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Review

Transformation Processes for Energy Production Alternatives from Different Biomass Sources in the Highlands and Semi-Desert Areas of Mexico

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Abstract: Biomass revalorization is a worldwide trend which can contribute to diversifying the energy sector and to obtaining added value products. The objective of the present review is to discern potential sources of biomass and their corresponding alternatives for transformation, with a particular emphasis on energy generation within the Mexican highlands and semi-desert regions. Methodologically, this review was conducted by reviewing various search engines, identifying articles related to energy production, the transformation processes, and the obtained product, establishing the relevance of each contribution, and including the information that was deemed pertinent. From this information analysis, it was found that most of the studies are conducted at theoretical and laboratory levels; then, scientific knowledge has been generated in this topic. However, low interaction with the social and industrial sectors is observed. It is required to develop strategies to transfer the generated knowledge and to scale up the studied transformation processes to generate ecological, economic, and social benefits. According to the information obtained it can be concluded that the agricultural and forestry sectors in the highlands and semi-desert regions of Mexico hold significant promise for generating bioenergy via the utilization of residual biomass, including stubble, straw, branches, stems, and sawdust. Moreover, the implementation of these sophisticated techniques for the conversion of residual biomass into biofuels and other forms of bioenergy contribute to the improvement of the adverse effects associated with the use of fossil fuels while fostering a more environmentally sustainable economy.

Keywords: biomass waste; residues; biomass conversion; biofuel; calorific value

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1. Introduction

The Sustainable Development Goals defined in the 2030 agenda adopted by all United Nations Member States in 2015 include affordable and clean energy as well as sustainable cities and communities. Circular economy strategies oriented towards integral biomass revalorization is a current trend to achieve these goals throughout the world. In this way, biomass is more and more studied as raw material for the development of added value products, including biofuels and electric and thermal energy. However, the use of biomass is conditioned by its availability, which depends on several factors such as anthropogenic activities and geographic and weather conditions.

In Mexico, these conditions and activities are very different from one region to another, so that the biomass produced in each region is also different and consequently, the transformation strategies are specific according to the country's regions. The highlands and semi-desert zone is a particular case, since it is a large area that covers 18 States of the Mexican territory, with varied geographic conditions and elevation from 1000 to 5700 above sea level. Despite the water scarcity, the agro-industrial sector is an important element of socioeconomic development in the region, from natural or induced plant growth. Some species are processed to obtain specific products, such as fibers, phytochemicals, flavonoids, and others, that are used in applications such as the formulation of fungicides, herbicides, cosmetics, etc. However, the fraction of the plant which is used to obtain commercial products is low. This means the production of large amounts of waste which do not have applications, inducing environmental and health risks.

In the same way, agricultural activities for food production generate large amounts of biomass such as foliage, pruning wastes, and crop residues. Moreover, the use of seeds from different sources in agriculture could promote the presence of weeds and invasive plants. A fraction of that biomass is collected and used for animal feeding and a low portion is left in the soil to retain fertility; the other fraction is either disposed of (usually open air) or burned. In addition, forest wastes, non-timber species, and exotic plants are also considered to obtain added value commodities and energy production.

In several semi-desert areas of Mexico, economic activities are based on the use of non-domesticated plants; that is, raising species is done without implementing cropping systems. Thus, it is required to design strategies to avoid overexploitation and to promote systematic disposal or utilization of wastes generated in the processing of plants [1–3]. For example, in several ejidos (communal lands) of Coahuila, Nuevo León, San Luis Potosí, and Durango, *Agave lechuguilla* is used to obtain ixtle, a fiber used for the manufacture of products with high commercial value. Approximately 15% of the agave leaves corresponds to ixtle; meanwhile, the remaining 85% is a fibrous waste named guishe, which contains several phytochemicals and lignocellulosic material, which could be used to produce biofuels or thermal/electric energy [4]. In addition to *A. lechuguilla*, there are other plant species such as *Prosopis laevigata*, *Dodonaea viscosa*, *Larrea tridentata*, *Euphorbia antisyphilitica*, and others, which are the most used for exploitation; these species represent opportunity areas to develop integral revalorization strategies, including the synthesis of products with high energy value.

Moreover, some plants have been historically used for medicinal purposes [5–7] since they contain specific compounds that help treat headaches, flu, and muscle pains, among other discomforts affecting the human organism. Other species are processed to obtain products such as wax, fibers, food, and biochar [4,8]. In general, for these applications, only a fraction of the plants is considered for generating lignocellulosic wastes, which could be used for energy production. For these reasons, the scientific community's interest in native flora has increased, generating knowledge for its efficient use. However, strategies for transferring this knowledge to promote sustainable utilization of plants and, consequently, to improve the life quality of people are still required.

Biomass represents opportunities for developing whole plant utilization processes, which is a global trend in biorefinery design. The idea is to use all of the raw material, which allows including wastes in the processing schemes, generating benefits at economic and environmental levels. A general scheme for the integral use of biomass resources, including the revalorization of waste, is shown in Figure 1. An example is the tequila or mescal production process, both beverages obtained from agave plants across various states in Mexico. In these processes, the current byproducts generated are agave fibers and vinasse. The emerging products include livestock feed, substrates for plant production, and the production of biofuels in the form of pellets and briquettes.

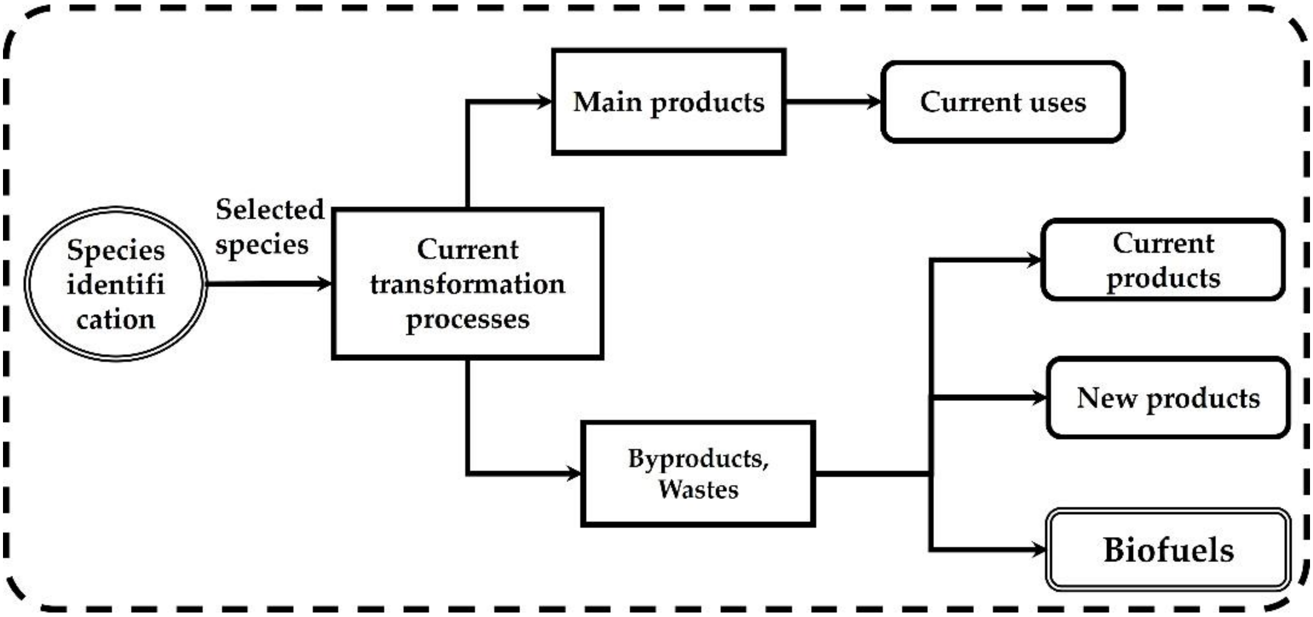

Figure 1. General scheme for the integral transformation of plants.

The main objective of this work was to conduct a comprehensive review of relevant information published in various sources regarding the different biomass resources present in the Mexican highlands and semi-arid areas. The central focus of this review is on exploring viable alternatives for the conversion of these biomass sources, with particular emphasis on energy production. Biofuels include gas, liquid, and solid fuels; this review focused on the solid fuels.

2. Representative Biomass Resources for Energy Production in the Highlands and Semi-Arid Regions of Mexico

2.1. Agro-Industrial Wastes

In Mexico, agriculture and livestock are very important economic activities that generate significant amounts of crop wastes (stubble and straw), which sometimes show difficulties for their management and efficient use in other productive areas. The most important species for agriculture and food are corn (*Zea mays*) and common bean (*Phaseolus vulgaris*), which generate wastes (stubble, straw, corn cob) used preferably as fodder and food mixtures for livestock during the dry season of the year. In the semi-arid highlands (Chihuahua, Zacatecas, Durango, and Coahuila), corn production is estimated at 1.9 million tons per year [9]. The common bean straw reaches a total of 954 thousand tons per year, considering the average area harvested with this plant species, between 2016 and 2020 (954 thousand hectares) and a ton of straw that is generated on average per hectare. In the case of fodder crops, including corn, oats, and sorghum, the entire aerial biomass is used for feeding livestock and is thus transformed into manure.

Another important waste in the north of Mexico is the pecan nutshell (pericarp and endocarp). The pecan nut (*Carya illinoinensis*) is native to North America and can be found from Nebraska and Iowa in the United States to southern Mexico [10]. The industrial production of walnuts began more than a hundred years ago, with the United States harvesting more than 80% of world production [10].

The pecan fruit is a nut containing a kernel enclosed by the shell, including the outer pericarp layer, mesocarp, and a hard inner endocarp. The pericarp and mesocarp are segmented structures in four parts that dehydrate when mature and open, allowing the exit of the endocarp and the seed. The proportion of the mesocarp and endocarp is known as ruezno [11], which is the external part of the nut, which in its development is green and turns brown until it reaches maturity and break (Figure 2). Maturation occurs in the autumn of the same growth season.

(**a**) (**b**) (**c**)

Figure 2. Pecan nuts (**a**) with pericarp, (**b**) without pericarp (with endocarp), (**c**) seeds.

According to the International Nut and Dried Fruit Council Foundation (INC), the world pecan crop in 2019/2020 was estimated at 139,739 tons. This production represents a 5% increase compared to the previous season and doubles the prior 10 years' average. Mexico and the USA led production with very similar shares, 47% and 43%, respectively. South Africa, Australia, and Brazil accounted for the following 10%.

Harvesting and processing of the nut generates a large amount of waste in the form of pericarp and endocarp shells, estimated at 40–50% of the fruit [12,13], which is usually left in the soil of the plantations without any use or is burned, representing an important cause of environmental pollution. According to the Emission Protection Agency (EPA), when 1 ton of agricultural residue is burned on the field, about 1400 kg of CO_2, 58 kg of CO, 11 kg of particulate matter, 4.9 kg of NOx, and 1.2 kg of SO_2 are released in the atmosphere, contributing to global warming, smog formation, increased oxidant levels, acid deposition, and visual impairment [14]. In addition, it also causes nutrient loss and soil degradation [15]. The possibility of using these residues as a substrate for the cultivation and production of plant and fungus species is being explored [16]. However, the main alternative of use implemented for the pecan nutshell is fundamentally focused on its use in energy production.

