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Investigating the energy use of vegetable market waste by briquetting

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ABSTRACT

The present paper reports a study conducted at Sardar Patel Renewable Energy Research Institute, aiming at transforming vegetable market waste (VMW) into an energy-briquette. The raw green vegetable market waste gave about 15–20% dry matter after open sun drying. The dried mass of the VMW was converted into a pulverized form and subsequently into briquettes without using any external binding agent. Although the lignin contents of the VMW were low (3.23–5.51%) as compared to other lingo-cellulosic biomass, good quality briquettes were produced without using any binding agent. The bulk densities of briquettes were almost 10–15 times higher than the material in dry loose form. The calorific value of four different types of VMW used in this study ranged 10.26–13.70 MJ kg^{-1} of dry matter.

1. Introduction

Energy and fuels are the important links in civilization and human development. The issues associated with the use of the fossil fuel, demand and supply gap, ever increasing prices, global warming and other environmental issues made the world to think for alternate sources of energy like solar, wind, ocean and biomass which are the only indigenous renewable energy sources capable of replacing large amount of solid, liquid and gaseous fossil fuel [1]. Biomass energy has attracted as one of the potential alternatives as it is an ideal renewable energy source with several advantages like lower sulfur, CO_2 neutral emission, and abundant availability generally in the form of waste from agriculture as well as other sources [2]. Bioenergy derived from biomass is a promising, inexhaustible, sustainable source and can help in minimizing the rising environmental, economic, and technological issues related to depleting fossil fuels. Utilization of waste for deriving secondary fuel has received a worldwide acceptance as it can provide fuel and at the same time solution to waste disposal maintaining the environment.

The population across the globe is increasingly getting inclined towards healthy and processed food products, about one-third of it gets wasted globally and accounted roughly 40–50% for root crops, fruits and vegetables at various stages like agricultural production, post-harvest handling and storage, processing and packaging, distribution and consumption [3]. Food losses in developing countries, more than 40% loss occurs at post-harvest and processing levels, while in industrialized countries, almost the same losses occur at retail and consumer levels [3].

The biomass, particularly available in India is waste from agriculture, forest, municipal or different food processing industries. Vegetable and fruit waste is one of the major parts of such wastes generated at different stages. India is the second largest producer of fruits and vegetables (after China) in the world and contributes about 10 and 14% of fruit and vegetable in the world production [4]. According to Agricultural Statistics at a Glance 2010 [5] during 2008–09, it produced 69.453 million tonnes of fruits, 133.071 million tonnes of vegetables and 44.291 million tonnes of flowers. About 25–30% of fruits and vegetables are spoiled/wasted in handling, transport and in retail marketing. According to NAAS Policy Paper [6], out of the total production (202.52 million tonnes) of fruits, vegetables and other horticultural crops in India in 2008–09, the estimated availability of their processing and market waste was about 83.34 million tonnes (41.15%). Thus India, with rich agricultural resources, accounts for 50 million tonnes of waste, which is about 30% of its total production [7]. These wastes either get spoiled causing environmental pollution or are used mainly for making farm yard manure.

In China, with economy and social progresses, urbanization and steadily growing population, the amount of municipal solid wastes (MSW) increased rapidly in recent years. China Statistical Yearbook 2009 by China Statistics Press, estimated 154 million tonnes MSW generated and disposed in year 2008. A steep rise of 86.7% was seen from 60.1 million tonnes in 1995 to 112.2 million tonnes in 2009 and about 90.5% of MSW disposed by landfilling and small percentage is disposed through incineration and composting

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creating massive and multiple environment issues, including air pollution, soil and water pollution and garbage that affect China's environmental quality and the sustainable development of cities [8]. The MSW mainly composed of sorted organic wastes, sometimes higher than 60% due to high percentage of fruit–vegetable waste and food waste with high water content about 75–95% [9] which associate with incomplete combustion, unsteady/higher air pollutants emission, and inefficient energy recovery [10,11]. Worldwide MSW generation is about two billion tonnes per year, which is predicted to increase to 3 billion tonnes by 2025 [12]. The production of fruit and vegetable waste is also very high and becoming a concern in municipal landfills because of its high biodegradability [13].

Technological options available for disposal of the MSW are landfill, incineration, composting or anaerobic digestion of organic portion. Landfill is a low cost and easy solution for waste disposal with advantage of landfill gas as a by-product for household and industrial uses but it associates with disadvantages like requirement of large land area; high land cost, ground and water pollution, air pollution, often far away due to public resistance and space limitation. Incineration or direct combustion reduces substantial volume of waste, and requires minimal pre-processing of waste but it requires more space than other technologies, high capital, high operational and maintenance cost, significant operator expertise, treatment of the flue gas and fly ash disposal [14]. Municipal waste involves the generation of climate-relevant emissions of CO_2 (carbon dioxide) as well as N_2O (nitrous oxide), NO_x (oxides of nitrogen), NH_3 (ammonia) and organic carbon [15].

