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Agribusiness potential of castor oil plant (*Ricinus communis* L.) in Mexico

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ABSTRACT

Objective: To describe the agribusiness potential of the castor oil plant in Mexico through the collection and analysis of agricultural, industrial and commercial information that allows decision making for the formulation of future productive projects to generate economic, social and technological impacts.

Design/Methodology/Approach: The study is descriptive with a transactional design. The information was collected on national and international agrifood statistical and documentary information platforms.

Results: Different attempts have been made in Mexico in commercial and research projects related to the cultivation, production and transformation of castor oil, with results that are not very encouraging due to the lack of knowledge about productive, technological and commercial processes. However, on the other hand, the need for the industrial sector to import oil to produce high-value products is evident.

Study Limitations/Implications: Isolated efforts have been made by each of the actors in the castor oil agribusiness, which has prevented the sector's consolidation.

Findings/Conclusions: An intelligent management of agricultural production must be implemented through the establishment of commercial crops with the adoption of basic technological packages applied to each region in particular, with great attention to the availability of planting seed, which should have agronomic potential, use of nutrition and management of pests and diseases, as well as to foresee all the cultural tasks of maintenance of the crop and harvesting modality that guarantee yield in the field and quality raw material. Currently, there is a deficit in the castor oil market in the country, which leads to high business prospects and business opportunities.

Keywords: Agroindustry, international trade, import substitution, productive projects, added value.

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INTRODUCTION

The castor oil plant (*Ricinus communis* L.) is an inedible crop. Its agricultural production is exploited predominantly in arid and semi-arid regions of the world (Kallamadi *et al.*, 2015) a non-edible oilseed crop of the tropics assumes commercial importance due to its great utilization value in industry, medicine and agriculture. The present investigation has been

Image by Alejandro Sánchez

undertaken to assess the extent of genetic diversity in 31 accessions of castor representing seven geographic areas in the world using RAPD (random amplified polymorphic DNA. The center of origin is quite contested; some authors consider it to be probably native of the region of Ethiopia in Eastern Africa, others from the Northwest and Southwest of Asia, or from the Arabic Peninsula, subcontinent of India and China (Rukhsar *et al.*, 2018). This plant is distributed from sea level up to 2,500 masl (Naik, 2018), and a water requirement between 75 mm and 1.178 mm has been reported, depending on the type of soil, irrigation method and location (Ramanjaneyulu *et al.*, 2013).

This plant is mistakenly considered to be a weed, because of the places where it is seen to grow, although in should actually be considered to be a crop, which requires an adequate agronomic management. The cultivation of castor oil plant should be thought of as a competitive production system, which does not jeopardize food security and does not compete with the lands destined to food production (Navas). The expansion of its cultivation happened primarily due to its ability to adapt to different environmental conditions and the various possibilities of use of its main product, the oil extracted from its seeds (Jachmanian *et al.*, 2009), which has a broad possibility of applications of high value such as being considered as a bioenergetics crop because its oil can be converted into biofuel (biodiesel, bioturbosine) for the automotive or aeronautic sector; for domestic use as a pharmaceutical in the elaboration of different products such as a laxative agent for the digestive system; as well as for shampoo, cream, cosmetics, detergents, medicinal soaps, lubricants, nylon, paper, perfume, plastics, laminates, paints, polyurethane, coating, textiles, dyes, and illumination with torches, among other functions (Mutlu and Meier, 2010; Ogunniyi, 2006; Freire, 2001). The residue from the oil extraction is considered an agroindustrial byproduct that can be used as organic fertilizer or feed for animals (prior elimination or decrease of ricin, a toxin present in the seed); this residue contains approximately 40% of raw protein, although it is deficient in the essential amino acids lysine, methionine and tryptophan (Kole, 2011). Likewise, seeds and leaves are used for the preparation of extracts to control insects, pests, rodents, mollusks and phytopathogens, with successful results (Cuadra, 1981; Upasani *et al.*, 2003; Rodríguez, 2005).