The previous examples demonstrate that biomass residue not only serves as an important source of biomass but also could provide significant energy values. These residues, often considered agricultural waste, have the potential to be used as fuel for renewable energy generation. Their high organic matter content and ability to release energy when burned make them an attractive option for heat and electricity production. Table 1 summarizes some important energy characteristics of agricultural residues.

Table 1. Basic properties and description of commune species and residues they generated in the Mexican highlands and semi-arid region.

N°	Biomass	Description of Residue Used	Residue Type	Residues Production (t/ha)	Proximate Analysis (%)			Higher Heating Value (MJ/kg)	References
					Ash Content	Volatile Material	Fixed Carbon		
1	Corn cob (a)	The central core or cylindrical part of a corn ear from which the kernels grow	Agroindustrial wastes	0.66–2.41	1.6	78.9	10.8	17.4	[17–20]
2	Corn husks (a)	The outer fibrous layers that surround a corn cob		2.0	2.7	78.6	10.5	17.6	[19,20]
3	Bean straw	The dried stalks or stems of bean plants after the beans have been harvested		1.39	6.8	69.1	24.1	17.6	[21,22]
4	Pecan nutshell	The hard, protective outer covering of a pecan nut		0.25	3.3	66.0	30.8	20.8	[23,24]
5	Pecan nut branches	The woody, elongated branches, twigs, and stems sections of an apple tree that are pruned	Pruning waste	0.99	4.1	19.2	75.7	16.5	[25]
6	Apple branches	The woody, elongated branches, twigs, and stems sections of a pecan tree that are pruned.		3.4	2.5	80.4	16.5	19.7	[24]
7	Quelite cenizo (*Chenopodium album*)	Annual plant with alternate leaves; the upper surface of the leaves is green, while the lower surface may have a whitish or grayish appearance	Weeds and bioenergy crops	8.2 to 9.5	1.5	73.6	19.4	0.015	[26]
8	Chicalote (*Argemone mexicana* and *A. ochroleuca*) (b,c)	This plant is commonly known as Mexican prickly poppy, it is a flowering plant with yellow flowers and spiny leaves.		8.2 to 9.5	4.9	87.8	4.3	0.148 27.39	[27] [28]
9	Mostacilla (*Sisymbrium irio*)	This plant is commonly known as London rocket, it is a plant with small yellow flowers and lobed leaves.		8.2 to 9.5	22.7			16.39	[29]
10	Malva (*Malva parviflora*)	This plant is commonly known as small-flowered mallow, it is a plant with pink or purple flowers and rounded leaves		8.2 to 9.5	7.2			0.019	[30]
11	Fox tail (*Reseda luteola*)	This is commonly known as dyer's rocket or weld, it is a plant with small yellow flowers and lance-shaped leaves.		8.2 to 9.5					[30]
12	Sawdust (*Pine* spp.)	They are fine particles or shavings that are produced from cutting or milling pine wood.	Commercial plantations	0.1 *	0.3	88.3	11.9	18.9	[31]
13	Maralfalfa (*Pennisetum* sp.)	This plant is commonly known as fountain grass, it is a plant with long, slender stalks and feathery plumes that resemble flowing water.		11 to 46	9.7	71.9	18.4	18.2	[32]
14	Bagasse (*Agave durangensis*)	This is the fibrous residue left after extracting juice or pulp from the agave plant.	Bagasse wastes	5.1 to 13.2	10.6	82.3	7.2	14.5	[31]
15	Jarilla (*Dodonaea viscosa*)	This is a shrub with small, leathery leaves and clusters of inconspicuous flowers, native to arid regions and known for its medicinal properties.	Other biomass sources	17.0	0.8	82.0	17.2	21.1	[33,34]
16	Pink grass (*Melinis repens*)			0.7 to 2.9					[35]
17	Buffel grass (*Cenchrus ciliaris*)	This is a perennial grass with dense clumps of tufted leaves and cylindrical seedheads, commonly used for forage in arid and semi-arid regions.		2.1 to 9.5					[36]

Table 1. *Cont.*

N°	Biomass	Description of Residue Used	Residue Type	Residues Production (t/ha)	Proximate Analysis (%)			Higher Heating Value (MJ/kg)	References
					Ash Content	Volatile Material	Fixed Carbon		
18	*Acacia farnesiana* (c)	This tree species is also known as sweet acacia or needle bush, it is a small tree with fragrant yellow flowers and feathery, fern-like leaves.	Firewood	7.35 to 17.4 **	3.6	10.5	84.1	31.6	
19	*Prosopis spp.* (a)	This species is commonly known as smooth mesquite, is a medium-sized tree with thorny branches and green, fern-like foliage.		10.34 to 20.67 **	1.3	6.4	17.3	30.2	[37]
20	*Ebenopsis ebano* (c)	This is also known as Texas ebony; it is a dense, slow-growing tree with dark, heavy wood and small clusters of fragrant, white flowers.		10.98 to 21.96 **	4.1	13.0	79.2	29.7	[38]
21	*Quercus sideroxyla* (a)	This tree is commonly known as Mexican blue oak, it is a medium-sized tree with distinctive blue-gray leaves and rugged bark.		0.1 *	1.0	83.1	16.0	20.4	[32]

(a) Information based on pellets; (b) based on briquettes; (c) based on charcoal. * cubic meter from each sawn log; ** calculated from sawmill industry.

2.2. Pruning Wastes

The formative, selective, thinning, and production pruning are practices carried out during the growth of trees of species used in the cultivation of fruit trees, such as pecan nut (*Carya illinoensis*) and apple (*Malus domestica*), which generate wastes, derived from branches, twigs, and stems (Table 2). The volume generated in this activity would seem minimal at the level of each tree, but when collecting the wastes from one hectare, high amounts of biomass are obtained, which shows different levels of lignification. In addition, pruning and weeding the orchard are necessary activities to avoid sanitary problems and insect infestation. It has been established that annual orchards grown with pecan and apple trees generate a total of 1.5 t/ha of pruning residues [39]. Other studies have established that the volumes of biomass available as a result of pruning reach up to 5.4 tons of dry matter per ha/year [40]. It is necessary to advance studies that allow the precise establishment of biomass production levels derived from pruning in apple and pecan orchards, and other species cultivated in the semi-arid highlands of Mexico. Moreover, the most important utility of biomass obtained in fruit orchards should be established.

In addition to the energy production of pecan and apple residues obtained from pruning, chips and sawdust from wood are used to smoke meat. This is a common practice in gastronomy, particularly for preparing grilled and smoked meats, having low levels of polycyclic aromatic hydrocarbon concentration [41]. These woods are highly valued for their delicate, sweet flavor that adds a distinctive and enjoyable taste to the grilled meat [42]. Table 1 summarizes some important energy characteristics of pruning wastes.

Table 2. Availability of pruning wastes from fruit production in the semi-arid highlands of Mexico.

Crop	Cultivated Area (ha)	Yield (t/ha)	Wastes (t/ha/year)	Total Residues (t/year)
Pecan	118,624	1.44	* 1.5 + 0.88	177,936 + 104,389
Apple	46,418	5	1.5	69,627

* Branches + shell [43,44].

2.3. Weeds and Bioenergy Crops

Weeds are another option to obtain biomass and grain for the production of low-cost bioenergy because they occur when the plants are allowed to grow freely in what is known as "resting land", mainly performed during the winter. In the semi-arid highlands of Mexico, some plants grow naturally in agricultural lands during the winter. Among these plants, the quelite cenizo (*Chenopodium album*), chicalote (*Argemone mexicana* and *A. ochroleuca*), mostacilla (*Sisymbrium irio*), malva (*Malva parviflora*), and fox tail (*Reseda luteola*) are mentioned. In addition to obtaining inputs for bioenergy, these species are used to cover the soil, preserve beneficial microorganism populations, and reduce wind erosion.

It has been observed that the quelite cenizo provides from 8.2 to 9.5 t/ha of dry biomass without a considerable investment of resources, since it grows spontaneously during the winter, with the remaining moisture from the spring–summer growth cycle and winter rains. In the case of a small lot, grain yields from 840 to 1739 kg/ha were obtained. It is advisable to quantify the biomass produced by the multiple weed species and those established for ornamental purposes in gardens and public parks. The latter generate high amounts of wastes that are considered a management problem and should be included in the biomass and bioenergy inventories currently available in the semi-arid highlands of Mexico. Table 1 presents some important bioenergy characteristics of weeds and bioenergy crops.

2.4. Commercial Plantations

Commercial plantations have been established in the semi-arid highland region of Mexico for species with the potential for bioenergy production. Pine plantations have an average yield from 3 to 14 m^3/ha/year, given a coniferous wood density of approximately 0.4 t/m^3; these types of plantations produce between 1.2 and 5.6 t of biomass depending on the species used and the planting site [45]. For maguey (*Agave* spp.), an annual average yield from 8.5 to 22.0 t/ha has been reported [46]. In addition, it is estimated that there is a marginal area (20.0 ha) established with maralfalfa (*Pennisetum* sp.), whose yield has been estimated between 11 and 46 t/ha of valuable biomass as fuel, depending on the frost-free season, irrigation condition, fertilizer application, and cutting date [47].

The number of commercial plantations is variable, species-based, and should be corroborated to increase the accuracy of the actual availability of each energy biomass source. Establishing biomass requirements for energy purposes and productivity levels obtained with the selected species is necessary. At the same time, operational personnel should be trained in production methods, the machinery used, and the evaluation of quality characteristics applied to classify the biomass obtained. The quality criteria vary based on the utility that will be given to the biomass produced in the highlands and semi-arid areas of Mexico. Despite the high potential for utilizing wood in the form of chips or sawdust, as well as the fiber and biomass obtained from the plantations mentioned in this section, there are few examples in Mexico of appropriate bioenergy use. Table 1 shows some important bioenergy characteristics of commercial plantations.

2.5. Bagasse Wastes from Mexican Semi-Arid Areas

Other waste materials, such as maguey bagasse derived from mezcal production, become a problematic material to handle due to their consistency, microbial load, and a high degree of lignification (21%) [48]. It is considered that 1000 t of dry bagasse, derived from the mezcal industry, are produced annually in México. In Durango State, located in the semi-arid highlands, 300 t of dry maguey bagasse is produced. This material can become an input for bioenergy generation. In some areas, other alcoholic beverages are produced, such as tequila, sotol, and bacanora, which also generate bagasse waste, requiring complex management for their lignification and environmental persistence. In some cases, plant wastes are empirically used for soil recuperation or as fuel for heat generation. For example, the foliage of plants and trees is left in the soil after collecting primary materials. Sometimes, branches and stems are used as firewood in either simple stoves or campfires. Some important bioenergy characteristics of bagasse wastes are presented in Table 1.

2.6. Other Biomass Sources

In the semi-arid highlands of Mexico, there are many exotic species, such as jarilla or cockroach shrub (*Dodonaea viscosa*), pink grass (*Melinis repens*), and buffel grass (*Cenchrus ciliaris*) that have been ecologically successful. Jarilla is a shrubby plant with erect stems and resinous leaves that occupies disturbed areas. Currently, the jarilla is considered an invasive species in different states of the semi-arid highlands, and with its dense and durable wood, it can be used as construction material and fuel [49], as well as in developing fishing tools and traps. Jarilla stems are also used as tutors in the production of vegetables with climbing guides (tomato and beans) and in the elaboration of crafts.

