most common ecosystem (table 1) was semi-deciduous tropical forest (STF), and subperenifolia (semi-evergreen tropical forest) distributed in thickets.

The climate of this area was Aw, tropical with marked wet and dry seasons. Soils were in general sandy-loam and clay loam (table 2). Physiography and ecological conditions of each collection site is described below.

- Puerto Vallarta. Specimens grew preferably on ground level where sandy-loam soils were deep as in Valle de Banderas (140 m a.s.l.). In this place, parota was abundant and coexisted with other species such as *Brosimum alicastrum* Sw, *Ficus* sp., *Orbignya cohune* (Mart.), *Bursera simaruba* (L.) Sarg. and *Acacia* sp.
- La Huerta. The collection site is in the valley La Huerta-Purificación on nonagricultural areas, *E. cyclocarpum* occupied protected sites along seasonal streams, on sandy loam soils. It grew frequently in conjunction to *Hymenaea courbaril* Linneaus and *Pithecellobium dulce* (Roxb.) Benth., *Ficus* sp. and *Cordia elaeagnoides* A. DC. This site was higher in altitude (300 m a.s.l.) than Valle de Banderas in Puerto Vallarta.
- Tomatlán. A collection of samples was done in the location known as Llano Grande-los Lindos with a hilly physiography, sandy loam soils. *Enterolobium cyclocarpum* was abundant, with trunk diameters between 30 and 40 cm and coexisted with *Sabal pumos* (Kunth) Burret, *Ficus* sp., *Castilla elastica* sp., *Pseudobombax ellipticum* (Kunth) Dugand, *Hura polyandra* Baill., *Spondias mombin* L., *Bursera* sp. and *Acacia* sp.
- Autlán. This was the highest collection site of the tro-

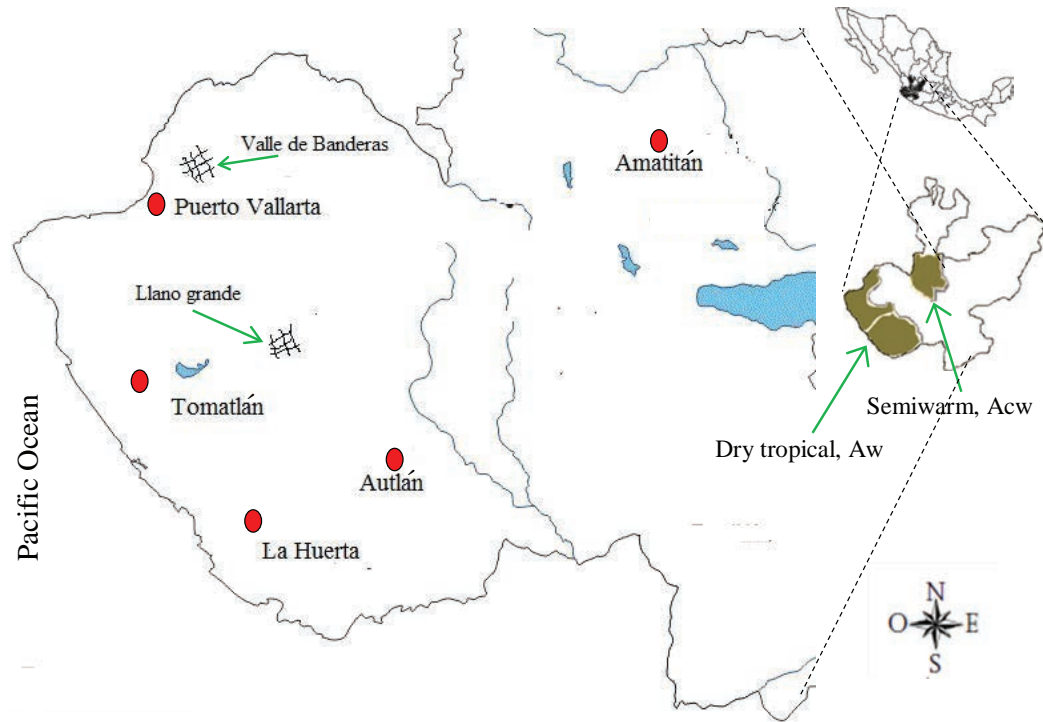


Figure 1. Collection sites. The map shows the geographical region in which the seeds of *E. cyclocarpum* were collected. Red dots show the capital cities of different regions, near collection sites.

