Saving of Firewood and Improvement of Smallholder's Income through Combined use of Solar and Biomass Energy in Crop Drying

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Abstract

Sun drying is still the most common drying method for cocoa beans used by smallholders in Indonesia causing the low quality of the Indonesian cocoa. On large plantations mechanical dryers are used requiring 3.0 kg of firewood per kg of cocoa beans. To overcome this energy and quality problems, a Solar Processing Centre was developed. The thermal energy for drying is provided by a roof integrated solar air heater and a newly developed high efficient biomass furnace. This reduces the firewood consumption from 3.0 to 0.3 kg/kg dry beans. A simple temperature control allows automated temperature control of the drying air.

Keywords: solar energy, biomass, energy, drying, cocoa

Introduction

The production of estate crops such as cocoa, coffee, tea and spices are of great importance for the Indonesian economy. With a yearly production of 365 000 t/a, corresponding to 12 % of the world production, cocoa is the third most important Indonesian estate crop in terms of export revenues after rubber and coffee (Anonym, 1998). Almost 85% of cocoa is cultivated by smallholders owning between 1 - 2 ha of land. Due to the lack capital and appropriate postharvest technologies for smallholders, the quality of the cocoa beans is relatively poor and characterised by partially fermented beans, high shell content, off flavour, acid taste and mouldy beans. This low quality is not matching the requirements of the international markets. Therefore Indonesian cocoa is discounted up to US$ 200 per ton.

Smallholders and even some plantations still use traditional sun drying, which causes high losses and insufficient quality. During peak harvest which coincide with rainy season the cocoa bean cannot be dried to the moisture content of 7% which is required for a safe storage (Pass, 1996). Extended drying periods and storage of partially dried beans causes growth of microorganism greatly influencing the flavor of the beans (Thome, 1991).

On plantations high temperature batch or continuous flow dryers are used to dry cocoa beans at 60°C. Since kerosene is too expensive thermal energy required for heating the drying air is provided by a biomass furnace. Due to the low efficiency of 15 – 20 % of the wood fired air heaters, about 3 kg of firewood is required for the production of 1 kg of dry cocoa beans (Sri Mulato, et al., 1995). This leads to high consumption of firewood and increases the production cost. Another problem is the risk of overheating the beans because the drying air temperature cannot be controlled. Due to the small fuel load of the wood furnace the operation time is short and an operator is needed to charge the furnace in short intervals.

To solve these quality and energy problems a Solar Processing Centre (SPC) for cocoa and coffee was developed and tested by the Institute for Agricultural Engineering in the Tropics and Subtropics in co-operation with the Indonesian Coffee and Cocoa Research Institute, Jember. Since firewood is becoming more and more scarce and expensive and fuel oil is not an economic alternative due to its high price, an optimised biomass furnace in combination with solar energy was found to be a promising solution.

Solar Processing Centre

The Solar Processing Centre (SPC), **Figure 1**, consists of a low cost substructure in which fermentation, drying, grading and storage can be simultaneously conducted under the same roof. The yearly capacity amounts to about 180 tons of dried cocoa beans which is enough to serve 100 to 200 smallholders. Thermal energy required for drying is provided by a roof integrated solar air heater and a biomass furnace which is used as back up heating system during night and adverse weather conditions. The flat bed dryer with a capacity of about 5 tons is equipped with 7 axial flow fans providing the required airflow of about 5100 m3/hour. At a drying air temperature of 60 °C a 30 cm thick layer could be dried within 40 hours.
The function of the SPC is illustrated in **Figure 1**. Ambient air is drawn from the eaves through the solar collector to the ridge of the roof. The heated air is sucked from the horizontal main air duct through the biomass furnace downwards to the dryers. A more detailed description is given elsewhere by Sri Mulato et al.(1997) and Ritterbusch et al. (1997). However, difficulties appeared concerning accurate temperature