Some attempts have been made to cultivate fast-growing plant species under irrigated conditions to increase water productivity and optimize biomass yield. In this region, plants of a short growth cycle and low water requirement are preferred due to the low availability of water and the limitations imposed by frost occurring season, in which freezing temperatures occur from October and extend until March of the following year. With the use of high-productivity species, significant yield increases will be achieved in favorable years for biomass production, in which a high quantity (>450 mm) and appropriate distribution of rainfall are observed. The characterization of cultivated species is also required for biomass production and to implement the use of technological tools that allow accurate irrigation planning and to predict the phenology, yield, and productivity of water [50,51].

Assessment of water productivity in all species used for biomass energy is considered necessary. This will facilitate the selection of efficient species in bioenergy production with minimal input and resource use efficiency. In the common bean, it was established that water productivity ranges from 3 to 8 kg/mm/ha [47], although values were calculated for the case of grain without specifying the value for the production of straw, waste of interest for animal feed and bioenergy generation.

2.7. Potential Use of the Common Species from the Mexican Highlands and Semi-Arid Areas

Revalorization processes are available commercially; however, in most cases, additional studies are required to adapt the technology to a specific raw material. In fact, particular operating conditions may be required due to the weather conditions in semi-arid areas. The following section is devoted to exposing the different transformation processes which are used for biomass processing from an energy point of view. Table 3 lists some species exploited in semi-arid zones with the main product, waste, and potential energy products.

Table 3. Identification of wastes from the Mexican semi-arid plant species.

Species	Current Product/Use	Waste
Agave lechuguilla	Ixtle/ropes, mats, bags, brushes [4]	Guishe
Euphorbia antisyphilitica	Wax [8,52]	Bagasse
Yucca filifera	Plant, flowers, fruits/food, saponins [53,54]	Bagasse
Vitis vinifera	Wine/alcoholic beverage [55–57]	Stem, bagasse, seed
Dasylirion wheeleri	Ethanol (Sotol)/alcoholic beverage [58]	Foliage, bagasse
Larrea tridentata	Extracts/medicinal usage [59,60]	Bagasse
Lippia graveolens	Thymol, carvacrol/essential oils, cooking [61]	Bagasse
Jathopha dioica	Extracts/medicinal usage [62]	Bagasse
Acacia tortuosa	Biochar, firewood	Foliage
Atriplex canescens	Extracts [63,64]	Bagasse
Cassia fistula	Extracts [65]	Bagasse
Opuntia	Prickly pear, leaves/food, fodder [66–68]	Husk
Agave tequilana, A. salmiana	Ethanol/alcoholic beverage [59,69,70]	Bagasse
Propopis laevigata	Firewood, biochar/fuel [71]	
Crops	Vegetables, fruits, fodder	Foliage, fodder wastes
Non-timber	Firewood	Foliage

3. Particular Cases

3.1. Pecan Waste from Northeastern Mexico

Pecan nut shells' use for energy generation has been explored as an important alternative for waste revalorization. Candlenut shells consist of 49.2% holocellulose and 54.5% lignin, constituting an interesting alternative energy raw material, which has the potential as a renewable fuel both used as liquid fuel (bioethanol) and solid fuel [63]. When pecan shell is used as a raw material to produce bioethanol, it is necessary to eliminate or reduce the levels of lignin to increase the cellulose component's porosity, improving accessibility to enzymes that break down polysaccharide polymers into sugar monomers. The delignification process includes the use of NaOH, considered as an effective and inexpensive method. High levels (76%) of cellulose content were obtained from candlenut shells at 15% NaOH concentration [63]. Studies on the delignification of pecan shells are still scarce and the appropriate proportion of NaOH to get the optimal cellulose levels is not yet determined. However, although this method produces higher cellulose content, it results in alkaline solutions, such that Dewi et al. [72] tried to combine the decomposition of lignin through chemical and physical processes, reaching 82.4% in lignin level reduction, and concluding that this combination reduces levels of lignin and increases cellulose levels better than just physical or chemical separately. The process consisted of using a microwave with 440 Watts power and the addition of NaOH to the candlenut shell. Delignification using microwaves aims to break down the complex lignin structure into simpler constituent structures.

Candlenut shells, as we know, are very hard so they will automatically contain more lignin, unlike other biomass wastes, such as rice straw, bagasse, and banana fronds.

Regarding the use of pecan nut shells as solid biofuel, Berberi et al. [73] investigated their thermal power in an experimental burner, and the calorific power was calculated, obtaining values of 0.70, 0.72, and 0.80%, which indicates that pecan nut shells have the potential to be considered as an alternative fuel.

3.2. Forest Wastes from the Mexican Semi-Arid Region

Forest residues represent a source of biomass that is used only in some countries. It is estimated that in forest harvesting, only 20% is used commercially, 40% is left in the forest as waste, and the remaining 40% becomes byproducts of the chipping process, bark, and sawdust [74,75]. Forest residues (tree tips and branches) are obtained from harvesting forestry treatments, thinning, and cleaning of forest areas. In contrast, forest industry residues such as sawdust and bark are obtained by harvesting in these industries. The total annual volume of dry biomass currently generated from the extraction of forest logs and waste generated by the forest industry in Mexico is estimated at 700,000 t [76].

Biomass-producing plants and tree species in Mexico are diverse and serve as an important source of energy. Species preference does not follow a general pattern, but is mainly based on farmer experience, seedling availability, and ease of use in each region. However, when multiple species are available in a production area, preference is given to those that generate more heat, produce more embers, or provide a longer duration of fire [77]. From these wastes, firewood is an important source of energy in many rural and urban households in Mexico, since it is used to cook, bake, and heat food in 60% of households, corresponding to an annual consumption of firewood of 1,609,829 m^3 [68]. In some States of Mexico with semi-arid areas such as Nuevo León and Tamaulipas, up to 42 species used as fuel have been reported, from which eight are used to produce charcoal through the pyrolysis process, and the rest are used as firewood [68]. Pyrolysis is a thermochemical transformation of organic matter by the action of heat in the absence of oxygen [78,79]. This process is an efficient method for energy production, using low-quality biomass and transforming it into valuable products [78]. Heat applied to biomass in an inert atmosphere promotes thermal decomposition, generating chemical reactions and mass-to-heat transfer processes. When pyrolysis occurs, lignin, hemicellulose, cellulose, fats, and starches, as natural polymeric constituents of the biomass, are broken down by the increasing temperature [80]. Under pyrolysis conditions, three types of products are formed: pyrolytic gas, which is composed of condensable and non-condensable gases that leave the reaction system; bio-oil, a condensed vapor formed by freely flowing organic liquid fragments and composed of acids, alcohols, aldehydes, esters, ketones, and phenolics [81]; and solid biochar, a carbonaceous product composed by aromatic hydrocarbons and approximately 60% of carbon [79,82]. The pyrolysis process is illustrated in Figure 3.

Forest waste is used efficiently in a market that is constantly increasing, in addition to the emergence of new wood products and new processes, such as densification, to reduce the space occupied by biofuels, which facilitates its storage and transportation. The increasing demand of products with enhanced calorific value and the required reduction of pollutants emitted to the atmosphere are considered important. The adoption of new technologies such as densification is necessary to obtain heat generation products and to promote the integral use of the natural resources [77].

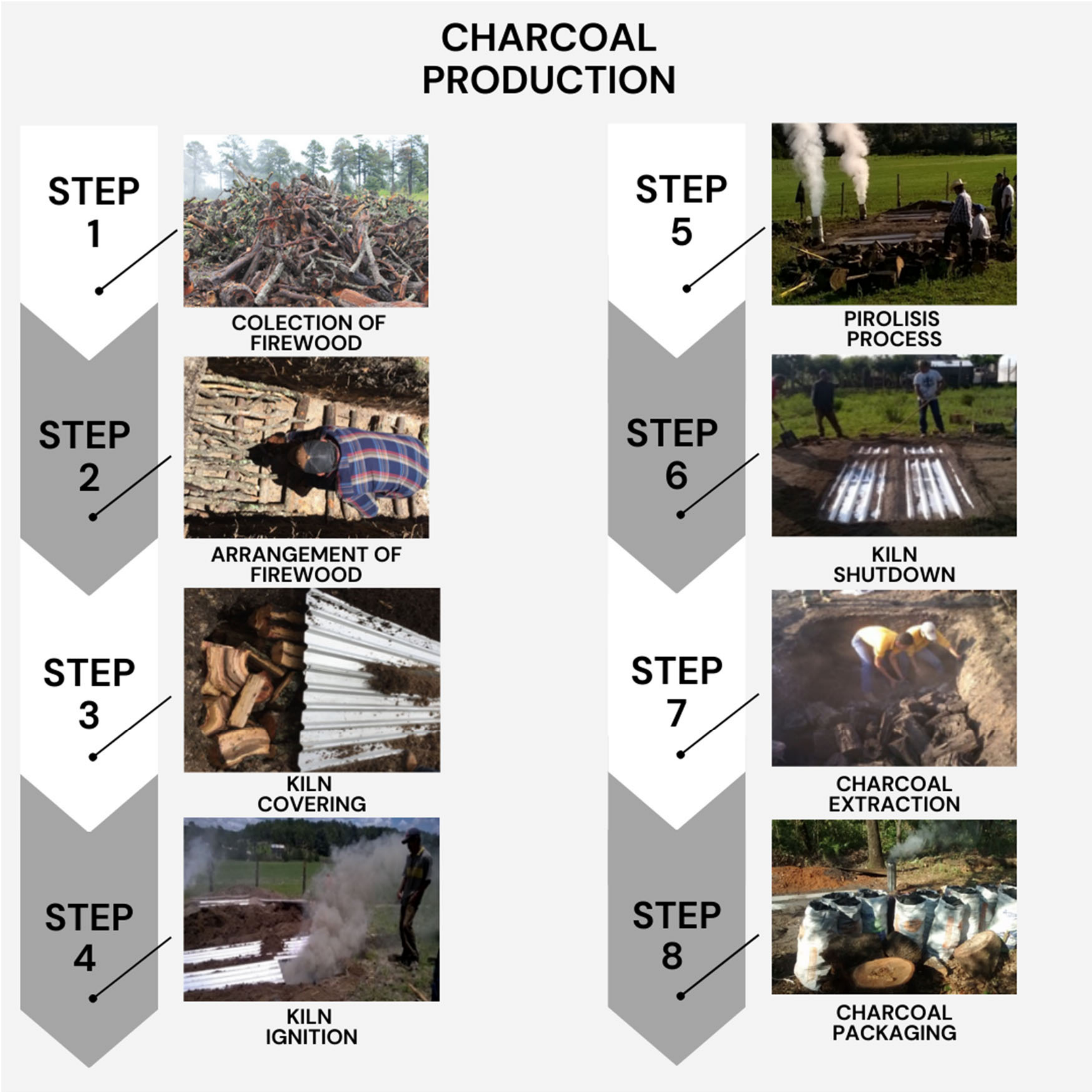

Figure 3. Pyrolysis process employed in highlands and semi-arid regions from Mexico.

