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Rice Straw Characteristics And Its Potential Energy In Valencia (Spain)

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***Abstract*— Rice straw is attractive as a fuel for heat and power generation. High amount of straw is generated annually from rice cultivation in Valencia. This amount could be converted to a valuable energy product such as gas through direct combustion, biogas from anaerobic digestion, syngas through gasification or in the form of liquid as bio-oil from pyrolysis and ethanol through biochemical. Thus, the theoretical energy from this amount of rice straw through the different techniques was estimated in this study. Furthermore, the characteristics of rice straw as source of energy have been studied. The results showed that the direct combustion represents the highest technique for recovering energy from rice straw followed by pyrolysis, gasification, biochemical conversion and finally anaerobic digestion. The results of rice straw analysis indicated that its major constituents are cellulose (32.95%) and hemicellulose (25.86%), making it a good candidate for ethanol production. Furthermore, it has high volatiles (85.22%) and carbon content (40.40%), indicating its potential towards biogas production. Its low moisture content (8.94%) makes it well feedstock to thermochemical conversion technologies. Thus, these factors make it an excellent waste to energy resource.**

***Keywords*— Rice straw, Characteristics, Potential energy, Valencia.**

I. Introduction

Using the biomass wastes becomes a significant way to produce the bioenergy. Among the available biomass wastes, rice straw is one of the favorable waste sources of bioenergy, because it is the residue from the end use of the biomass products [1]. The reutilization of rice straw not only saves the cost of disposal but also produces valuable bioenergy, achieving the goal of resources recovery and reuse [2].

Spain is the second-largest rice-producer in the EU after Italy [3,4]. Valencia, Spain's third largest city, is host to one of the most breathtaking areas on the Mediterranean: the Albufera Nature Reserve [5]. Around 800 million kg straw from rice cultivation are disposed of, traditionally by burning in situ, causing real environmental problems [6].

Rice straw as residual biomass can be converted into a renewable fuel for heat and power generation. It is a viable alternative to fossil fuels, and also has the advantage of preventing pollution from rice straw open burning [7]. Energy from rice straw can be produced directly, by combustion, or indirectly, by producing an intermediate form such as gasification to produce syngas, pyrolysis to produce bio-oil, anaerobic digestion to produce biogas and biochemical conversion to produce ethanol [8,9].

The characteristics of rice straw and its composition are factors that may affect the energy yield could be obtained via different techniques [1]. Furthermore, rice straw may contain some troublesome compounds that could cause some operating problems in thermal conversion systems [10]. Thus, in this work the physical, chemical and thermal characteristics of rice straw in Valencia will be studied. Moreover, the theoretical potential energy could be recovered from rice straw amount that generated in Valencia using different techniques such as direct combustion, anaerobic digestion, gasification, pyrolysis and biochemical conversion will be estimated.

II. Experiment

The used rice straw was collected from Valencia (Spain) and its size was reduced to less than 0.5 mm before analysis. Moisture content was determined by air oven at 105º C to a constant weight, according to UNE-EN 14774-2 [11]. Ash contents were determined by igniting the grinded straw in muffle furnace according to UNE-EN 14775 [11], and the ash concentrations at higher temperatures 700, 800, 900 and 1000º C for 2 h were determined to check for weight changes and ash behavior. Volatile matter content was determined at 900º C according to UNE-EN 15148 [13]. Elemental analysis for the straw samples was performed according to UNE-EN 15104 [14]. Elemental composition for the ash obtained at 550º C through X-Ray Fluorescence was analyzed according to UNE-EN 15290 [15]. Environmental Scanning Electron Microscope (ESEM) and chemical analysis of selected spots for ash samples prepared at 550°C were performed using ESEM, FEI model Quanta 400.

