THE USE OF COTTON STALKS AND COTTON GINNING TRASH AS FEEDSTOCKS FOR ETHANOL FUEL PRODUCTION

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Abstract

Cotton stalks and cotton ginning trash both present management problems for growers and processors within the cotton industry. One option, now being considered, is to use these materials to produce ethanol fuel. One of the biggest influences on the viability of producing ethanol, however, is the cost of the material used.

To identify if cotton wastes were viable feedstocks, a model of the cost to collect and transport cotton stalks and ginning trash was developed on a spreadsheet. Two variables were allocated triangular probability distributions: the biomass yield (tonne per hectare), and the biomass transport weight (tonne per transport unit). Sensitivity analysis was carried out by varying the contract rates, transport rates, and transport distance.

The best collection method identified, was to forage harvest the cotton stalks into boll buggies, and transport it (over an assumed 50 km) compacted as modules or pallets; costing \$30-\$40/tonne, (\$0.10-\$0.13/litre of ethanol produced). Sensitivity analysis indicated the contract rates had the biggest effect on collection costs, transport rates had the least effect, and increasing the transport distance to 100 km increased the cost of the best collection method by \$6.00/tonne (\$0.02/litre of ethanol produced).

It was concluded that given the collection costs identified and current estimates of plant economics, the operation of a lignocellulosic ethanol production plant using cotton stalks or cotton ginning trash, was a viable proposition.

Introduction

Some of the management problems of handling cotton stalks after picking are associated with the possibility of disease and pest carryover if the stalks are left standing, and the blockages of irrigation recirculation systems by stalk parts if the stalks are cultivated. One common system is to slash the cotton stalks, rake them into heaps, burn them, and then to proceed with cultivation. There are many arguments against this practice, typically centering around the long term soil structural stability of this system from continuous organic matter removal. The removal of cotton stalks for the production of ethanol would provide an alternative to burning the stalks. Further, if cotton ginning trash could also be used, then processors would also have a use for a waste product which currently has a disposal cost.

Ethanol (ethyl alcohol) is the alcohol contained in alcoholic beverages. It has long been extensively used throughout the world in food, pharmaceutical, cosmetics, chemical industries and as a fuel for internal combustion engines. As a motor fuel, ethanol can be used neat in modified engines, or as a blend with diesel or petrol (up to 20% ethanol) in unmodified engines.

The ethanol used in the USA and Brazil is mainly produced from the fermentation of plant sugars and starch material such as corn, grains and sugar cane. However new technology has revolutionised the production of ethanol by enabling the lignin surrounding plant cell walls to be broken down, allowing access to the sugar within plant cells. Because of this, basically any plant material of a straw or woody makeup (termed: lignocellulosic material) can now be used to produce ethanol.

Australia is a world leader in the development of a fungus which produces the required enzyme for this process. These techniques have consequently led to a doubling of the ethanol yield from cellulosics. This, in combination with an Australian developed technique which enables the extraction of the ethanol from the fermentation broth without the need for energy expensive (and, hence, costly) distillation, has substantially improved the viability of producing ethanol from lignocellulosics. Lignin is a by-product which can be recovered from the process and depending on the biomass feedstock, it is, at least, valuable as a boiler fuel within the ethanol production plant (worth $30/tonne).

The benefits of using ethanol as a blend with diesel are numerous. It would assist Australia's balance of trade position by improving our fuel self sufficiency. Because it is a renewable source of fuel, there is a reduction in the net release of carbon from diesohol (diesel and ethanol) fuel as compared to straight diesel fuel. This, in effect, reduces greenhouse gas emissions. There is also a reduction in combustion pollutants (vehicle emissions) such as lead, carbon monoxide, and nitrous oxides. These factors would also assist Australia to attain the goals associated with local and international climate agreements. Because a blend of up to 20% ethanol and 80% diesel requires no engine modifications, there would be no adjustments required to incorporate this product into everyday diesel usage.

