Producing fuel briquettes from sugarcane waste

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Abstract

Prakti Design have developed an improved cooking stove to be fuelled by briquettes; in order to tackle inefficient fuel combustion, emissions and the accompanying serious health risks. Prakti Design is based in one of the highest sugarcane producing regions in the world. This paper looks at the potential of briquetting sugarcane waste and production of this alternative to fuel-wood in order to address the global concerns of deforestation and the related environmental degradation.

Keywords

Fuel Briquette: compacted material that is suitable for use as an alternative to wood and other sources of energy such as charcoal and LPG (Liquefied Petroleum Gas).

Sugarcane Waste: covers all the by-products and secondary by-products that come from cane sugar production. (S.C.W)

Introduction

The sugarcane plant is an exemplar of how nature can provide us with renewable resources to sustain ourselves without dependency upon unsustainable and damaging fossil fuels. Across the world research is being done to see how this humble plant can be used to provide alternatives to anything from petrol to plastics. More interest is being generated in the alternative uses of such plants and agro-waste as the impacts of global warming and deforestation become more and more evident. Deforestation is harmful both on a global scale, with diminished overall potential for CO_2 sequestration, and on a local scale, with increased risk of soil erosion which can lead to desertification and subsequent malnutrition or even famine.

The geographical location of Puducherry in relation to the Western Ghats mountain range means it has a natural aridity, which, combined with often heavily-irrigated agriculture and the monsoon climate mean soil erosion and subsequent desertification are more likely. Project Green Hands, a tree-planting NGO in the region set up in 2005 in response to the tsunami, set itself the goal of increasing green-cover back up to 33% to reverse the environmental degradation. (Project Green Hands, 2010) India is not well known for deforestation rate, but *"If one subtracts plantations from total forest cover then India's native forests have actually declined at an alarming pace, from 0.8% to 3.5% per year,"* meaning during 2000-2005 India suffered from a higher rate of forest loss than even Brazil and Malaysia. (Puyravaud, Davidar, & Laurance, Vol. 329, July 2010) Briquetted agricultural waste (agro—waste) from existing crops can provide an alternative to wood and can therefore reduce the deforestation rate.

The usage of agro-waste products, such as S.C.W, also avoids the cost and environmental impact of otherwise dealing with them. In some regions, S.C.W is burnt in-field, but this is a waste of energy and adds to Green House Gas (GHG) emissions.

Prakti Design

In 2009 Prakti Design won the Partnership for Clean Indoor Air (PCIA)'s Special Achievement Award and reached the finalist stages of the Sankalp Awards, India's first social enterprise and investment forum. The organisation designs and develops affordable improved cooking stoves used in communities from Mauritania to Haiti, and have recently adapted a stove specifically to be used with briquettes. They have previously been linked with EWB-UK projects after being found as an in-field contact (Selco ICS project, 2008).

Briquetting

The densification of biomass into briquettes brings the advantages of:

- Removing moisture from the material
- Improving bulk density
- Increasing the net calorific value per unit volume, subsequently reducing cost per calorific value of fuel.
- Cost reduction in transportation
- Cost-effective for user

- Usage of biomass beyond its availability period. (Organisation for Economic Co-operation and Development, 2004)

Crushing season is usually November to May in the vicinity (Puducherry Cooperation Sugar Mill, 2007) Briquetting enables year-round usage of ready-to-use agro-waste, with efficient storage and transportation thus reduced costs. The idea of using S.C.W from existing crops was to generate fuel from a product that would otherwise be thrown away or used inefficiently; rather than the wood commonly used, reducing both cost and GHG emissions associated with otherwise disposing of waste, as well as reducing fuel-related deforestation.

S.C.W, in particular bagasse, has been used in the form of carbonised briquettes in Haiti amongst other places, but the decision was made to investigate non-carbonised briquettes to simplify the process, to encourage production and usage and make the cheapest effective briquettes possible.

Availability

India is the second biggest sugarcane growing country in the World, only behind Brazil. Puducherry has many sugarcane plantations of its own, and surrounding Tamil Nadu is one of the biggest sugarcane growing states in India. The main waste product of sugarcane production is a material known as bagasse.