3.3. Wastes from Non-Timber Species

Non-timber resources are abundant in Mexican semi-desert areas; most of them correspond to vegetable products, such as fibers, wax, beverages, leaves, and charcoal, which are obtained from plants [83]. According to the Mexican Ministry of Environment and Natural Resources (SEMARNAT), the semi-arid zones produce 65,927 t/year of non-timber resources, which represents around 40% of all the non-timber resources of the country [44].

Two species have been specially studied by the scientific community: *Agave lechuguilla* (lechuguilla) and *Euphorbia antisyphilitica* (candelilla) (Figure 4). In this section, the reported information about these plant species is analyzed from the perspective of energy production potential.

Figure 4. Collection of lechuguilla and candelilla for fibers and wax extraction in Coahuila, Mexico.

Agave lechuguilla is a shrub that grows along the semi-desert region of Mexico and the southern United States [84], which is used to obtain ixtle. Ixtle is a natural fiber used to obtain products with high commercial value, such as ropes, carpets for luxury cars, handbags, brushes, and others. Approximately 15% of the lechuguilla plant is ixtle; meanwhile, the remaining 85% is a residue known as guishe that is disposed of outdoors without any treatment, implying environmental risks. However, guishe contains several phytochemicals and lignocellulosic components, which could be used as raw materials for producing fungicides, herbicides, cosmetics, and other products. In addition, lignocellulosic components could serve to produce biofuels or thermoelectric energy by using thermochemical processes such as pyrolysis and gasification. The gasification process consists of the transformation of biomass into a gaseous mixture by thermochemical reactions under controlled conditions: partial oxidation reactions take place in the presence of amounts of oxygen lower than those required stoichiometrically [85,86].

Therefore, several studies have addressed taking advantage of the characteristics of guishe. Integrated processes to valorize guishe have been proposed; it was shown that it can be used as a raw material to obtain added value products, including energy [4]. Table 4 reports some works related to the processing of *A. lechuguilla* for biofuels and energy production.

According to the reported works, the production of ethanol by fermentation is the main objective from an energy perspective. Fermentation is an ancient bioprocess where carbohydrates become smaller and less complex molecules through the metabolism of some microorganisms [87,88]. Specifically, alcoholic fermentation is the transformation of sugars to ethanol by yeast metabolism [89]. Yeast is the most useful microorganism in the fermentation of sugars to produce ethanol; however, some bacteria are also used. The main parameters involved in the fermentation process to produce ethanol are the feedstock, fermenting microorganism, and operating conditions (temperature, dilution rate, and pH) [90]. The operating conditions and type of microorganism have been deeply studied and are well established. Regarding feedstock, many kinds of agricultural wastes have been assayed.

The trend to revalorize biomass wastes into ethanol is based on the Law to Promote and Develop Biofuels (Ley de Promoción y Desarrollo de los Bioenergéticos), recently published by Mexican Government, considered an important strategy to diversify the national energy matrix. Due to the availability of large amounts of biomass all around Mexico, ethanol has been one of the most studied biofuels. Regarding the use of *A. lechuguilla* biomass to this purpose, from the analysis of the reported documents, some remarks should be made:

- Most of the conducted research considers lechuguilla leaves, which implies competition with the current use of the plant (fiber extraction). To avoid this competition, only guishe should be considered to obtain added value products. This is feasible since fresh guishe recovered from leaves carving for ixtle extraction contains several compounds. Thus, this waste could be used as a platform for a biorefinery scheme [4].
- The production of ethanol requires a pre-treatment of the biomass. This pre-treatment includes at least one step to obtain fermentable compounds which are required for ethanol production. The implementation of a pathway to valorize *A. lechuguilla* biomass requires solvents, specialized equipment, and significant investments. Moreover, currently, the ethanol yields are too low to supply the requirements [91,92]. Research is required to overcome the challenges imposed by ethanol production; this is one of the most relevant opportunity areas regarding the exploitation of *A. lechuguilla*.
- Biofuels other than ethanol need to be explored. Since the pre-treatment of *A. lechuguilla* biomass produces fermentable sugars [93], different microorganisms must be identified to obtain biofuels such as hydrogen and methane. Since anaerobic fermentation is a mature technology, it could be an adequate pathway to diversify biofuel production from non-timber resources [4].
- Thermochemical transformation is considered to obtain biochar, ash, and syngas [4,94], transforming solid material with low moisture content in high-value products. Leaves from *A. lechuguilla* and fresh guishe present a high moisture level; therefore, a drying period is required for the biomass used in a thermochemical process. These processes should be incorporated to transform lignocellulosic biomass from *A. lechuguilla*, since after the extraction of phytochemicals and fermentable sugars, large amounts of biomass are still available, which can feasibly be transformed by either gasification or pyrolysis [4]. Incineration transforms dried biomass to produce heat, which is an important source of energy during cold season.
- The technical and economic feasibility of biofuel production should be evaluated. Most experiments have been performed at lab scale for knowledge generation; however, it is important to determine the scaling up feasibility. Thus, economic, technical, and environmental feasibility need to be evaluated.

Table 4. Research about the valorization of guishe to produce energy in Mexico.

Guishe Fraction	Process	Product	Highlights	Ref
Liquid guishe	Fermentation	Ethanol	Simulation study in a biorefinery scheme	[4]
Solid guishe	Gasification	Methane, hydrogen	Simulation study in a biorefinery scheme	[4]
Heart with attached leaf bases	Fermentation	Ethanol	Autohydrolysis and enzymatic digestion before fermentation	[91]
Heart with attached leaf bases	Fermentation	Ethanol	Autohydrolysis before fermentation. Different configurations of fermentation	[95]
Heart with attached leaf bases	Fermentation	Ethanol	Acid pre-treatment before fermentation	[92]
Solid guishe	Combustion	Heat	Secondary product	[96]
Leaves	Fermentation	Ethanol	Biomass pre-treated with fungi	[97]
Leaves	Anaerobic digestion	Hydrogen	Pre-treated by hydrolysis	[93]
Leaves	Consolidated Bioprocessing	Hydrogen	Pre-treated by autohydrolysis and acid treatment	[95]
Guishe	Physico-chemical treatment	Catalysis for biodiesel production	Biochar obtained by pyrolysis	[94]

Candelilla (*Euphorbia antisyphilitica*) has received attention due to its economic importance at different regions in the Semi-arid areas of Mexico [8,98]. Candelilla is a shrub composed of 200–1000 stems which are thin, long, upright, bluish-green, and pencil-like; in spring and early summer, candelilla produce small pink-white flowers [99]. Estimation results showed that there are ~19 million hectares suitable for candelilla forestry use in Mexico; however, only ~650,000 ha could have permission to exploit the plant, and only ~150,000 ha are actually in use, distributed in Chihuahua, Coahuila, Durango, Hidalgo, Nuevo Leon, Tamaulipas, and Zacatecas [98,100]. The exploited area represents only 24% of the total authorized in Mexico; however, more than 3500 candelilla producers have received economic benefits for several years [101]. Currently, the main product obtained from candelilla is wax [59], which has applications in several areas such as food industry [98], cosmetics and pharmaceutical products [102], chemical industry [103,104], and many others [59].

The candelilla wax is obtained by extraction with a heated acid solution and the process has been modified to reduce the environmental impact and to improve the extraction yield [59,99]. According to a report of the Comité de Flora [105], the raw wax represents up 4% of the plant, but losses are registered during the crude wax extraction (6% of wastes) and the wax refining process, where another 3% of the plant components are lost. Large amounts of wastes are registered during the candelilla transformation process and considering that around 3000 t of wax are produced annually in Mexico [102,106], ~150,000 t of candelilla stems need to be processed. Estimations showed that 147,000 t of candelilla wastes are produced every year, which are usually discarded [106–108]. Candelilla wastes revalorization includes obtention of polyphenolic compounds [109], ellagic acid [108], cellulose [110], edible film [100], and compost [111]. Candelilla is also considered a petro-plant since it contains hydrocarbons which can be used to produce biofuels [102,112–114]. A small fraction of the candelilla lignocellulosic wastes is used to produce heat (by combustion) during the wax extracting process [106–108]. Table 5 lists the reported works related to the use of candelilla stems to produce energy and biofuels.

Table 5. Studies related to candelilla use as an energy crop.

Candelilla Use	Process	Product	Highlights	Reference
Crop	Agriculture techniques	Petro-crop	Candelilla adaptation under degraded soils	[112]
Crop	Catalytic cracking	Petroleum	Biofuel production	[115]
Bagasse	Extraction, hydrolysis, TEMPO oxidation	Nanocrystalline cellulose	Industrial waste, lab scale experimentation	[110]
Plant	Extraction	Hydrocarbons	Methanol and hexane used as extraction solvents	[113]
Raw wax	Cracking-Fractioned distillation	Liquid biofuel	Candelilla-based biofuels	[114]
Bagasse	Composting	Additive for plastics	Multiple candelilla-based products	[111]
Stem residues	Combustion	Heat for wax extraction	Empirical knowledge	[106–108]

Candelilla waste underuse for energy generation was observed in Mexico and research on the revalorization of these residues needs to be done. Candelilla wastes could be used to obtain some chemicals [106,108,109] and for biofuel production, such as biogas (anaerobic digestion), ethanol (fermentation), liquid fuels (pyrolysis) and syngas (gasification), and heat generated by residue combustion. The next diagram illustrates the integrated use of the candelilla plant (Figure 5).

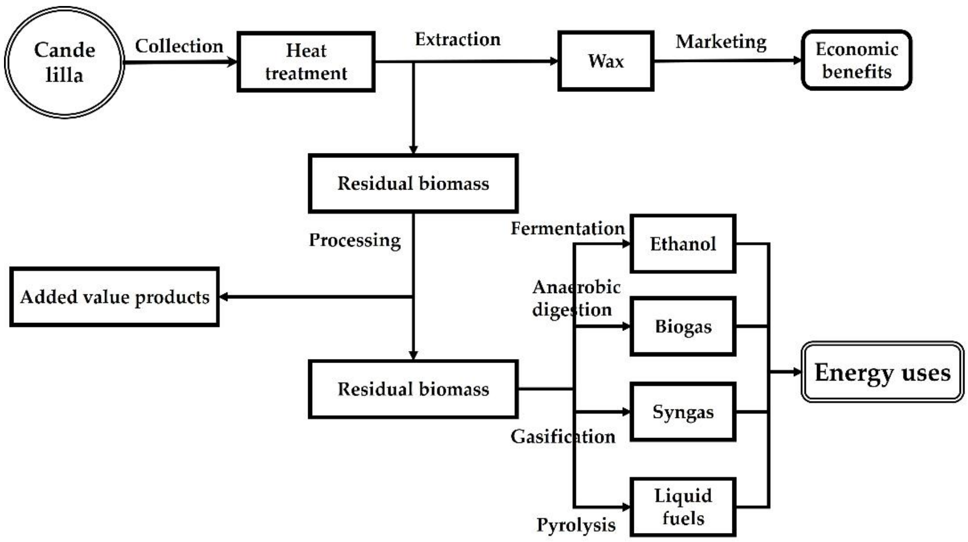

Figure 5. General diagram for integral candelilla use.