Sitios de colecta. En el mapa se muestra la región geográfica en la que fueron colectadas las semillas de *E. cyclocarpum*. Los puntos rojos indican las capitales políticas de las diferentes regiones, cercanas a los sitios de recolección.

Table 1. Environmental and geographical characteristics of the collection sites.

Características ambientales y geográficas de los sitios de colecta.

Site	Elevation (m a.s.l.)	North latitude	Length West	Pluviometry ¹ (mm year ⁻¹)	Temperature ¹ (°C)	Weather	Vegetation type
Puerto Vallarta†	140	20° 27′	104° 55′	892.2	26.9	Aw	SELF
Tomatlán†	450	19° 56′	105° 14′	803.5	26.3	Aw	STF
Autlán†	900	19° 34′	104° 07′	689.3	22.9	ACw	STF
La Huerta†	300	19° 20′	104° 31′	908.4	27.0	Aw	STF
Amatitán *	1,200	20° 42′	103° 37′	853.6	22.2	ACw	STF (relict)

†Dry tropical region. *Semiwarm central zone. m a.s.l., meters above sea level. ¹Average 1985-2010 (Ruiz *et al.* 2012).

Aw; tropical wet and dry; ACw; semi-warm (García 1973). STF; semi-deciduous tropical forest; SELF; Semi-evergreen lowland forest.

pical zone at 900 m a.s.l. Its physiography was relatively constant, with flatland surrounded by mountains of considerable altitude. Autlán had a deep loam soil, good for agriculture, only few areas remain with the original flora. *E. cyclocarpum* grew on the alluvial plains and along seasonal streams as well as some agricultural lands. Parota cohabited with *Ipomoea intrapilosa* Rose, *Eucalyptus camandulensis* Dehnh, *Bursera* sp., *Lysiloma acapulcensis* (Kunth) Benth., *Prosopis lea-*

vigata (Humb. *et* Bonpl. ex Willd) and *Pithecellobium* sp. as the most salient specimens of the local flora.

- Amatitán. Situated at 1,200 m a.s.l., was the only collection zone outside the tropics; it is located in central Jalisco. This site presents relics of an old tropical forest, now modified by agricultural activities. In the Achío Canyon microclimate, *E. cyclocarpum* grew coexisting with *Ficus cotinifolia* Kunth, *Annona* sp., *Pithecellobium* sp. and *Bursera* sp.

Sampling. The area for sampling was one hectare for each study site. The taxonomic identification was carried out by analyzing the anatomy of seeds, branches and foliage collected from five randomly determined trees, which were compared with already existent specimens at the Department of Botany Herbarium, University of Guadalajara (IBUG), Mexico. Soils were sampled by taking portions of around 20 g at a depth of 15 cm, in three different zones in the site; subsequently, they were mixed to produce a composite sample, which was afterwards stored in jars. Soil texture was evaluated by the hand texture method (USDA 1999).

Sample preparation. The seeds were manually extracted from the pods, washed in distilled water and dried at 55-60 °C for 48 h. One kg of dried seeds for each site was ground using a mill (Wiley, 60-mesh screen) to flour consistency. Moisture was determined for dry matter estimation. Flour samples were stored in sealed plastic bags, at 5 °C to prevent fungal and microbial contamination, for subsequent analyses. Chemical analyses of the samples were carried out in triplicate (n = 3) and the arithmetic means were expressed on a dry weight basis.