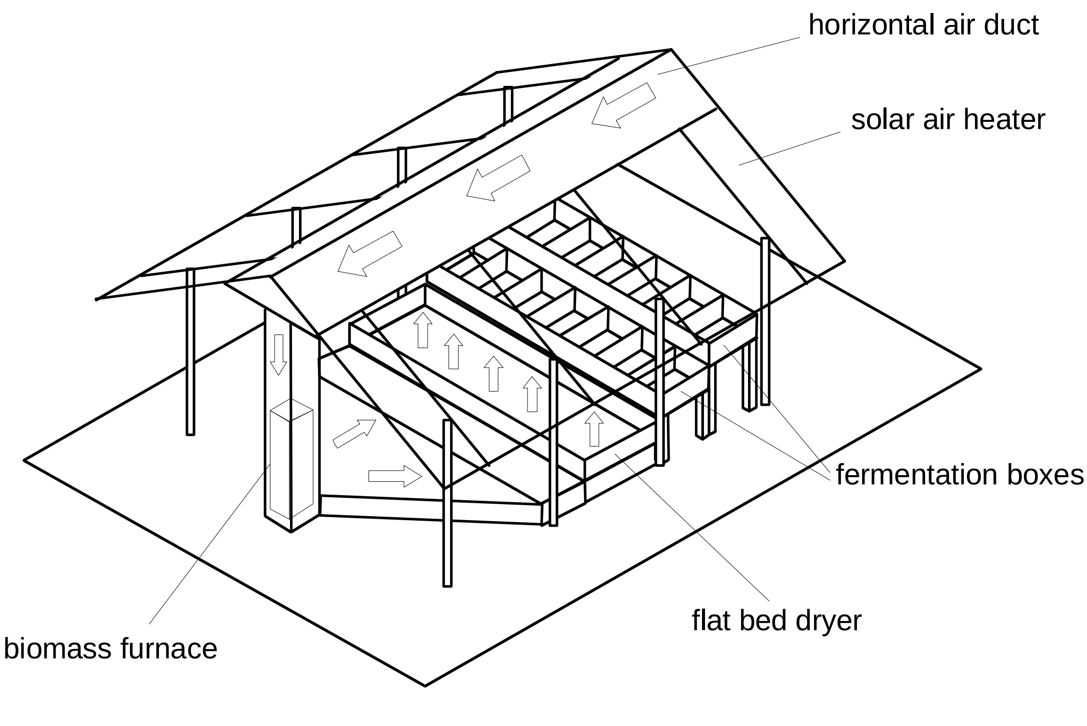

Figure 1: Overview of the Solar Processing Centre (SPC)

adjustment, continuos operation, live time and efficiency of the furnace. The desired drying temperature had to be adjusted continuously by an operator. Also the short burning time per load of wood did make a continuos surveillance and a reloading of the furnace in intervals of a few hours necessary. This increases the cost and leads to unsteady drying conditions resulting in a fluctuating product quality. Problems concerning the life-span of the furnace, such as corrosion appeared around the combustion chamber because of the high temperatures of 800 to 1000°C.

Objectives

To solve the mentioned problems, to decrease the operating and investment cost further and to extend the application of the SPC for other products, several objectives concerning the biomass furnace can be formulated:

- Increase of efficiency higher than 70%
- Heat protection of the steel to prevent corrosion
- Simple temperature control system, accuracy +/- 3K
- Firewood supply for 10 hours operation

Methodology

The research work concerning the biomass furnace focused on improving the combustion chamber design, the air supply and the heat exchanger using locally available material. A control unit that allows to adjust the thermal power of the biomass furnace according to the varying need was developed and tested.
All investigations and design developments were carried out at the test stands of the Institute for Agricultural Engineering in the Tropics and Subtropics in Stuttgart Hohenheim. The improved version of the biomass furnace was then installed in an existing SPC at the Indonesian

Coffee and Cocoa Research Institute in Jember. Field tests were carried out to determine the possible drying air temperature range and the set point accuracy. Wood from Leucaena leucocephala has been used as fuel for this experiments. Leucaena leucocephala is commonly used as shadow tree in cocoa plantations. Its heating value is 18.400 kJ/kg (absolute dry wood) and corresponds to the average value of most wood species (Anonym 1980).

