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Energy Recovery Potential from Spent Grains in Breweries of Nepal

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Abstract
Today, Energy recovery from wastes has been an important component of a company's environmental strategy. Spent grains are the wastes generated in breweries, creating urgency and difficulties to manage since it is mandatory to use them as soon as possible after reception and to make sure that they are in good condition before utilization. The objective of the study is to estimate the Energy Recovery potential and Green House Gases (GHG) emission potential from the spent grain generated in breweries of Nepal. Samples were collected with high moisture content (71%) on wet basis, then dried under natural circumstances to reduce the excess moisture and proximate analysis was carried out. The ash, volatile matter and fixed carbon content were 4.3 - 7.2%, 45.2 - 51%, 35.4 - 40.4% by dry weight respectively after proximate analysis. The gross calorific value was 9.6 - 11.3 MJ/Kg at 8.1 - 9.3% moisture content on dry weight basis. The total energy potential from breweries of Nepal was estimated to be about 51,948 GJ/Year with 2,288.9 tones CO_2-Equivalent/Year GHG potential. The energy value of spent grain can be enhanced by reducing the moisture level and can be used as non-conventional fuel to generate heat and electric power in the brewery industries.

Keywords
Spent Grain, Combustion, Proximate Analysis, Breweries, Energy Recovery

1. Introduction

Breweries are relatively large scale plants and highly energy consuming industries. These industries generate relatively large amount of wastes; spent grain which has potential for conversion to energy [1], spent hops and yeast being the most common. Spent grains are the largest source of wastes of brewing industries, representing approximately 85% of total by-products generated[2]. It is on average 31% of the original malt weight and 20 kg per 100 liters of beer produced [3]. It is obtained from barley and is essentially the outer pericarp seed coat layer of the malted barley grain that remains after the mashing process[4].

Nowadays, there is great political and social pressure to reduce the pollution arising from industrial activities. The brewing industries are seeking options of recycling these wastes for economical processing. Recent advancement in waste to energy technologies ensure that spent grain is no longer regarded as a waste but rather a feedstock for energy production. Energy can be harnessed from the spent grain either through combustion, anaerobic digestion or gasification [5]. The energy recovery from spent grain idea is relatively new for Nepalese breweries. In the combustion technology, spent grain can be burned directly in the furnace to generate heat and electricity. The process can be used in breweries to generate steam in the boiler.

Spent grain contains net and gross calorific values of 18.64 and 20.14 MJ/Kg dry mass respectively and therefore can be considered as an interesting raw material to produce energy by combustion [6]. Finnish company Wärtsilä, today known as Heineken claims to be the first company to use power plants in the world ever to produce, with high efficiency, both electricity and heat using spent grain as fuel mixed with wood chips [7]. They claim that each plant has a thermal output of 7.4 MW and an electrical output of 3.1 MW. They say its solution represents a major step towards sustainable energy self-sufficiency for the brewing industry. Sorghum brewers spent grain fired boiler unit generates 1 megawatt of electricity [8]. The brewery company is currently generating 24 tons per day of sorghum brewers spent grain biomass waste which was used as a source of boiler fuel for this work. They also claims that spent grain can be used as an alternative to coal as boiler fuel.

The wastes generated from breweries of Nepal create urgency and difficulties to manage due to lack of free space for storage. High moisture content leads in decomposition of wastes creating environmental pollutions and increase in potential of negative health impacts. It is mandatory to use them as soon as possible after reception and to make sure that they are in good condition before utilization [9]. Breweries in Nepal sell these wastes to local farmers at low cost for animal feed as they are still rich in protein, fiber and other nutrients. Although these wastes are sold out or donated, it doesn't seem to be a waste management technique for the manufacturers.

The purpose of this work was to explore the potential of energy recovery in breweries of Nepal from these wastes i.e. spent grain through combustion technology by proximate analysis of waste generated and calculate the GHG emissions from energy recovery process.

