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SWOT Analysis Applied to Wheat Straw Utilization as a Biofuel in Mexico

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Abstract

Wheat is one of the main crops worldwide with a production of 733 million of tons by 2015. By 2013, the wheat grain production in Mexico was 3,357,307 t. Wheat straw is generated as a biomass waste once the wheat is harvested. However, the agricultural biomass waste has acquired international relevance as a source of bioenergy. The utilization of bioenergy has significant environmental benefits, and also economic benefits because the biomass waste is valorized as biofuel. The use of wheat straw as raw material for any productive process presents diverse factors that must be considered. Among those factors are the low density of biomass, handling and high transportation cost, an attractive heating value, and the physicochemical characterization. Therefore, the aim of this work was to apply the SWOT analysis to wheat straw utilization as a biofuel in Mexico. The main findings highlighted an estimation of 4,612,950.23 t of wheat straw generated. The experimental results of proximate analysis were 64.42% volatile matter, 19.49% fixed carbon and 16.09% ash. The higher heating was 14.86 MJ/kg. An energy potential of 69 PJ per agricultural cycle was calculated, equivalent to 19% of the biomass energy share reported in Mexico's National Energy Balance, by 2014.

Keywords: biofuel, SWOT analysis, wheat straw, biomass, agricultural waste

1. Introduction

Wheat is one of the main crops of the world with an annual production of 733 million tons reported in 2015 [1]. In Mexico, it was ranked 7th among all the crops in 2013, with a harvested surface of 683,044.42 ha [2]. The most common harvested wheat varieties are *Triticum aestivum* and *Triticum durum*. Note that 90% of wheat production is obtained in the fall-winter season, and the remaining 10% corresponds to the spring-summer season. The harvest season is done mainly in May and June [3]. The Northwest region is the largest area for wheat crop production. Hence, the major quantity of wheat straw is generated in that region. It was estimated that 4,612,950.23 t of wheat straw was generated in Mexico. Approximately, 85% of that biomass waste is burned as a traditional practice performed by farmers at the end of the agricultural cycle [4]. The burning of agricultural waste biomass is regulated by NOM-015-SEMARNAT/SAGARPA-2007 that establishes the technical specifications of methods on the use of fire in forest land and agricultural land use, in order to prevent and reduce forest fires. However, it is not applied because of the lack of human resource to inspect and supervise those events [5]. In **Figure 1**, the burning practices and their impact on the environment are depicted. Generally, the burning practice is done in uncontrolled and unsafe conditions that cause air pollution, soil organic nutrients loss, elimination of microorganisms, and pH soil modification. However, wheat straw is a biomass resource that can be valorized and used as a biofuel because it has an attractive heating value.



Figure 1. Wheat straw burning practices in Mexico [source: by the authors].

Using wheat straw as a raw material for any productive process presents diverse factors that must be considered. Among those factors are the constant supply of wheat straw, the low density, handling and high transportation cost, the higher heating value, and the physico-chemical characterization. Due to the type of the different factors involved, the SWOT (strengths, weaknesses, opportunities, and threats) methodology is a useful tool for analyzing such factors. Therefore, the aim of this work was to apply the SWOT analysis to wheat straw utilization as a biofuel in Mexico.

1.1. Power generation through wheat straw

Traditionally, biomass has been used for heating in open fireplaces or stoves. Currently, the biomass utilization as fuel for electricity generation has gained more importance internationally. It is a productive alternative to the exploitation of waste biomass generated in the agriculture and forestry, annually.

With the purpose of reducing greenhouse gases (GHG) emissions and depletion of nonrenewable energy sources, there is an increase in the share of renewables worldwide. Bioenergy plays a vital role in the reduction of GHG and climate change.

