INCREASED PRODUCTION OF CHARCOAL BRIQUETTES THROUGH SOLAR DRYING

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ABSTRACT

The charcoal production by Green Heat Uganda Ltd. depended on weather conditions because of a sun drying process. Frequent downpours during rainy seasons cut the production to half of its capacity. Since moisture content is a quality characteristic of charcoal, it has to be reduced from 50 % to below 10 % before sale. Thus the dependency on weather conditions meant a financial risk to the company.

Considered as one of the cheapest drying options, CREEC recommended the use of a solar dryer. Only very few commercial solar dryers are used in Uganda. Furthermore, there is virtually no local market comprising of solar dryer businesses.

To support the commercial use of solar dryers in Uganda CREEC is implementing a demonstration project at Green Heat Uganda Ltd.. Objectives are to make a simplified designing scheme available and enabling local fabricating. To identify crucial parameters, measurements will be carried out and used for revising the draft.

The analyzing of the implementation and operational cost of the solar dryer realized by Green Heat Uganda Ltd. will evaluate cost efficiency compared to other technologies such as electric dryers. The solar dryer allows an increased turnover with simultaneous improvement of product quality and reliability of the production process.

1 INTRODUCTION

The Centre for Research in Energy and Energy Conservation (CREEC) is a not-for-profit organization for research, training and consultancy in renewable energies. It is located at the College of Engineering, Design, Art and Technology within Makerere University. [1] The centre was founded in 2001 by a lecturer as a project and was legally registered in 2010 as a company limited by guarantee without share capital.

Green Heat Uganda Ltd. is a Ugandan start-up enterprise installing biogas digesters for three years now. [2] Beginning this year Green Heat Uganda Ltd. also started the production of charcoal briquettes seen in Figure 1.They are made of charcoal dust and carbonized agricultural waste. Therefore these briquettes are an environmentally friendly low cost alternative to traditional fuels such as firewood and regular charcoal.

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Figure 1: Charcoal briquettes

2 CHARCOAL PRODUCTION

The first step producing briquettes is to mix charcoal dust with carbonized banana peelings and crush them into a fine powder. Following molasses and water are mixed under the power after the powder to bind it. After mixing the mixture can be pressed to briquettes using an electric charcoal press. The last step before packing the briquettes into sacks they are sun dried under the open sky. Therefore they are spread on a tarpaulin for drying lasting from 4 days under sunny weather conditions up to 7 days in rainy seasons.

Beside the lower radiation, movements to protect the briquettes from the rain increase the drying time. These movements also cause an increased number of broken briquettes which have to be recycled again. It makes the drying process also labour intensive because the whole production has to be moved by hand every morning, every evening and before and after every rain pour. The long drying time also makes the briquette handling challenging with the risk of mixing up the wet briquettes produced on different days.

The produced wet charcoal briquettes have a moisture content of 50 % immediately after pressing.

Moisture content of charcoal briquettes is a quality feature and influences directly the customer's decision to buy. If the moisture content is above 10 % the charcoal briquettes burn slower and lighting up takes longer, which implies poor quality to the customers.

In the first months, the charcoal briquette production reached its maximum with 180 kg charcoal briquettes a day, limited to 85 kg a day in rainy season. In the long run, 1 tonne a day is aimed with an equipment capacity up to 3 tonnes a day. The production output is determined by limited space for sun drying, whereby a required space of 1 acre is estimated for the aimed production of 1 tonne a day.

The limitation of the production output to less than half due to dependency on weather results in an even higher financial loss because fixed costs still have to be covered.

3 SOLAR DRYING TECHNOLOGY

3.1 Background

Solar drying uses the sun as source of the energy. Solar dryers are often made of a simple structure increasing the percentage of radiation used, compared to sun drying. This is done by focusing the sun energy collected to the drying object by using the green-house-effect, airflow or reflectors. Compared to sun drying, solar dryers can generate higher air temperatures, reducing drying time and space needed.

Solar dryers usually consist of collectors, collecting the sun's energy and directing it to the goods that are being dried in the drying chamber. Depending on the application there are various systems that can be used. These include starting from a simple green-house to systems working with an airflow heated up in the collector up to schemes using solar water heaters combined with a heat exchanger.

The biggest advantage of solar dryers compared to other drying technologies such as electric or kerosene dryers is the energy free of charge, resulting in lower operational costs.

The most common solar drying application in Uganda is food drying. Fruits are mainly preserved by solar drying to prevent spoilage and to target new markets. Compared to sun drying, solar drying has the advantages of less chance of goods getting spoiled since they are no longer dried in the open and a reduced drying period resulting in higher product quality.

Other goods dried solar dried can be grain, seeds or coffee.

3.2 Industrial Solar Drying

Solar drying is a simple technology that has been in existence for a long time. Also for decades, there have been projects to promote and implement solar drying technology. However the commercial use of solar dryers is very rare in Uganda. CREEC knows only three companies using a solar dryer for drying fruits, one drying herbs and two working on solar drying of briquettes. [3] Moreover, there are no Ugandan companies specialised in design and implementation of solar dryers known to CREEC.

That solar drying is a simple and cheap technology but still used very rarely raises questions. What are the points of failure and the challenges in the use of solar dryers in Uganda?

To address these questions CREEC chose the way of implementing a solar dryer by practical purposes using measurements on the constructed system to verify theoretical calculations, identify crucial features and detect reengineer criteria to improve the system, combined with research to get further non-technical findings.