2. Methodology

Source of Wastes The number of breweries in Nepal and their production capacities were explored using secondary data obtained through published reports, annual reports, websites, etc. Then the secondary data obtained were validated through primary data from the selected sites during field visits works. Primary data included production and raw materials used data. The amount of wastes generated was calculated using the data of total beer produced in breweries of Nepal.

Analysis of Feedstock About 400 grams, fresh generated solid wastes were collected as samples (S1, S2, and S3) from three different breweries of Nepal and moisture content was determined. For determination of moisture content, 10 grams of the sample was dried in oven at 105±1 °C until the mass of the sample was constant according to ASTM D2016-25.[10] The change in weight after 60 min was then used to determine the moisture content. Then, the samples were dried in natural circumstances for 4 days to reduce excess moisture. The samples were analyzed in a private laboratory to determine their physiochemical properties, which included Moisture Content (MC), Ash Content (AC), Volatile Matter (VM), Fixed Carbon Content (FC) and Gross Calorific Value (GCV). The moisture content of freshly generated spent grain and physiochemical characteristics are indicated in Table 1 and Table 2 respectively.

Energy Potential Estimation The amount of dry spent grain that can be generated is estimated by subtracting the excess moisture content present in the freshly generated spent grain with high moisture content. The product of Gross calorific values obtained from analysis of feedstock and amount of dry spent grain generated in breweries was used to estimate the potential of energy recovery. The study limits the use of net calorific value of spent grain due to variation of samples. The net calorific value should be considered to estimate the exact potential of energy recovery. Also, ArcGIS 10.5 trial version application was used to show the energy recovery potential of different breweries of Nepal with their geographical locations.

GHG Emission Estimation The study includes calculation of CO_2, CH_4 and N_2O emissions from combustion of spent grain. The GHG potential was calculated in terms of Kg CO_2-Equivalent/Ton. Emission Factors of CO_2, CH_4 and N_2O were used to estimate the CO_2-Equivalent. The emission was calculated using Analysis of Fuel Input method in terms of (Kg CO_2/Ton) [11]. Emission factor of CO_2 was calculated using the formula as:

CO_2 Emitted (Kg CO_2/Ton)

$$= \frac{44 * Carbon\ Content\ of\ the\ Fuel * Mass\ of\ Fuel}{12}$$

Emission Factor of CH_4 and N_2O were taken from the reference [11]. Finally, emissions were calculated in terms of CO_2-Equivalent.

GHG emission Estimate(Kg CO_2-Equivalent) = CO_2 Emitted + (CH_4 Emitted*GWP of CH_4) + (N_2O Emitted*GWP of N_2O)

where, GWP= Global Warming Potential

GWP of CH_4= 25 and GWP of N_2O= 298 [11]

3. Results and Discussion

The wet spent grain generated in breweries of Nepal is indicated in Figure 1. Energy recovery potential from combustion of spent grain in breweries of Nepal per day was estimated as shown in Figure 3. Gorkha Brewery dominates other breweries by consuming the beer market with 61% share and has the highest spent grain generation and energy recovery potential about 31,432 GJ/Year. The GIS Map of energy recovery potential from spent grain in breweries of Nepal is shown in Figure 4. The GHG Emission factor was calculated to be about 478.03 Kg CO_2-equivalent/Ton of spent grain burnt completely. (Rice husk = 453 Kg CO_2-equivalent/Ton)[12]. Table 3 indicated the composition of Green House gases from combustion of spent grain. More than 99.9% emission releases CO_2 and the rest are CH_4 and N_2O gases. Figure 4 presents the potential of emission of GHG from different breweries of Nepal. Gorkha Brewery has a potential of 1,394 Tons CO_2-equivalent/Year GHG emission from the combustion process of energy recovery.