The ethanol yields from lignocellulosic material subjected to the University of NSW/APACE Pty Ltd. technologies are around three hundred litres of ethanol per tonne of dry biomass. In addition and depending on the feedstock, about 180 kg of lignin per dry tonne of feedstock is yielded from the conversion process. More accurate estimates can be made of the full potential for conversion to ethanol, however to date, the efficiency of the conversion process is not 100%, hence less than the potential is produced. Table 1 presents estimates of composition for cotton stalks and ginning trash, and their predicted ethanol and lignin production potential, using the new technology.

On the basis of laboratory scale research it is likely that ethanol could be produced from lignocellulosic materials for around $0.25-$0.30/litre, assuming a feedstock cost of around $0.07-$0.12/litre ($25-30/tonne), and including revenue from the sale of lignin (Bartle and Reeves, 1993). This is equivalent to the current wholesale price of petrol and diesel at the prevailing crude oil price. Ethanol produced using conventional technology, and starch or sugar feedstocks that are waste streams, (therefore cheaper than base crops), costs approximately $0.55/litre. At $0.25/litre the production of ethanol from lignocellulosics therefore compares favourably to ethanol produced traditionally.

There are a number of recent developments which have further increased the competitiveness of ethanol as fuel blend. In early 1993 the Federal Government exempted ethanol fuel from the $0.29/litre excise tax, and the NSW Government waived the $0.07/litre state tax. In late 1993 the Federal Government announced an $0.18/litre bounty to Australian producers of ethanol for blending with fuels.

There has been no investigation of the costs of collecting cotton stalks from the paddocks, within Australia. Some work has been done however, in America. Jenkins, *et al.* (1984) identified the options for cotton stalk collection being to chop the stalks in the field first. They considered transportation loose, moduled and cubed. The least cost system they identified was to module or cube the cotton stalks (depending on the end requirements).

This paper analyses the viability of the new technology available to produce ethanol from cotton stalks and cotton ginning trash, by establishing the costs to collect these feedstocks. The structure of the spreadsheet, the sensitivity analysis and the assumptions made are discussed within the methodology. The results are presented in both cost per tonne of cotton stalks or ginning trash, and cost per litre of ethanol produced (from a tonne of feedstock). A number of factors contingent to the collection costs are discussed such as storage costs, royalty costs and supply interruptions. The paper ends with conclusions on the best collection methods, their costs and the overall viability of using cotton stalks and ginning trash to produce ethanol using the new technology available.

Methods

Assumptions were made to restrict the retrieval methods analysed to those that involved machinery currently available or machinery requiring only minor modifications for operation. The methods were also limited to those requiring little or no change to existing agricultural practices, and to those which were able to remove the residue from the paddock in a "reasonable" amount of time, to allow normal farming operations to proceed. Residue was collected in a final form of a module, a pallet, a bale (of varying size) or as loose material. The collection methods analysed are presented in Table 2.

Contract rates were established through extensive discussions with contractors statewide, for all the collection operations necessary to retrieve crop stubbles. The likely range of stubble yields (t/ha), and stubble transport weights (t/bale etc.) were also established this way. Information available in the literature on average stubble yields was combined with the contractors information. It was assumed that the stubble would be transported fifty kilometres and that standard trucking charges would apply.

To enable these results to be presented as a feedstock collection cost per litre of ethanol produced (from a tonne of feedstock) a stubble conversion rate was assumed. The amount of ethanol which can be produced from stubble was identified as 300 litres of ethanol per tonne of crop stubble (Bartle and Reeves, 1992).

A spreadsheet was then constructed to model the cost to collect crop stubbles, with a triangular probability distribution attached to two groups of variables: stubble yields and stubble transport weights. The model was run for the base analysis and the results were collated.

