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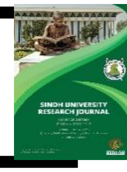

Determination of Calorific Values of *Prosopis cineraria*, *Acacia Senegal* and *Salvadora oleoides* and their Blends

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Abstract

The research work describes the elemental composition and properties like ash content, wood density, and calorific values of *Acacia senegal*, *Prosopis cineraria* and *Salvadora oleoides*. The calorific values of plants were calculated by bomb calorimeter. The results show that indigenous species *Acacia senegal* and *Prosopis cineraria* as fuelwood species is well appropriate and have low ash content, high wood density. The best auspicious product shows the blend of *Acacia senegal* and *Prosopis cineraria* (50% + 50%) has 23.109 KJ/g which is maximum calorific value. An elemental analysis results show that the *Acacia senegal* and *Prosopis cineraria* has higher Carbon which indicates the high calorific values, in the *Salvadora oleoides* the least calorific value and low carbon content.

Keywords: Thar, Calorific value, Biomass, Wood fuel, blends

Introduction

District Tharparkar is located in the south east Sindh. Tharparkar Sindh Pakistan is the 18thlargest desert and one of the fertile desert in the world. The Thar coalfield by a resources potential of coal is in tons 175 billion and area covers over 9000 km^2 (Energy Department GOS-2011). Although all of its uniqueness, living life of Thari people is still tough with low living standard and smaller developed structure. Generally, it thrives on rain water and it is saying that, for Thari people rains are blessing, otherwise it is a daunting and fatal desert (Govind M Herani, *et al.*, 2007). The importance of the renewable energy use has been increasing rapidly in the last few decades, because of the global warming problem and constant reduction of fossil fuels. Biomass has lots of advantage due to its used as individually, or in blend with fossil fuel (Aurel Lunguleasa, *et al.*, 2020). The indigenous energy source is Biomass and is available in various countries can ensure secure supply as well as diversify energy. The resources of energy renewable are alternatives and favorable for fossil fuels as well as their products can have less of an undesirable environmental effect. Nevertheless, the shortage of biomass energy and domestic animals cannot overcome the requirement energy of the region (Colm D Everard, *et al.*, 2012). So, fuelwood consumption for domestic and commercial cooking and still heating is basic economy for rural household in most developing countries mainly those of desert Thar of Pakistan. It has been reported that more than70% of the domestic energy is consumed in the communities of rural areas of third world (developing) nations generated from fuelwood (Andrew Agbontalor Erakhrumen 2009). In villages of Desert Thar, main energy source for supplying is fuel wood and mostly requirements for cooking.

Considerable research can be found on tree species fuelwood properties in Latin America, Northeastern India, southern and central Africa, but in Desert area of Thar, relatively little research involved for shrub species improvement programs and native tree have recently been initiated to increase the quality and quantity of fuelwood in the region (Carmen Sotelo Montes, *et al.*, 2011).

In Thar Desert commonly trees like, *Acacia senegal, Acacia nilotica*, *Prosopis cineraria*, *Salvadora oleoides*, *Prosopis julifora*, *Capparis decidua*, and *Zizyphus mauritiana* are used for burning. The size of *Prosopis cineraria* tree is a small to medium, native to South Asian and western arid part. Especially in Pakistan region it is found in the Desert Thar. *Prosopis cineraria* is an adaptable species and provides fodder, timber, shade, fuel, firewood and affecting sand dune stabilization and soil improvement (Santosh Kumar Sharma, *et al.*, 2011) .*Acacia Senegal* (kumbat) is one of the deciduous thorny trees from the Acacia genus, and is known by some common names, including senegal gum, Gum Arabic tree and Gum acacia. In India and Pakistan parts, it is recognized as Khor, Kher or Kumbat. Wood is valued for charcoal and fuel wood, humans used dried seeds as a food. It has been speciously used for the properties of bronchitis, astringent, to delight bleeding, gonorrhea, typhoid fever, cough, diarrhea, leprosy, catarrh, and upper respiratory tract infections. *Salvadora oleoides* is an evergreen shrub or tree found in India and Pakistan. Khejri is a small to medium size tree with a numerous drooping branches dense crown. Prosopis cineraria is common plant in arid tracts but becomes unusual where conditions of rainfall are better. Khejri is picked from the remote for local use as a source of materials and medicine, it is sometimes grown to protect the soil and as a shelterbelt, and to enjoy its dense shade it is also planted. It is often goat fodder and lopped for camel.