In recent years, composting has been presented as an environmental friendly and sustainable alternative to manage and recycle organic solid wastes with a quality organic product, known as compost, to be used as organic amendment in agriculture. Composting is associated with some environmental impacts like generation of polluted or odorous gaseous emissions; one of the major concerns in developed countries [16]. Ammonia is one of the main compounds responsible for generation of offensive odors and atmospheric pollution when composting organic wastes [17] with high nitrogen content. Ammonia gas can cause adverse effects on vegetation and can be converted to N_2O, a powerful greenhouse gas [18] as well as MSW composting cannot be justified on financial grounds [19].

Organic waste can be transformed into viable organically beneficial products, organic fertilizers and animal feed via bioconversion [7,20] and has been recognized as a valuable and lucrative energy resource [21–23]. Vegetable wastes generally disposed in municipal landfill or dumping sites [24] or dumped on open land creating nuisance environment by emitting a foul odor and health hazards. Studies reported on the anaerobic digestion of solid refuses like municipal solid wastes [25–27], canteen wastes [28], banana peel [29], market wastes [30], water hyacinth [31], sugar mill press mud waste [32] and fruit and vegetable processing wastes [33–35], mixture of vegetable wastes including carrot, beans and brinjal [36]. Vegetable wastes, due to high biodegradability nature [37,38] and high moisture content (75–90%) seemed to be a good substrate for bio-energy recovery through anaerobic digestion process and could be an appealing option in the future [39]. A major limitation of anaerobic digestion of vegetable wastes is the rapid acidification due to the lower pH of wastes and the larger production of volatile fatty acids (VFA), which reduce the methanogenic activity of the reactor [13]. Preliminary treatment is required to minimize organic loading rate, hence aerobic processes are not preferred for vegetable wastes [40].

Large quantities of vegetable and fruit wastes are left unused or allowed to decompose creating serious environmental problems. However; these problems can be overcome by drying them and converting into high density briquettes [41,42]. Generally the vegetable waste could be collected and used partly as animal feed and compost and partly for energy purposes. Another important derivative could be a solid densified material which can give flexibility in storage, transportation as well as the use as per requirement, may be one of the promising solutions to these problems.

Briquetting technology involves densification of material for improving its handling characteristics and enhancing the volumetric calorific value. Lignin in biomass assumed to be helpful in binding particles [41,43]. Several studies on binderless briquettes reported, like mixture of spent coffee grounds, coal fines, saw dust and paper pulp [44], saw dust, bagasse, cotton stalk, pearl millet and jatropha shell [42], rye straw and meadow hay (1:1 ratio); rye straw and leaves (1:1 ratio); aye straw and cucumber plant (1:1 ratio) [45], been reported with good density range between 710 and 770 kg m^{-3}; biomass waste with some added percentage of plastic waste were [46], as well as banana peel using molasses as the binder [47], saw dust with starch, cow dung and wood ash [48].

The present study focuses on the strategic application of thermo chemical conversion of vegetable wastes into environmentally friendly and low-cost production of biofuel. Good quality briquettes were produced from dried loose vegetable market wastes without using any external binder. These briquettes can be used as a fuel in domestic cook stoves [49], boilers and gasifier [50]. The general waste to energy conversion process and energy use of vegetable market waste briquettes is shown in Fig. 1.

2. Material and methods

2.1. Collection of raw vegetable market waste

The raw green vegetable market wastes (VMWs) were collected mainly from the city vegetable markets, directly from farmer's fields where they used to throw away cauliflower/cabbage stem and leaves and vegetable processing industries. Nearly eight tonnes of the raw green vegetable market wastes (VMWs) were collected from different places. Depending upon season, there were fluctuations in the quantity and nature of waste generated daily from the vegetable market. Four different types of vegetable waste materials available during the period of experimentation were collected namely cauliflower (*Brassica oleracea*)/cabbage leaves (*Brassica oleracea capitata*), coriander stalks and leaves (*Coriandrum sativum*), field beans (*Dolichos lablab*) and green pea pods (*Pisum sativum*) and their conditions at the time of collection are given in Table 1.

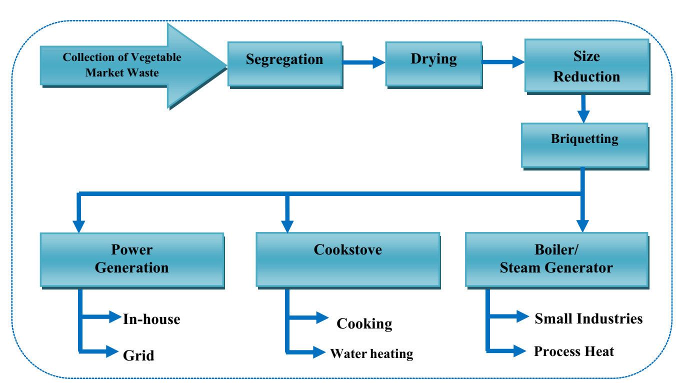

Fig. 1. Energy conversion and utilization route of vegetable market waste.