Sensitivity analysis was conducted on three factors: the contract rate charges, transportation rate charges, and the transportation distance. The contract rates and transportation rates assumed were varied from 100% to 75% and 50% of the base rate. The transportation distances were varied from the base distance of 50 km, to 150 km, at 50 km intervals. The model was run keeping all variables fixed at the base rate except those under analysis and these results were then also collated.

Estimations of the yield of cotton stalks was combined with Australian Bureau of Statistics information on the area of dryland and irrigated cotton in four regions within NSW, the Macquarie Valley, the Namoi Valley, the Gwydir Valley and the Woody Weeds Region. An average value for the yield of cotton stalks of 4 tonnes per hectare was used; and ginning trash was taken as 10% of the number of tonnes of seed cotton harvested. Discussions with those involved in the cotton industry and the Water Resources Department enabled estimates of the areas of concentration of cotton production. Hence conclusions could be drawn on the areas with access to the most cotton stalks and ginning trash.

Results and Discussion

Twenty two different methods of collecting cotton stalks were analysed (see Table 2). These centered around the options of forage harvesting; using a modified cotton stalk mulcher; building modules, pallets, large square bales, large round bales and small bales, and transport as loose chopped material.

As can be seen the cheapest options involved using a forage harvester or a modified cotton stalk mulcher; the most expensive options involved baling the stubble. Blowing the forage harvested or stalks mulched material directly into trucks in the paddock was the cheapest option. However, this would mean loaded trucks would be driven over the paddock, hence soil compaction considerations may make these options undesirable.

Transportation as loose material would cause storage problems, unless the material was used as quickly as it was harvested. For this reason the options involving loose transportation would also appear unattractive. The best options remaining, involve making modules or "pallets" from the cotton stalks, and storing them in this form. A pallet builder is not yet commercially released, however trials of the machine indicate it could compact cotton stalks into bales 1.2 x 1.2 x 2.4 m weighing in the vicinity of 2 tonne.

Of the currently available options then, forage harvesting or using a cotton stalk mulcher to produce a module of cotton stalks appear to be the most practical.

If a royalty was to be paid to the owner of the cotton stalks, then this would most likely be on a par with the commercial value of stubble from other crops or its value for other uses. At the same value as cereal stubbles the royalty would be in the vicinity of $3-$5/tonne. This will depend on a large number of factors, including the quality and density of the cotton stalks, the overall collection costs (particularly if pulling, slashing and raking are already done), and the overall viability of the system. At a yield of 4 t/ha, there is potential for the cotton stalk owner to earn an extra $12-$20/hectare. The importance of cotton stalks within the farming system needs to be assessed before the removal of cotton stalks is advocated, however its removal off farm is much more desirable than the option of burning the cotton stalks.

The total consumption of automotive diesel fuel in NSW is around 2,434 million litres per annum. Therefore the production of a diesel-ethanol (diesohol) mix of 80% diesel and 20% ethanol would require an ethanol production of 486 million litres per annum.

400 million litres would require around 1.3 million tonnes of crop stubble, or at a biomass yield of four t/ha, around 300,000 hectares of crop stubble retrieved yearly. It should be remembered that there are a very diverse range of other lignocellulosic material which can be used to supplement this requirement, these include forestry off-cuts, sugarcane bagasse, industrial (timber) wastes or even woody weeds.

If New South Wales plants are built based on crop stubbles it is likely they will be built in the highly productive irrigation area of the Gwydir Valley. Over a million tonnes of crop stubble are available every year in this region, of which approximately 70% would be within 50 kilometres of a Walgett and Moree site (Fraser *et al.*, 1993).

As can be seen from Table 3, the production of ethanol based purely on cotton stalks and cotton ginning trash would contribute significantly to this goal. There are vast amounts of other biomass wastes which could also be sourced to produce the ethanol required, such as forestry thinnings, other crop residues and even woody weeds.