Bagasse is *the fibrous residue that remains in large quantities upon the crushing of sugarcane to remove the sugar juices. For each tonne of sugarcane crushed, about 300 kg of bagasse is retrieved.*

Many Indian sugarcane factories operate co-generation plants, where about 50% of the bagasse produced is used to power the factories themselves. The majority that rests is sold to paper-mills as an alternative to wood pulp. Tamil Nadu has one of the world's largest bagasse-based paper mills, *Tamil Nadu Newsprint & Papers Ltd.* (CPCB, 2010). The paper-making process requires de-pithed bagasse, creating a second waste, bagasse pith. (Hurter, 2007)

Bagasse Pith is *cellulose but not fibrous, and must be removed from bagasse in order to make good quality pulp from which to produce paper. Bagasse pith is usually removed in a process known as "moist de-pithing" in the sugar factory itself.*

Methods and Results

Current Fuel

Research done with Prakti gave the characteristics of the fuel-wood to compete with, as shown in *Table 1*.

Fuel	Cost	Calorific Value (when completely dry)	Quantity Required for 1 average meal*	Cost of fuel/meal
Split Wood	5 Rs/kg	19-21 MJ/kg	1.34 kg	6.7 Rs
Non-split Wood	4 Rs/kg			5.4 Rs

Table 1: Characteristics of the Fuel-wood used in the region

* The average cooking time was calculated for lunch: traditional meals were prepared by a local cook, on an Improved Cooking Stove (ICS) designed by Prakti, and the average wood used was recorded. The average weight of food cooked was 3.53 kg, a large meal, to feed 4 people, including rice, and several different vegetables. This gives 0.335kg wood/person/meal, however the ICS gives an approximate 50% fuel reduction. Based on Prakti's experience in both India and Africa, wood consumption in a traditional 3-stone cooking stove is roughly 1kg/person/day.

Properties of Sugar Cane Waste

The first stage of the research into finding the solution was to decide upon what type or types of S.W.C. to briquette. Bagasse, press mud, molasses and bagasse pith were all considered. Sugar cane factories were only able to provide samples of bagasse and bagasse pith for testing, because the crushing season had ended, but other data sources were found to compare properties.

The main problems in briquetting bagasse are that it requires a lot of processing, due to:

- large particle sizes (10mm average length)
- "springy nature"
- high moisture content

These factors could be addressed in the press design although the added complexity would increase both immediate and long-term (maintenance) costs.

Bagasse pith is a fraction of the cost of bagasse, the local sugarcane factory charged approximately 4% of the cost of bagasse, at only 450 Rs/tonne (about £6.40/tonne). This is also much cheaper than municipal waste in the region being collected by local waste-collecting NGO Shuddham (e.g. cardboard at 4000-6000 Rs/tonne (Shuddham, 2010)) previously considered as a source of briquetting material). Secondly, although research uncovered experimentation to find a use for bagasse pith in other domains, such as cattle fodder, no published evidence has been found of usage in briquetting.

A bomb calorimeter was used to find calorific value, results shown in *Table 2* illustrating that bagasse pith has a comparable calorific value to briquettes currently used around the world, and other fuel-sources. Being organic materials, the S.C.W from the region could differ significantly in properties from that from a region in a different climate, (University of Natal, Mechanical Engineering Department, 1977), so this experimentation was vital.

Calorific Values of Organic Samples								
	Bagasse Try 1	Bagasse Try 2	Bagasse Briquette (Compressed Bagasse with possible binder)	Bagasse Pith	Sawdust	Sawdust/ binder (Kerala briquette)	Sawdust/ Paper/ Cardboard (Haiti briquette)	Waste paper/ coffee husks (Bangladesh briquette)
Weight (dry) [g]	0.9252	0.966	0.99901	1.0101	1.0365	1.02261	1.02	1.02
Temperature Change [°C]	1.644	1.6389	1.88255	1.7409	2.0532	1.8457	2.0532	1.78
Calorific Value [MJ/kg]	18.1	17.3	19.2	17.6	20.2	18.4	*20.5*	17.8

Table 2: Calorific values of samples as found using the bomb calorimeter.

