RESEARCH ARTICLE

Association of Biometric Attributes and Feed Stock Quality on Lignocellulosic Ethanol Yield

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ABSTRACT

Investigations were carried on the eight identified lingo cellulosic ethanol feed stock *viz., Acrocarpus fraxinifolius, Casuarina* MTP2, *Chukrasia tabularis, Eucalyptus* MTP 1, *Melia dubia, Populus deltoids, Leucaena leucocephala* and *Thespesia populnea* in order to identify the association of biometric attributes (height, basal diameter and volume index), physical and proximate characters (bulk density, basic density, acid insoluble lignin, moisture, holocellulose, fibre wall thickness, fibre diameter, fibre length and lumen diameter) of feed stock on ethanol yield. The study revealed that holocellulose (0.416), volume index (0.325) and basic density (0.199) had exhibited significant positive correlation with ethanol yield. Whereas, moisture (-0.413) and bulk density (0.010) recorded negative and significant correlation and lignin (-0.343) showed negative and non-significant correlation with ethanol yield. Thirteen principal components were generated and five principal components *viz.,* holocellulose (0.416), bulk density (0.010), basic density (0.199), fibre length (0.594) and fibre diameter (0.144) had contributed maximum to ethanol yield and the other traits *viz.,* lignin (-0.343), moisture (-0.413) and height (0.266) had exerted minimum contribution to ethanol yield.

Keywords: *Association studies; Lignocellulosic ethanol; Feedstock quality.*

INTRODUCTION

Nation's prosperity and development demands energy resources, mainly relying on oil consumption. Considering that world-wide geopolitical, economical and market forces control oil availability, its prices and demand, governments have encouraged renewable energy development. Issues like environmental pollution and climate change, in combination with the well-documented drawbacks of fossil fuels, are driving the search for clean carbon-neutral fuels. Hence, the necessity for alternative and renewable energy sources became a priority. Biofuels derived from renewable plant biomass may both reduce our dependence on oil and other fossil fuels as well as restrain mankind's activities that contribute to environmental instability. Biomass, as a versatile renewable energy source with high potential, could contribute to the energy needs of modern society in short to medium term. Even though other renewable sources can be used for the production of heat and electricity, biomass is unique in terms of conversion into a transportation fuel that is compatible with the currently existing infrastructure (Theoni Margaritopoulou, 2016).

India has 0.5 per cent of the oil and gas resources of the world but supports 16 per cent of the world's population with the result that the country depends heavily on oil imports to meet the domestic demand (Sukumaran and Pandey, 2009). The demand for motor gasoline has been growing at an average annual rate of approximately 7 per cent during the last de- cade, and it shows an increasing trend (MPNG, 2009). With the ever-increasing demand for energy and the fast depleting petroleum resources, globally, there is an increased interest in alternative fuels, especially in lignocellulosic ethanol (ICRIER, 2011) since it mitigate greenhouse gas emissions for a sustainable environment (Bishnu Joshi *et al.,* 2011). In the year 2003, the Planning Commission, Government of India brought out an extensive report on the development of biofuels (Planning Commission, 2003) and bio-ethanol and biodiesel were identified as the principal biofuels to be developed for the nation. Elaborate policies for promoting lignocellulosic ethanol were formulated and the time frames for implementation of policies were defined. The blending targets for ethanol in gasoline and petroleum diesel were also proposed as 10 per cent and 20 per cent by 2016 and 2017 respectively (Planning Commission, 2003) and currently, 5 per cent ethanol blend in gasoline was

made mandatory. Bio-ethanol from lignocellulosic biomass is one of the important alternatives being considered due to its cleaner fuel with higher octane rating than gasoline (Wheals *et al.,* 1999; Grad, 2006). It is estimated that consumption of petrol for transportation needs during 2016 -2017 was 2078.5 billion litres and the demand for bioethanol at 5 per cent blending level itself will be 103.9 billion litres against the mandatory level of 20 per cent blending (415.7 billion litres) as per the National Biofuel Policy 2009. A comparison between the available lignocellulosic feedstocks with current use shows that about two-fifths of the exist- ing ligno cellulosic feed stock potential is used and the current biomass use is clearly below the available potential. Therefore, increased biomass use is possible for the production of bioethanol.

