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ASSESSMENT OF BIO-ENERGY POTENTIAL IN TEA INDUSTRIES OF INDIA

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Abstract

Tea production is an energy intensive agro-processing trade. Since high demand of energy and increased in fuel prices, tea waste can be utilized to supplement part of energy required in tea processing. This study was conducted in tea estates of Assam (North Lakhimpur, Sonitpur, and Silchar), India. The total energy consumption in tea manufacturing was found to be 4.2-8.5 kWh/kg of made tea. Thus, total energy consumption (5 kWh/kg of tea) for manufacturing of 1197 million kg of tea from 564 thousand hectare tea plantation in India (during 2014-2015) was 5.985×10^{9} kWh. The total obtainable energy from tea waste was estimated and the conversion efficiency of calorific value to electrical energy was assumed to be 10%, which is the least value of conversion efficiency. Energy potential in processing and garden waste was found to be 11.999×10^{7} kWh and 3.492×10^{10}kWh, respectively, and corresponding electrical energy was estimated to be 1.1999×10^{7} kWh and 3.492×10^{9} kWh, respectively. Thus, comparing the energy that could be generated from wastes in tea estate and that required in tea manufacturing, it can be concluded that the huge amount of energy could be saved with the utilization of tea waste.

1. INTRODUCTION

India is the second largest producer of tea next to China. It occupies an important place and plays a very vital role in India's national economy. It is perhaps the only industry where India has retained its leadership for over the last 150 years (Gupta & Dey, 2010; Pou, 2016). The major tea producing states in India are Assam, West Bengal, Tamil Nadu, Kerala, Himachal Pradesh, and Karnataka. Of these, Assam state is the major contributor. Tea Board of India (TBI) (2016) has reported that China is leading in production share and Kenya in export share as shown in Fig. 1 and 2, respectively. TBI (2016) has shown the total production of tea in India during 2014-2015

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was 1197 million (m) kg. The total area under tea plantation in India is 564 thousand hectare. Assam contributes 56% of total tea plantation area and produces about 55% of total tea production of India (Kumar *et al*., 2014).Tea processing involved different unit operations namely, plucking, withering, rolling, maceration, fermentation, drying, grading, and packing, which are highly energy intensive. Tea drying is the most energy intensive unit operation in tea manufacturing (Dutta & Baruah, 2014).The processes consume huge energy in the form of thermal energy and electrical energy at the ratio of 85:15 (Baruah *et al*., 2012). Thermal energy is mostly used during withering and drying operations while electrical energy is utilized for running motors, fans, humidifiers, and lighting purpose. In Indian tea industry parlance, thermal energy requirement is mainly obtained from firewood, coal, briquetted biomass/coal, natural gas, and furnace oil. The specific energy consumption varies from 4-10.4 kWh/kg of made tea (Baruah *et al*., 2012). The plantation and transportation also consumes a large amount of energy in the form of petro-fuels (Saikia *et al*., 2013).

Therefore, considering the energy use pattern in tea industries it is necessary to take great care in energy consumption patterns for sustainable production of tea. Tea manufacturing involves various operations of intensive energy consumption. Part of this energy requirement can be supplemented with the utilization of tea waste. Tea waste comprises of processing (factory) waste as well as garden waste. The processing waste is generated during sorting or grading of made tea. During this process, the fibers are separated from the main tea. On the other hand, garden waste is generated from pruning/skiffing of tea bushes during off season. Garden waste consists of leaves and branches of tea bushes and shade trees.According to Tea Research Association (TRA), Tocklai, Assam, India (2016), *Albizziaodoratissima*, *Albizziachinesis*, *Albizziaprocera*, *Accacialenticularis*,and*Derris robusta*are most commonly used shade trees for dropping of excessive heat and light radiation. The tea bush waste varies from 2-2.5 kg (wet matter basis) per bush per year in a 4 year pruning cycle. TBI (2016) has reported the tea waste generation is about 2% of the total tea production. Thus, during the year 2010-2015 the tea waste generated in India was approximately in the range of 19-24 m kg annually. Therefore, utilization of tea waste in a positive manner could meet the part of energy required in the processing of tea.Tea waste is a biomass; energy can be obtained by pyrolysis and gasification of this biomass (Rao *et al*., 2012).

