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DESIGN AND DEVELOPMENT OF A PORTABLE COPRA DRYER

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ABSTRACT
Coconut plantation is abundant in Papua New Guinea. Smallholders can improve their incomes through value added activities in downstream processing of coconut. One such activity would be to dry copra for preservation and subsequent oil extraction. Traditionally, smallholders employ either open fire or the sun drying process. In both the processes, copra quality can deteriorate significantly due to either open fire smoke or mold-growth in sun drying. The sun drying cycle time is about seven days depending on the availability of the sun. It is too long and the main cause for mold growth. The paper presents the design of a portable dryer that overcomes these problems. In designing the dryer, a review is made of the existing dryers used in large copra plantation. The design takes into account of the type of fuel to be used, temperature control and reduction of drying cycle time. It also considers such factors as operation, maintenance and cost of the dryer.

Keywords: Copra dryer, Temperature control, Cycle time

1. INTRODUCTION
Dried copra is one of the major agricultural exports of Papua New Guinea. Copra should be dried to specified moisture content for the purpose of both preservation and maintaining copra quality for oil extraction. Wet copra contains about 50% moisture by weight, and this level should be reduced to between 6 to 8%. Proper drying of copra is thus an important downstream process requirement prior to exporting.

The problem of copra drying is serious with smallholders in rural areas of Papua New Guinea; they resort to drying by either the sun or open fire. Both these methods of drying have adverse effects on the copra quality. With sun-drying, the drying cycle for a batch of copra is 5 to 7 days depending on the availability of the sun. The drying cycle is long, and copra can develop molds that reduce oil contents and give bad odor. Coconut husk and shell are used as fuels as these are abundantly available. However, smoke from burning husk and shell can affect copra quality in open fire drying process.

Using a clean hot air drying process under controlled condition, the copra drying factors have been identified in an earlier study [1]. The drying cycle was found to depend on temperature of the hot air and the size of copra. The velocity of hot air passing over the copra bed had minimal effect. The maximum temperature level, size of copra and air velocity all have their limitations. For example, a temperature over 90 ^{0}C is not suitable for it tends to 'boil' the copra, and very small copra size will result in the excessive loss of oil. High velocity hot air quickly develops a dry surface on copra particles inhibiting moisture loss. Also, for efficient drying, temperature level needs adjustment as the moisture content decreases. It was found that heat should be applied at three temperature levels: High (70 -85 ^{0}C), Medium (55 – 70 ^{0}C) and Low (40 – 55 ^{0}C). With these three levels of temperature, it was found that a drying cycle of 10-15 hours could be achieved without compromising the copra quality. These findings were useful in designing and developing the new dryer.

The paper starts with reviewing two conventional dryers used in large scale drying. It then goes on to propose the design of the portable dryer. Some initial experimental results on temperature distribution within the drying chamber for various operating conditions are presented. It also comments on the operational, maintenance and cost aspects of the proposed dryer.

2. EXISTING DRYERS AND DRYING METHODS
A number of dryers are in use for large plantations [6]. These include (a) Ceylon type, (b) Samoan type and (c) Forced Draft type. They vary in size, construction and the mode of operation. Forced draft type is relatively more complex in operation and expensive, and is not as common as the other two. The proposed dryer has some similarities with the other two dryer types, so they will be considered in the paper.

The Ceylon type is more common with large plantations. Figure 1 shows a schematic cross-sectional diagram of the Ceylon dryer. It is a shed or small house measuring up to 8m long x 4m wide x 3m high with walls of concrete-block constructions. It has a slant sliding roof that protects copra from rain and also takes advantage of solar drying when convenient.

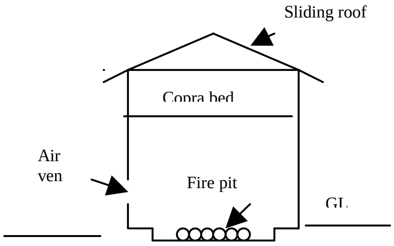

Figure 1: Schematic diagram of Ceylon dryer

First the coconut is husked and the shell with wet kernel is split into two halves. Half shells with wet kernel are then placed on a wire mesh copra bed about 2.7 m above the open fire pit located on the ground. The pit is made up of a number of rows of dried shells as the fuel. The dried-shell rows are lit from one end and let the fire burn progressively to the other. The hot combustion gases from the burning shells pass through the half-shell copra bed thereby removing moisture from the kernel. There are a number of problems with this drying process: fuel is limited to dried shells only, smoke from the burning shells may affect the copra quality, heating is not uniform across the copra bed, and there is no control on the temperature level. The drying cycle is about 24-30 hours [6].