Agribusiness productive projects carried out in Mexico

In Mexico different attempts have been made in commercial and research projects that refer to the cultivation, production and transformation of the castor oil plant, in states like Michoacán, Chiapas and Oaxaca, without any success. This is because of the absence of an established productive chain, the lack of transference of knowledge and technology by the agricultural institutes and/or research centers of the country, the low productivity expressed in the cultivation fields, and the low interest from the government sector in terms of federal subsidies.

According to Fernández-Carpio *et al.* (2012), improved varieties from Brazil were sown in the state of Michoacán, which have adapted with difficulty to the agroecological conditions of the state, presenting in the crops susceptibility to attacks from pests and diseases, and also, low production yield in the field.

For its part, the State Commission on Bioenergetics was created in the state of Chiapas in the year 2006, with the objective of producing biofuels from the castor oil plant and another alternative crop, project that did not have good results due to insufficient planning from the state commission in terms of scientific research, technical information, specialized consultancy, and almost null information that producers received on the agronomic management of the plantations (Valero-Padilla *et al.*, 2011).

Meanwhile, in the state of Oaxaca, there are various castor oil extraction plants that are functioning, one of which dates from the year 1935; that is where they elaborated the ricin oil for the use of illumination in lamps for the households, pharmaceutical use, and even as purgative. The agricultural production of the grain has been decreased, although the base price in the production plant is around ten thousand pesos per ton (El Universal, 2018). For their part, Rodríguez Hernández *et al.* (2013) performed a study of the competitiveness of the castor oil plant compared to traditional crops such as corn and bean in the region of Valles Centrales in Oaxaca, place where the castor oil crops are established; in their research, the authors deduce that according to the results, agricultural producers require technological changes during the cultivation, such as use of improved seeds, application of soil fertilization, harvest and postharvest technology, factors that could impact the increase in yield per area sown; also, to make the prices per ton more attractive.

This is why the need to describe the agribusiness potential of the castor oil plant in Mexico becomes clear, through the collection and analysis of agricultural, industrial and commercial information, to allow decision making for the formulation of future productive projects that generate economic, social and technological impacts.

MATERIALS AND METHODS

A descriptive type study with trans-sectional design was suggested for the information analysis. The statistical data on the castor oil plant in Mexico and the world was obtained from sources of information such as the informatics program called Agrifood Consultation Information System (*Sistema de Información Agroalimentaria de Consulta*, SIACON), as well as international archives such as Trade Statistics for International Business Development (https://www.trademap.org/) and the Food and Agriculture Organization of the United Nations (http://www.fao.org/statistics/es/).

RESULTS AND DISCUSSION

National context

The incipient development of this crop present in the country opens a great opportunity to conduct research that generates technological innovations, in the different stages of cultivation, sowing, development, harvest and post-harvest, because many of the innovations generated do not reach agro-industrial producers, since the process of transference of innovation is deficient in space and time, and it does not achieve the consolidation of the full use of knowledge and technology.

Ecosystem of the castor oil agribusinesses in Mexico

The Higher Education Institutions and Research Institutions have developed various scientific, technological and innovation projects with the interest of generating information and analyzing the agro-industrial potential of the castor oil plant. The research group that belongs to the Universidad Autónoma de Querétaro and Colegio de Postgraduados Campus San Luis Potosí, has coordinated research studies for the quantification of nutraceutical and chemical properties in castor oil plant leaves (Vasco *et al.*, 2021), the evaluation of morphology and phenology (García-Herrera *et al.*, 2019), growth, development and field yield of wild materials (García-Herrera *et al.*, 2019a), the physicochemical characterization of seeds and oils (Vasco *et al.*, 2018; Isaza *et al.*, 2018; Mosquera *et al.*, 2016; Perdomo *et al.*, 2013), in addition to establishing castor oil crops from research and demonstrative platforms for the transference of knowledge and technology to the productive sector. Likewise, there are different government agencies in charge of formulating public policies and sectorial strategies that have attempted to stimulate the agroindustry of the castor oil plant through different plans and programs that support the cultivation and the transformation into oil for industrial use or bioenergetics (DOF, 2018). In this context, the companies that demand oil in the country have shown interest in having raw material of Mexican origin, with the objective of substituting imports and minimizing the dependency on international suppliers, avoiding the exit of foreign currency through such commercial transactions, and fostering the national agricultural production to consolidate this productive chain, in addition to generating employment in the rural zones, among others. However, the results in the production zones have not been encouraging and therefore the import process is the main alternative to satisfy these needs. Finally, there are various companies that supply machinery and equipment, which have found the opportunity for creating, fabricating, importing and transferring the technology necessary to solve the problems of cleaning the fruit, classifying the grain, extraction, refining and transformation of the oil into high value products. Next, Table 1 presents the actors of the agribusiness sector ecosystem of the castor oil plant in Mexico.