The results for bagasse were comparative to other results found from various sources including Biofuelsb2b (Biofuelsb2b, 2007) which listed 17-18 MJ/kg. However results for bagasse pith were much higher than that found in Avant Garde India, which listed 2000 kcal/kg, the equivalent of about 8.4 MJ/kg, less than half of the 17.6 MJ/kg found in the bomb calorimeter experiment run.

Waste	Percentage of weight of Sugarcane Crushed
Bagasse	30%
Bagasse Pith	[50% of weight of bagasse to be de-pithed]
Press Mud	3-8%
Molasses	3-5%

Table 3: Quantities of waste per weight processed (Sugar Industry Waste, 2010), (Avant Garde India)

Table 3 shows quantity but the actual availability of waste was also vital- in order to handle molasses in India, a special permit is required due to the fact that molasses can be used to make alcohol. Alcohol is a controlled substance in Tamil Nadu and the sale of alcoholic beverages is the monopoly of the state government. Molasses has a low calorific value, and would only have been considered as a potential binding agent for the main agro-waste. As we wanted small businesses or schools to benefit from briquetting, and the briquetting material to which the press would be tailored, molasses was eliminated as a potential binding agent.

Chosen Waste

Bagasse pith was decided upon as the calorimeter data supported the good physical briquetting property of bagasse pith, as shown in *figure 2*.

Bagasse pith has an ash content of 8% (RWEDP Energy) which is acceptable for a fuel briquette. However, containing 48% - 52% moisture (Avant Garde India), the material remained damp, even months after being removed from the factory. Therefore, research needed to be done into the value that drying the material might bring to briquette quality, and how this could be achieved.

Figure 1: Image of bagasse pith briquette made on car-jack press constructed in Puducherry

Investigation into Drying

*P*rakti Design has its own solar drier, as shown in *Figure 2*. Investigation will be carried out into how well bagasse pith can be dried without the use of any extra energy. The monsoon season in Puducherry runs from October till December, with heavy rains starting as early as August, and the ability of the solar drier to work under such conditions would also need research. Investigation into how successfully bagasse pith responds to drying is being carried out in England, through simple radiator experiments where it has been found to dry quite successfully within a few weeks.

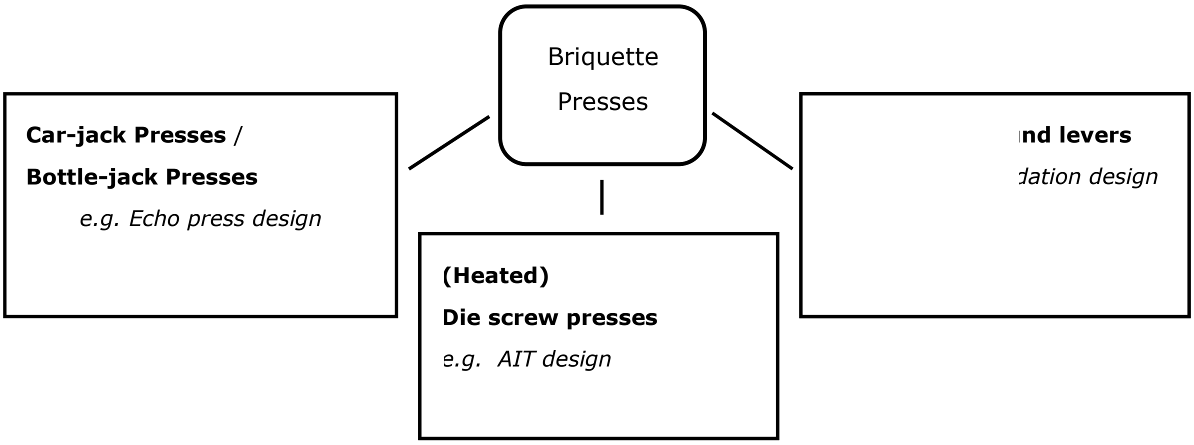
Figure 2: Prakti Design's Solar Drier

Investigation of Press Designs: Brief discussion of types of presses available

Discussion with the CEO of Prakti Design generated the outline design specification for the briquetting press:

- Less than 100 USD
- Largely Manual
- Production of 50 briquettes/day possible
- Cheap to run and maintain

Above all, we wanted the press to use appropriate technology- to be constructed from locally available materials, in local workshops using techniques that were already practised or that could be taught and passed on. Research was conducted into briquette presses used on a similar small scale in international development, from simple lever presses used in communities to the more complex heated die screw-press.