The Samoan dryer (Figure 2) is also a shed having about the same size as the Ceylon dryer with concrete walls and a sliding roof to take advantage of solar drying [6]. The difference lies in the heating system. The Samoan dryer uses indirect heating. It is a clean hot air dryer. It uses a fire tube for burning any woody mass such as coconut shell, husk and fire wood as its fuel. For large dryers, a number of fire tubes may be used. The tube is generally made of 44 gallon oil drums coupled together with steel bands. The fire tube can also be made of large steel tubes welded together. Coconut shells and husks burn at one end of the tube, and combustion gases exit through a chimney located at the other end (not shown).

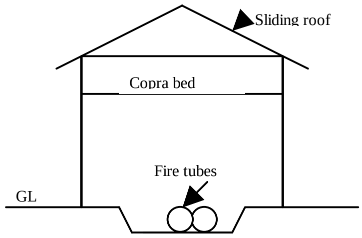

Figure 2: Schematic diagram of Samoan dryer

The firing end can be closed off to regulate air intake to control the rate of burning and hence the heat output. Since the tube is located in the ground, there is no direct air vent around it. Any air that enters the drying chamber does so from sides and top of the walls. Heat for drying is a combination of natural convection and radiated heat. The copra bed is located at about 1.25 m above the fire tube. There is a considerable heat leakage into the ground and variation of temperature level within the drying chamber. The drying cycle is reported to vary between 24-48 hours.

No published scientific data such as temperature distribution at the copra bed, fuel burning rate, and efficiency of these dryers are available.

3. THE PROPOSED PORTABLE DRYER

3.1 Design Objectives

The purpose of the current study is to develop a copra dryer for smallholders. The design requirements include (1) the use of biomass fuel such as copra husks, shells, cocoa pods, firewood, dried leaves, and so on, (2) no fouling and discoloration of copra from combustion gases, (3) shorter drying cycle time. The dryer will utilize radiated heat and hot air rising by natural convection for copra drying. The dryer will be developed for batch production with the capacity of about 50 kg of wet copra per tray per batch.

3.2 Description of the Portable Dryer

Figure 3 shows the schematic diagram of the portable dryer. The overall dimensions of the dryer are 1800 mm long x 740 mm wide x 1250 mm high. It is a clean hot air dryer. It consists of a fire tube (combustion chamber) fabricated from a steel tube with dimensions 300mm diameter, 3mm wall thickness and 1800mm length. Copra husks and shells are burnt at one end of the tube. Combustion gases exit through a small chimney located at the other end. The amount of fresh air intake into the tube can be regulated to control the rate of burning. The fire tube is located within a frame welded from rectangular profiles. The frame is covered by plywood sheets forming four vertical walls. There is a provision for placing in and taking out copra trays from the drying chamber. Copra tray is made of wire mesh welded to a metal frame and placed at intervals within the drying chamber.

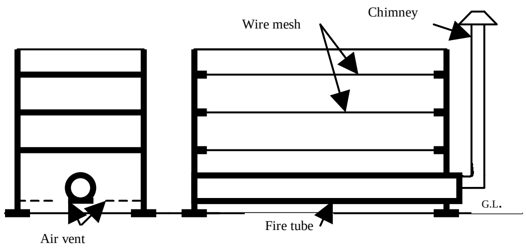

Figure 3: Schematic diagram of the portable dryer

The entire space from the bottom of the fire tube to top tray forms the drying chamber. The air vent around the fire tube for entry of fresh air into the drying chamber can be regulated. A wire mesh screen is also placed about 150mm above the fire tube in order to create turbulence in the hot air rising from the tube. Turbulence ensures greater uniformity of temperature within the drying chamber.

The proposed dryer is some ways similar to the Samoan dryer, but there are important differences too. Both dryers are based on indirect heating, and suitable for any woody mass fuels to be used in the fire tube. They are clean hot air dryers, so no fouling occurs from the combustion gases. The main differences between the two dryers lie in the location and control of air vents, temperature distribution and control of temperature within the drying chamber. In the proposed dryer, air vent is around the fire tube, so practically no heat is lost to the ground. Temperature level within the drying chamber can be controlled by regulating the air vent. The drying cycle time is a direct function of temperature; it is thus possible to shorten the cycle time by proper control of temperature. There is also a provision for creating greater turbulence in the hot air to obtain uniformity of temperature within the drying chamber.