Agricultural production in Mexico

According to the information provided by SIACON (2022) and described in Table 2, the surface sown in Mexico between the years 2016 and 2020 shows a decrease of 89% by going from 9,520 to 1,044 hectares; this indicator shows the decreasing trend that is reflected in the production of the castor oil grain. In turn, the yield per hectare had an upwards trend, showing a minimum of 1.41 ton/ha and a maximum of 3.55 ton/ha. For its part, the mean rural price per ton of grain of castor oil plant between the years 2016 and 2020 ranged between 277.94 and 384.63 US dollars, generating production values of the castor oil grain in Mexico between the years 2016 and 2020, from 33 thousand US dollars (2019) to 3.4 million US dollars (2016).

Agricultural production of the castor oil plant per state

According to the results presented in Table 3, the state of Sonora is the state with highest productive interest, since it has the Castor Fields plant which has the objective of

Table 1. Actors of the castor oil plant agribusiness in Mexico

Ciencia, Tecnología e Innovación	Instituciones Federales y/o Estatales	Empresas Demandantes	Empresas que Proveen Maquinaria y Equipos
Universidad Autónoma de Querétaro	Secretaria de Agricultura Desarrollo Rural (SADER)	ASA (Ciudad de México)	REINMAC
Universidad Nacional Autónoma de México	Secretaria de Energía (SENER)	ARTLUX (Querétaro)	DERTEK
Universidad Autónoma Chapingo	Secretaria de Medio Ambiente y Recursos Naturales, (SEMARNAT),	BIOR (Baja California)	GRIMA BIODIESEL
Universidad Autónoma de Nuevo León	Secretaria de Hacienda y Crédito Público (SHCP)	Agracast (Nayarit)	
Universidad Autónoma Agraria Antonio Narro	Secretarias Estatales de Desarrollo y Fomento al Sector Agrícola	Castorfields (Sonora)	
Colegio de Postgraduados	Fideicomisos Instituidos en Relación con la Agricultura (FIRA)	GRIMA BIODIESEL (Puebla)	
Instituto Tecnológico de Perote	Financiera Nacional Rural de Desarrollo Agropecuario, Rural, Forestal y Pesquero (FND)	SOLBEN (Nuevo León)	
Instituto Tecnológico del Roque	AGROASEMEX	DERTEK (Oaxaca)	
Instituto Politécnico Nacional	Servicio Nacional de Inspección y Certificación de Semillas (SNICS)	Industria Torres Barriga (Oaxaca)	
INIFAP Campo experimental: Valles Centrales Bajío Valle del Guadiana Rosario Izapa Valle del Fuerte Norman E. Borlaug	Sistema Nacional de Investigación y Transferencia de Tecnología para el Desarrollo Rural Sustentable (SNITT)	Oleoquímicos de México (Tamaulipas)	
Red Mexicana de Bioenergéticos (REMBIO)	Comisión Nacional del Agua (CONAGUA)	Grupo Neoken (Nuevo León)	
		Egon Meyer (Estado de México)	

Source: Prepared by the authors.

Table 2. Agricultural production of the castor oil crop in Mexico 2016 to 2020.

	2016	2017	2018	2019	2020
Planted area (ha)	9,520	1,888	321.50	304.50	1,044
Harvested area (ha)	6,622	1,768	101.50	33.50	953
Production (ton)	9,321.68	3,478	281.64	119	3,123
Yield (t ha^{-1})	1.41	1.97	2.77	3.55	3.28
Rural price media (US$/t)	367.01	384.63	374.22	277.94	341.35
Production value (US$)	3,421,112.63	1,337,736.43	105,394.06	33,074.66	1,066,021.57

Source: Prepared by the authors with data obtained from SIACON (2022).