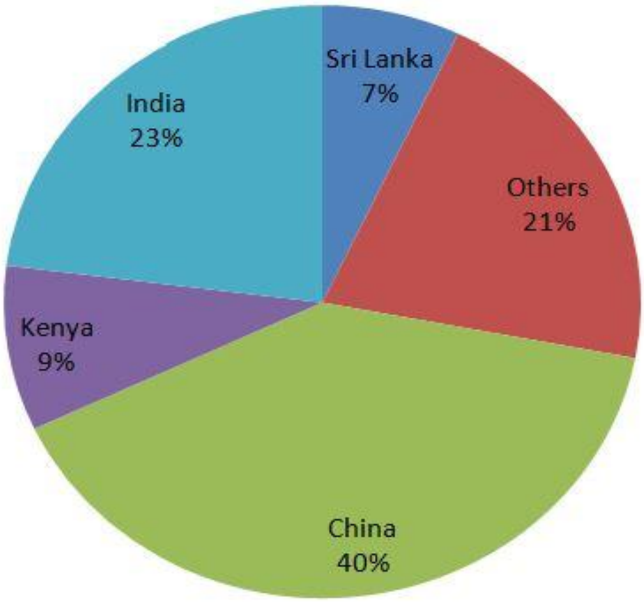

Figure 1: Production share of major tea producing countries during 2014-2015

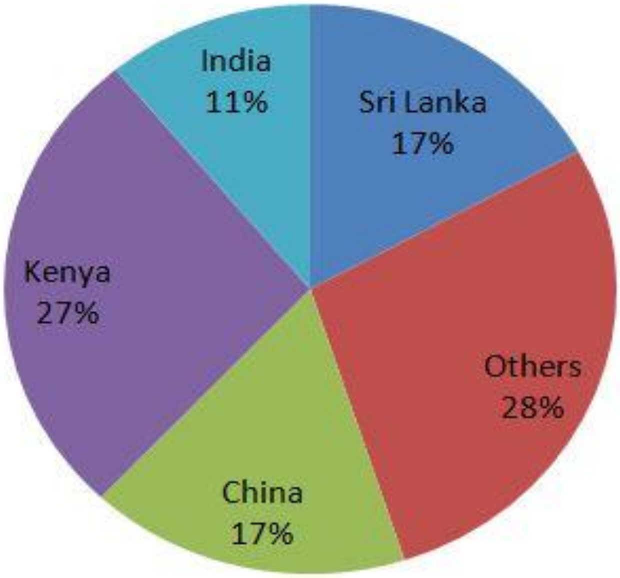

Figure 2: Export share of major tea producing countries during 2014-2015

2. MATERIALS AND METHODS

This study was carried out in Assam (North Lakhimpur, Sonitpur, and Silchar), India. The samples and necessary information were collected from the various tea industries in Assam. The samples consist of both processing (factory) waste and garden waste (tea bush and shade tree pruned materials).

2.1. Moisture content (MC) determination

Moisture content of factory waste, garden waste leaves and branches were calculated as shown in Eq.1. The samples were chipped into smaller pieces and placed in muffle furnace at 105 $^{\circ}$C for 24 hours.

$$MC = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100 \qquad \text{----------------------- (1)}$$

2.2. Calorific value

The calorific value of the sample was measured using bomb calorimeter. A bomb-calorimeter is a device to measure heat created by sample burnt under an oxygen atmosphere in a closed vessel, which is surrounded by water, under controlled conditions. The heat created during the burning process, which can be determined by the combustion process, is transferred into the surrounding water and the rise in the temperature is determined by calorimeter. The calorific value of the sample can be calculated as given in Eq. 2.

$$\text{Calorific Value (kWh/kg)} = \frac{W_w\ X\ (T_2 - T_1)}{W_s} \times C \qquad \text{---------------------- (2)}$$

Where,
W_w = 2322 =Weight of water equivalent to calorimeter (g)
T_1 = Stabilized temperature before firing (°C)
T_2 = Maximum temperature after firing (°C)
W_s= Weight of sample (g)
C = 0.00116 (Constant)

2.3. Estimation of energy potential of tea waste

2.3.1. Processing tea waste

The energy potential of processing (factory) tea waste can be calculated as given in Eq. 3.

$$\mathrm{E_p}(\mathrm{kWh}) = P(kg) \times 0.02F_{cv}\ (kWh/kg) \qquad \text{----------------------- (3)}$$

Where,
E_p = Energy potential (kWh)
P = Total tea production (kg)
F_{cv} = Calorific value of factory (processing) tea waste (kWh/kg)
0.02 = Constant, percentage of tea waste generated