The calorific value for fuelwood quantity is an important indicator: The wood calorific value totally depends on the compound's moisture content, chemical composition, and ash content. Fuel produce heat by burning process. Different types of fuels on burning produced heat that is called calorific value. The fuelwood performance are affected by main physical properties are wood density, moisture content, chemical, and elemental composition. Main elements are oxygen, carbon, nitrogen, sulphur, and Hydrogen for calorific value contribution. For an oven dried wood, the calorific value of wood varies between 17 and 20 MJ/kg that can be related to its elemental composition. Biomass fuels are described by using elemental analysis and are also used to determine calorific values and their expectable impact on the atmosphere (JI Nirmal Kumar, *et al.*, 2011). Chemically it has been recognized that hemicellulose is the first compound to be get affected due to the heating, because of its branched structure and amorphous nature. Degradation of the acetyl groups of hemicellulose begins with the cleavage and as a result of release of acetic acid and further de-polymerization of polysaccharides (Idalina Domingos, *et al.*, 2020).

Biomass burning also releases carbon dioxide into the atmosphere, also grown another energy fuel and it will takes up released CO_2 during the photosynthesis process into the atmosphere, making of carbon dioxide free during this process because carbon dioxide is neither taking away or added.

Effective process of co-firing parts depends on the composition and fuels content. The Fuel moisture in wood samples varies from 5 to 55% and had quiet significant impact on the other properties, like calorific value (Nerijus Pedišius, *et al.*, 2021). When fuels are combined, the ash properties cannot be predicted directly according to the single fuel ash behavior, meanwhile the behavior of the inorganic and some organic constituents is not necessarily with the amount of each fuel in a blend in a linear relationship. During the biomass combustion ash transformation is a very composite phenomenon, which can show many basically different situations. Therefore, without enough enquiry blending leads to reduced efficiency and capacity. When the fuel blend behavior is insufficiently explored under combustion conditions, unpredicted behavior of around favorable and many unfavorable may occur with blend. Hence, knowing the effect of a certain blend on the assets of the final ash is important when taking suitable mixtures with desired properties and behavior of ash melting.

The recent work describes the properties such as ash content, calorific values, wood density, and elemental composition of *Acacia senegal*, *Prosopis cineraria* and *Salvadora oleoides* are determined then correlated with properties in addition environmental impact when burned. Furthermore, a fuel blend of *Acacia senegal*, *Prosopis cineraria* and *Salvadora oleoides* were also prepared.

Materials and Method

Instrumentation

The calorific value of wood samples of oven dried powder was determined with a bomb calorimeter (LECO AC 500 Isoperibol Calorimeter.), wood samples about 1 gm were totally combusted with pure oxygen under a pressure of 3000 kPa. The water at 20 °C to 25 °C was filled in calorimeter vessel and the prepared sample was placed in the water jacket. Before the firing, initial temperature of the water was noted and the final temperature reached was recorded after 15 to 20 minutes. The samples were weighed before and after drying in an oven at 100°C for 48 hour to calculate moisture content. The difference in weight was measured according to the following equation.

M= (M2-M3)/ (M2-M1) ×100

M1= empty dish weight

M2= moisture weight

M3= weight (dry)

EDS is an analytical technique used for the chemical characterization or elemental analysis of a sample. Energy dispersive X-ray Analytics (EDS) - JEOL JED-2300 Analysis Station was used for this study.

Sample Collection and Sample Preparation

In this study all wood species investigated, *Acacia Senegal* (Kumbat), *Prosopis cineraria* (Khejri) and *Salvadora oleoides* (Khabar) are natural and freely obtainable from Thar Desert Pakistan. *Acacia senegal*, *Prosopis cineraria* and *Salvadora oleoides* are collected as charcoal source and fuelwood and sold to different regions of Pakistan. During study, collected samples analysis were accepted out through for moisture content, calorific value, ash content, and wood density. Wood samples were obtained randomly from stems of the species. About 1 inch thickness disc of wood was cut from the trunk of each of the spices of freshly cut trees. The fresh trunk of samples were removed, the samples of wood trunk bark were used for the wood density and moisture content determination. The wood samples were chipped into 1-2" chips, using a Carthage machine, the wood chips were crushed in a Bauer Mill. The mesh size was determined by mini sieve was-40+60 mesh and the powdered samples were subjected for the analysis.The six blends were made by different proportions of the three plants; percentage composition is given in the **Table 1.**

Results and Discussion

Properties such as ash content, wood density,and elemental compositionof Kumbat,Khejri, and Khabar plants are calculated and then connected with calorific value and evaluated in relative to properties and environmental effect when burning process occur.