In 2012, the installed biomass power generation capacity reached 83 gigawatt-electric (GWe), equivalent to 1.5% of global power generation capacity [6]. Denmark is a pioneer in developing power plants using agricultural wastes; the first commercial straw power plant, Haslev, has been developed since 1989. Four power plants were developed and operated with wheat straw as the sole fuel. Moreover, large-scale straw power plants also have been commissioned in the United Kingdom (38 MW, Ely in 2002) and Spain (25 MW, Sangüesa in 2002) [7]. The biggest advantage of using straw in the energy sector is that it is a CO₂ neutral fuel, which does not contribute to an increase of the atmosphere's content of greenhouse gases.

1.2. Biomass share in the Mexican energy matrix

By 2014, the biomass share in the energy matrix of Mexico was 4.07%, and it represented the highest among all the renewable energy sources [8]. The biomass considered by the National Energy Balance was only firewood and sugarcane bagasse. The energetic use of biomass in Mexico is limited to food cooking processes in rural places and as a fuel in power generation plants in sugar refineries. The biomass electricity generation has a total capacity of 634 MW [9].

The current economic situation of the energy sector of Mexico is leading to many opportunities to increase the renewable energy share in the energy matrix. Renewable energy is an alternative to a petroleum-based economy that in the recent years has shown high prices fluctuations of crude oil. The regulatory framework was already established, and it is comprised in the laws of energy transition, promotion and development of bioenergy, and renewable energy from Baja California. However, there is the need to create mandates accompanied with the right energy policy to encourage and increase the renewable energy market in Mexico.

1.3. Renewable energy regulation in Mexico

In 2014, the energy situation in Mexico had experienced a radical change with the approval of the energy reform. Its aim to maintain the energy security of the country and economic connectivity and make energy as a motto of the Mexican economy to create jobs and attract investments and technology. The main structural changes are established in the reform, such as the opening of the electricity market. These changes are reflected in the modifications performed to the articles 27 and 28 of the Mexico’s Constitution [10]. The article 27 establishes that the planning and control of the national electricity system, energy transmission, and distribution are exclusive functions of the nation. It is forbidden to provide concessions to private companies related to the mentioned functions. However, it allows the State to have contracts with the private sector on behalf of the nation, to carry out financing, maintenance, management, operation, and expansion of the necessary infrastructure to provide the public service of transmission and distribution of electricity. The elimination of the exclusivity to generate electricity by the State was the main modification to the article 28. Nevertheless, the planning and control of the national electricity system and the public service of electricity transmission and distribution are exclusive areas of the State.

The energy reform allows the private electricity producers to sell energy, not only in the self-supply modality as previously, but openly. Also, it removed entry barriers of the energy sector, allowing greater flexibility for private sector investment and promoting equitable and competitive conditions for all private generations including the Federal Electricity Commission. This reform represents an opportunity for the increment of the biomass share in the national energy matrix.

In 2015, the Law of Energy Transition was enacted. The purpose of this law is to regulate the sustainable use of energy as well as the obligations of clean energy and reduction of pollutant emissions from the electricity industry while maintaining the competitiveness of the productive sectors [11]. In this law, it is established that power consumption is met by a portfolio of alternatives that include energy efficiency and an increasing proportion of clean energy generation in conditions of economic viability. Through clean energy and energy efficiency goals, the Secretariat of Energy will encourage electricity generation from clean energy sources to reach the levels established in the Mexican General Law on Climate Change. The Secretariat should consider the biggest boost to energy efficiency and clean energy generation that can be supported in a sustainable way under the economic conditions and the electricity market in the country. Policies and measures to boost energy efficiency and renewable resources to replace fossil fuels in final consumption will be considered.

2. Wheat straw generation in Mexico

2.1. Wheat producers in Mexico

Table 1 shows the wheat producers in Mexico, the wheat harvested area, and the wheat straw generated. Sonora and Baja California were responsible for the production of 61.69% of wheat straw.