Table 3. Statistical data of the agricultural production of castor in States of Mexico.

Year	Mexican state	P.A (ha)	H.A (ha)	P (t)	Y (t ha^{-1})	RPM (US$/t)	P.V (US$)
2020	Baja California	34.69	34.69	60.35	1.74	377.19	22,763.41
	Nayarit	201.68	201.68	817.33	4.05	513.78	419,931.33
	Sonora	756.63	716.63	2,245.43	3.13	277.61	623,363.91
	Tlaxcala	51	0	0	0	0	0
2019	Baja California	9	9	18	2.0	378.45	6,812.03
	Sonora	244.50	24.50	101	4.12	260.03	26,262.66
	Tlaxcala	51	0	0	0	0	0
2018	Baja California	53	53	80.34	1.52	375.93	30,203.01
	Nayarit	20	20	93.60	4.68	501.25	46,917.29
	Sonora	248.50	28.50	107.70	3.78	262.52	28,273.68
2017	Nayarit	340	340	1,196.80	3.52	526.31	629,894.74
	Sonora	1,548	1,428	2,281.20	1.60	310.29	707,841.60
2016	Nayarit	300	300	405	1.35	496.14	200,936.84
	Sinaloa	1,000	1,000	930	0.93	300.75	279,699.25
	Sonora	8,220	5,322	7,986.68	1.50	368.17	2,940,477.19

Note: P.A (Planted area), H.A (Harvested area), P (Production), Y (Yield), RPM (Rural price media) P.V (Production value). Source: Prepared by authors with data obtained from SIACON (2022).

ensuring the supply of castor oil grain to the industrial plant Castor Produkte for its future transformation in ricin oil at competitive prices (Grupo Alego, 2016). Likewise, it shows that the state of Sinaloa went from being a producing state for the year 2016, to lacking representativeness in the four years after. For its part, in the year 2020 the state of Nayarit presented a new drive in the area sown of castor oil crop, with a total of 201.68 ha; it should be highlighted that it is the agricultural productive development with the highest yields per area planted in the country, having as reference the period covered between the year 2016 and 2020, while other states such as Tlaxcala and Baja California have lower proportion of agricultural crops. According to this, the castor oil crop in Mexico has been established primarily in the northwest region of the country in recent years, where industries of great interest in the castor grain and oil have been installed, which are in agreement with the establishment of agricultural crops.

Imports of castor oil in Mexico

Presently, the agribusiness exploitation of this raw material is an urgent need in face of the demand for the national market and low offer of the Mexican agricultural production; therefore, this productive sector has required importing the oil primarily from India with an approximate value of 31 million US dollars, between the years 2016 and 2020 (TRADEMAP, 2022). This evidences a high dependency on the imports of the cited product from this country, which can generate adverse situations in the supply in face of occasional changes in the conditions of the international market, agroclimate problems, and geopolitical events, among others, which can place at risk the offer of raw material for its agribusiness exploitation (Table 4).

Table 4. Importation of castor oil in Mexico (2016-2020)

Countries	2016	2017	2018	2019	2020
	(thousand US$)				
India	5,516	6,179	6,699	6,325	6,461
Germany	106	102	88	24	137
Brazil	77	85	120	30	332
USA	66	296	146	170	45
Spain	287	515	633	498	302
World totals	6,068	7,345	7,728	7,047	7,276

Source: Prepared by authors data obtained from TRADEMAP (2022).

International castor oil market

Production and area harvested in the main producing countries of castor oil plant

According to data from FAO (2021) expressed in Table 5, between the years 2016 and 2019, the largest area of castor oil plant harvested in the world has been concentrated in India, becoming the highest offeror of this product in the international market.