Analytical methods. Proximate composition was determined following the methods of the Association of Official Analytical Chemists (AOAC 1990): moisture, ash, nitrogen, ether extract (EE or fatty compounds), crude fiber (CF) and crude protein (CP) (% N x 6.25). Nitrogen free extract (NFE or total digestible carbohydrates) was calculated by difference:

$$NFE \% (Dry\ basis) = 100 - (CP \% + CF \% + Ash) \quad [1]$$

Using these results, other nutritional qualities were calculated as follows: Total digestible nutrients yield (TDN) for a legume was assessed using the formula:

$$TDN \% = 74.43 + 0.43 CP \% - 0.73 CF \% \quad [2]$$

(Adams *et al.* 1964)

In addition, energy content, by using the formula:

$$\frac{kJME}{100g} = 18 CP + 39 EE + 17 NFE \quad [3]$$

Where,

ME = metabolisable energy (Schoenmaker and Beynen 2001).

Moreover, in order to perform amino acid analyses, samples were hydrolyzed with 6N HCl at 105 °C for 24 h under inert atmosphere; afterwards, the samples were neutralized with 6N NaOH and the solids were separated by filtration (Urribarri *et al.* 2004). Using precolumn derivatization with O-phthalaldehyde (OPA), the amino acid profile analysis was performed by reversed phase (C18 column)

HPLC (Varian) with fluorescence detection. Limiting essential amino acids were determined using as reference the standards established by the World Health Organization/ Food and Agriculture Organization of the United Nations/ United Nations University (WHO 2007). Chemical score measures the ratio among amino acids and the pattern of reference through the following equation:

$$\begin{aligned} &\text{Essential amino acids chemical score} \\ &= \frac{\text{g of amino acids in sample}}{\text{g of amino acids in pattern (WHO)}} \times 100 \quad [4] \end{aligned}$$

Protein efficiency ratio (PER) and dry matter digestibility *in vivo* (DMD) were assayed according to AOAC (1990) methodology. Twenty male Wistar rats (28 days old) were used, placed individually in separate cages. Five lots, of four animals each, were fed during four weeks with a balanced diet that included the flour of *E. cyclocarpum* seeds from each collection site, to achieve a level of 10 % of protein content in the feed preparation; casein was used as the protein source for the control (Ruiz and Sotelo 2001). The diets were regulated to have the same protein content. Food and water were offered *ad libitum*. Intake degree and body weight were recorded every two days, during 28 days.

Mineral composition analyses in soils and seeds were carried out by atomic absorption spectrophotometry (AAS) using a Perkin-Elmer spectrophotometer, model 2280. The content of macrominerals (calcium, magnesium, nitrogen (Kjeldahl method), phosphorus, potassium and sodium) and microminerals (copper, zinc) (Perkin Elmer 1996) was determined.

Statistics. The statistical design used for the chemical composition analyses was completely randomized, with the nutrimental parameters of seeds of each site as response variables. Data were analyzed using common descriptive statistics determining the mean and the standard deviation.

RESULTS

Minerals and characteristics of soils. All sites (table 2) exhibited sandy and clay loam soils with a pH slightly acidic or neutral.

Autlán soil presented the highest content in soil organic carbon (SOC) with 5.09 %; soil organic matter, 2.95 %; and phosphorus 0.09 %. Tomatlán soil composition showed the second highest content of soil organic carbon (4.96 %) and the highest content of nitrogen (0.34 %), as well as a high content of soil organic matter (2.84 %). In contrast, Puerto Vallarta possessed the lowest content of soil organic carbon (1.11 %), soil organic matter (0.64 %), nitrogen (0.04 %), potassium (0.07 %) and phosphorus (0.01 %). This zone showed the highest content of magnesium (0.47 %).

Minerals in seeds. Regarding nutrient and mineral content in seeds (table 3), samples from the Autlán site presented the highest mineral content (minerals mean = 0.89 %); minerals such as nitrogen (2.91 %), magnesium (0.32 %) and phosphorus (0.37 %). These relatively high nitrogen and mineral contents in seeds could be attributed to some

factors such as soil quality (morphology, chemistry, acidity) and the moderate climatic conditions of the transition forests of this region. In contrast, Puerto Vallarta seeds showed the lowest value of nitrogen (2.07 %) and phosphorus (0.25 %), although they presented the highest content of calcium (1.71 %).

Table 2. Minerals in soil and soil texture of collection sites of *Enterolobium cyclocarpum*.