Results

Biomass furnace and combustion control

In contrast to the biomass furnaces commonly used in Indonesia a down draft furnace was developed which allows an almost complete combustion of the volatile components of the firewood, **Figure 2**. This leads to a high efficiency with low emission. The upper part of the furnace serves as wood stock to achieve the desired long burning period of 6 to 10 hours at typical operation. The position of the primary air duct in the lower part limits the combustion zone to the so called pyrolysis zone. The exhaust gas fan forces the flame downwards into the combustion chamber where secondary air supply allows to reach a complete combustion. In order to prevent high temperatures causing corrosion problems of the steel, fire resistant concrete insulates the combustion zone. Afterwards the hot combustion gases flow through the air to air heat exchanger into the chimney. With the variation of primary combustion air supply, the pyrolysis reactions can be controlled and by this the thermal power of the furnace. To reach an optimum heat transfer to the drying air, the furnace is directly integrated into the drying air channel. This reduces the steel temperatures, prevents corrosion and increases the life-span as well as the total efficiency.
The control unit measures the temperature of the drying air, exhaust gas temperature and the excess air of the combustion process with a lambda-probe. Depending on these values the air supply and the speed of the exhaust gas fan are adjusted.

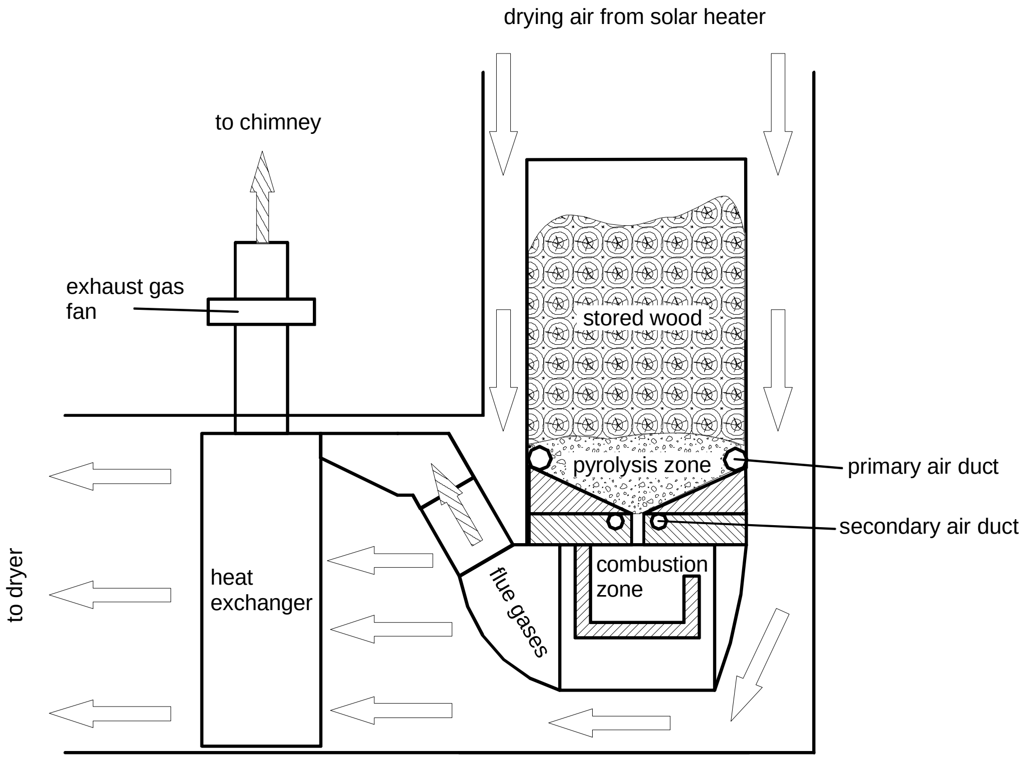

Figure 2: Design of the new biomass furnace

By this the thermal power of the furnace can be varied in a range of 30 to 70 kW without a considerable reduction of efficiency and an increase of noxious emission.