Global imports of castor oil in the world

According to Table 6, with information from TRADEMAP (2022), the statistics of international trade of castor oil identified with the tax fraction 151530, the approximate value of imports trade of castor oil for the year 2020 in the world was 879 million dollars. The largest importer for this tax fraction was China with an import value of 362 million dollars, followed by Germany (88 million USD), United States of America (81 million USD), and France (78 million USD). It should be highlighted that the trend in global imports of the product according to the figures reported is increasing, with the exception of the year 2020, derived from the conditions from the sanitary contingency generated by COVID-19.

Table 5. World's top seed producers/harvested area (2016-2019).

Countries	2016		2017		2018		2019	
	Production (t)	Harvested area (ha)	Production (t)	Harvested area (ha)	Production (t)	Harvested area (ha)	Production (t)	Harvested area (ha)
India	1,376,000	1,037,000	1,568,000	960,000	1,567,560	824,130	1,196,680	751,320
China	40,000	23,000	55,000	30,000	27,000	16,000	36,000	21,000
Mozambique	77,475	202,110	79,944	206,734	82,598	218,521	85,089	224,007
Etiopia	10,000	6,354	9,287	5,759	10,919	6,599	11,157	6,587
Brasil	24,620	44,351	13,481	47,147	14,224	46,075	16,349	50,567
Tailandia	1,100	1,300	1,200	1,300	1,616	1,652	1,588	1,605
Myanmar	12,529	15,108	12,575	15,127	12,886	15,803	13,051	15,881
Paraguay	6,000	6,000	7,000	6,000	7,000	6,000	6,000	6,000
México	9,322	6,622	3,478	1,768	282	102	119	34

Source: Prepared by authors with data obtained from FAO (2021).

Table 6. World imports of castor oil (2016-2021).

Countries	2016	2017	2018	2019	2020	2021
	(thousand US$)					
China	275,026	384,506	388,317	400,242	362,313	-
France	100,102	93,384	108,252	97,022	78,362	124,257
USA	72,577	96,784	98,609	100,167	81,448	145,932
Germany	45,641	91,755	92,457	115,484	88,327	122,961
Netherlands	35,841	48,196	49,331	57,862	45,526	-
Thailand	28,169	35,841	30,781	32,760	24,627	29,343
Italy	20,714	28,915	25,209	27,920	22,237	-
Japan	19,270	25,871	25,384	28,448	19,237	28,369
United Kingdom	11,685	14,601	17,566	18,786	15,436	16,718
Total in the world	733,459	983,119	989,487	1,036,354	879,099	-

Source: Prepared by authors with data obtained from TRADEMAP (2022).

CONCLUSIONS

Mexico has broad agricultural and commercial potential in the agribusiness of the castor grain and oil to supply the industrial sector, which leads to high prospects of business and entrepreneurial opportunities. The agribusiness projects that are undertaken ought to take into account the necessary agronomic management to generate productivity and competitiveness. There should be staff that has knowledge in the management of the castor oil crop or otherwise of oleaginous plants, so that the cultivation cycle can be planned according to specific technological packages for every agroclimate condition, ensuring the supply of improved seed for sowing, establishing calendars for the different phenological stages of the crop and contemplating needs for irrigation and nutrition to guarantee field yield and physicochemical quality in grain and oil.

REFERENCES

Cuadra, V.D. (1981). *Ricinus communis* L. Ariprospectos: Investigación en Química Aplicada (Folleto) Saltillo, Coahuila, México. 4p.

Kole, C. (2011). Wild crop Relatives: Genomic and Breeding Resources: Oliseeds, Springer, London, pp 254. doi: 10.1007/978-3-642-14871-2

DOF (2008). Diario Oficial de la Federación. Ley de Promoción y Desarrollo de los Bioenergéticos. Disponible en: https://www.diputados.gob.mx/LeyesBiblio/pdf/LPDB.pdf

El Universal (2018). La Ultima aceitera que ilumina Oaxaca. Disponible en: http://www.eluniversal.com.mx/Estados/historia-la-ultima-aceitera-que-alumbra-oaxaca

FAOSTAT (2021). Food and Agriculture Organization of the United Nations. Disponible en: http://faostat.fao.org.