Investigation into each of these types of press designs to find their relative merits and disadvantages will be done, to add to general brainstorming, also taking into account the feasibility of building the presses with cheap locally-available resources.

Feedback from Field Trip

Due to some experience of international development projects communication difficulties were expected, but not to the extent experienced. Time expected to complete tasks was increased by problems such as:

- locating sugarcane factories
- arranging meetings
- obtaining samples of S.C.W

This was due to a variety of factors- for example:

- *Research* done whilst in England was found on arrival to be *out of date*, with sugarcane factories listed which had since changed contact details, location, or even ceased to exist.
- *Sugarcane plantations* only rarely had their own websites (unsurprisingly) making it difficult if not impossible to contact anyone without actually travelling to location. This also took time away from other research that needed to be done in the field.
- *Bureaucracy* involved in obtaining samples, meaning more trips.
- *Changes in address* or *poor infrastructure*
- *Language barriers and subsequent dependency on colleagues*, as it was difficult to find an appropriate time to trips to other sugarcane factories that were further away due to their own work commitments. Language barriers also occasionally led to miscommunication of information between myself and my colleagues.

The very short time period between finalising the project and going out on the field trip, which unfortunately was unavoidable, meant that I was not as prepared as I would have liked to have been. Before any subsequent trip I would try to:

1. *Contact more organisations in advance*, particularly to arrange meetings and raise interest
2. *Find more technical external contacts* in the field beforehand
3. *Improve my Tamil*, particularly technical vocabulary.

However, the act of going to the location and working with the partner organisation *before* officially starting the dissertation research really helped the progress of the project, and I recommend it. I was able to attack the project well from the start, knew what I was doing when I officially began my dissertation and had continued support from those that I had worked with during working at Prakti Design.

Conclusion and Future Steps

<u>Bagasse pith is:</u>

- *available*, being
    - the secondary waste product of sugarcane, an abundant crop both in Puducherry and India as a whole, where the majority of factories de-pith and sell the bagasse not required for co-generation to paper mills
    - and without a distinct alternative use; of which all current uses still require considerable processing

- *relatively high calorific value* (similar to bagasse and the composition of briquettes currently used in the calorimetry test)

- *relatively low cost* (4% cost of bagasse which is already used in briquetting)

and naturally comes in

- *small particles* (particularly compared to bagasse, already used in briquetting).

Pre-processing

Investigation to determine how much pre-briquetting drying will be conducted; if solar drying experimentation proves successful, great expense and energy-usage will be saved. but the issue of solar drying during monsoon conditions will still need investigation.

Briquette Composition

Briquette "recipes" and pressure applied will be experimented with. The addition of a binding agent may also need to be considered, depending on the results of initial performance testing using a simple press (simulation) arrangement. Possible locally-availabel materials to be considered as binders include clay and cassava starch.

Press Designs

Although likely to be conducted outside the time-scale of the final year project, a press tailored to bagasse pith briquette production will be constructed, leaving an educational tool to be used for training events, particularly for EWB-Sheffield. Detailed plans using appropriate local technology would become open-source on the internet if deemed different enough to existing presses.

Application

A briquette enterprise that could be set up with the press would introduce new jobs into a community- from collection of the raw materials and management of any processing required such as solar drying, to operating and maintaining the press and distribution of the briquettes. Schools and cooperatives interested in using the briquettes are being researched. Prakti's specially designed stove is currently successfully being trialled in Haiti by a school, and it was found that the local sugarcane factory to Puducherry has built its own school especially for the children of its workers. This is being focused on as a possible benefactor of fuel briquette production. With

- favourable prices likely
- no transport costs- if production could be done on school-site (next to factory)
- potential for agro-briquette educational workshops to demonstrate solutions to deforestation and global warming and teach the production technique,

briquette production could prove not only particularly cost-effective, but also beneficial here.

If the overall cost of the briquette could compete with fuel-wood per tonne then they could be used elsewhere on a similar scale, perhaps eventually even in other big sugarcane producing Indian states, making some leeway into tackling deforestation.

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