Moisture content

Moisture content is main factor affecting the property fuel wood. Amount of heat obtained from the wood is decrease with increasing of moisture content, from such moist wood maximum amount of energy is used in fuel wood to disappear the moisture, which causes to minimize the combustion productivity. The Table 2 shows the moisture percentage in the *Acacia senegal*, *Prosopis cineraria*, and *Salvadora oleoides.* In all the trees under study moisture content ranged between 27.12 to 48.733%. However, fuel wood with moisture content in different seasons varies with dimension of branches. Hence, for fuel wood of two species moisture content cannot be considered as part as part of the intrinsic value.

Table 1. The six blends composition of *Acacia senegal, Prosopis cineraria, and Salvadora oleoides.*

Blend 01	**Blend 02**	**Blend 03**
***Prosopis cineraria* (50%)** ***Acacia senegal* (25%)** ***Salvadora oleoides* (25%)**	*Acacia senegal* (50%) *Prosopis cineraria* (25%) *Salvadora oleoides* (25%)	*Salvadora oleoides* (50%) *Prosopis cineraria* (25%) *Acacia senegal* (25%)
Blend 04	**Blend 05**	**Blend 06**
***Prosopis cineraria* (50%)** ***Acacia senegal* (50%)**	*Acacia senegal* (50%) *Salvadora oleoides* (50%)	*Prosopis cineraria* (50%) *Salvadora oleoides* (50%)

Table 2 Moisture content in *Prosopis cineraria, Acacia senegal, and Salvadora oleoides*

Sample ID	Moisture content (%)
Prosopis cineraria	48.733
Acacia senegal	27.12
Salvadora oleoides	42.244

Ash content

The calorific value is directly affected by ash content which is important parameter. As a fuel plant part makes it less desirable with high ash content. Before placed in a furnace wood samples were weighed out and heat up at 500 °C for 4 h. After sample combustion to prevent moisture absorption placed in a desiccator while cooling. According to equation determined, subsequently weighed out ash and the ash content.

Table 3 Ash content in *Prosopis cineraria, Acacia senegal, and Salvadora oleoides*

Sample ID	Ash content (%)
Prosopis cineraria	2.58
Acacia senegal	2.26
Salvadora oleoides	16.61

Percentage of ash content = $Mass_{ash} \times 100 / Mass_{oven\ dry}$

Wood density

The wood density denotes its solidity of wood as being genetic feature of wood sample.

Depending upon chemical composition and anatomical structure because it differs species to species. The higher wood density species is chosen as fuel wood; because of their slow burning properties and greater energy per unit volume. The density of wood *Salvadora oleoides, Acacia senegal*, and *Prosopis cineraria* are shown in table 4.

Table 4.The density of *Salvadora oleoides, Acacia senegal, and Prosopis cineraria.*

Sample ID	**Wood density (g/cm^3)**
Prosopis cineraria	0.492
Acacia senegal	0.551
Salvadora oleoides	0.588

Value index of Fuelwood (FVI)

The value index of fuelwood (FVI) too functioned, the positive characteristics are calorific value and wood density, and negative characteristics are ash content and water content as. The fuelwood value index of the *Acacia senegal* (Kumbat), *Prosopis cineraria* (Khejri), and *Salvadora oleoides* (Khabar) plants are given in the table 5.The results showed that the *Acacia senegal* has highest FVI 4.099 among the three plants.

Table 5 Fuelwood value index of three plants

Sample ID	**Fuelwood value index (FVI)**
Prosopis cineraria	3.534
Acacia senegal	4.099
Salvadora oleoides	0.492

Table 6. Calorific values of wood samples and blends

Sample ID	**Calorific value (KJ/g)**
Prosopis cineraria	18.533
Acacia senegal	16.815
Salvadora oleoides	13.909
Blend-01	17.738
Blend-02	16.472
Blend-03	16.233
Blend-04	23.109
Blend-05	16.595
Blend-06	16.340

Calorific value

Studies indicated that two species which contain low ash content and low nitrogen percentage, high calorific values have high wood density. Bomb calorimeter is used to calculate calorific values of *Acacia Senegal* and *Prosopis cineraria*. Moreover, six blends of *Acacia senegal, Prosopis cineraria* and *Salvadora oleoides* were also prepared, in order to measure blends calorific value. The blend's literature works show that the appropriate part of the species has some times larger calorific values as related to the basic ones. Generally, higher moisture wood species decreases its CV (calorific value) and denser wood value because slow burning rate and