4. Uses and Potential Transformation Processes of Selected Species for Energy Production in Mexican Highlands and Semi-Arid Areas

4.1. Firewood

Firewood refers to a type of fuel obtained from wood that undergoes combustion, producing heat and energy [116]. It is a renewable resource that has been widely utilized for centuries as a primary source of heat in homes and for cooking [117]. In the highlands and semi-arid land of Mexico, the firewood is typically obtained from trees that are collected for this purpose and derived as byproducts from forest management. The selection of tree species commonly used for firewood includes both hardwoods, such as *Prosopis* sp., *Acacia* sp. and *Quercus* sp., and softwoods, such as *Pine* sp. Firewood is prepared by cutting and splitting wood into varying lengths and diameters, based on the intended use. The quality of firewood varies depending on several factors, such as the tree species, tree age, and the firewood moisture content. High-quality firewood exhibits properties of high density and low moisture content, facilitating efficient and clean combustion. Firewood finds applications in heating homes and buildings, cooking, and various recreational purposes. Figure 6 shows the main energy products resulting from biomass transformation processes.

Figure 6. Products derived from different biomass transformation processes implemented for energy purposes.

4.2. Charcoal

The process to produce charcoal is old and continues to be used in many regions of the world due to the modernization of some components of technology. Thermal decomposition of biomass in atmospheres with low oxygen content and high temperatures produce charcoal, as well as condensable and non-condensable gaseous products. After a pyrolysis process, firewood doubles its energy content and reduces the original weight by 75%, making it easier to transport and store [118]. In Mexico, this process is carried out in various types of furnaces, such as parva type, pits, portable metal furnace, and brick [119].

In semi-arid regions, various firewood species are used to produce charcoal; the most relevant is mesquite (*Prosopis* sp.), which is considered of premium quality, reaching calorific values of 30,241 kJ/kg, while ebony (*Ebenopsis* sp.) and other plant species registered values of 29,725 kJ/kg [37].

4.3. Torrefacted Wood

Torrefaction is a thermochemical conversion process that involves the slow heating of lignocellulosic biomass in an oxygen-free environment to improve its fuel properties [120]. This process entails the application of mild heat to the biomass in the presence of an inert gas such as nitrogen, resulting in temperatures ranging between 200 °C and 300 °C [121]. The duration of the torrefaction process varies from a few minutes to an hour [122]. The thermal treatment of biomass during torrefaction brings about several chemical, physical, and structural transformations, which result in improvements in fuel properties, such as higher calorific value, enhanced grindability, and reduced moisture content. The absence of oxygen during the torrefaction process results in minimal oxidation, which helps preserve the chemical composition of the biomass. Overall, torrefaction offers a promising approach for the conversion of lignocellulosic biomass into a high-quality fuel source.

4.4. Briquettes

Biomass briquetting is a process of compacting lignocellulosic materials (such as wood residues, leaves, and straw) to produce briquettes that are used as fuels for heat and energy generation. Briquettes have high energy density and are burned efficiently, making them ideal for use in stoves, boilers, and other heating and renewable energy systems. In addition, briquetting biomass reduces its volume, facilitating storage and transport, also contributing to waste reduction and climate change mitigation. The briquetting method produces briquettes from 15 to 250 mm long by 50 mm in diameter.

The briquetting densification method was used to make briquettes from pecan nut shells to evaluate their energy content (calorific value) [71]. Calorific value is defined as the chemical energy of biomass that is transformed for energy generation when submitted to a combustion process. Increments for calorific value were observed ranging from 17.00 MJ/kg for the base material to around 18.00 MJ/kg for briquettes, concluding that the physical transformation of the pecan pericarp into briquettes improved its quality as a solid biofuel [123]. Agricultural and agroforestry residues, coconut shells and husks, sugar cane bagasse, palm kernel shells (PKS), and cashew shells are considered excellent options for replacing coal, reducing greenhouse gas (GHG) emissions [124].

4.5. Pellets

Pelletization is another method for biomass densification used to elaborate bioenergy products by increasing the density and reducing the moisture content of raw materials. Pellets are obtained at 0.3–1.3 cm diameter, and with a pressure of 7 kg/mm^3, taking the shape of a long cylinder which is then cut to the desired length. The process of pellet densification is illustrated in Figure 7.

Pelletization showed higher potential for use since it reduces biomass transportation and storage costs, making it viable for income generation. The quality of pellets differs according to several factors such as ash content and emissions level, but the decisive factor is the type of waste used, since biomass presents variation in some traits such as calorific value, moisture content, and biomass density, as well as transportation and storage costs. All these factors determine the quality of the waste used in the energetic industry and the energy level of the densification products. Biomass densification processes transform wastes with little value into readily transportable energy products, capable of functioning as an alternative to coal and fossil fuels. Significant reductions in air pollution emissions will be also achieved.

The densification process has been found to provide dense, uniform, and durable properties to lignocellulosic biomass, which significantly influences the transportation, handling, and storage facility of the products. Experimental results demonstrated that torrefaction and densification technologies were effective methods to obtain higher quality torrefied pellets compared to regular wood pellets [125,126]. The pelletization process was also used to revalorize the wastes from the mezcal industry [31], by using mixtures of *Agave durangensis* fiber and pine sawdust. The proportion of 80% of *A. durangensis* fiber: 20% pine sawdust registered: volatile material 86.2%, ash 6.5%, fixed carbon 7.3%, calorific value 14.1 MJ/kg, and bulk density of 726.0 kg/m^3. Results showed that research needs to be reinforced to improve pellet quality according to international standards. Figure 8 shows the pellets produced with fibers of *A. durangensis* and pine sawdust.

Figure 7. Densification process for pellets manufacturing.

Figure 8. Pellets obtained from mixtures of *Agave durangensis* fiber–pine sawdust at the proportions of 100–0 (**left**) and 80–20 (**right**).

5. Final Remarks

The agricultural, livestock, and forestry production systems in the highlands and semi-desert areas of Mexico present great potential for bioenergy production from the residual biomass they generate such as stubble, straw, branches, stems, and sawdust. Numerous species, such as *Zea mays*, *Phaseolus vulgaris*, *Pennisetum* sp., *Agave* sp., and *Pinus* sp., sourced from natural habitats or commercial plantations, generate significant quantities of residues that could be efficiently utilized in the production of biofuels and other bioenergy products. Various technological approaches, such as pyrolysis and densification, have the capacity to enhance the energy characteristics of the biomass wastes generated in the highlands and semi-arid areas of Mexico. These technologies have the potential to convert low-quality biomass into high-quality bioenergy products, contributing to the development of sustainable and renewable energy sources. The utilization of pyrolysis and densification for converting biomass waste into biofuels and other bioenergy products could help to mitigate the adverse impacts associated with the use of fossil fuels while promoting a greener economy in Mexico. Furthermore, the adoption of these technologies fosters improved management and utilization of agricultural and livestock wastes, resulting in reduced environmental impacts and the promotion of circular economy practices. By harnessing the untapped potential of biomass resources in these regions, Mexico can enhance its energy security, reduce greenhouse gas emissions, and advance its transition towards a more sustainable future.

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References

1. Alanís Torres, G.; Ballester Franzoni, C. *El valor de nuestras plantas*; Fondo Editorial de Nuevo León: Monterrey, Mexico, 2007; p. 151. ISBN 9709715267.
2. González Medrano, F. *Las zonas áridas y semiáridas de México y su vegetación*; Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT): México D.F., Mexico, 2012; p. 173. ISBN 9786077908692.
3. Torres Lima, P.A.; Martínez Cano, A.G.; Portes Vargas, L.; Rodríguez Sánchez, L.M.; Cruz Castillo, J.G. Construcción local de indicadores de sustentabilidad regional. Un estudio de caso en el semidesierto del noreste de México. *Región Y Soc.* **2016**, *20*, 25–60. [CrossRef]
4. Díaz-Jiménez, L.; Carlos-Hernández, S.; Jasso de Rodríguez, D.; Rodríguez-García, R. Conceptualization of a biorefinery for guishe revalorization. *Ind. Crops Prod.* **2019**, *138*, 111441. [CrossRef]
5. Biljana Bauer, P. Historical review of medicinal plants' usage. *Pharmacogn. Rev.* **2012**, *6*, 1–5.
6. Dar, R.A.; Shahnawaz, M.; Qazi, P.H. General overview of medicinal plants: A review. *J. Phytopharm.* **2017**, *6*, 349–351. [CrossRef]
7. Halberstein, R.A. Medicinal plants: Historical and cross-cultural usage patterns. *Ann. Epidemiol.* **2005**, *15*, 686–699. [CrossRef]
8. Vargas-Piedra, G.; Valdez-Cepeda, R.D.; López-Santos, A.; Flores-Hernández, A.; Hernández-Quiroz, N.S.; Martínez-Salvador, M. Current and future potential distribution of the xerophytic shrub candelilla (euphorbia antisyphilitica) under two climate change scenarios. *Forests* **2020**, *11*, 530. [CrossRef]
9. Reyes, L.; Camacho, T.; Guevara, F. *Rastrojos. Manejo, uso y mercado en el Centro y Sur de México*; Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP): Aguascalientes, Mexico, 2013; Libro Técnico Núm. 7; p. 235. ISBN 9786073701709.
10. McDaniel, C.; Jadeja, R. Pecan and walnut food safety concerns: A mini review. *Adv. Nutr. Food Sci.* **2021**, *3*, 1–15. [CrossRef]
11. López, R.R.; Palafox, A.R.; Medina, S.M.; Ballesteros, F.G.; Rivera, M.M. Análisis de rentabilidad del cultivo de nogal pecanero en la costa de Hermosillo. *Rev. Mex. Agronegocios* **2014**, *34*, 872–882.
12. Paist, A.; Kask, Ü.; Kask, L.; Vrager, A.; Muiste, P.; Padari, A.; Pärn, L. Potential of biomass fuels to substitute for oil shale in energy balance in estonian energy sector. *Oil Shale* **2006**, *22*, 369–379. [CrossRef]
13. Pinheiro do Prado, A.C.; Aragão, A.M.; Fett, R.; Block, J.M. Antioxidant properties of pecan nut [*Carya illinoinensis* (Wangenh.) C. Koch] shell infusion. *Grasas y Aceites* **2009**, *60*, 330–335. [CrossRef]