Opportunities to match feedstock physical and chemical properties to ethanol conversion efficiency are manifold and have long been recognized. Attempts to capitalize on such opportunities, however, have been limited by several concerns. According to Dinus (2001), the wood physical and chemical properties *viz.,* moisture content, specific gravity, fibre morphology, ash, lignin, cellulose and extractives of the ligno cellulosic biomass feedstock are the important attributes that had contributed significant impact on bioethanol conversion efficiency. However, information pertaining to the influence of specific traits on ethanol yield and the cumulative effect of various traits are not available for many lignocellulosic species. Besides this, the Principal Component Analysis enables an easier understanding of impacts and association among the different traits by finding and explaining them (Vasic *et al.,* 2008). Earlier the use of Principal Component Analysis was very well documented in many tree species to understand the level of association among the investigated parameters and their contribution to the character of interest. Hence it is essential to determine the association among the physical and chemical properties of the lignocellulosic feedstock as well as their contribution to the bioethanol yield through a systematic investigation.

MATERIAL AND METHODS

The experimental materials for the current study consisted of fifteen lingo cellulosic ethanol feedstock plantation trial comprising of various potential species *viz., Acacia auriculiformis, Albizzia falcataria, Anthocephalus cadamba, Acrocarpus fraxinifolius, Cassia siamea,* Casuariana MTP2*, Chukrasia tabularis, Dalbergia sissoo,* Eucalyptus MTP1*, Gmelina arborea, Leucaena leucocephala, Melia dubia, Populus deltoides, Swetinia macrophylla* and *Thespesia populnea* it was established at Seshasayee Paper and Boards Limited, trial field,

Erode. After preliminary screening for Holo cellulose content, eight species *viz., Acrocarpus fraxinifolius*, Casuarina MTP 2, *Chukrasia tabularis*, Eucalyptus MTP 1, *Melia dubia, Populus deltoids, Leucaena leucocephala* and Thespesia *populnea* were deployed for growth assessment, ethanol recovery and further association studies. Association between Biometric attributes of lingo cellulosic feedstocks (Height, Basal Diameter, Volume Index), chemical composition (Holo cellulose, Lignin, Moisture, Bulk Density, Basic Density) and fiber characters (Fibre Length, Fibre Diameter, Fibre Wall Thickness, Fibre Lumen Width) on ethanol yield were studied through a correlation based on the method suggested by Dhillon *et al* (1992). Clustering of genotypes into similar groups was performed using Ward's hierarchical algorithm based on squared Euclidean distances. For the three groups of traits *viz.,* biometric attributes, chemical composition, and fiber characters of lingo cellulosic feedstocks, the data were standardized to have a mean of zero and a variance of one prior to squared Euclidean distance calculation. The pseudo F statistic and the pseudo-T^2 statistic were examined to establish the numbers of clusters using the Statistical Package for Social Studies (SPSS) version 16.0.1 software (SPSS, 2007). In order to identify the patterns of variation, Principle Component Analysis was also conducted.

RESULTS AND DISCUSSION

Ethanol yield is a complex entity associated with many parameters, which are themselves *inter* related. Such *inter*relationship of various biometric, physical and proximate parameters are highly essential to understand the relative importance of each character involved. If correlations are high, attempts to obtain a response in one character by selecting for the associated traits may be worthwhile.

In the present investigation, the association of biometric, physical and proximate characters on ethanol yield revealed that holocellulose (0.416), volume index (0.325) and basic density (0.199) had exhibited a significant positive correlation with ethanol yield. Whereas, a non-significant but positive correlation was observed with fibre length (0.594), fibre diameter (0.144), fibre wall thickness (0.058), fibre lumen width (0.390), height (0.266), basal diameter (0.206) as ethanol yield. All the other characters *viz.,* moisture and bulk density recorded a negative and significant correlation with ethanol yield but the lignin content exhibited negative and non-significant correlation with ethanol yield (Table 1). Based on the current investigations, the significant and positively correlated parameters *viz.,* holocellulose, volume in- dex and basic density could be used as in selection dices for the selection of high yielding short-rotation ligno cellulosic species

for ethanol production. Similar indices were also reported by a plethora of workers *viz.,* Krishnakumar (2013) in *Bambusa balcooa* and *Bambusa vulgaris*, Bamboo species (Thiruniraiselvan, 2012), *Melia dubia* (Saravanan, 2012), Eucalyptus clones (Vennila, 2009), *Leucaena leucocephala.* The positive correlation between cellulose and ethanol and a negative correlation between lignin and ethanol yield could be used as an ideal indicator for screening lignocellulosic species for ethanol production.