Freire, R.M. (2001). *Ricinoquímica. O agronegócio da mamona no Brasil. Brasília*. *In*: Azevedo, D.M.P., de Lima, E.F. (Eds.), Embrapa Informacão Tecnológica: Cap. XIII, 295–335.

Fernández Carpio, V., E. Andrio Enríquez y M. M. Elos. (2012). Aprovechamiento de la higuerilla (*Ricinus communis*) para uso bioenergético en La Biodiversidad en Guanajuato: Estudio de Estado vol. I. México. *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (conabio)/Instituto de Ecología del Estado de Guanajuato* (iee), pp. 234-240.

García-Herrera, E. J., Olivares-Ramírez, A., Amante-Orozco, A., Hernández-Ríos, I., Rossel-Kipping, E. D., Pimentel-López, J., ... & Gómez-González, A. (2019). Evaluación de colectas de higuerilla (*Ricinus communis* L.) del altiplano centro-norte de México. *Agroproductividad, 12*(1), 25-32. doi: 10.32854/agrop.v0i0.1334

García-Herrera, E. J., Cedillo-Martínez, I., Gómez-González, A., Hernández-Ríos, I., Amante-Orozco, A., & Rossel-Kipping, E. D. (2019a). Recolecta, establecimiento y caracterización de semilla de higuerilla (*Ricinus communis* L.) en el altiplano centro-norte de México. *Agroproductividad, 12*(3), 89-97. doi:10.32854/agrop.v0i0.1126

Grupo Alego (2016). *Biofields Renewable & Sustainable*. Disponible en: https://grupoalego.com/resources/files/ReporteSustentabilidad2016web.pdf

Isaza, C., Anaya, K., de Paz, J. Z., Vasco-Leal, J. F., Hernandez-Rios, I., & Mosquera-Artamonov, J.D. (2018). Image analysis and data mining techniques for classification of morphological and color features for seeds of the wild castor oil plant (*Ricinus communis* L.). *Multimedia Tools and Applications, 77* (2), 2593-2610. doi:/10.1007/s11042-017-4438-y

Jachmanian I. Pérez G. E. Villamil J., Villamil J.J. (2009). El cultivo de tártago (*Ricinus communis* L.) en el Uruguay: Información preliminar. Instituto Nacional de Investigación Agropecuaria. Montevideo Uruguay. 20 p.

Kallamadi, P. R., Nadigatla, V. G. R., & Mulpuri, S (2015). Molecular diversity in castor (*Ricinus communis* L.). *Industrial crops and products, 66*, 271-281. doi:10.1016/j.indcrop.2014.12.061

Mosquera-Artamonov, J.D., Vasco-Leal, J.F., Acosta-Osorio, A.A., Hernandez-Rios, I., Ventura-Ramos, E., Gutiérrez- Cortez, E., & Rodríguez-García M.E. (2016). Optimization of castor seed oil extraction process using response surface methodology. *Ingeniería e Investigación, 36*(3), 82-88. doi: 10.15446/ing.investig.v36n3.55632

Mutlu, H. y Meier, M. A. R. (2010). Castor oil as a renewable resource for the chemical industry. *European Journal Lipid Science and Technology. 112*:10–30. doi:10.1002/ejlt.200900138

Naik, S. N., Saxena, D. K., Dole, B. R., & Khare, S. K. (2018). Potential and perspective of castor biorefinery. *In Waste Biorefinery* (pp. 623-656). Doi:10.1016/B978-0-444-63992-9.00021-5

Ogunniyi, D.S., (2006). Castor oil: A vital industrial raw material. *Bioresource Technology, 97*, 1086–1091. doi:10.1016/j.biortech.2005.03.028

Perdomo, F. A., Acosta-Osorio, A. A., Herrera, G., Vasco-Leal, José F., Mosquera-Artamonov, J. D., Millán-Malo, B. & Rodríguez-García, M.E. (2013). Physicochemical characterization of seven Mexican *Ricinus communis* L. seeds & oil contents. *Biomass and Bioenergy. 48*:17-24. doi:10.1016/j.biombioe.2012.10.020

Ramanjaneyulu, A. V., Reddy, A. V., & Madhavi, A (2013). The impact of sowing date and irrigation regime on castor (*Ricinus communis* L.) seed yield, oil quality characteristics and fatty acid composition during post rainy season in South India. *Industrial crops and products, 44*, 25-31. doi:10.1016/j.indcrop.2012.10.008

Rodríguez, H.C. (2005). Plantas contra plagas 2; epazote, hierba de la cucaracha, paraíso, higuerilla y sabadilla. RAP-AL, RAPAM, SOMAS, CP e ITA Tlaxcala. Primera edición. Texcoco, Estado de México. México. 290p.