14. Bhuvaneshwari, S.; Hettiarachchi, H.; Meegoda, J.N. Crop residue burning in India: Policy challenges and potential solutions. *Int. J. Environ. Res. Public Health* **2019**, *16*, 832. [CrossRef] [PubMed]
15. Lohan, S.K.; Jat, H.S.; Yadav, A.K.; Sidhu, H.S.; Jat, M.L.; Choudhary, M.; Peter, J.K.; Sharma, P.C. Burning issues of paddy residue management in north-west states of India. *Renew. Sustain. Energy Rev.* **2018**, *81*, 693–706. [CrossRef]
16. Bonatti, M.; Karnopp, P.; Soares, H.M.; Furlan, S.A. Evaluation of Pleurotus ostreatus and Pleurotus sajor-caju nutritional characteristics when cultivated in different lignocellulosic wastes. *Food Chem.* **2004**, *88*, 425–428. [CrossRef]
17. Córdoba, J.A.; Salcedo, E.; Rodríguez, R.; Zamora, J.F.; Manríquez, R.; Contreras, H.; Robledo, J.; Delgado, E. Caracterización y valoración química del olote: Degradación hidrotérmica bajo condiciones subcríticas. *Rev. Latinoam. Quimica.* **2013**, *41*, 171–184.
18. SIAP (Servicio de Información Agroalimentaria y Pesquera). Anuario Estadístico de la Producción Agrícola, 2023. Available online: https://nube.siap.gob.mx/cierreagricola/ (accessed on 11 August 2023).
19. Pordesimo, L.O.; Hames, B.R.; Sokhansanj, S.; Edens, W.C. Variations in corn stover composition and energy content with crop maturity. *Biomass Bioenergy* **2005**, *28*, 366–374. [CrossRef]
20. Prasertpong, P.; Tippayawong, N.; Sittisun, P. Densification of corn residues for producing pelletized biomass fuels. In *AIP Conference Proceedings*; AIP Publishing LLC: Melville, NY, USA, 2022; Volume 2681, p. 020003.
21. Romo, F.C.S.; López, C.; Kohashi, J.S.; Martínez, R.C.G.; Miranda, S.C.; Aguilar, V.H.R. Rendimiento de biomasa acumulada en frijol común bajo riego y secano. *Rev. Mex. Cienc. Agrícolas* **2021**, *12*, 1363–1376.
22. Okot, D.K.; Bilsborrow, P.E.; Phan, A.N. Briquetting characteristics of bean straw-maize cob blend. *Biomass Bioenergy* **2019**, *126*, 150–158. [CrossRef]
23. Orona, C.I.; Sangerman, J.D.M.; Fortis, H.M.; Vázquez, V.C.; Gallegos, R.M.A. Producción y comercialización de nuez pecanera (*Carya illinoensis* Koch) en el norte de Coahuila, México. *Rev. Mex. Cienc. Agrícolas* **2013**, *4*, 461–476. [CrossRef]
24. Carrillo-Parra, A.; Núñez-Retana, V.D.; Prieto-Ruíz, J.A.; Garza-Ocañas, F. Potencial energético de residuos de ocho cultivos agrícolas en México. In *Optimización de los Procesos de Extracción de Biomasa Sólida Para Uso Energético. Cuaderno de la Red Iberomasa*; Velázquez Martí, B., Ed.; Programa Iberoamericano De Ciencia Y Tecnología Para El Desarrollo (CYTED): Valencia, España, 2020; ISBN 978-84-15413-44-8.
25. Sierra-Zurita, D.; Santana-Espinoza, S.; Rosales-Serna, R.; Ríos-Saucedo, J.C.; Carrillo-Parra, A. Productivity and Characterization of Biomass Obtained from Pruning of Walnut Orchards in Mexico. *Energies* **2023**, *16*, 2243. [CrossRef]
26. Pecha, D.B.; López-Díaz, D.A. Gaseificação de carvão, biomassa de Chenopodium album, e cogaseificação de uma mistura de carvão e biomassa mediante análise termogravimétrico de gases. *Rev. Fac. Ing.* **2019**, *28*, 53–77.
27. Singh, D.; Singh, S.P. Low cost production of ester from non edible oil of Argemone mexicana. *Biomass Bioenergy* **2010**, *34*, 545–549. [CrossRef]
28. Pandey, S.P.; Kumar, S. Valorisation of argemone mexicana seeds to renewable fuels by thermochemical conversion process. *J. Environ. Chem. Eng.* **2020**, *8*, 104271. [CrossRef]
29. Shehata, H.F. Ecology and nutritive status of *Sisymbrium irio* L. in the Nile delta, Egypt. *J. Exp. Biol.* **2014**, *10*, 127–142.
30. Rosales, S.R.; Ríos, S.J.C.; Jiménez, O.R.; Domínguez, M.P.A.; Santana, E.S. *Importancia de la materia orgánica en el fortalecimiento de la fertilidad de suelos agrícolas en Durango. Desplegable para Productores*; Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP): Durango, Mexico, 2018; 2p.
31. Blancarte-Contreras, E.; Corral-Rivas, S.; Domínguez-Gómez, T.G.; Lujan-Soto, J.E.; Goche-Télles, J.R.; Montiel-Antuna, E. Improving the physical, mechanical and energetic characteristics of pine sawdust by the addition of up to 40% *Agave durangensis* gentry pellets. *Energies* **2022**, *15*, 3711. [CrossRef]
32. Carrillo-Parra, A.; Rutiaga-Quiñones, J.G.; Ríos-Saucedo, J.C.; Ruiz-García, V.M.; Ngangyo-Heya, M.; Nava-Berumen, C.A.; Núñez-Retana, V.D. Quality of pellet made from agricultural and forestry waste in Mexico. *BioEnergy Res.* **2021**, *15*, 977–986. [CrossRef]
33. Rosales, S.R.; Ríos, S.J.C.; Domínguez, M.P.A.; Jiménez, O.R.; Carrillo, P.A.; Santana, E.S.; Nava, B.C.A. Productividad y composición fibrosa de la biomasa en especies vegetales con potencial bioenergético en Durango. *Agrofaz* **2018**, *18*, 91–100.
34. Ruiz-Aquino, F.; Jiménez-Mendoza, M.E.; Santiago-García, W.; Suárez-Mota, M.E.; Aquino-Vásquez, C.; Rutiaga-Quiñones, J.G. Energy Properties of 22 Timber Species from Oaxaca, Mexico. *South-East Eur. For. SEEFOR* **2022**, *13*, 107–113. [CrossRef]
35. Díaz, R.A.; Flores, A.E.; de Luna, J.A.; Luna, R.J.J.; Frías, H.J.T.; Olalde, P.V. Biomasa aérea, cantidad y calidad de semilla de *Melinis repens* (Willd.) Zizka, en Aguascalientes, México. *Rev. Mex. Cienc. Pecu.* **2012**, *3*, 33–47.
36. Beltrán, L.S.; Loredo, O.C.; Núñez, Q.T.; González, E.L.A.; García, D.C.A.; Hernández, A.J.A.; Urrutia, M.J.; Gámez, V.H.G. *Buffel Titán y Buffel Regio, nueva variedad de pastos para el Altiplano de San Luis Potosí (Establecimiento y producción de semilla)*; Folleto Técnico Núm. 35; INIFAP-CIRNE-Campo Experimental San Luis: San Luis Potosí, Mexico, 2008; 36p.
37. Carrillo-Parra, A.; Foroughbakhch-Pournavab, R.; Bustamante-García, V. Calidad del carbón de *Prosopis laevigata* (Humb. & Bonpl. ex Willd.) MC Johnst. y *Ebenopsis ebano* (Berland.) Barneby & JW Grimes elaborado en horno tipo fosa. *Rev. Mex. Cienc. Forestales* **2013**, *4*, 62–71.
38. Ngangyo-Heya, M.; Pournavab, F.R.; Carrillo-Parra, A.; Colin-Urieta, S. Bioenergy potential of shrub from native species of northeastern Mexico. *Int. J. Agric. Policy Res.* **2014**, *2*, 475–483.
39. Dupri, I. *Estimación de los residuos agrícolas generados en la isla de Tenerife*; Servicio Técnico de Agricultura y Desarrollo Rural: Tenerife, Spain, 2006; pp. 3–20.

40. Gallino, A.; Castro, A.B.; Bernaus, M.; Gaioli, F. Estudio de potencial de mitigación—Biomasa y Biocombustibles de 2° y 3° generación. Tercera Comunicación Nacional sobre Cambio Climático, Secretaría de Ambiente y Desarrollo Sustentable de la Nación, Argentina. 2015, p. 41. Available online: http://3cn.cima.fcen.uba.ar/docs/3Com-Resumen-Ejecutivo-de-la-Tercera-Comunicacion-Nacional.pdf (accessed on 14 August 2023).
41. Racovita, R.C.; Secuianu, C.; Ciuca, M.D.; Israel-Roming, F. Effects of smoking temperature, smoking time, and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages. *J. Agric. Food Chem.* **2020**, *68*, 9530–9536. [CrossRef] [PubMed]
42. Emel, O.Z. Effects of smoking with different wood chips and barbecuing on some properties of salmon fish. *Gıda* **2020**, *45*, 1–8.
43. Barrera, J.M.; Madrid, L.; Hernández, K. *La producción forestal en México a lo largo del tiempo: Avances y retrocesos*; Consejo Civil Mexicano para la Silvicultura Sostenible: Ciudad de México, Mexico, 2021; p. 47.
44. SEMARNAT. *Anuario Estadístico de la Producción Forestal*; Secretaría de Medio Ambiente y Recursos Naturales: Ciudad de México, Mexico, 2018; p. 297.
45. Brown, C. *Perspectivas Mundiales del Suministro Futuro de Madera Procedente de Plantaciones Forestales*; FAO: Roma, Italy, 2000; p. 161.
46. Davis, S.C.; Kuzmick, E.R.; Niechayev, N.; Hunsaker, D.J. Productivity and water use efficiency of Agave americana in the first field trial as bioenergy feedstock on arid lands. *GCB Bioenergy* **2017**, *9*, 314–325. [CrossRef]
47. Rosales-Serna, R.; Flores-Gallardo, H.; López-González, J.C.; Rubiños-Panta, J.E.; Ortiz-Sánchez, I.A.; Flores-Magdaleno, H.; Santana-Espinoza, S.; Domínguez-Martínez, P.A. Fenología y productividad del agua en variedades mejoradas de frijol pinto cultivadas en Durango, México. *Rev. Fitotec. Mex.* **2021**, *44*, 511. [CrossRef]
48. Satyanarayana, K.G.; Flores-Sahagun, T.H.S.; Pereira-Dos-Santos, L.; Dos-Santos, J.; Mazzaro, I.; Mikowski, A. Characterization pf blue agave bagasse fibers of Mexico. *Compos. Part A* **2013**, *45*, 153–161.
49. Salazar, L.M.; Rosales, R.; Jiménez, R.; Ríos, J.C.; Sigala, J.A.; Carrillo, A.; Dominguez, P.A.; Martínez, M. Optimización calorífica en especies vegetales con potencial para la producción de biomasa dendroenergética en Durango. *Agrofaz* **2015**, *15*, 147–154.
50. Araujo de Medeiros, G.; Antonio Daniel, L.; Hashimoto Fengler, F. Growth, development, and water consumption of irrigated bean crop related to Growing Degree-Days on different soil tillage systems in Southeast Brazil. *Int. J. Agron.* **2016**, *2016*, 8065985. [CrossRef]
51. Chaves de Oliveira, E.; Nogueira da Costa, J.M.; José de Paula Júnior, T.; Marques Ferreira, W.P.; Barbosa Justino, F.; de Oliveira Neves, L. Desempenho do modelo CROPGRO-Dry bean na simulação do rendimento de feijão (*Phaseolus vulgaris* L.). *Acta Sci. Agron.* **2012**, *34*, 239–246.
52. Muñoz-Ruiz, C.V.; López-Díaz, S.; Covarrubias-Villa, F.; Villar-Luna, E.; Medina-Medrano, J.R.; Barriada-Bernal, L.G. Effect of abiotic stress conditions on the wax production in candelilla (Euphorbia antisy. philitica Zucc.). *Rev. Latinoam. Química* **2016**, *44*, 26–33.
53. Aragón-Gastélum, J.L.; Flores, J.; Jurado, E.; Ramírez-Tobías, H.M.; Robles-Díaz, E.; Rodas-Ortiz, J.P.; Yáñez-Espinosa, L. Potential impact of global warming on seed bank, dormancy and germination of three succulent species from the Chihuahuan Desert. *Seed Sci. Res.* **2018**, *28*, 312–318. [CrossRef]
54. González-Salvatierra, C.; Flores, J. Water-shortage tolerance and recovery after rehydration in the Chihuahuan Desert plant Yucca filifera (Asparagaceae). *J. Torrey Bot. Soc.* **2019**, *146*, 128–137. [CrossRef]
55. Almendra-Paxtian, L.; García-Martínez, O.; Robles-Hernández, V.E.; Sánchez-Peña, S.R. Cicadomorpha1 in a vineyard at Parras, Coahuila, Mexico, and vectors of diseases. *Southwest. Entomol.* **2021**, *46*, 147–151. [CrossRef]
56. Amaya-Chantaca, D.; Flores-Gallegos, A.C.; Iliná, A.; Aguilar, C.N.; Sepúlveda-Torre, L.; Ascacio-Vadlés, J.A.; Prado-Barragán, L.A.; Chávez-González, M.L. La industria vinícola como fuente de valiosos residuos agroindustriales. *CienciaAbierta* **2021**, *1*, 123–145.
57. Gómez-García, R.; Martínez-Ávila, G.C.G.; Aguilar, C.N. Enzyme-assisted extraction of antioxidative phenolics from grape (*Vitis vinifera* L.) residues. *3 Biotech* **2012**, *2*, 297–300. [CrossRef]
58. Pinales-Quero, I.; González-Vázquez, V.M.; Castillo-Reyes, F.; Aguilar, C.N.; Reyes-Valdés, M.H.; Rodríguez Herrera, R. Genetic diversity of sotol (*Dasylirion cedrosanum* Trel.) at different elevations. *Ecosistemas y Recur. Agropecu.* **2017**, *4*, 201–211.
59. De León-Zapata, M.A.; Aguilar, C.N. Extraction methods and common uses of candelilla wax. In *Food Process Engineering and Quality Assurance*; Apple Academic Press: Palm Bay, FL, USA, 2020; pp. 505–524.
60. Reyes-Melo, K.Y.; Galván-Rodrigo, A.A.; Martínez-Olivo, I.E.; Núñez-Mojica, G.; Ávalos-Alanís, F.G.; García, A.; del Rayo Camacho-Corona, M. Larrea tridentata and its biological activities. *Curr. Top. Med. Chem.* **2021**, *21*, 2352–2364. [CrossRef]
61. Jasso-de Rodríguez, D.; Rodríguez-García, R.; Hernández-Castillo, F.D.; Aguilar-González, C.N.; Sáenz-Galindo, A.; Villarreal-Quintanilla, J.; Moreno-Zuccolotto, L.E. In vitro antifungal activity of extracts of Mexican Chihuahuan Desert plants against postharvest fruit fungi. *Ind. Crops Prod.* **2011**, *34*, 960–966. [CrossRef]
62. Ramírez-Moreno, A.; Delgadillo-Guzmán, D.; Bautista-Robles, V.; Marszalek, J.E.; Keita, H.; Kourouma, A.; Ramírez-García, S.A.; Rodríguez-Amado, J.R.; Tavares-Carvalho, J.C. Jatropha dioica, an Aztec plant with promising pharmacological properties: A systematic review. *Afr. J. Pharm. Pharmacol.* **2020**, *14*, 169–178.
63. Moreno-Limon, S.; Gonzalez-Luna, R.; Garza-Aguirre, R.; Forughbackhch-Pournavab, R. Leaf, stem and root content of proline in Atriplex canescens and Suaeda nigra. *Int. J. Bio-Resour. Stress Manag.* **2014**, *5*, 82–85. [CrossRef]
64. Mata-González, R.; Abdallah, M.A.B.; Trejo-Calzada, R.; Wan, C. Growth and leaf chemistry of Atriplex species from Northern Mexico as affected by salt stress. *Arid Land Res. Manag.* **2017**, *31*, 57–70. [CrossRef]

