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Assessment of Pyrolysis Material Selection Using Weighted Sum Model as an Auxiliary Tool

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Abstract

Human life depends on energy, but it is predicted that in the years to come, those resources will become scarce, with potentially harmful effects on the environment. Currently, "fossil fuels like coal, oil, petroleum products, and natural gas" are used to provide for the world's energy needs. Due to the presence of numerous criteria, including social, economic, and environmental concerns, producing energy from agricultural wastes is particularly difficult in the current stage of energy development. "Fast pyrolysis" can be used to convert biomass into renewable fuels and chemicals. However, the development of the comparatively straightforward and efficient conversion technology is severely hampered by "the biomass recalcitrance, the limitations of the quick pyrolysis process/reactor, and the poor qualities of the final products".Choosing the best biomass material for the greatest amount of bio-oil conversion during pyrolysis is one of the most significant issues and a "multi-criteria decision-making (MCDM)" challenge. In this paper, the "Weighted Sum Model (WSM)" method was used to assess the viability of utilising readily available biomass in the area. In this paper "Sunflower shell, Hardwood, Wheat straw, Sugarcane bagasse and Corn cob" were taken as alternative parameters. "Cellulose, Hemicellulose, Volatile matter, Moisture content and Ash content" are evaluated for the selection of the pyrolysis process. The rank Sunflower shell is second, Hardwood is first, Wheat straw is fifth, Sugarcane bagasse is third and Corn cob is fourth by using the WSM method. Hardwood is placed first among the five biomass materials, trailed by sunflower shells.
Keywords: MCDM, Biomass selection, Pyrolysis,cellulose, volatile matter and moisture content.

Introduction

"Pyrolysis process" is a sustainable, cost-effective, and efficient method for turning biomass into fuels and chemicals. It also helps to address the political and environmental issues raised by traditional fuels. For a very long time, biomass has been acknowledged as "a possible, sustainable and renewable source of fuels, chemicals, and other carbon-based materials" [1].With the use of fossil fuels declining, biomass energy, clean renewable energy, has become more popular. In light of the current global energy problems, it is an optimistic eco-friendly potential source of renewable energy. The use of biomass as energy is growing daily throughout the world. The vast majority of biomass energy is made from discarded wood and its by-products. The biomass components mostly consist of "carbon, hydrogen, oxygen, and nitrogen, with very little Sulphur" [2].In contrast to fossil fuels, biomass often has a more complex makeup and has less quantity of ash, nitrogen, and sulphur. As a result, burning biofuel produces fewer emissions like sulphur dioxide and nitrogen oxides. Physical, biological, and thermochemical processes can turn biomass into biofuel. The process of biological conversion is frequently extremely selective. It yields a high yield of a few distinct products [3].Various and sophisticated goods are produced through thermal conversion. Since liquid fuel can be stored, transported with ease, and used in a variety of applications, including "combustion engines, boilers, turbines, etc.,""pyrolysis" has drawn the most attention among the other biomass energy conversion methods. Although pyrolysis has been used for the manufacturing of charcoal for over 4,000 years, it has only been in the last three decades that "fast pyrolysis" has attracted significant attention. When compared to conventional slow pyrolysis, this technique produces a "maximum liquid yield of up to 75% at mild temperatures of about 500 °C" [4]. Fast pyrolysis methods have been devised to produce speciality chemicals, fuels, and food flavours instead of the older, slower methods, which had significantly lower yields. These use reactor temperatures of 500 °C and very brief vapour residence durations ranging from 30 to 1500 ms [5,6].In this paper "Sunflower shell, Hardwood, Wheat straw, Sugarcane bagasse and Corn cob" were taken as alternative parameters. "Cellulose, Hemicellulose, Volatile matter, Moisture content and Ash content" are evaluated for the selection of the pyrolysis process.The most studied materials in "herbaceous biomass pyrolysis" are stalks from various types of crops, including wheat, corn, and rice. The huge quantity and widespread dispersion of stalks make them an advantageous feedstock for pyrolysis research. The drawbacks are also readily apparent, such as the enormous variety, seasonal instability, and susceptibility to climate, soil types, and planting methods [7,8].These biomass types can also be used as fuels, fertiliser, papermaking raw materials, edible fungus bases, feed, etc. Because the biomass pyrolysis process competes and coexists with other resource utilisation methods and will eventually replace them as the primary resource utilisation method, researchers studying biomass pyrolysis must find suitable methods for gathering raw materials, optimise production processes, and reduce the native impact on the environment in the manufacturing process of improving the output and economic values [9,10].