Table 1. Correlation co-efficients of biometric, physical and proximate parameters on ethanol yield

	Holo cellulose	Lignin	Moisture	Bulk Density	Basic Density	Fibre Length	Fibre Diameter	Fibre Wall Thickness	Fibre Lumen Width	Height	Basal Diameter	Volume Index	Ethanol Yield
Holo cellulose	1.000	-0.083	-0.679	0.364	0.576	0.158	-0.075	0.275	-0.131	0.594	-0.125	0.008	0.416**
Lignin		1.000	0.479	-0.262	-0.075	-0.108	-0.684	-0.237	-0.479	-0.333	-0.364	-0.373	-0.343
Moisture			1.000	-0.373	-0.471	-0.560	-0.381	-0.002	-0.388	-0.845**	-0.357	-0.521	-0.413*
Bulk Density				1.000	.906**	0.236	0.083	0.435	-0.045	-0.062	-0.098	0.024	-0.010*
Basic Density					1.000	0.304	-0.035	0.297	-0.092	0.130	-0.085	0.061	0.199*
Fibre Length						1.000	0.657	0.241	0.765*	0.446	0.823*	0.902**	0.594
Fibre Diameter							1.000	0.447	0.938**	0.267	0.843**	0.828*	0.144
Fibre Wall Thickness								1.000	0.246	-0.202	0.196	0.169	0.058
Fibre Lumen Width									1.000	0.282	0.866**	0.874**	0.390
Height										1.000	0.444	0.540	0.266
Basal Diameter											1.000	0.977**	0.206
Volume Index												1.000	0.325**
Ethanol Yield													1.000

The Principal Component Analysis is one the multivariate analysis method and provides an easier understanding of impacts and connections among different traits (Kovacic, 1994). In the present investigation, with respect to lignocellulosic species, out of thirteen principal components generated, nine principal components *viz.,* holocellulose (41.04), bulk density (62.62), basic density (78.91), fibre length (90.36), fibre diameter (95.94), fibre wall thickness (99.37), fibre lumen width (100), basal diameter (100) and volume index (100) had contributed the maximum to ethanol yield (data not shown). The other three principal components *viz.,* lignin, moisture and height had exerted minimum contribution to the ethanol yield (Figure 1).
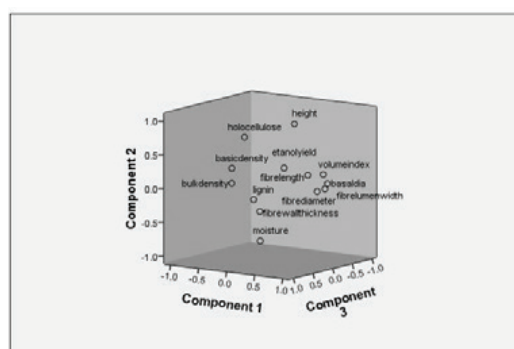
Figure 1. Principal Component analysis of biometric, physical and proximate characters on Ethanol yield – rotated values

Thus, it is concluded from the current investigation that even though nine principal components had contributed maximum to ethanol yield, the cumulative effect principal components *viz.,* holocellulose, bulk density, basic density, fibre length, fibre diameter accounted for more than 95.947 per cent correlation to-wards ethanol yield. Hence, these parameters could be most influential or associated traits for the ethanol yield. The principal component analysis had also been used as an effective tool to confirm the impacts and association among the different traits in *Bambusa vulgaris, Bambusa balcooa* (Krishnakumar, 2013), which lend support to the current study.

CONCLUSION

The association studies of biometric, physical and proximate characters on ethanol yield revealed that holocellulose, volume index and basic density had exhibited a significant positive correlation with ethanol yield. At the same time, moisture and bulk density re- corded negative and significant correlation and lignin showed negative and non-significant correlation with ethanol yield. Thirteen principal components generated and five principal components viz., holocellulose, bulk density, basic density, fibre length and fibre diameter had contributed the maximum to ethanol yield. Other traits *viz.,* lignin, moisture and height had exert- ed minimum contribution to ethanol yield.

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