No.	State	Wheat harvested area (ha)	Wheat straw generated (t)
1.	Sonora	304,547.50	2,223,196.75
2.	Baja California	86,731.00	633,136.30
3.	Tlaxcala	33,912.00	247,557.60
4.	Jalisco	30,676.00	223,934.80
5.	Guanajuato	30,626.50	223,573.45
6.	Chihuahua	28,522.05	208,210.97
7.	Michoacán	25,213.07	184,055.41
8.	Nuevo León	24,876.20	181,596.26
9.	Sinaloa	17,670.57	128,995.16
10.	Oaxaca	10,324.00	75,365.20
11.	Estado de México	9,239.00	67,444.70
12.	Zacatecas	7,748.00	56,560.40
13.	Coahuila	7359.82	53,726.69
14.	Baja California Sur	4,786.00	34,937.80
15.	Puebla	4,183.30	30,538.09
16.	Durango	3,365.17	24,565.74
17.	Hidalgo	2,130.81	15,554.91
	Total	631,910.99	4,612,950.23

Table 1. Wheat producer's states in Mexico in 2013 [12].

The states of Mexico that produce wheat were ranked and localized geographically through the analysis of the statistical information system of crops. **Figure 2** illustrates the location of the states from Mexico that produced wheat in 2013.

Based on data reported by the Secretariat of Energy, a generation index of 7.3 t/ha [13] of wheat straw was used for the estimation of the wheat straw availability. The experimental determinations were performed to *Triticum aestivum* that is one of the most common wheat varieties that is harvested in Mexico. The proximate analysis and higher heating value determinations were applied to the wheat straw. The proximate analysis was conducted according to ASTM E870-82, and the heating value was determined following the ASTM E711. Based on the wheat straw estimation and the experimental results, the SWOT methodology was applied to evaluate the internal and external factors affecting the utilization of wheat straw as biofuel in Mexico.