During its research about solar dryers in Uganda CREEC interviewed a company exporting dried fruits. This company was using solar dryers of different designs for 4 years before changing to an electric dryer. With the electric dryer the drying time was reduced from 24 hours to 7 hours. Beside increased production volumes, the reduced drying time increased the shelf life of the products from 7 months to 18 months. For the benefits of increased productivity through weather independency and enhanced product quality make it worth for the company to spend 50% of the total production cost for electricity.

Briquette drying in comparison to food drying has the advantage that there is no tight temperature range and the drying rate is not influencing the quality.

4 THE CHARCOAL SOLAR DRYER

4.1 Design and Implementation

The design requirements of the charcoal solar dryer were to dry 400 kg of charcoal briquettes per day using locally cheap available materials for construction. A system consisting of a collector and drying chamber made of timber covered with transparent foil to use the green-house effect was chosen. Inside the collector a black foil works as an absorber heating up the surrounding air flowing into the drying chamber by natural draft. In the drying chamber, the hot air flows through staked drying trays filled with briquettes before it is released through defined air outlets. The system of stacked drying trays enables practical handling and a cheap construction. This solar dryer is shown below.

Figure 2: Solar dryer of Green Heat Uganda Ltd.

The thermodynamic model used for dimensioning considers the amount of water contained in the briquettes to be evaporated and how much water can be absorbed by the penetrating airflow. The energy required for heating up the initial air and charcoal load can be ignored because it is less by factor 10 than the energy for heating up the airflow and evaporating. The results give the size of the collector to absorb enough energy and the dimensions of the air outlets for a controlled airflow.

According to this designing procedure a collector surface of 58 m^2 is needed. This calculation considers an ambient temperature of 25 °C, average air humidity of 50 % and an associated standard irradiation of 1000 W/m^2 for 5 hours a day. The rated power would be 35 kW.

Because of the huge dimensions, limited space the dryer was designed for 200 kg of charcoal per day with the option to enlarge the collector. Thus the collector and drying chamber were realized with a surface of 35 m^2 and will be enlarged after determining the real efficiency and operation parameters through measurements during operation. Furthermore the real efficiency depending on construction details could not be calculated reliable and was probably underestimated which makes it advisable to construct the dryer in two steps.

During the construction several challenges were overcome. The large dimensions make the dryer vulnerable for wind. That requires a strong foil, which is expensive. Also a proper fixing of the foil is needed which required strengthening of the wooden structure with a significant higher timber demand than expected. The big dimensions and the swampy ground made side preparation costly.

Because the location of the solar dryer can be affected by floods, the foundations are 50 cm from ground level. Due to this distance, wind could push the whole structure from underneath. To avoid such a scenario a small brig-wall is built around the dryer.

4.2 Financial Aspects and Benefits

The initial investment costs of constructing the solar dryer are 880 USD. This includes costs for building material and labour. A breakdown of the cost of the solar dryer is shown in Table 1.

Table 1: Breakdown solar dryer costs

No.	**Item**	**Cost (USD)**
1	*Building Material*	
	Timber	200
	Concrete and bricks	160
	Foil, mesh and nails	280
2	*Labour*	
	30 men days	240
	Total	**880**

The annual maintenance and repair costs of the dryer are estimated at 10% of the investment cost per year which is 88 USD. Annual operational costs for the dryer are estimated at 2,000 USD which only constitute operators' salary. Initial investment, maintenance, repair and operational costs calculated over a solar dryer lifetime of 3 years gives annual costs of 2,381 USD. Drying of briquettes will only take place when there is sunlight, whereby Uganda has on average 5 hours of sunshine per day referred to full sunshine of 1000W/m^2. An assumed efficiency of 40 %, which was reached for similar systems, gives the solar dryer a rated power of 14 kW, which brings the price per kWh to 0.14 USD/kWh. [4, p. 30]

Instead of a solar dryer, an electric dryer could be used for drying charcoal briquettes. From the interviewed company using an electric dryer CREEC got the following figures. The investment costs of the 17 kW rated dryer is about 60,000 USD. Annual maintenance and repair costs are estimated at 10% of the dryer cost which is 6,000 USD. There are also estimated annual operational costs which constitute of electricity bills of 13,000 USD and operators' salaries for double shift of 4,000 USD. Maintenance, repair and operational costs calculated over the electric dryer's lifetime of 10 years come to total annual costs of 29,000 USD. An average load of 75 % of the dryers rated power assumed brings a price per kWh of

0.56 USD/kWh.

Drying one kilogram of charcoal briquettes needs around 2,700 kJ. That brings costs of 0.11 USD per kilogram of charcoal briquettes using a solar dryer compared to 0.42 USD using an electric dryer. This underlines the question why solar dryers are used so rarely yet they have very low running costs.

It seems that for the interviewed company non-weather dependency and shorter drying times can justify significantly higher costs.

4.3 Conclusion

Investigations show that charcoal briquette drying is a suitable application for solar dryers. Drying temperatures and time do not really influence the quality of the charcoal briquettes. This poses a minor disadvantage as temperatures are hard to control within a solar dryer.

The financial estimations show low drying costs for solar dryers. The cost per kWh for solar dryers is about one quarter of the cost for an electric dryer.

The technical parameters of the solar dryer will be assessed by measurements to identify crucial features and parameters to find ways of improving it.

The investigations about solar drying in Uganda turned out that this technology is hardly used, little known and hardly promoted. Poor awareness among the population, lack of support by government and other organisations as well as a non-existing commercial solar dryer market seem to be big hurdles.

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