Minerales en suelo y textura de suelo de los sitios de colecta de *E. cyclocarpum*.

Site	Texture and minerals (mg 100 ⁻¹ g ⁻¹)								
	Soil	pH	SOC	SOM	Ca	Mg	K	N	P
Tomatlán	SL	6.3	4.96 ± 0.74	2.84 ± 0.62	0.30 ± 0.12	0.33 ± 0.12	0.15 ± 0.06	0.34 ± 0.17	0.03 ± 0.02
P Vallarta	SL	7.9	1.11 ± 0.16	0.64 ± 0.31	0.39 ± 0.21	0.47 ± 0.08	0.07 ± 0.05	0.04 ± 0.04	0.01 ± 0.01
Autlán	CL	6.2	5.09 ± 0.11	2.95 ± 0.70	0.57 ± 0.31	0.27 ± 0.15	0.38 ± 0.20	0.24 ± 0.13	0.09 ± 0.08
La Huerta	SL	6.7	2.73 ± 0.68	1.58 ± 0.62	0.67 ± 0.33	0.20 ± 0.16	0.25 ± 0.11	0.18 ± 0.15	0.01 ± 0.01
Amatitán	L	6.7	4.35 ± 0.46	2.50 ± 0.44	0.47 ± 0.30	0.27 ± 0.14	0.73 ± 0.28	0.22 ± 0.13	0.01 ± 0.01

SOC, soil organic carbon; SOM, soil organic material; N, nitrogen; Ca, calcium; K, potassium; P, phosphorus. SL, Sandy-Loam. CL, Clay-Loam. L, Loam.

Table 3. Chemical composition (dry matter basis), energy and mineral content of *Enterolobium cyclocarpum* mature seeds from collection sites.

Composición bromatológica (base seca), energía y contenido de minerales de semillas maduras de *E. cyclocarpum* de los diferentes sitios de colecta.

Nutrient (%)	Collection site ($\bar{x} \pm sd$)				
	Tomatlán	Puerto Vallarta	Autlán	La Huerta	Amatitán
Moisture	9.05 ± 0.59	13.16 ± 0.29	10.0 ± 0.62	9.82 ± 0.65	11.35 ± 0.05
Dry matter	90.95	86.84	90.0	90.18	88.65
Crude protein (Nx6.25)	23.46 ± 0.52	20.93 ± 0.89	30.34 ± 0.75	22.11 ± 0.7	19.56 ± 0.58
Ether extract	1.42 ± 0.51	1.93 ± 0.11	3.22 ± 0.30	1.66 ± 0.55	1.98 ± 0.47
Crude fiber	14.19 ± 0.61	14.55 ± 0.59	13.50 ± 0.60	8.52 ± 0.45	8.14 ± 0.67
Ash	4.0 ± 0.53	3.5 ± 0.43	4.0 ± 0.65	3.8 ± 0.70	4.6 ± 0.61
NFE	56.93 ± 0.92	59.09 ± 2.00	48.94 ± 1.68	63.91 ± 2.09	65.72 ± 1.89
ME	1445.47 ± 10.8	1456.5 ± 13.7	1503.68 ± 24.1	1549.2 ± 6.62	1546.5 ± 16.9
TDN	72.28 ± 0.98	71.17 ± 0.17	75.20 ± 0.22	75.95 ± 0.15	75.34 ± 0.43
DMD	62.1 ± 2.31	54.3 ± 0.53	62.1 ± 0.78	61.1 ± 0.82	58.2 ± 0.69
PER	1.5 ± 0.48	1.2 ± 0.52	1.5 ± 0.46	1.0 ± 0.28	1.1 ± 0.72
Minerals:					
Nitrogen	2.21 ± 0.71	2.07 ± 0.56	2.91 ± 0.80	2.53 ± 0.40	2.49 ± 0.49
Calcium	1.59 ± 0.36	1.71 ± 0.55	1.58 ± 0.52	1.62 ± 0.54	1.12 ± 0.17
Potassium	0.82 ± 0.07	0.79 ± 0.44	0.77 ± 0.70	0.79 ± 0.39	0.81 ± 0.10
Magnesium	0.32 ± 0.03	0.32 ± 0.06	0.32 ± 0.06	0.32 ± 0.09	0.28 ± 0.10
Sodium	0.19 ± 0.02	0.19 ± 0.11	0.12 ± 0.07	0.09 ± 0.07	0.12 ± 0.07
Phosphorus	0.28 ± 0.02	0.25 ± 0.05	0.37 ± 0.07	0.35 ± 0.05	0.32 ± 0.06
Copper	0.05 ± 0.02	0.17 ± 0.13	0.16 ± 0.07	0.02 ± 0.01	0.26 ± 0.06
(minerals mean)	0.78	0.78	0.89	0.82	0.77