Materials and methods

Among the earliest and most straightforward techniques utilised in MCDM is the WSM. The approach is ideal for straightforward issues because it is straightforward and essentially only coversthe one-dimensional issue. By assigning ratings, WSM enables comparison of the alternatives, and using these scores, standard values are created for the alternatives being thought about [11]. Overall, the outcomes fall into the categories of good, better, and best. According to each criterion's severity, a weight is assigned; the total of these weights must be 1. Every attribute is taken into account when evaluating each choice [12].With detailed descriptions of" the alternatives, criteria, and their respective scores and weights", WSM enables well-structured issue formulation. It is a more straightforward, convenient, and ideal strategy for resolving problems with several criteria. The depiction of the weighted criterion and the complete process is reasonably simple and obvious [13,14].The fact that the weight is assigned voluntarily and demands not just profound insight but also relatively accurate assignment is a significant limitation that can be seen in nearly all MCDM systems. When qualities are additive, or different from one another in some way, weight summation can be accurate, albeit this requirement is sometimes unachievable [15,16].

Step 1. "Design of decision matrix and weight matrix"

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

"The weight vector" may be expressed as,

$$w_j = [w_1 \quad \cdots \quad w_n], \qquad where \ \sum_{j=1}^{n}(w_1 \quad \cdots \quad w_n) = 1 \quad (2)$$

Step 2. Normalization of DM

$$n_{ij} = \begin{cases} \frac{x_{ij}}{max.x_{ij}} & | \ j \in B \\ \frac{min.x_{ij}}{x_{ij}} & | \ j \in C \end{cases} \quad (3)$$

Where n_{ij} is "the normalized value of the i^{th} alternative for the j^{th} criterion", $max.x_{ij}$ and $min.x_{ij}$ are "maximum and minimum values of x_{ij} in the j^{th} column for the benefit (B) and cost criteria (C)" respectively.

Step 3. Weighted normalized Decision Matrix

$$W_{n_{ij}} = w_j n_{ij} \quad (4)$$

Step 4. Ranking of alternatives

$$S_i^{WSM} = \sum_{j=1}^{n} w_j n_{ij} \quad (5)$$

Where, S_i^{WSM} is the ranking score of the i^{th} alternative, w_j is the weight of the j^{th} criterion. Then the alternatives are ranked in descending order with the highest S_i^{WSM} being ranked highest

In this study, various biomass samples such as "sunflower shell, hardwood, wheat straw, sugarcane bagasse and corn cob" were taken as alternatives and five evaluation criteria such as" cellulose, hemicelluloses, volatile matter, moisture content and ash content" were focused to choose the suitable sample.

Cellulose: The most prevalent bioresource produced on the planet is cellulosic biomass. Even if it is simple to make bioethanol from starch, turning edible food into fuel is not an option given that there is an endless supply of food. To preserve edible food, a method of manufacturing biofuel from inedible biomass has been created. One of the most important methods for producing sustainable energy should be the use of widely accessible cellulosic biomass [17].

hemicelluloses: The second crucial component of wood, hemicelluloses, is a sugar polymer as well. Hemicelluloses are made of glucose and several additional water-soluble sugars, as opposed to cellulose, which is only made of glucose. Hemicelluloses have a lower degree of polymerization because their molecules are shorter than those of cellulose. 20–35% of the dry weight of wood is made up of them. Hemicelluloses come in a wide variety and have distinctly different compositions in softwoods and hardwoods. In general, hardwoods have a substantially higher proportion of hemicelluloses than softwoods [18].

"Volatile matter": The gaseous phase that results from the material's heat breakdown is known as volatile matter. It is split into two categories: "light volatiles and tar (which comprises the bigger molecules that condense at ambient temperature)". Many different types of biomasses naturally include large levels of volatile materials. Because of this quality, biomass is simple to ignite. Due to its high oxygen content, biomass's volatile matter has a low LHV. “The type of pyrolyzed material, as well as the pyrolysis circumstances, temperature, and heating rate”, have a significant impact on the amount of volatile matter present [19].

Moisture content: “The amount of water present in biomass”, expressed as a percentage of the mass of the material as a whole, is known as moisture content. Depending on the type of biomass, the moisture content varies greatly under natural conditions (without any further processing), from less than 15% in cereal straw to more than 90% in algae biomass. Given that it significantly affects the conversion efficiency and heating value when using biomass as a source of energy, this is a crucial variable. Additionally, “a high moisture content” creates challenges since it weakens the energy and cost balances and increases the tendency to disintegrate, which results in energy loss during storage [20].