2.3.2. Garden waste

The energy potential of tea bush waste and shade tree waste can be calculated as shown in Eq. (4) and (5), respectively.

$$E_p(kWh) = B_w(kg) \times N \times A\ (ha) \times G_{cv}(kWh/kg) \qquad \text{----------------------- (4)}$$

Where,
E_p = Energy potential (kWh)
B_w = Tea bush waste (kg)
N = Number of tea bush/hectare
A = Tea bush plantation area (ha)
G_{cv} = Calorific value of tea bush waste (kWh/kg)

$$\mathrm{E_p}\ (\mathrm{kWh}) = \mathrm{S_w}(\mathrm{kg}) \times \mathrm{N} \times \mathrm{A}(\mathrm{ha}) \times \mathrm{S_{cv}}(\mathrm{kWh/kg}) \qquad \text{----------------------- (5)}$$

Where,
E_p = Energy potential (kWh)
S_w = Shade tree waste (kg)
N = Number of tree per hectare
A = Tea plantation area (ha)
S_{cv} = Calorific value of shade tree waste (kWh/kg)

3. RESULTS AND DISCUSSION

Most of the tea industries considered in the studies are more than 50 years old. The processing waste generated during sorting was approximately 2 % of total tea production. The energy requirement in different unit operations for tea production was found to be withering (35%), crush tear curl (CTC) operation (6%), fermentation (0.6%), drying (57%), sorting (0.6%), packaging (0.1%), and auxiliary operation (0.5%). The total energy consumption in tea processing was found to be 4.2-8.5 kWh/kg of made tea. The average pruned tea leaves and branches obtained were recorded as 10 kg/tea bush/pruning cycle. Thus, the average annual pruned material obtained in a pruning cycle of 4 year was 2.5 kg/tea bush. On the other hand, the pruned material obtained from the shade tree was approximately 5 kg dry biomass/tree. The average moisture content of processing (factory) waste, tea bush pruned leaves, tea bush pruned branches, shade tree pruned leaves, and shade tree pruned branches were determined as 2 %, 80 %, 58 %, 76 %, and 60 % (wet basis), respectively.

3.1. Estimation of energy in tea waste

3.1.1. Calorific value of tea waste

The calorific value of processing (factory) tea waste samples were determined using bomb calorimeter and the average calorific value of factory tea waste was obtained as 5.012 kWh/kg of tea waste.Similarly, the calorific value of collected garden waste samples (tea leaves and branches) were analysed and the average calorific value was found to be 4.302 kWh/kg, as shown in Table 1.

Table 1: Calorific value of tea bush waste

Type of garden waste	Calorific value (kWh/kg)	Average calorific value (kWh/kg)
Tea leaves	4.281	4.302
Branch of tea bush	4.323	

3.1.2. Calorific value of shade tree waste

Similarly, the calorific value of shade tree (leaves and branches) were estimated and the average calorific value was recorded as 4.555 kWh/kg, as given in Table 2.

Table 2: Calorific value of shade tree waste

Type of garden waste	Calorific value (kWh/kg)	Average calorific value (kWh/kg)
Shade tree leaves	4.120	4.555
Branch of shade tree	4.990	

3.2. Energy potential of tea waste

The energy potential from processing tea waste (approximately 23.94 m kg) in India during the year 2014-2015 was calculated as 11.999×10^{7} kWh as represented in Table 3. On the other hand, the energy obtainable from the garden tea bush pruned materials (leaves and branches) was estimated as 3.478×10^{10}kWhas shown in Table 4.

Table 3: Energy potential of processing tea waste

Parameters	Value
Annual tea production in India, 2014-2015 (million kg)	1197
Tea waste (million kg)	23.94
Calorific value (kWh/kg)	5.012
Energy potential (kWh)	11.999×10^{7}

Table 4: Energy potential of garden tea bush waste

Parameters	Value
Tea plantation area in India, 2014-2015 (hectare)	563980
Spacing between rows (m)	1.05
Spacing between bushes (m)	0.70
Bush/area (m^2)	$1.05\times0.70=0.735$
Bush/area (hectare)	13605
Total number of bush	7.7×10^{9}
Garden tea waste/bush/year (wet matter basis) (kg)	2.5
Garden tea waste/bush/ per year (dry matter basis) (kg)	1.05
Total garden tea waste (dry matter basis) (kg)	8.085×10^{9}
Calorific value/kg of garden tea waste (kWh/kg)	4.302
Total energy production from garden tea waste (kWh)	3.478×10^{10}

3.3. Energy potential of shade tree waste

As observed in Table 5, the energy potential from the shade tree waste including leaves and branches was found to be 1.387×10^{8} kWh.Consequently, the total energy that could be generated from the garden waste (tea bush and shade tree) was estimated as 3.492×10^{10} kWh. Thus, the total energy potential of tea waste (factory and garden waste) was calculated as 3.504×10^{10} kWh.