65. Castro-López, C.; Rojas, R.; Martínez-Ávila, G.C.G. Screening of the Cassia Fistula phytochemical constituents by UPLC-ESI-QTOF-MS. *Clin. Oncol.* **2018**, *3*, 1477.
66. Chávez-Moreno, C.K.; Tecante, A.; Casas, A. The Opuntia (Cactaceae) and Dactylopius (Hemiptera: Dactylopiidae) in Mexico: A historical perspective of use, interaction and distribution. *Biodivers. Conserv.* **2009**, *18*, 3337–3355. [CrossRef]
67. Reynoso-Camacho, R.; González de Mejía, E. Nopal (*Opuntia* spp.) and other traditional Mexican plants. In *Nutraceuticals Glycemic Health & Type 2 Diabetes*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2008; pp. 379–399. [CrossRef]
68. Torres-Ponce, R.L.; Morales-Corral, D.; Ballinas-Casarrubias, M.D.; Nevárez-Moorillón, G.V. El nopal: Planta del semidesierto con aplicaciones en farmacia, alimentos y nutrición animal. *Rev. Mex. Ciencias Agrícolas Mex. Cienc. Agríc.* **2015**, *6*, 1129–1142. [CrossRef]
69. Pinal, L.; Cornejo, E.; Arellano, M.; Herrera, E.; Nuñez, L.; Arrizon, J.; Gschaedler, A. Effect of Agave tequilana age, cultivation field location and yeast strain on tequila fermentation process. *J. Ind. Microbiol. Biotechnol.* **2009**, *36*, 655–661. [CrossRef] [PubMed]
70. Puente-Garza, C.A.; Gutiérrez-Mora, A.; García-Lara, S. Micropropagation of Agave salmiana: Means to production of antioxidant and bioactive principles. *Front. Plant Sci.* **2015**, *6*, 1–9. [CrossRef] [PubMed]
71. Prieto-Ruiz, J.Á.; Rosales-Mata, S.; Sigala-Rodríguez, J.Á.; Madrid-Aispuro, R.E.; Mejía-Bojorques, J.M. Producción de Prosopis laevigata (Humb. et Bonpl. ex Willd.) M.C. Johnst. con diferentes mezclas de sustrato. *Rev. Mex. Ciencias For.* **2018**, *4*, 50–57.
72. Dewi, R.K.; Zuhroh, S.T.; Zulaikha, S. Delignification of chandlenut shell waste with alkali pretreatment method as an alternative fuel feedstock. *Int. J. Mech. Eng. Technol.* **2018**, *9*, 271–278.
73. Berberi, R.O.; Smoisman, S.; Sandoval, D.; Rey, N.; Arenas, M.; Killy, N.; Piatti, L.F. Potencia térmica en un quemador experimental utilizando cáscaras de nuez Pecan como biocombustible. *Extensionismo Innovación y Transferencia Tecnológica Claves para el desarrollo* **2019**, *5*, 196–202. [CrossRef]
74. Atuesta, L.E.; Vargas, F.S. Caracterización fisicoquímica de pellets producidos a partir de mezclas 50/50 carbón bituminoso/madera residual. *Inf. Técnico* **2015**, *79*, 18–25. [CrossRef]
75. Quiñones-Reveles, M.A.; Ruiz-García, V.M.; Ramos-Vargas, S.; Vargas-Larreta, B.; Masera-Cerutti, O.; Ngangyo-Heya, M.; Carrillo-Parra, A. Assessment of pellets from three forest species: From raw material to end use. *Forests* **2021**, *12*, 447. [CrossRef]
76. Amezcua-Allieri, M.; Torres, E.; Eguía-Lis, J.; Magdalenno, M.; Melgarejo, L.; Palmerín, E.; Rosas, A.; López, D.; Aburto, J. Valorization of residues from forest industry for the generation of energy. *Int. J. Energy Environ. Eng.* **2018**, *5*, 1–6.
77. Villalón-Mendoza, H.; Carrillo-Parra, A. Plantas productoras de leña y carbón. In *De la lechuguilla a las biopelículas vegetales. Las plnatas útiles de Nuevo León*; Alvarado-Vázquez, M.A., Rocha-Estrada, A., Moreno-Limón, S., Eds.; Universidad Autónoma de Nuevo León: Monterrey, Mexico, 2010; pp. 267–280.
78. Amenaghawon, A.N.; Anyalewechi, C.L.; Okieimen, C.O.; Kusuma, H.S. Biomass pyrolysis technologies for value-added products: A state-of-the-art review. *Environ. Dev.Sustain.* **2021**, *23*, 14324–14378. [CrossRef]
79. Dhyani, V.; Bhaskar, T.A. Comprehensive review on the pyrolysis of lignocellulosic biomass. *Renew. Energy* **2018**, *129*, 695–716. [CrossRef]
80. Batista, R.R.; Gomes, M.M. Effects of chemical composition and pyrolysis process variables on biochar yields: Correlation and Principal Component Analysis. *Floresta Ambient.* **2021**, *28*, 1–12. [CrossRef]
81. Lee, J.H.; Lee, I.G.; Jeon, W.; Ha, J.H.; Lee, K.Y. Catalytic upgrading of bio-tar over a MgNiMo/activated charcoal catalyst under supercritical ethanol conditions. *Catal. Today* **2018**, *316*, 237–243. [CrossRef]
82. Yang, X.; Kang, K.; Qiu, L.; Zhao, L.; Sun, R. Effects of carbonization conditions on the yield and fixed carbon content of biochar from pruned apple tree branches. *Renew. Energy* **2020**, *146*, 1691–1699. [CrossRef]
83. Villavicencio-Gutiérrez, E.E.; Cano-Pineda, A.; Castillo-Quiroz, D.; Hernández-Ramos, A.; Martínez-Burciaga, O.U. Manejo forestal sustentable de los recursos no maderables en el semidesierto del norte de México. *Rev. Mex. Ciencias For.* **2021**, *12*, 31–63. [CrossRef]
84. Reyes-Agüero, J.A.; Aguirre-Rivera, J.R.; Peña-Valdivia, C.B. Biología y aprovechamiento de Agave lechuguilla Torrey. *Boletín Soc. Botánica México* **2000**, *67*, 75–88. [CrossRef]
85. Tezer, Ö.; Karabağ, N.; Öngen, A.; Çolpan, C.Ö.; Ayol, A. Biomass gasification for sustainable energy production: A review. *Int. J. Hydrogen Energy* **2022**, *47*, 15419–15433. [CrossRef]
86. Molino, A.; Chianese, S.; Musmarra, D. Biomass gasification technology: The state of the art overview. *J. Energy Chem.* **2016**, *25*, 10–25. [CrossRef]
87. Behera, S.S.; Ray, R.C.; Das, U.; Panda, S.K.; Saranraj, P. Microorganisms in fermentation. In *Essentials in Fermentation Technology*; Berenjian, A., Ed.; Springer: Hamilton, New Zealand, 2020; pp. 1–40. ISBN 978-3-030-16230-6.
88. Dashko, S.; Zhou, N.; Compagno, C.; Piškur, J. Why, when, and how did yeast evolve alcoholic fermentation? *FEMS Yeast Res.* **2014**, *14*, 826–832. [CrossRef] [PubMed]
89. Zamora, F. Biochemistry of alcoholic fermentation. In *Wine Chemistry and Biochemistry*; Moreno-Arribas, M.V., Polo, M.C., Eds.; Springer: Berlin/Heidelberg, Germany, 2009; pp. 3–25. ISBN 9780387741161.
90. Mears, L.; Stocks, S.M.; Albaek, M.O.; Sin, G.; Gernaey, K.V. Mechanistic fermentation models for process design, monitoring, and control. *Trends Biotechnol.* **2017**, *35*, 914–924. [CrossRef] [PubMed]
91. Ortiz-Méndez, O.H.; Morales-Martínez, T.K.; Rios-González, L.J.; Rodríguez-de la Garza, J.A.; Quintero, J.; Aroca, G. Bioethanol production from Agave lechuiguilla biomass pretreated by autohydrolysis. *Rev. Mex. Ing. Química* **2017**, *16*, 467–476.