Rodríguez Hernández, R.Zamarripa Colmenero, A. (2013). Competitividad de la higuerilla (*Ricinus communis*) para biocombustible en relación a los cultivos actuales en el Edo. de Oaxaca, Mex. *Revista Mexicana de Agronegocios, vol. 32*, pp. 306-318

Rukhsar, Patel, M. P., Parmar, D. J., & Kumar, S (2018). Genetic variability, character association and genetic divergence studies in castor (*Ricinus communis* L.). *Annals of Agrarian Science, 16*(2), 143-148. doi:10.1016/j.aasci.2018.02.004

Severino L. S., Dick L. Auld, Marco Baldanzi, Magno J. D. Cândido, Grace Chen, William Crosby, D. Tang, Xiaohua He, P. Lakshmamma, C. Lavanya, Olga L. T. Machado, Thomas Mielke, Máira Milani, Travis D. Miller, J. B. Morris, Stephen. A. Morse, Alejandro A. Navas, Dartanhã J. Soares, Valdinei Sofiatti, Ming L. Wang, Maurício D. Zanotto and Helge Zieler. (2012). A Review on the Challenges for Increased Production of Castor. *Agronomy Journal. Volume 104* (4). doi:10.2134/agronj2011.0210

SIACON (2022). Sistema de Información Agroalimentaria de Consulta (SIACON). Secretaría de Agricultura y Desarrollo Rural (SADER)

TRADEMAP (2021), Estadísticas del comercio para el desarrollo internacional de las empresas. Disponible en: https://www.trademap.org/Index.aspx

Upasani, S.M., Kotkar, H.M., Mendki, P.S y Maheshwari V.L. (2003). Partial characterization and insecticidal properties of *Ricinus communis* L. foliage flavonoids. *Pest Management Science. 59* (12), 1349-1354. doi:10.1002/ps.767

Valero Padilla, J., Cortina Villar, H. S., & Vela Coiffier, M. P. (2011). El proyecto de biocombustibles en Chiapas: experiencias de los productores de piñón (*Jatropha curcas*) en el marco de la crisis rural. *Estudios sociales (Hermosillo, Son.), 19*(38), 119-144.

Vasco-Leal, J. F., Hernández-Ríos, I., Méndez-Gallegos, S. D. J., Ventura-Ramos Jr, E., Cuellar-Núñez, M. L., & Mosquera- Artamonov, J. D. (2017). Relación entre la composición química de la semilla y la calidad de aceite de doce accesiones de *Ricinus communis* L. *Revista Mexicana de Ciencias Agrícolas, 8*(6), 1343-1356. doi:10.29312/remexca.v8i6.299

Vasco-Leal, J.F., Mosquera-Artamonov, J. D, Hernández-Ríos, I., Méndez-Gallegos, S. D. J., Perea-Flores, M.J., Peña-Aguilar, J.M., Rodriguez-García, M.E. (2018). Physicochemical characteristics of seeds from wild and cultivated castor bean plants (*Ricinus communis* L.). *Ingeniería e Investigación, vol. 38* No. 1, (24-30). doi:10.15446/ing.investig.v38n1.63453

Vasco-Leal, J.F., Cuellar-Nuñez, M.L., Luzardo-Ocampo, I., Ventura-Ramos, E., Loarca-Piña, G., & Rodríguez-García, M.E. (2021). Valorization of Mexican *Ricinus communis* L. leaves as a source of minerals and antioxidant compounds. *Waste and Biomass Valorization. 12*(4). 2071-2088. doi: 10.1007/s12649-020-01164-5