Table 5: Energy potential of shade tree waste

Parameters	Value
Tea plantation area in India (hectare)	563980
Shade tree/area (m^2)	13.7×13.7=187.69 (medium shading, square)
Shade tree/area (hectare)	54
Shade tree waste/ tree/ year (dry matter basis) (kg)	5
Total shade tree waste (dry matter basis) (kg)	3.0455×10^7
Calorific value/kg of shade tree waste (kWh/kg)	4.555
Total energy production from shade tree waste (kWh)	1.387×10^8

3.4. Energy Consumption in tea industries

Total energy consumption in tea manufacturing was found to be 4.2-8.5 kWh/kg of made tea. Therefore, total energy consumption (5 kWh/kg of tea) for manufacturing 1197 m kg of tea from 564 thousand hectare tea plantation in India during the year 2014-2015 was 5.985×10^9 kWh. Hence, thermal energy consumption per kg of tea production was around 5.67 times that of electrical energy (Baruah *et al*., 2012).

3.5. Estimation of amount of energy saving using tea waste

Energy available in waste generated in tea estate of India was 3.504×10^{10} kWh. Energy conversion efficiency of calorific value to electrical energy was assumed to be 10%. The total amount of energy in terms of electrical energy that can be obtained from wastes in tea estates was estimated to be 3.504×10^9kWh. Hence, the total energy available from tea waste compared with total energy consumption annually during manufacturing of tea (5.95×10^9 kWh, 5 kWh/kg of made tea) shows that good amount of energy required in manufacturing of tea could be saved with the positive utilization of tea waste generated from tea industry.

4. CONCLUSION

Tea manufacturing process is an energy intensive operation which consumed energy in the form of thermal energy and electrical energy. The prime sources of thermal energy are coal, firewood, natural gas, and briquetted biomass. Tea waste comprises of processing (factory) waste as well as garden waste. The calorific value of factory waste, garden tea bush waste, and shade tree waste were found to be 5.012, 4.302, and 4.555 kWh/kg, respectively. The total energy potential of tea waste (factory and garden waste) was estimated as 3.504×10^{10} kWh. Thus, with the positive utilization of tea waste, part of the energy requirement in processing of tea could be met.

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References

Baruah, B. P., Khare, P., & Rao, P. G. (2012). The energy utilization pattern in tea industries of NE India and environmental issues. *Two and a Bud*, 59(2), 9-13.

Dutta, P. P., & Baruah D. C. (2014). Gasification of tea (Camellia sinensis (L.) O. Kuntze) shrubs for black tea manufacturing process heat generation in Assam, India. *Biomass and Bioenergy*, 66, 27-38.

Gupta, R., & Dey, S. K. (2010). Development of a productivity measurement model for tea industry. *ARPN Journal of Engineering and Applied Sciences* 5, 16-25.

Pou, J. K. R. (2016). Fermentation: The key step in the processing of black tea. *Journal of Biosystems Engineering*, 41(2), 85-92.

Kumar, S., Nilling, J. J., Imchen, L., Bhutia, P. L., & Pranav, P. K. (2014). Estimation of waste and its energy potential in tea estates of Assam.*International Symposium on Aspects of Mechanicaal Engineering and Technology for Industry*, 1, 314-319.

Rao, Y. K. (2012). *Performance of downdraft gasifier using bamboo, khokan and kadam biomass feedstock*. Unpublished M. Tech. Thesis, Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli.

Saikia, M., Bhowmik, R., Baruah, D., Dutta, B. J., & Baruah, D. C. (2013). Prospect of bioenergy substitution in tea inustries of North East India. *International Journal of Modern Engineering Research (IJMER)*, 3(2), 1272-1278.

Tea Board of India (2016). http://www.teaboard.gov.in/.

Tea Research Association, Tocklai, Assam, India. (2016). http://www.tocklai.net/activities/tea-cultivation/shade-shade-trees/#.