Average of triplicate analyses. sd, standard deviation; NFE, N-free extracts; ME, metabolisable energy (kJ 100⁻¹g⁻¹); TDN, Total digestible nutrients; DMD, dry matter digestibility *in vivo* (degradability of dry matter); PER, protein efficiency ratio (casein control value, 2.4).

Seed proximate composition and digestibility. Results obtained in the proximate chemical composition (table 3) showed that, in the case of crude protein (CP), the extreme values observed are between 19.56 % and 30.34 % from Amatitán and Autlán sites, respectively. The highest content of crude fiber (CF) (14.55%) belonged to seeds from Puerto Vallarta, whereas the lowest contents were from Amatitán (8.14%) and La Huerta (8.52 %). The highest nitrogen free extract (carbohydrates) contents were found in samples from Amatitán (65.72 %) and La Huerta (63.91 %). In contrast, samples of Autlán showed the lowest value of this parameter with 48.94 %. Ether extract (EE) content (3.22 %) of seeds from Autlán was the highest of all collection locations, while seeds from Tomatlán showed the lowest content (1.42 %). Total digestible nutrients (TDN), equation [2], and metabolisable energy (ME), equation [3], values involve the content of crude protein, ether extract and nitrogen free extract. The highest values of total digestible nutrients (75.95 % and 75.34 %) and metabolisable energy (1549.2 kJ 100⁻¹ g⁻¹ and 1546.5 kJ 100⁻¹ g⁻¹) were observed in seeds from la Huerta and Amatitán, respectively. These high relative metabolisable energy values in samples of La Huerta and Amatitán were due to the high content of nitrogen free extract (63.91 % and 65.72 %), notwithstanding these samples did not show the best values in crude protein and ether extract. Seeds from Autlán and Tomatlán

showed the best digestibility properties, *i.e.* protein efficiency ratio 1.5 % and dry matter digestibility 62.1 %.

Amino acids found in *E. cyclocarpum* seeds (table 4), are expressed in grams of amino acid per 100 grams of protein.

The amino acids (mean) of the collection sites were close or above the values established by the Food and Agricultura Organization (WHO 2007). Aspartic acid had the highest mean value (9.77 g 100⁻¹ g⁻¹) followed by leucine (7.84 g 100⁻¹ g⁻¹, chemical score of 124.4 %) and arginine (7.38 g 100⁻¹ g⁻¹). Likewise, the lowest mean values corresponded to the aromatic amino acid phenylalanine with 4.08 g 100⁻¹ g⁻¹ and chemical score of 88.7 (4.6 % pattern, WHO 2007) and the sulfur amino acid methionine with 2.35 g 100⁻¹ g⁻¹, 90.7 chemical score (2.6 % pattern, WHO 2007), therefore these amino acids constituted the limiting in seeds from almost all locations. This is to be expected for a legume. Another important result was the mean by collection sites. Samples from La Huerta showed the highest average with 6.17 g 100⁻¹ g⁻¹, followed by Autlán with 5.36 g 100⁻¹ g⁻¹, and Tomatlán was the lowest with 4.82 g 100⁻¹ g⁻¹. Seeds from La Huerta showed the highest content of any amino acid, aspartic acid (11.77 g 100⁻¹ g⁻¹), and methionine from Tomatlán was de lowest with 1.75 g 100⁻¹ g⁻¹ (chemical score 67.3 %). When compared to soybeans (Salunkhe *et al.* 1992), samples of *E. cyclocarpum* showed higher values in methionine, tyrosine, lysine, histidine, alanine, glycine,

Table 4. Amino acids from *Enterolobium cyclocarpum* mature seeds from different collection sites referenced to the Food and Agricultural Organization standard (WHO 2007) (g 100⁻¹ g⁻¹) and soybean.