The lignin content was determined by acid hydrolysis according to Sluiter et al. [16] and was measured by UV-Spectrophometry (Ɛ205= 110 L/g cm). Glucose was quantified with the Glucose-TR kit (Spinreact) and the reducing sugars were determined with the Somogyi-Nelson method [17]. Finally, the cellulose content was calculated from the glucose and the difference between total reducing sugar and glucose corresponded to the sugars from hemicellulose, using an

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anhydro correction of 0.90 and 0.89 for calculating cellulose and hemicellulose, respectively.

III. Results and Discussion

High amount of straw is generated annually from rice cultivation in Valencia. Around 800 million kg straw could be converted to a valuable energy product such as gas through direct combustion, biogas from anaerobic digestion, syngas through gasification or in the form of liquid as bio-oil from pyrolysis and ethanol through biochemical [8]. The theoretical energy from this amount of rice straw through the different available techniques was estimated, as indicated in Table 1. It has been found that the direct combustion represents the highest technique for recovering energy from rice straw, accounting 12.80 petajoules (PJ), followed by pyrolysis, gasification, biochemical conversion and finally anaerobic digestion. Thus, thermal conversion of rice straw through direct combustion is considered attractive option to recover its energy. However, the thermal conversion of rice straw causes some operating problems that affect thermal conversion systems [10]. These problems could be related to straw composition. So, the physical, chemical and thermal analyses of rice straw have been studied.

Table 1: Properties of the Media Used in this Study.

Process	***Product***	***Product Yield***	***Heating value (MJ)***	***Calculated theoretical Energy (PJ)***
Pyrolysis	Bio oil	68% Wt.	19.00 /Kg oil [18]	10.34
Gasification	Syngas	1.84 m3/Kg	6.01/m^3 gas [19]	8.85
Biochemical conversion	Ethanol	416 L/dry ton*	19.6/L ethanol [20]	5.88
Direct combustion	Gas	---	16.00/Kg straw [21]	12.80
Anaerobic digestion	Biogas	---	6.81/Kg straw [21]	5.45

* Dry rice straw is 90 % Wt [19].

The results of rice straw analysis (based on dry weight except moisture content) and its ash composition are presented in Table 2. As indicated in the table, the major constituents of rice straw are cellulose and hemicellulose. In addition, it has high volatile solids and carbon content, and low moisture content. These factors make it an excellent waste to energy resource. The low moisture content of rice straw (8.94%) make it well feedstock to thermochemical conversion technologies like combustion, gasification and pyrolysis [18,19]. The high content of cellulose (32.95%) and hemicellulose (25.86%) that can be readily hydrolysed into fermentable sugars make it a good candidate for ethanol production through biochemical conversion processes [20]. Furthermore, it has high volatiles (85.22%) and carbon content (40.40%), indicating its potential towards biogas production in anaerobic digestion plants, possibly by co digestion with sewage sludge, animal wastes and food wastes [9].

The rice straw as feedstock has the advantage of having relatively low alkali content (K_2O and Na_2O, 9.65% and 0.79 % of total ash, respectively) [22]. However, rice straw has also shown relatively high lignin and ash content (21.45% and 15.41%, respectively), moreover, high silica content in ash (67.76%) was detected, which are representing limiting factors in rice straw quality as a feedstock energy generation [9]. Furthermore, soil and mineral contamination for the used straw during storage and handling may lead to higher ash content [23]. In consequence, the straw should be carefully collected and stored to avoid mineral contamination and it could be treated before its use by means such as water washing to reduce alkali and alkaline compounds or by chemical and biological treatments to reduce the problems related to high silica and lignin content, consequently improving in feedstock quality could be obtained [24].