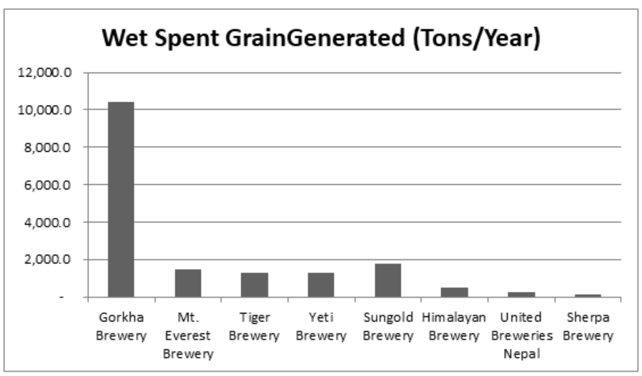

Figure 1: Wet Spent Grain Generated/Year

Table 1: Moisture content of Wet Samples

Samples	A (gm)	B (gm)	MC (%, w/w)
S1	10	2.81	74
S2	10	3.09	71
S3	10	3.48	67

where, A= Wt. Before Oven Drying

B= Wt. After Oven Drying and

MC = Moisture Content i.e.(A-B)/A

Table 2: Physio-chemical Characteristics of Dried Spent Grain

Sample	MC (%)	AC (%)	VM (%)	FC (%)	GCV (MJ/Kg)
S1	9.3	4.3	51	35.4	10.4
S2	8.7	7.2	47.8	36.3	11.3
S3	8.1	6.3	45.2	40.4	9.6

Note: MC- Moisture Content, AC- Ash Content, VM-Volatile Materials, FC- Fixed Carbon, GCV- Gross Calorific Value, analysed at Aastha Scientific Lab., Dillibazaar, 2074

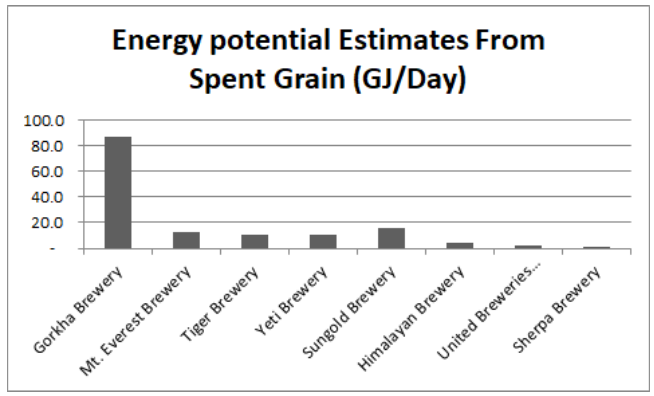

Figure 3: Energy potential in breweries of Nepal (GJ/Day)