Results show a possible temperature range for the drying air between 40°C and 90 °C, which allows the drying of various other commodities like coffee, copra, corn or paddy. The set point accuracy was investigated in two steps. First during night in stand alone operation of the furnace where the heat demand for the drying process is constant. In **Figure 3** a fluctuation in drying air temperature of less than +/- 2 K can be observed at a set point of 60°C.

In a second step the set point accuracy during a typical day with fluctuating insolation was determined. **Figure 4** shows that the temperature of the drying air is in a range of +/-3 K even during a variation of the insolation from 500 to 900 W/m². This accuracy is at least equal to that attainable with highly sophisticated oil burners.

The operating period of the biomass furnace per load depends on the drying air temperature and weather conditions. During the tests the furnace operated between 8 to 10 hours per load. This leads to continuous operation during the whole night without recharging.

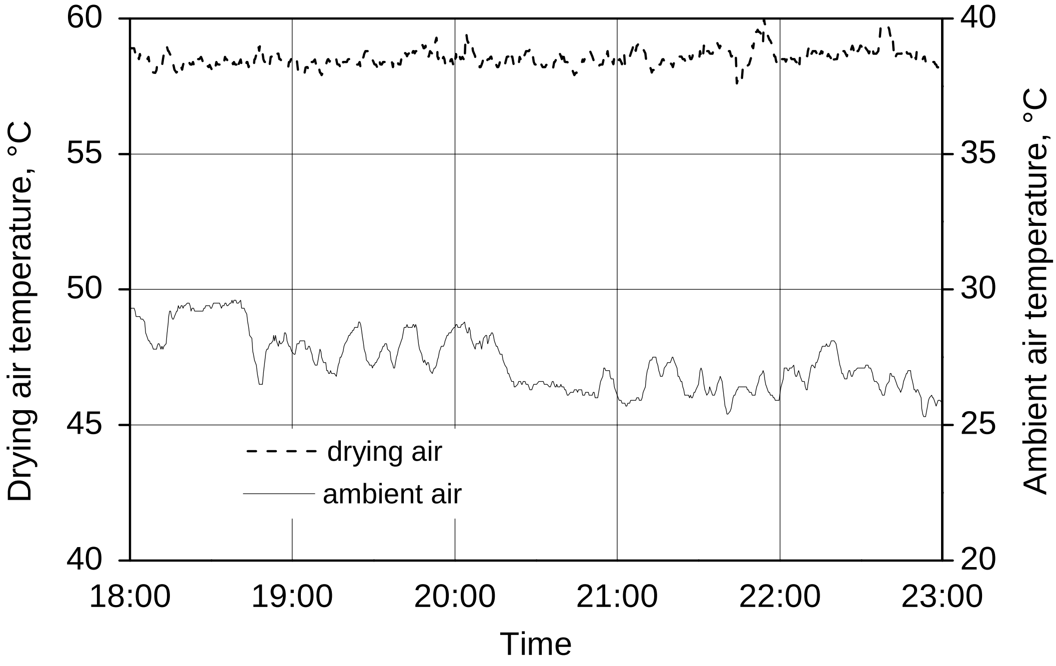

Figure 3: Drying air and ambient temperature during stand alone operation of the furnace at 60°C setpoint

