Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 63–69

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Biogas Tri-generation for Postharvest Processing of Agricultural Products in a Rural Community: Techno-economic Perspectives

Rasaq.O.Lamidi[a]* ;Yaodong Wang[a]; Pankaj. B. Pathare[a]; A.P. Roskilly[a] and Marcelo Calispa Aguilar[a]

[a]Swan Centre for Energy Research, School of Engineering, Newcastle University,United Kingdom.

Abstract

One third of the global food production ends up in the bins such that food waste now ranks third when placed amongst the world's CO_2 emitters. Bulk of food waste occurs at the early stage of food value chain in the developing countries where many people ironically suffer from food insecurity. To reduce this trend, a biogas driven tri-generation system which synchronizes power generation with food drying and cold room storage is designed and analyzed in context of the current renewable energy policy of the Nigerian government. Using Aspen Plus simulator, market wastes from a rural community is analyzed for biogas generation. The biogas is subsequently used to fuel a 72kWe internal combustion engine which drives a generator to generate electricity. The recovered heat from the engine's exhaust is used for drying and cooling of agricultural products while heat from the cooling jacket is used to maintain the anaerobic digestion process. The results from this study show that the system's efficiency increases from 25.66% to 76.02% for electricity only and tri-generation respectively. The results also indicate that the system is able to provide electricity, drying energy requirements and postharvest cold storage for 322, 56, and 922 farming households respectively. This amounts to drying of 20.35MT, 2.313MT and 3.75MT of cassava tubers, maize and tomato respectively per household per year while 3.75MT of tomato is also cold stored. The results equally demonstrate that with the current electricity tariffs for remote areas being charged at USD 13.1/MWh and Feed-in Tariffs (FITs) of USD 122.48/MWh, the Net Present Value is positive regardless of FITs availability and the current banks' lending rates. However, the payback period is sensitive to FITs and lending rates and varies between 2.1years to 7.19 years depending on the lending rates.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: *Tri-generation; postharvest loss; biogas; feed-In-Tariff.*

* Corresponding author. Tel.: *+44 (0) 191 208 6000*
E-mail address: R.O.Lamidi1@ncl.ac.uk

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.011

1.0 Introduction

The world's population is expected to increase significantly due to rising industrialization, income and food consumption patterns. To ensure food security for the projected 9 billion world populace, food production is expected to increase at least by 70% in 2050. One of the ways of increasing food production capacities, without placing further strain on already limited land, water and energy resources, is to reduce system inefficiencies across all the levels of the food value chain. Each year, it is estimated that approximately 1.3 billion tonnes of food are discarded or lost, a third of the food produced globally [1]. In industrialised nations, food loss and waste amounts to 670 million tonnes (MT) annually. This is typical at the retail and consumer levels with economic losses of about US$ 680 billion. In developing economies, more than 600 MT of food are lost at the post-harvest stage costing about US$ 310 billion annually (FAO [2]). In Sub-Sahara Africa alone, about US$4 billion worth of grain is lost between the time the crop is harvested and consumed. This value of loss is estimated to be equal to the total amount of food imported into the region and exceeds the foreign aid received for a decade [2]. Thus, the reduction of global food loss and waste across all levels of the food chain has become a global priority, particularly for food-producing communities in developing and least developed countries. The averted loss of food could reduce economic losses, costs of food production, waste generation and land degradation. Food insecurity in the developing and least developing countries has been attributed to some of the following reasons: extreme weather conditions, enormous post-harvest loses, high prevalence of diseases, lack of value added products from processing of foods, poor infrastructure, poor farming practises and productivity and poor governance. However, the use of renewable energy technologies for food processing in rural areas has been shown to not only capable of lifting rural people out of poverty but significantly increases food security [3]. Therefore, using a Nigerian village as case study, this study presents a techno-economic evaluation of a biogas powered tri-generation plant for power and postharvest processing of agricultural products. The aim of the paper is to assess viability of a combined power, drying and cold room storage of agricultural products in context of the prevailing renewable energy policies of the Nigerian government.

2.0 Materials and methods

The methods used in this work involve field work, data collection and analysis of a local cattle market waste details of which is described by the earlier work by the authors [4]. Data from the Nigerian Bureau of Statistics; Federal Ministry of Agriculture and Rural Development; Food and Agricultural Organisation and relevant empirical studies were used to synthesis daily energy demand of Nigerian farming households presented in the Table 1. From the table, it can be seen that an average rural farming households requires 225W, 794W and 7.5W of energy per day for electricity, drying and cold storage of agricultural products respectively. However, energy requirement for cooking is not captured as the focus is more on the energy requirements for processing than domestic use. Given necessary thermodynamics data especially operating conditions and the equipment models, Aspen Plus process simulator is selected as a tool for simulation of the whole system as follows: a) analysis of potential biogas production through anaerobic digestion; b) simulation and evaluation of power and heat recovery from an internal combustion engine; c) modelling of a convective dryer and d) simulation of an ammonia-water absorption chiller. Finally, based on the outcome from the above simulation, an economic analysis of the system is also presented.

Table 1: Daily energy demand per rural household.

Energy Types	Peak	Base	Average
Electricity (W)	330	100	225
Drying (W)	-	-	794
Cooling (W)	-	-	7.5

2.1 The system design of the biogas tri-generation system.

The design of the combined power, cold and drying system is shown in the Figure 1. Waste from the cattle market is anaerobically digested under thermophilic conditions. The produced biogas is pumped through a $Ca(OH)_2$ column for removal of part of CO_2. Thorough purification of the biogas is not intended as the chose ICE mover is designed to work on low grade fuels of about 67% CH_4 [5]. The cleaned biogas is then used to drive a 72KWe CAT engine. Heat is recovered from both the exhaust and water jacket of the engine which is subsequently used for the thermally driven