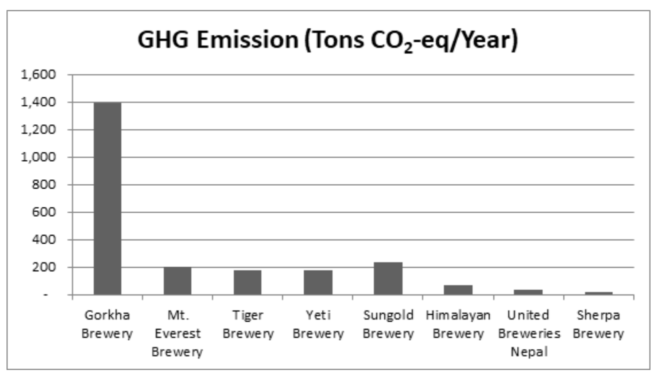

Figure 4: GHG Emission potential in breweries of Nepal

Table 3: Composition of gases from spent grain combustion

Kg CO_2/Ton	Kg CH_4/Ton	Kg N_2O/Ton
461	0.264	0.035

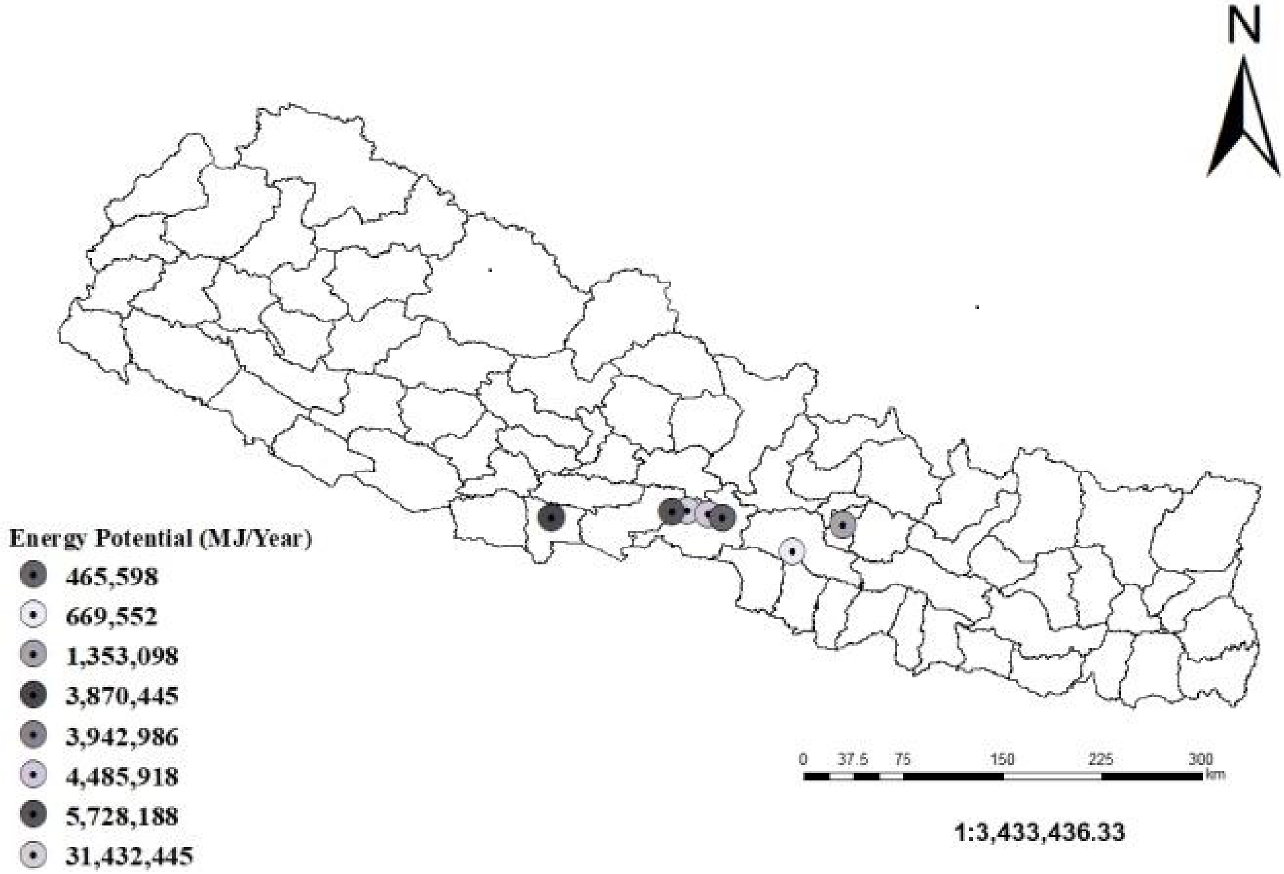

Figure 2: GIS Map of Energy Potential in Breweries of Nepal

4. Conclusion

The study explores that about 17,110.33 tons of wet spent grain is generated from breweries of Nepal. The wet spent grain contained 71% moisture on average from breweries of Nepal. The amount of dry spent grain that can be used as fuel for boiler was estimated to be 13,783.3 Tons/Year. The Gross Calorific Value of the spent grain was found to be (9.6-11.3) MJ/Kg. The total energy potential from breweries of Nepal was estimated to be about 51,948 GJ/Year. Gorkha brewery has the potential to harvest about 31,432 GJ/Year of energy from combustion of spent grain. The GHG emission was found to be about 2,288.9 tones CO_2-equivalent/Year from spent grain combustion generated in breweries of Nepal. Gorkha Brewery has the maximum GHG emission potential of about 1,394 tons CO_2-equivalent/Year, which is directly correlated to the amount of waste generated.

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