Ash content: The byproduct of combustion is ash. Ash made from biomass is naturally acidic. Wood typically has a low ash content; however, some biomasses can have up to 20% bulk ash. Ash fusion points are typically lowered by the alkali nature of biomass ashes, which causes fouling and slagging. Pozzolans in types of cement can be replaced by light combustion ashes. Additionally, contamination from soil, rocks, plastic, metals, chemical processes, etc. may cause a rise in the ash content. These pollutants have the potential to cause serious issues such as pollutant development, fouling, and slagging [21].

Result and Discussion

TABLE 1. Biomass Materials properties

	Cellulose	**Hemicellulose**	**Volatile matter**	**Moisture content**	**Ash content**
Sunflower shell	47.3	33.5	72.6	3.61	4.11
Hardwood	46.4	23.9	78.1	3.71	2.31
Wheat straw	35.9	21.4	57.7	16.21	4.21
Sugarcane bagasse	37.9	46.5	79.1	5.51	3.21
Corn cob	51.4	31.4	77.29	12.88	2.41

Table 1 shows The characteristics of the biomass materials employed in this investigation are displayed in.“Sunflower shell, hardwood, wheat straw, sugarcane bagasse and corn cob” were taken as alternatives and five evaluation criteria such as “cellulose, hemicelluloses, volatile matter, moisture content and ash content” were taken.

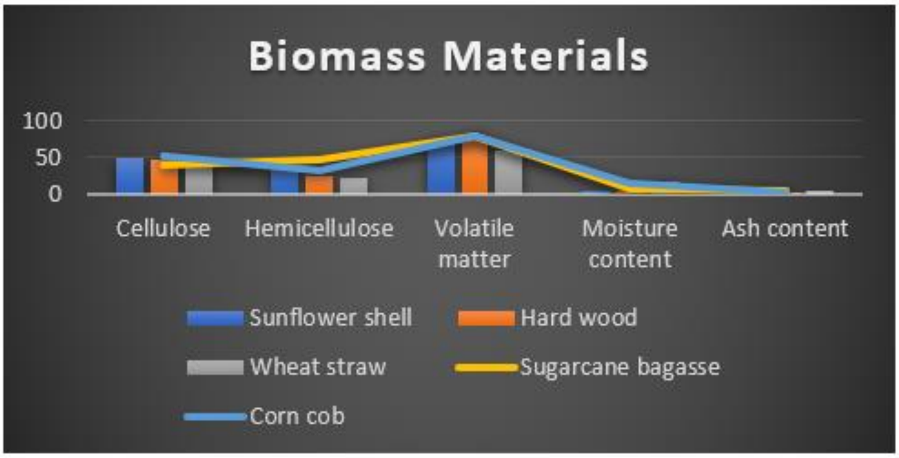

FIGURE 1. Biomass Materials properties

Figure 1 shows The characteristics of the biomass materials employed in this investigation are graphically represented“Sunflower shell, hardwood, wheat straw, sugarcane bagasse and corn cob” were taken as alternatives and five evaluation criteria such as “cellulose, hemicelluloses, volatile matter, moisture content and ash content” were taken.

TABLE 2. Normalized DM

0.92023	0.72043	0.91783	1.00000	0.56204
0.90272	0.51398	0.98736	0.97305	1.00000
0.69844	0.46022	0.72946	0.22270	0.54869
0.73735	1.00000	1.00000	0.65517	0.71963
1.00000	0.67527	0.97712	0.28028	0.95851

Table 2 shows Normalized Data shows the informational set for properties of biomass materials. The normalized matrix was calculated using equation 3.

TABLE 3. Weight Distributed

0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20

Table 3shows the weight distributed equally among evaluation parameters “cellulose, hemicelluloses, volatile matter, moisture content and ash content”. The sum of weight distributed among evaluation parameters is one.

TABLE 4. Weighted Normalized Decision Matrix

0.18405	0.14409	0.18357	0.20000	0.11241
0.18054	0.10280	0.19747	0.19461	0.20000
0.13969	0.09204	0.14589	0.04454	0.10974
0.14747	0.20000	0.20000	0.13103	0.14393
0.20000	0.13505	0.19542	0.05606	0.19170

Table 4 shows the “weighted normalized decision matrix” values. This is calculated by multiplying the normalized matrix with the weight matrix using equation 4.

TABLE 5. Preference score

	Preference Score
Sunflower shell	0.82411
Hardwood	0.87542
Wheat straw	0.53190
Sugarcane bagasse	0.82243
Corn cop	0.77823

Table 5 shows the preference score values of the alternatives. This is calculated using equation 5.The preference scores of Sunflower shell are 0.82411, Hardwood0.87542, Wheat straw0.53190, Sugarcane bagasse0.82243 and Corn cob 0.77823.