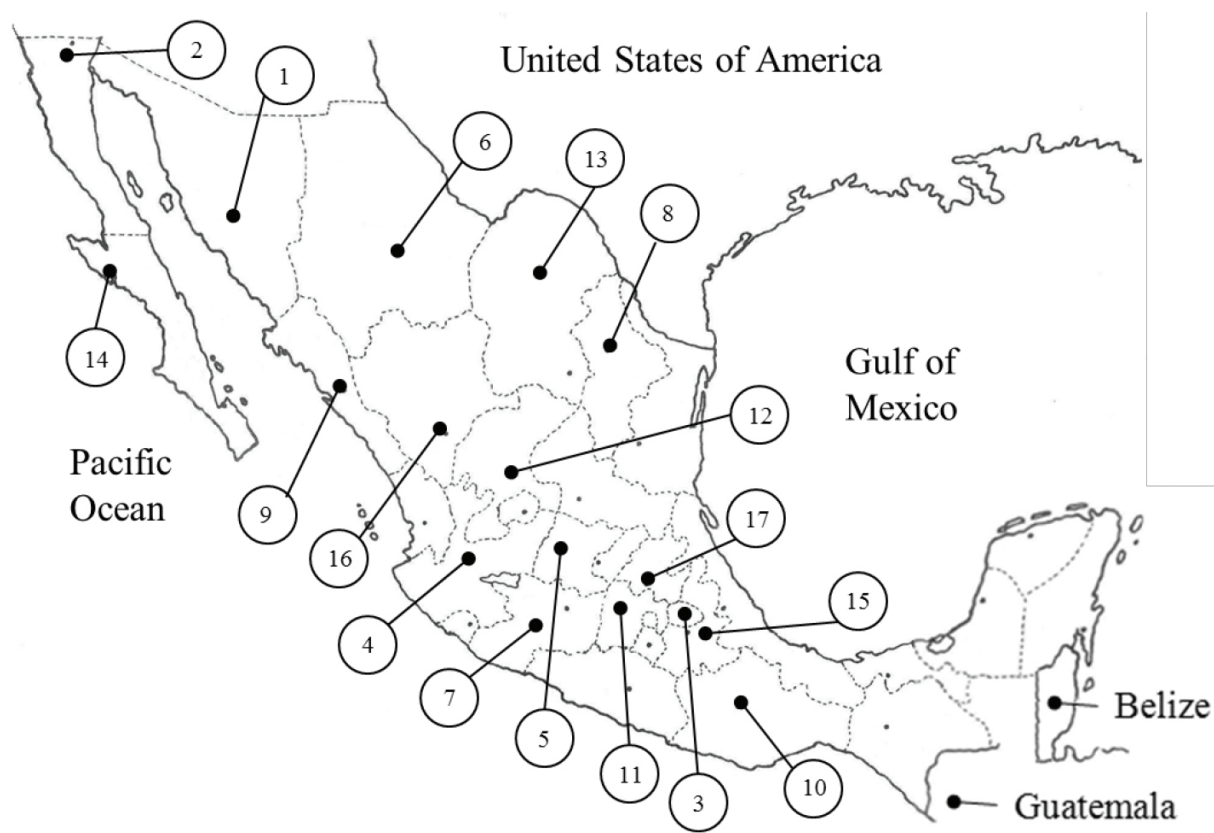


Figure 2. Location of wheat producer's states in Mexico.

2.2. Wheat straw experimental determinations

The proximate analysis and higher heating value determinations were applied to the wheat straw. The analysis procedures were conducted according to ASTM E870-82 (2006), and the heating value was determined according to ASTM E711 [14, 15].

2.3. Proximate analysis

Among the analysis for physicochemical characterization of the biomass, the proximate analysis is the one with less complexity. It does not require sophisticated laboratory equipment. The proximate analysis allows determining the weight percentages of moisture (M), volatile matter (VM), fixed carbon (FC), and ash of the biomass. With the results obtained from this analysis, it is possible to define the most suitable biomass conversion process, e.g., biological or thermochemical processes. It also permits establishing fuel quality criteria, among others [16].

2.4. Higher heating value

The heating value is an important parameter that must be determined in the evaluation of any fuel and to analyze and design bioenergy systems [17]. It is a measure of the amount of energy that can be released per unit mass, through an oxidation reaction. It is one of the most important

characteristics to define the suitability of a solid biomass as a fuel. The heating value was determined experimentally by employing an adiabatic calorimetric bomb IKA WERKE; model C2000 basic.

2.5. SWOT analysis

The SWOT analysis evaluates the strengths, weaknesses, opportunities, and threats related to the development of a project. The strengths and weaknesses of the project are internal characteristics and are controllable while opportunities and threats are external factors but can react at a determining moment in their favor [18]

The implementation of the SWOT analysis allows understanding the strengths of a project and to exploit its opportunities and plan based on them. Also, it contributes to recognize treat or avoid the weaknesses and protect against any threat known [19]. The SWOT methodology was applied to evaluate the internal and external factors affecting the utilization of wheat straw as biofuel in Mexico.

3. Results

The main findings highlighted an estimation of 4,612,950.23 t of wheat straw generated in Mexico. The states of Sonora and Baja California were responsible for 61.69% of the wheat straw generation.

The results of proximate analysis experimentally obtained were 64.42% volatile matter, 19.49% fixed carbon, and 16.09% ash.

The experimental higher heating of wheat straw determined was 14.86 MJ/kg. Based on these results, an energy potential of 69 PJ per agricultural cycle was calculated, equivalent to 19% of the biomass energy share reported in Mexico's National Energy Balance, in 2014.

Table 2 depicts the results of the SWOT analysis applied to evaluate the internal and external factors affecting the utilization of wheat straw as biofuel in Mexico.

The main strength identified for the use of wheat straw as biofuel in Mexico was its higher heating value and high intensive activity in the agricultural sector, specifically, wheat harvesting. The higher heating value of the wheat straw is an attractive and the most important characteristic from the energy point of view. The amount of wheat straw generated annually in the Mexican agriculture is considerable and highlights high resource availability. It is an important aspect because it can contribute to ensuring the biomass supply. The valorization of wheat straw for energy applications can foster the economic development of the agricultural sector of Mexico, provide to energy security, and reduce the fossil fuel use. It is a sustainable alternative that helps to control and reduce the pollutant emissions by avoiding the open burning practices of waste agricultural biomass. In the global market, there are proven technologies for the utilization of agricultural waste as biofuel. In Mexico, there is experience in power generation by waste biomass from the agriculture. It is an advance regarding the learning curve.