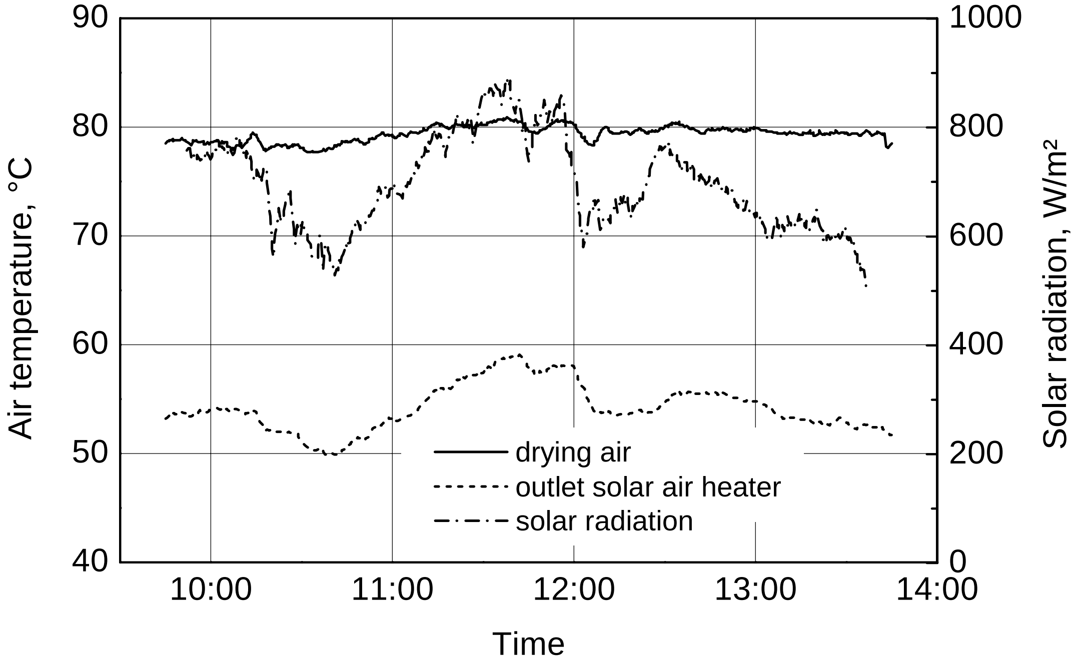

Figure 4: Drying air temperature, preheated air temperature and solar radiation during fluctuating insolation at 80°C target temperature.

Emission of carbonmonoxide showed typical values of 300 ppm at an CO_2 content of 12.6 % during full load operation. This matches even the relatively strict requirements of German emission control standards.

Fuel Consumption

The controlled operation of the furnace in combination with the solar air heater leads to an optimum utilisation of both, biomass and solar energy. The fuel wood consumption is therefore substantially lowered compared to traditional wood fired dryers. To show this effect, the wood consumption for cocoa bean drying was investigated. At the conditions mentioned above, the fuel consumption in the SPC to dry cocoa beans with an initial moisture content of 60 % was 0.3 kg per kg of dry product on average. Compared to commonly used dryers consuming up to 3 kg of wood per kg dry product the fuel consumption of the SPC was reduced to 10 %.

Conclusion

A biomass furnace as a back up heating system for a Solar Processing Centre for cocoa developed by the Institute for Agricultural Engineering in the Tropics and Subtropics of the University of Hohenheim in cooperation with the Indonesian Coffee and Cocoa Research Institute in Jember was improved to reduce the firewood consumption, the operating cost and the life-span of the furnace. With a newly developed automatic control unit the drying air temperature can be adjusted between 40 and 90 °C with an accuracy of +/- 3 °C. This allows a continuous operation during night and even during day with highly fluctuating insolation. A burning period of up to 10 hours allows continuous operation during night without refilling the furnace. Tests on an Indonesian cocoa plantation have shown, that the novel biomass furnace fulfils all requirements of the users in terms of firewood consumption, temperature control, simple

operation and maintenance and life-span of the furnace. They showed also that firewood consumption for cocoa drying can be reduced to 10 % through the combination of solar with biomass energy.
The production of coffee and other agricultural products like, corn, paddy or copra is fraught with similar postharvest problems like those of cocoa. Insufficient drying leads to a high risk of mould increasing post harvest losses. To dry these products in the SPC, can therefore solve not only most post harvest and quality problems but also increase the economic efficiency of the SPC during off season of cocoa harvesting. Especially copra production is interesting due to the mixed cultivation of cocoa and coconut palm by smallholders in large areas of Sulawesi.

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