The use of cotton ginning trash would be one of the cheapest potential feedstocks, as it is already "collected" at sites. If cotton stalks could be collected as suggested here for around $30-$36/tonne ($0.10-$0.12/litre), and if a royalty of around $3-$5/tonne ($0.01-$0.02/litre) was also paid, then it is likely that ethanol fuels could be produced for around $0.25-$0.30/litre.

At this price it is comparable with the cost of diesel (before tax, freight and margins are included). However, at the moment ethanol has the added price advantage of not incurring a Federal government tax. This means that as a blend with diesel, ethanol would not increase the fuel price, and could possibly decrease it slightly.

All these factors combined make the production of ethanol from cotton stalks and ginning trash an attractive proposition.

References

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Table 1. Potential ethanol and lignin production given composition estimates for cotton stalks and cotton ginning trash.

Material	Composition (% of material makup)			Yields (per tonne of biomass)	
	Cellulose	Hemi-cellulose	Lignin	Ethanol	Lignin
Cotton Stalks	40.8%	10.6%	20.3%	325 litres	203 kg
Cotton Ginning Trash	38%	28%	26%	420 litres*	260 kg

* Other material within the cotton ginning trash such as silica (soil) can inhibit the production of ethanol, hence this figure could be considerably lower.

Table 2. Estimated collection costs for a range of cotton stalk collection methods.

Collection methods	Collection costs	
	$/tonne of cotton stalks collected	$/litre of ethanol produced
Pull-Gessner-Boll buggy-Module-Truck	$38 /t	$0.13 /l
Pull-Gessner-Boll buggy-Pallet-Truck	$35 /t	$0.12 /l
Pull-Gessner-Boll buggy-Truck	$32 /t	$0.11 /l
Pull-Gessner-Truck	$31 /t	$0.10 /l
Forage harvest-Boll buggy-Module-Truck	$32 /t	$0.11 /l
Forage harvest-Boll buggy-Pallet-Truck	$29 /t	$0.10 /l
Forage harvest-Boll buggy-Truck	$22 /t	$0.08 /l
Forage harvest-Truck	$22 /t	$0.07 /l
Grasslands forage harvester-Hoppers-Truck	$26 /t	$0.09 /l
Pull-Rake-Large Square Bale-Dump-Truck	$72 /t	$0.24 /l
Pull-Rake-Large Square Bale-Truck	$72 /t	$0.24 /l
Pull-Large Square Bale-Dump-Truck	$76 /t	$0.26 /l
Pull-Large Square Bale-Truck	$77 /t	$0.26 /l
Slash-Rake-Large Square Bale-Dump-Truck	$73 /t	$0.24 /l
Slash-Rake-Large Square Bale-Truck	$74 /t	$0.25 /l
Orkel forage-round bale-Truck	$67 /t	$0.23 /l
Pull-Rake-Large Round Bale-Truck	$74 /t	$0.25 /l
Pull-Large Round Bale-Truck	$76 /t	$0.26 /l
Slash-Rake-Large Round Bale-Truck	$70 /t	$0.23 /l

Pull-Rake-Small Bale-Truck	$109/t	$0.37 /l
Pull-Small Bale-Truck	$118 /t	$0.40 /l
Slash-Rake-Small Bale-Truck	$102 /t	$0.34 /l

Table 3. Quantity of cotton stalks and cotton ginning trash in four regions of NSW.

Valley	Estimated annual production (tonne per annum)		Potential ethanol production (million litres per annum)*	
	Cotton ginning trash	Cotton stalks	Cotton ginning trash	Cotton stalks
Macquarie Valley	8,985	77,573	2.695	23.271
Namoi Valley	35,157	303,525	10.547	91.057
Gwydir Valley	15,061	130,024	4.518	39.007
Woody Weeds Region (Bourke-Menindee)	2,788	24,067	0.836	7.220
Totals	61,991	535,189	18.597	160.556

* Assuming conservatively 300 litres of ethanol is produced per tonne of biomass.