Table 7 Elemental composition of *Prosopis cineraria*

Element	(keV)	mass%	Error%	At%	K
C K	0.277	65.00	0.07	71.52	71.53
O K	0.525	33.92	0.55	28.02	26.92
F K*	0.677	0.09	0.69	0.06	0.093
Na K*	1.041	0.24	0.30	0.14	0.276
Mg K*	1.253	0.06	0.25	0.03	0.068
K K*	3.312	0.21	0.47	0.07	0.328
Ca K*	3.690	0.49	0.57	0.16	0.805
Total		100		100	
Fitting Coefficient : 0.3182					

Table 8 Elemental composition of *Acacia senegal*

Element	(keV)	mass%	Error%	At%	K
C K	0.277	60.25	0.04	67.29	64.6979
O K	0.525	38.34	0.26	32.15	33.1234
F K*	0.677	0.04	0.37	0.03	0.0470
Na K*	1.041	0.04	0.16	0.02	0.0440
Mg K*	1.253	0.17	0.13	0.10	0.1889
Si K*	1.739	0.13	0.14	0.06	0.1885
K K*	3.312	0.07	0.24	0.02	0.1171
Ca K	3.690	0.96	0.29	0.32	1.5931
Total		100.00		100.00	
Fitting Coefficient : 0.1938					

higher energy content per unit volume (B.P. Bhatt, *et al.*, 2002). The three plant spices results and their blends are given in the table 6.

The calorific values of the three species and their blend are ranged from 13.909 to 23.109 KJ/g. Compared with untreated biomass (*Acacia senegal* and *Prosopis cineraria*) and their blend had a related pyrolysis process but their different pyrolysis characteristics. The results tell us that the blend (*Acacia senegal* 50% and *Prosopis cineraria* 50%) has maximum calorific values.

Elemental analysis

The spectra of *Acacia senegal*, *Prosopis cineraria* and *Salvadora oleoides* are given in figure 1, figure 2 and figure 3 respectively. The *Prosopis cineraria* and *Acacia senegal* contains almost same amount of Carbon (54.13 % and 54.25%) contents. The detailed elements compositions are given in the table 7, table 8and table 9 below.

Conclusion

In rural Thar area of Pakistan wood energy is recognized as the chief source of energy. In Tharparkar commonly 03 (Three) trees used for fuelwood are Kumbat *(Acacia senegal),* Khejri *(Prosopis cineraria)* and Khabar *(Salvadora oleoides).*The current work describes different properties, like ash content, wood density, calorific values, and elemental composition of tree plants are determined. Furthermore, blends of these plants were also studied.

Table 9 Elemental composition of *Salvadora oleoides*

Element	(keV)	mass%	Error%	At%	K
C K	0.277	52.50	0.03	61.12	48.7684
O K	0.525	41.93	0.15	36.65	41.6131
Na K*	1.041	0.34	0.09	0.21	0.4114
Mg K	1.253	0.31	0.08	0.18	0.3709
S K	2.307	0.86	0.08	0.38	1.5422
Cl K	2.621	1.09	0.09	0.43	1.9599
K K	3.312	0.98	0.14	0.35	1.7313
Ca K	3.690	1.98	0.17	0.69	3.6029
Total		100.00		100.00	

We accomplish that the *Acacia Senegal* (50%) and *Prosopis cineraria* (50%) are best appropriate for the biomass of Domestic in Thar region Pakistan. On the basis of results, it is advised that the *Salvadora oleoides* use as biomass fuel should be restricted. It was exposed that the highest woods calorific value does not essentially establish the greatest choice as wood fuel, if the composition of wood element is occupied into story. The density of wood and calorific value of wood fuel were taken as positive characters, meanwhile moisture content and ash content are negative characters.

Table 10 Comparison of the Elemental percentage of *Prosopis cineraria, Acacia senegal and Salvadora oleoides.*

Element	PC	AS	SO
C K	65.00	60.25	52.50
O K	33.92	38.34	41.93
F K*	0.09	0.04	--
Na K*	0.24	0.04	0.34
Mg K*	0.06	0.17	0.31
K K*	0.21	0.07	0.98
Ca K*	0.49	0.96	1.98
Si K	--	0.13	
S K			0.86
Cl K			1.09

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