Aminoácidos de semillas maduras de *E. cyclocarpum* de los diferentes sitios de colecta, referidos a los estándares de la Organización para la alimentación y la agricultura FAO/WHO/UNU (g 100⁻¹ g⁻¹) y a la soya.

Amino acid	Collection site ($\bar{x} \pm sd$)					Amino acids (mean)	FAO (2007)	Soybean (Salunkhe <i>et al.</i> 1992)
	Tomatlán	Puerto Vallarta	Autlán	La Huerta	Amatitán			
Tyrosine	4.82 ± 0.09	5.38 ± 0.41	5.24 ± 0.32	6.06 ± 0.19	4.57 ± 0.19	5.21	4.6	3.8
Phenylalanine ^(*)	3.69 ± 0.02	4.27 ± 0.38	4.35 ± 0.14	4.54 ± 0.22	3.54 ± 0.11	4.08	4.6	5.0
Isoleucine	3.65 ± 0.03	4.11 ± 0.64	4.61 ± 0.22	4.75 ± 0.11	3.53 ± 0.04	4.13	3.1	4.6
Leucine	7.16 ± 0.09	8.53 ± 0.49	8.05 ± 0.25	8.61 ± 0.25	6.83 ± 0.43	7.84	6.3	7.8
Lysine	7.13 ± 0.23	8.06 ± 0.77	7.02 ± 0.65	7.66 ± 2.43	5.90 ± 4.14	7.15	5.2	6.4
Methionine ^(*)	1.75 ± 0.07	1.77 ± 0.46	1.85 ± 0.30	2.20 ± 0.15	4.18 ± 4.89	2.35	2.6	1.1
Threonine	3.67 ± 0.19	3.22 ± 1.59	3.15 ± 1.31	5.02 ± 0.24	3.93 ± 0.49	3.80	2.7	3.9
Valine	3.93 ± 0.04	4.24 ± 0.90	4.72 ± 0.38	4.94 ± 0.12	3.82 ± 0.11	4.33	4.2	4.6
Aspartic acid	8.70 ± 0.15	9.46 ± 1.46	10.05 ± 0.9	11.77 ± 0.2	8.86 ± 0.56	9.77	---	---
Alanine	3.99 ± 0.03	4.79 ± 0.19	4.57 ± 0.55	5.47 ± 0.23	4.31 ± 0.23	4.63	---	4.3
Arginine	6.92 ± 0.21	7.43 ± 0.47	7.76 ± 0.43	8.61 ± 0.11	6.17 ± 0.20	7.38	---	7.3
Glycine	4.10 ± 0.19	4.10 ± 1.04	4.17 ± 0.81	5.63 ± 0.6	4.51 ± 0.32	4.50	---	4.3
Histidine	3.41 ± 0.59	3.93 ± 1.56	4.54 ± 0.53	4.26 ± 0.16	3.32 ± 0.43	3.89	1.8	2.6
Serine	4.57 ± 0.15	5.50 ± 0.34	4.93 ± 0.97	6.81 ± 0.94	5.94 ± 1.01	5.55	---	5.5
(mean)	4.82	5.34	5.36	6.17	4.96	---	---	---

^(*)Limiting amino acid.

lesser values in isoleucine, phenylalanine, threonine and valine, and similar values in leucine, arginine and serine.