92. Díaz-Blanco, D.I.; de La Cruz, J.R.; López-Linares, J.C.; Morales-Martínez, T.K.; Ruiz, E.; Rios-González, L.J.; Romero, I.; Castro, E. Optimization of dilute acid pretreatment of Agave lechuguilla and ethanol production by co-fermentation with Escherichia coli MM160. *Ind. Crops Prod.* **2018**, *114*, 154–163. [CrossRef]
93. Rios-González, L.J.; Morales-Martínez, T.K.; Hernández-Enríquez, G.G.; De la Garza, J.A.R.; Moreno-Dávila, M. Hydrogen Production by anaerobic digestion from Agave lechuguilla hydrolysates. *BioResources* **2018**, *13*, 7766–7779. [CrossRef]
94. Figueroa-Díaz, A.B.; Carlos-Hernández, S.; Díaz-Jiménez, L. Crude glycerol/guishe based catalysts for biodiesel production: Conforming a guishe biorefinery. *Catalysts* **2021**, *11*, 3. [CrossRef]
95. Morales-Martínez, T.K.; Medina-Morales, M.A.; Ortíz-Cruz, A.L.; Rodríguez-De la Garza, J.A.; Moreno-Dávila, M.; López-Badillo, C.M.; Ríos-González, L. Consolidated bioprocessing of hydrogen production from agave biomass by Clostridium acetobutylicum and bovine ruminal fluid. *Int. J. Hydrogen Energy* **2020**, *45*, 13707–13716. [CrossRef]
96. Villarreal Sanchez, J.A.; Diaz Jimenez, L.; Escobedo Bocardo, J.C.; Carenas Palomo, J.O.; Guerra Escamilla, N.E.; Luna Alvarez, J.S. Effect of marine microorganisms on limestone as an approach for calcareous soil. *Sustainability* **2018**, *10*, 2078. [CrossRef]
97. Reyna Martínez, R.; Morales Martínez, T.K.; Castillo Quiroz, D.; Contreras Esquivel, J.C.; Ríos Gonzalez, L.J. Fungal pretreatment of Agave lechiguilla Torr. biomass to produce ethanol. *Rev. Mex. Cienc. For.* **2018**, *10*, 86–106.
98. Aranda-Ledesma, N.E.; Bautista-Hernández, I.; Rojas, R.; Aguilar-Zárate, P.; del Pilar Medina-Herrera, N.; Castro-López, C.; Martínez-Ávila, G.C. Candelilla wax: Prospective suitable applications within the food field. *LWT* **2022**, *159*, 1–13. [CrossRef]
99. Martínez-Ballesté, A.; Mandujano, M.C. The consequences of harvesting on regeneration of a non-timber wax producing species (*Euphorbia antisyphilitica* Zucc.) of the Chihuahuan Desert. *Econ. Bot.* **2013**, *67*, 121–136. [CrossRef]
100. Saucedo-Pompa, S.; Martínez-Ávila, G.C.G. National and international candelilla wax market. In *Food Process Engineering and Quality Assurance*; Taylor & Francis: New York, NY, USA, 2018; pp. 561–582.
101. Aguirre-Joya, J.A.; Rojas, R.; Ventura-Sobrevilla, J.M.; Aguilar-Gonzalez, M.A.; De La Garza, H.; Belmares, R.E.; Rodríguez-Herrera, R.; Aguilar, C.N. Candelilla plant (Euphorbia antisiphylitica Zucc.) approach and market. In *Food Process Engineering and Quality Assurance*; Taylor & Francis: New York, NY, USA, 2018; pp. 461–472.
102. Barsch, F. Candelilla (*Euphorbia antisyphillitica*): Utilisation in Mexico and international trade. *Med. Plant Conserv.* **2004**, *9*, 45–50.
103. Rojas, R.; Tafolla-Arellano, J.C.; Martínez-Ávila, G.C.G. *Euphorbia antisyphilitica* Zucc: A source of phytochemicals with potential applications in industry. *Plants* **2021**, *10*, 8. [CrossRef]
104. Buenrostro-Figueroa, J.; Ascacio-Valdés, A.; Sepúlveda, L.; De La Cruz, R.; Prado-Barragán, A.; Aguilar-González, M.A.; Rodríguez, R.; Aguilar, C.N. Potential use of different agroindustrial by-products as supports for fungal ellagitannase production under solid-state fermentation. *Food Bioprod. Process.* **2014**, *92*, 376–382. [CrossRef]
105. CITES. Evaluación del estatus de Euphorbia antisyphilitica en México dentro de los apéndices de la CITES: Decimoctava reunión del Comité de Flora, Buenos Aires, Argentina, 17–21 de marzo de 2009. Available online: https://cites.org/sites/default/files/common/com/pc/18/X-PC18-Inf10.pdf (accessed on 24 October 2022).
106. Rocha-Estrada, A.; Pournavab, R.F.; Guzmán-Lucio, M.A.; Alvarado-Vázquez, M.A. Candelilla (*Euphorbia antisyphilitica* Zucc.), Aprovechamiento tradicional en el norte de México. *Cienciauanl* **2021**, *24*, 1–23.
107. Martínez-Ávila, G.C.G.; Aguilar, C.N.; Sanchez-Alejo, E.J.; Ascacio-Valdes, J.A.; Aguilera-Carbó, A.F.; Rojas, R. Extraction of bioactive compounds, characterization, and its use. In *Food Process Engineering and Quality Assurance*; CRC Press: Boca Raton, FL, USA, 2020; pp. 541–550.
108. Ascacio-Valdés, J.A.; Aguilera-Carbó, A.; Martínez-Hernández, J.L.; Rodríguez-Herrera, R.; Aguilar, C.N. *Euphorbia antisyphilitica* residues as a new source of ellagic acid. *Chem. Pap.* **2010**, *64*, 528–532. [CrossRef]
109. Bautista-Hernández, I.; Aranda-Ledesma, N.E.; Rojas, R.; Tafolla-Arellano, J.C.; Martínez-Ávila, G.C.G. Antioxidant activity of polyphenolic compounds obtained from *Euphorbia antisyphilitica* by-products. *Heliyon* **2021**, *7*, e06734. [CrossRef] [PubMed]
110. Pulido-Barragán, E.U.; Morales-Cepeda, A.B.; Castro-Guerrero, C.F.; Koschella, A.; Heinze, T. Upgrading *Euphorbia antisyphilitica* fiber compost: A waste material turned into nanocrystalline cellulose. *Ind. Crops Prod.* **2021**, *160*, 113111. [CrossRef]
111. Rojas Molina, R.; Saucedo Pompa, S.; De León Zapata, M.A.; Jasso Cantú, D.; Aguilar, C.N. Pasado, Presente y futuro de la candelilla. *Rev. Mex. Ciencias For.* **2019**, *2*, 7–18. [CrossRef]
112. Dagar, J.C.; Yadav, R.K.; Ahamad, S. *Euphorbia antisyphilitica*: A potential petro-crop for degraded calcareous soils and saline water irrigation in dry regions of India. *J. Soil Salin. Water Qual.* **2012**, *4*, 86–91.
113. Kumari, A.; Kumar, A. Some potential biofuel plants for semi-arid and arid region and improving their growth and productivity. In Proceedings of the 14th European Biomass Conference, Paris, France, 17–21 October 2005; pp. 279–281.
114. Torres Castro, A.; Garza Navarro, M.; Ortiz Méndez, U.; González González, V. Candelilla del semidesierto mexicano como fuente de biocombustible. *Ingenierías* **2015**, *18*, 22–29.
115. Garg, J.; Kumar, A. Some potential biofuel plants for production of biodiesel in semi-arid and arid conditions: A review. *Afr. J. Plant Sci.* **2013**, *7*, 124–127. [CrossRef]
116. Schueftan, A.; Sommerhoff, J.; González, A.D. Firewood demand and energy policy in south-central Chile. *Energy Sustain. Dev.* **2016**, *33*, 26–35. [CrossRef]
117. Molina, C.; Toro, A.R.; Morales, S.R.G.; Manzano, C.; Leiva-Guzmán, M.A. Particulate matter in urban areas of south-central Chile exceeds air quality standards. *Air Qual. Atmos. Health* **2017**, *10*, 653–667. [CrossRef]

118. Cruz-Montelongo, C.D.L.; Herrera-Gamboa, J.; Ortiz-Sánchez, I.A.; Ríos-Saucedo, J.C.; Rosales-Serna, R.; Carrillo-Parra, A. Caracterización energética del carbón vegetal producido en el Norte-Centro de México. *Madera Bosques* **2020**, *26*, e2621971. [CrossRef]
119. García-Quezada, J.; Musule-Lagunes, R.; Prieto-Ruíz, J.A.; Vega-Nieva, D.J.; Carrillo-Parra, A. Evaluation of four types of kilns used to produce charcoal from several tree species in Mexico. *Energies* **2023**, *16*, 333. [CrossRef]
120. Bustamante García, V.; Carrillo Parra, A.; Prieto Ruíz, J.Á.; Corral-Rivas, J.J.; Hernández Díaz, J.C. Química de la biomasa vegetal y su efecto en el rendimiento durante la torrefacción: Revisión. *Rev. Mex. Cienc. Forestales* **2016**, *7*, 5–23. [CrossRef]
121. Chen, W.H.; Peng, J.; Bi, X.T. A state-of-the-art review of biomass torrefaction, densification and applications. *Renew. Sustain. Energy Rev.* **2015**, *44*, 847–866. [CrossRef]
122. Rousset, P.; Fernandes, K.; Vale, A.; Macedo, L.; Benoist, A. Change in particle size distribution of torrefied biomass during cold fluidization. *Energy* **2013**, *51*, 71–77. [CrossRef]
123. Ngangyo-Heya, M.; Romo-Hernández, A.L.; Foroughbakhch-Pournavab, R.; Ibarra-Pintor, L.F.; Díaz-Jiménez, L.; Heya, M.S.; Salas-Cruz, L.R.; Carrillo-Parra, A. Physicochemical characteristics of biofuel briquettes made from pecan (*Carya illinoensis*) pericarp wastes of different particle sizes. *Molecules* **2022**, *27*, 1035. [CrossRef]
124. Nunes, L.J.R. Biomass gasification as an industrial process with effective proof-of-concept: A comprehensive review on technologies, processes and future developments. *Results Eng.* **2022**, *14*, 100408. [CrossRef]
125. Peng, J.H.; Bi, H.T.; Lim, C.J.; Sokhansanj, S. Study on density, hardness, and moisture uptake of torrefied wood pellets. *Energy Fuels* **2013**, *27*, 967–974. [CrossRef]
126. Peng, J.H.; Bi, X.T.; Sokhansanj, S.; Lim, C.J. Torrefaction and densification of different species of softwood residues. *Fuel* **2013**, *111*, 411–421. [CrossRef]