Table 2: Rice straw analysis data and major elements of the straw ash

Analysis[2]		***Value (%)***
Component analysis	Lignin	21.45
	Cellulose	32.95
	Hemicellulose	25.86
Proximate analysis	Moisture	8.94
	Ash	15.41
	Volatiles	85.22
Ultimate analysis	C	40.40
	H	6.91
	N	0.43
Elemental composition of ash	SiO_2	67.76
	K_2O	9.65
	CaO	6.47
	MgO	3.26
	Na_2O	0.79
	P_2O_5	1.41
	SO_3	1.49

[2]Based on dry weight except moisture content

Ash content at 550 °C and its concentrations at different higher temperatures (550- 1000 º C) for the straw samples are indicated in Figure 1. Reduction in ash concentrations has been observed with temperature increasing. The reduction in ash concentration during temperature increase from 550 °C to 700 °C may be attributed to the oxidation of some organic components that had not been completely burnt, and to the evaporation of some inorganic matter from the ash with further increases in temperature [25].

While the reduction in ash concentration after 700 °C up to 1000 °C can be attributed to the removal and decomposition reaction of inorganic components such as chlorine and potassium, as well as, evaporation of potassium salts that retained by ash from soil [25]. On the other hand, the ash samples sintered and showed crystallized appearance at 1000° C. This may be due to the presence of silica in combination with potassium that can lead to sintering and slag and formation at high furnace temperatures, as found by Said et al. [10].

Samples of ash prepared at 550°C were inspected by ESEM. Figure 2 shows ESEM for two different zones in ash sample. It is possible to observe that the outer epidermis of rice straw ash is well organized and has a corrugated structure and the internal part has a lamella and porous structure. This appearance is corresponding to the high silica content with considerable superficial area, which is mainly localized in the tough interlayer and also filling in the spaces between the cells, as found by Liou [26].

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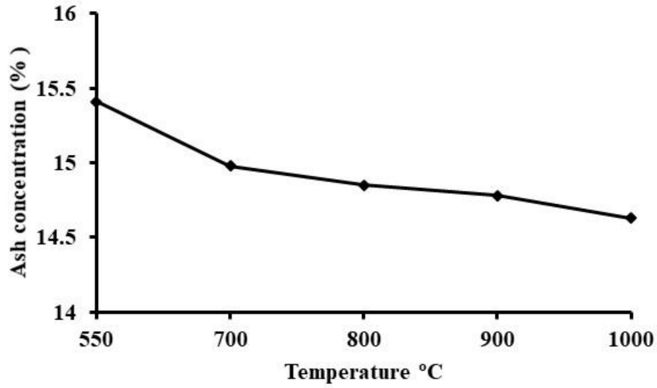
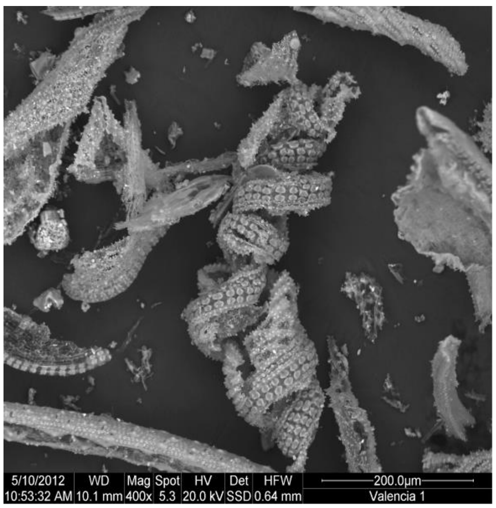


Figure 1: Ash concentrations at different temperatures.