DISCUSSION

Protein content found in the seeds of *E. cyclocarpum* is similar to those reported for the other common legumes such as bean (*Phaseolus vulgaris* L.) at 20.12 % (Ibrahim *et al.* 2012), chick-pea (*Cicer arietinum* L.) with 26.2 %, and green pea (*Pisum sativum* L.) with 21.3 % (Conklin-Brittain *et al.* 1999); compare favorably to cereals such as maize (*Zea mays* L.) with 7.6-10.2 % (Zárate *et al.* 2004), and sorghum (*Sorghum vulgare* L.) with 6 to 19.6 % (Brestenský *et al.* 2012); however they are lower than the 40 % of protein content in soybean (Solano *et al.* 2012). Crude fiber, carbohydrates, ether extract and some minerals are also favorable. These parameters should be viewed from a holistic view. Carbohydrates (NFE) results are similar to those found in other legumes such as common bean with 60-65 % (Sabuola *et al.* 2012). Carbohydrate fibers provide bulk character in food and are resistant to hydrolysis by enzymes, contributing also to absorption of water in the digestive tract (Sabuola *et al.* 2012). The ether extract values shown by *E. cyclocarpum* are similar to those shown by other legumes such as soybean meal (1.9 %) (Rodrigues *et al.* 2014) or faba bean (0.94 %) (Güzel and Sayar 2012). Lipids are an important source of energy and essential fatty acids (linoleic and linolenic acids), highly digestible by animals. They contain 2.25 times the energy found in carbohydrates (Ball *et al.* 2001). Total digestible nutrients values are higher than those reported for beans (61.13 to 65.43 %) (Abd El-Salam *et al.* 2013). Likewise, metabolisable energy values for *E. cyclocarpum* seeds are higher than those reported in conventional crops such as beans and peas (1318-1394 kJ 100⁻¹ g⁻¹) (Vadivel and Janardharan 2005), and higher than in soybean (1201.9 kJ 100⁻¹ g⁻¹) (Dourado *et al.* 2009).

Regarding collection sites, *E. cyclocarpum* seeds from Autlán and Tomatlán show the best nutritional properties. Thus, seeds from Autlán show the highest content in crude protein, ether extract, histidine, nitrogen and phosphorus; while seeds from Tomatlán exhibit the highest potassium and sodium content, and the second largest crude protein content. Furthermore, seeds from Autlán and Tomatlán also show the best digestibility (dry matter digestibility) properties. This could be explained by their high crude protein and ether extract values when contrasted with seeds from other collection sites. In contrast, although seeds from La Huerta and Amatitán show the highest total digestible nutrients and metabolisable energy values, seeds from Autlán and Tomatlán outdo them in the dry matter digestibility test. In addition, the soil of Autlán shows the highest content of soil organic matter, soil organic carbon and phosphorus, while in contrast Puerto Vallarta, La Huerta and Amatitán are the sites with the lowest soil characteristics in the above parameters. High content of soil organic mat-

ter (humus) is an important factor on the fertility and productivity of ecosystems because it is involved in the biological, chemical, and physical processes of the soil, such as water infiltration, water holding capacity, aeration and promotion of root growth that these trees require in order to support their large volume of biomass (Croswell and Lefroy 2001). Nitrogen as soil supply generally increases foliage protein content and can increase forage palatability (Rivera and Parish 2010). Phosphorus, potassium, and some other nutrients in soils that increase biomass yield, may slightly reduce its quality, due to promotion of rapid growth (Ball *et al.* 2001).

CONCLUSIONS

A direct comparison among samples and their relation with environmental, geographical and edaphic conditions allows observing a clear difference in the nutrimental parameters of the seeds from different sites.

Seeds collected from the locations near Autlán and Tomatlán show the best nutrimental characteristics. Soil quality, soil organic matter, soil organic carbon, water availability, mineral content and ecological conditions at these sites could have been favorable factors to account for their good nutritional content.

Environment of tropical zones, warm and dry, together with the other factors listed above, would contribute significantly to the nutritional values found in *E. cyclocarpum* seeds, confirming it as an alternative source of feed and food, inasmuch as these seeds possess comparable content of crude protein to other well-known edible legumes such as the common bean, the chick-pea and the green pea. Although lower than the protein content of soybean, parota seeds have a similar amino acid profile, with somewhat better content in lysine and methionine, including other amino acids.

It is interesting to observe that although semi-evergreen jungle-like lush vegetation characterizes Puerto Vallarta site, the nutritional properties of the seeds are not the best, probably due to, among other factors, unfavorable soil properties.

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