Renewable and Sustainable Energy Reviews 54 (2016) 202–216

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Environmental sustainability of bioethanol production from rice straw in India: A review

Renu Singh [a], Monika Srivastava [a], Ashish Shukla [b,*]

[a] Centre for Environment Science and Climate Resilient Agriculture, IARI, New Delhi 110012, India
[b] Coventry University, Priory Street, Coventry CV1 5FB, UK

ARTICLE INFO

Article history:
Received 19 January 2015
Accepted 1 October 2015
Available online 11 November 2015

Keywords:
Rice straw
Bio-ethanol
Life cycle
Greenhouse gas emission

ABSTRACT

Rice is the main staple food in most of the Asian countries and rice crops generate a huge amount of rice straw as crop residue in the fields. Unsustainable use of rice straw and open burning of crop in the field not only produces threat to environment by producing large amount of greenhouse gas (GHG) emission, but also make farmer's loose a very viable by-product. Rice straw can be used in bio-ethanol production and bring additional income and sustainable utilization. It will also provide clean energy solution to ever increasing energy demand in India. However, it becomes more important to study the sustainability of bio-ethanol production from rice straw and how it can make sense in today's Indian agricultural scenario. Although, the bioethanol obtained from rice straw is a carbon neutral in nature, but the concerns of environmental impacts have been raised for the whole process i.e. from rice cultivation, rice logistics, pretreatment techniques, bioethanol generation and transportation. The present review focuses on the environmental sustainability issues arising from use of rice straw for bioethanol production. The environmental impacts are assessed by studying the emission of greenhouse gases from each stage of life cycle. The paper presents an outlook on current status and future prospects of ethanol blending in the country.

Contents

* Corresponding author. Tel.: +442477658587.
E-mail addresses: ashish.shukla@coventry.ac.uk, ashish.physik@gmail.com (A. Shukla).

http://dx.doi.org/10.1016/j.rser.2015.10.005
1364-0321/

1. Introduction

The term "Sustainable agriculture" depicts an economically viable, environmentally safe and socially accepted food, fiber or fuel production system [1]. Sustainable agriculture has been traditionally existed in more western societies and it represented a more environmentally sound and socially responsible system of agriculture production [2]. UN Conference on Environment and Development in Rio de Janeiro [3] has brought out the concept of sustainability. Loon et al. [4] described sustainable agriculture as a set of post material values that emphasizes on conservation of agriculture and food, animal welfare and economic assistance to farmers. Agricultural sustainability involves ecological, economic and social dimensions and under each dimensions there are several attributes which are measured through indicators [5–8]. Some scientists have developed fundamental principle of sustainability [9–11] that includes:

1. Multidimensional approaches considering ecological, economic and social aspects at an equivalent level;
2. A systemic investigation that evaluate not only single factors but also complex functions and processes with various interactions between elements. This also includes the assessment of sustainability with regard to a suitable temporal and spatial scale;
3. A consensus based process of decision finding with special focus on ecological aspects of sustainability;
4. Transparent concepts offering clear recommendations for implementation;
5. Extremely flexible and dynamic strategies of assessment and implementation showing a high transferability to manifold systems (like different crop cultures, crop rotations, environmental conditions and/or marketing systems);
6. Focus on economic and social principles.

In order to achieve sustainable development, the environmental efficiency (i.e. the use of energy, space and raw materials) of current agricultural production methods must be increased with a factor of 20 by 2040 [12]. In 2005, United Nations defined Environmental sustainability as meeting the needs of the present without compromising the ability of future generations to meet their needs. Environmental sustainability can be perceived as balancing the three pillars of economic and social development with environmental protection. For a sustainable development, the development of economy and environment should go together as both are necessary for the development of human beings. Presently, the main problem of world is how to reduce emission of greenhouse gases (GHG) for mitigation of climate change and for sustainable growth of economy. This can be achieved by promoting new renewable sources of energy such as geothermal energy, wind energy, solar energy, biomass based energy (bioethanol, biodiesel, bio-hydrogen). Due to day by day increase in demand of energy and depletion of conventional sources of energy, the fossil fuel prices are rising very speedily. There is a need to find out an alternative source of energy which fulfills the criteria of sustainable development that means it not only enhances the world's economy, but also supports the environment. Bioethanol production from sugars, starch and lignocellulosic materials is an attractive alternative option for fossil fuels. It has higher octane number and higher heat of vaporization due to which it can be easily blend with the gasoline or use as alcohol in dedicated engines [13]. In U.S, corn starch and in Brazil, sugarcane juice and molasses are mainly used for bioethanol production and 89% of global ethanol production is contributed by both these countries.[1] In India, sugarcane molasses is mainly used for ethanol production and has about 330 distilleries with the annual production capacity of over 4.0 billion liters [14]. Only corn based or sugarcane based ethanol production cannot substitute the one trillion gallons of fossil fuel which is presently consumed worldwide each year [15]. Also, the utilization of these edible food crops for bioethanol production raises the question of food security and thus, it is not appropriate for sustainable development. So, there is a need to derive bioethanol from some other sources which do not put pressure on food crops. This led to the bioethanol production from inedible potential feed stocks [16]. More sustainable technologies for bioethanol production from lignocellulosic biomass have been investigated [17]. Utilization of lignocellulosic biomass for bioethanol production is the better opportunity as it does not compete with the food crops and animal feeder and moreover these cellulosic materials contribute to environmental sustainability [18]. A variety of lignocellulosic agricultural wastes are available for ethanol production such as sugarcane baggase, rice hull, timber species, willow, salix, switchgrass, softwood, rice straw, wheat straw etc. [19]. Among all the lignocellulosic substances, cereal straws are most abundant, cheap, renewable and easily available [20]. Rice straw is a promising alternative for bioethanol production [21].

Rice (*Oryza sativa*) is the main staple food of the Asian countries. In 2011, annual world rice production is 721.4 MT and 90.48% are from Asian countries [22] and this will generate 973.89 MT of rice straw in the fields [23]. Although, rice is the world's second largest cereal crop after wheat, but it generate largest amount of crop residues, approximately 330 MMT [24]. In India, major agro residues generated are Rice straw (112 MMT), rice husk (22.4 MMT), wheat straw (109.9), sugarcane tops (97.8) and baggase (101.3) (Fig. 1) [25]. Only 20% of rice straw produced in the world is utilized [26] and rest is left as waste. In most of the Asian countries, open burning of rice straw is in common practice for its disposal that leads to the air pollution [27]. In India, 23% of rice straw is either left or burnt in the field and the open burning of rice straw is a threat to atmosphere and climate as its contributes 0.05% to GHG emissions [28]. The energy content of rice straw is around 14 MJ per kg at 10% moisture content. The by-products are fly ash and bottom ash, which have an economic value and could be used in cement and/or brick manufacturing, construction of roads and embankments, etc. It should not be wasted by burning, unless utilize it for generation of energy.

Environment sustainability mainly deals with the emission of greenhouse gases (GHGs) during the entire process of bioethanol production and its use in transport sector. The green house gas (GHG) emission reduction target for the EU is 20% by 2020 (from

[1] http://www.ethanolrfa.org/industry/locations/