a

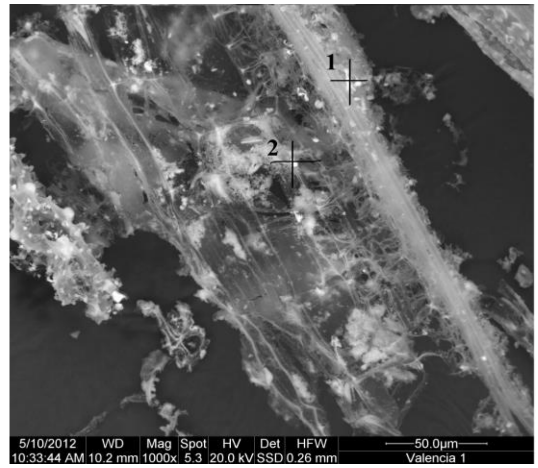


b

Figure 2: ESEM for two different zones of ash samples

The chemical analysis was applied for some spots in images of larger magnifications, as shown in Figure 3. ESEM inspection and the chemical analysis for some spots showed that the straw ash samples are consisting primarily of silica, high amounts of chlorine, potassium and observed amounts of other elements such as Ca and Mg at the selected spots, similar results have been found by Said et al. [10].

a



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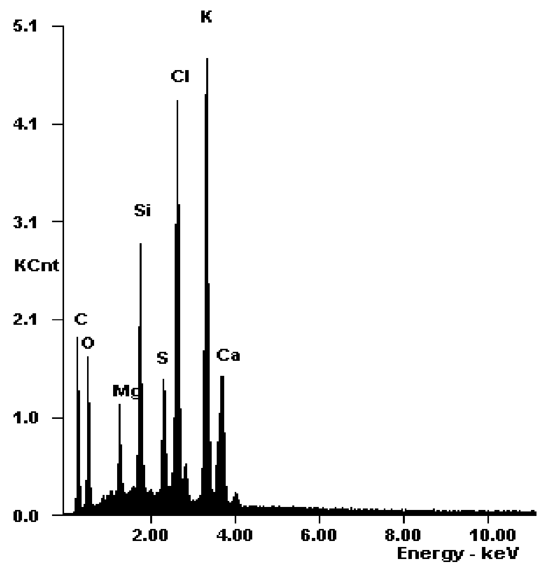

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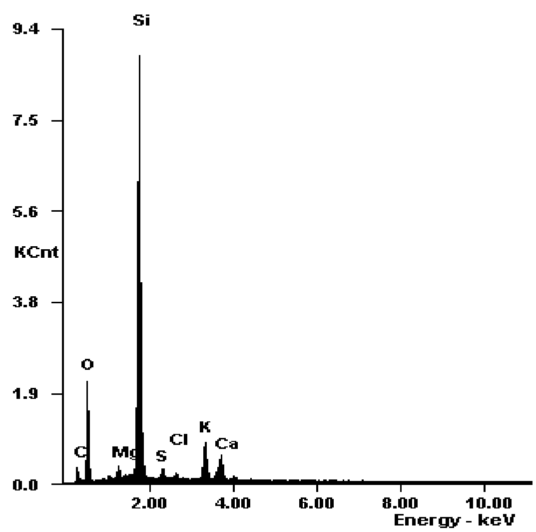

Figure 3: ESEM image for ash and spot analysis.

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IV. Conclusion

Utilization of rice straw as a source of energy is important from energetic, as well as, environmental viewpoint. Around 800 million Kg straw, generated annually from rice cultivation in Valencia, could be converted to a valuable energy product through different techniques. In this study, theoretical potential energy of rice straw has been estimated for different techniques. The results showed that the direct combustion represents the highest technique for recovering energy from rice straw (12.80 PJ) followed by pyrolysis, gasification, biochemical conversion and finally anaerobic digestion. The results of rice straw analysis indicated that its major constituents are cellulose (32.95%) and hemicellulose (25.86%), making it a good candidate for ethanol production. Furthermore, it has high volatiles (85.22%) and carbon content (40.40%), indicating its potential towards biogas production through anaerobic digestion process. Its low moisture content (8.94%) makes it well feedstock to thermochemical conversion technologies. Thus, these factors make it an excellent waste to energy resource. However, it has high lignin and ash content (21.45% and 15.41%, respectively), and high silica content in ash (67.76%), which may cause operating problems in thermal conversion systems. These problems could be solved by pre-treatment of rice straw before recovering its energy via different techniques.

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