About the weaknesses found, the wheat straw has a low density. It is an issue that requires physical conditioning and densification of the biomass to facilitate its collection, handling, transportation, and storage. The addition of these preprocessings increases the costs due to the implementation of specialized equipment, labor, and fuel consumption. The wheat straw is not concentrated in one place. Therefore, the long distances involved between the wheat straw generation fields represent a challenge to collect it.

Strengths	Weaknesses
A higher heating value of wheat straw.	Low bulk density of biomass.
Intensive agriculture activity in Mexico.	Large distance between biomass generation places.
Sustainable exploitation of residual biomass.	High handling cost.
Proven technologies for the utilization of agricultural waste as biofuel.	High transportation cost.
Fostering the economic development of agriculture sector.	Biomass is not concentrated.
Greenhouse gas emissions reduction by fossil fuels replacement.	The requirement of specialized equipment for the densification and handling of biomass.
Pollutant emissions reduction by avoiding open burning of crop residues.	Biomass market inexistent in Mexico.
Substitution and reduction of fossil fuels use.	
Ensure energy security.	
Opportunities	Threats
National Energy Transition Law.	Traditional open burning crop residues practices.
Recent Energy Reform.	Lack of public policy to foster the utilization of agricultural residues as biofuels.
Ambitious goals of the energy sector to increase fuels from renewable sources.	Ensuring the constant supply of waste biomass.
Favorable policies for the development of renewable energy in Mexico.	Price of residual biomass.
Research and development infrastructure available.	Crop harvested surface variations.

Table 2. SWOT analysis results.

The current situation in the energy sector of Mexico provides opportunities for the use of wheat straw as biofuel. The recent energy reform, the Law of Energy Transition, and the goals to increase the participation of renewable energy in Mexico are setting the platform to favor and to encourage the exploitation of waste biomass for energy applications.

Among the main threats analyzed are the biomass supply ensuring the annual crop harvested surface variations, the price of residual biomass, and the lack of public policy that promotes the valorization of waste biomass. There is another one, related to a sociocultural aspect, and it is the traditional burning practices of wheat straw performed by farmers across the country. Therefore, it is necessary to gain the social acceptability of farmers and the rural communities strategically to avoid burning of wheat straw and to assure the constant supply of wheat straw.

4. Conclusion

Due to the current situation that Mexico is facing concerning energy security, decreasing of dependence to conventional energetics, as well as the reduction of greenhouse gases emissions, it is necessary to find alternatives to diversify the energy sources. For that reason the Mexican government committed to sustainability has empowered the Secretariat of Energy based on international trends that postulate changing patterns of production and use of energy, to develop a national strategy for the energetic transition due to environmental, social, and economic issues. The energetic transition involves major changes, including the promotion of renewable energy sources, e.g., solar, wind, biomass, hydraulic, and the rational use of energy as key strategic actions. The main goal of the Law of Energy Transition is to increase the share of clean energy production to 25% by 2018, 30% by 2021, 35% by 2024, and 40% by 2035. The biomass and waste biomass can play a key role in the energy transition because the high intensive activity in the agriculture sector. The wheat straw stand out as an abundant biomass residue generated in Mexico and it has an important energy potential estimated at 69 PJ per agricultural cycle. The valorization and utilization of wheat straw for bioenergy purposes is equivalent to 19% of the biomass energy share reported in Mexico's National Energy Balance, in 2014.

The results of the SWOT analysis applied to evaluate the internal and external factors affecting the utilization of wheat straw as biofuel in Mexico depicted nine strengths, seven weaknesses, five opportunities, and five threats. The development of the SWOT analysis provided the consideration of the main factors for the utilization of wheat straw as a biofuel in Mexico. The actual conditions in Mexico are favorable for the exploitation of wheat straw as a biofuel.

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