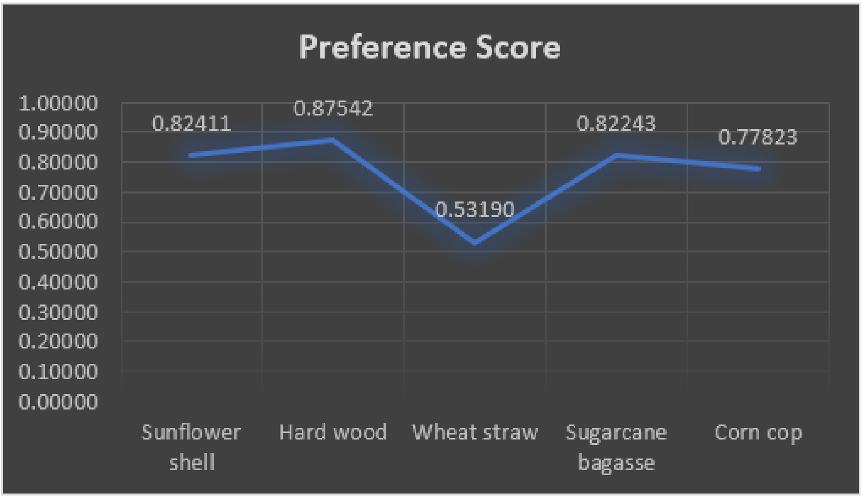

FIGURE 2. Preference score

Figure 2 shows the graphical representation of the preference score values of the alternatives. This is calculated using equation 5.The preference scores of Sunflower shell are 0.82411, Hardwood0.87542, Wheat straw0.53190, Sugarcane bagasse0.82243 and Corn cob 0.77823.

TABLE 6. Rank

	Rank
Sunflower shell	2
Hardwood	1
Wheat straw	5
Sugarcane bagasse	3
Corn cob	4

Table 6 shows the rank of alternatives using the WSM method. The rank Sunflower shell is second, Hardwood is first, Wheat straw is fifth, Sugarcane bagasse is third and Corn cob is fourth.

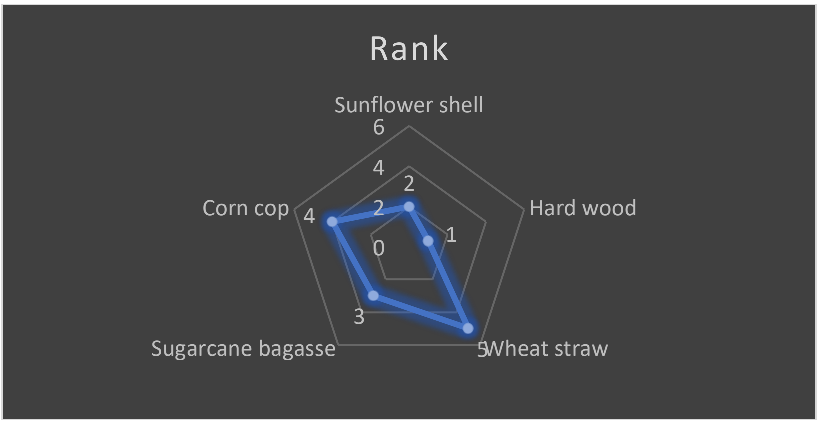

FIGURE 3. Rank

Figure 3 shows the graphical representation rank of alternatives using the WSM method. The rank Sunflower shell is second, Hardwood is first, Wheat straw is fifth, Sugarcane bagasse is third and Corn cob is fourth. Out of five selected biomass materials, hardwood is ranked top followed by Sunflower shell.

Conclusion

"Fast pyrolysis" is “a renewable, cost-effective, and efficient” method for turning biomass into fuels and chemicals, which also allays the political and environmental issues raised by traditional fuels. It can be used to address the energy needs of growing economies. For a very long time, biomass has been acknowledged as a potentially sustainable and renewable source of fuels, chemicals, and other carbon-based materials.The use of renewable energy is becoming more crucial in addressing environmental concerns about the use of fossil fuels and their role in the greenhouse effect. Wood and other biomass products are one of the fundamental sources of renewable energy and the sole resource of "renewable liquid, gaseous, and solid fuels".By using the WSM method, the rank of Sunflower shell is second, Hardwood is first, Wheat straw is fifth, Sugarcane bagasse is third and Corn cob is fourth.Out of five selected biomass materials, hardwood is ranked top followed by Sunflower shell.

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