The dryer operation is simple. A certain amount of husk/shell is placed on a grate at the firing end of the fire tube and then lighted. Once the desired temperature is reached, copra trays can be placed on shelves in the drying chamber through doors on one of the vertical walls. Thereafter it is necessary to recharge the fire tube to maintain a steady burning rate. Also, air vent is to be adjusted to obtain the desired temperature until the drying is complete. There is very little need for maintenance except removing the ash and cleaning the fire tube at regular intervals. The cost of the dryer is about US$ 150.

4. THE DRYING PROCESS

The drying process can be described as follows. A certain amount of fuel such as copra husk/shell (or any woody mass) is fed into the fire tube. As the fuel burns, the fire tube gets heated, and clean hot air rises from it by natural convection. The required air is drawn through the air vent around the fire tube. The hot air has the capacity to absorb moisture, and its capacity increases as the temperature is increased. So, when hot air passes though the copra bed, it removes any moisture from copra surfaces. As the copra gets heated, moisture from the interior of copra kernel migrates to its surface. The rate of moisture migration is a function of the copra temperature.

4.1 Temperature Control

In previous studies [2-6], temperature of drying was not related to drying cycle. But from [1], it was clear that temperature is a factor that influences the drying cycle. In general, higher the drying temperature, shorter is the drying cycle. There is however, a limit to which drying temperature can be increased. The limit is imposed by the quality and the loss of oil content in the copra. Copra can be dried at three levels of temperature: high, medium and low.

With a dryer of this type, temperature variation within the drying chamber is expected for several reasons: type and amount of fuel, location of burning along the fire tube and the length of the fire tube. Appendix-1 presents some data on copra properties and fuel values of coconut husks and shells.

The level of copra drying temperature depends on both the fuel burning rate in the fire tube and the rate of fresh air intake into the drying chamber. Fuel burning rate depends also on the amount of fuel available for burning at any one time and the natural flow of fresh air into the fire tube. Assuming that there is sufficient fuel in the fire tube, its fresh air intake was controlled by a gate valve. The fresh air intake was also controlled by varying the air vent to the drying chamber.

As mentioned, one of the problems encountered was the non-uniformity of temperature over the copra bed. Non-uniform distribution of temperature resulted from unrestricted flow of fresh air into the drying chamber as well as non-uniform distribution of temperature on the fire tube surface. This problem was significantly overcome by redistributing fuels along the length of the fire tube, controlling the air vent and introducing a wire mesh screen at a distance above the fire tube that created turbulence in the hot air rising from the fire tube.

5. EXPERIMENTAL DATA

A number of experiments have been conducted in order to determine the temperature distribution along the fire tube and within the drying chamber. This initial set of experiments was conducted without copra. Temperature measurements were taken at five stations at four equal distances along the length of the fire tube or the dryer. A temperature probe (ANSI T: Copper and Constantan Copper-Nickel alloy leads) with measuring range from -200 to + 350 ^{0}C and accuracy of 1 ^{0}C was used. Since air vent affects the level of temperature of the tube and the drying chamber, it is important to specify the percentage of air vent that was open. Air vent opening is defined in relation to the projected area of the fire tube. Air vent is considered to be fully open when the air vent area is equal to the projected area of the fire tube.

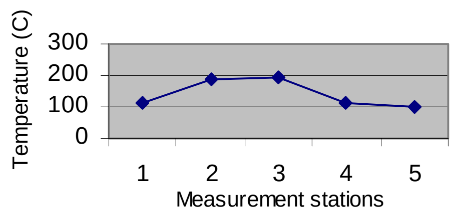

Figure 4: Average temperature distribution along the fire tube

Fuel was supplied at regular intervals to keep the fuel burning rate approximately steady. The inlet of the fire tube was fully open. The average surface temperature of the fire tube with 95% closed air vent condition is shown in Figure 4. The average temperature is calculated from four readings around the tube circumference at any one measuring station. A peak temperature of about 190 ^{0}C occurs at stations 2 and 3. It is the position of the burning husks. Towards the chimney end, the temperature tails off to about 103 ^{0}C. Summing up the temperature at all five stations along the tube, the average temperature was found to be 142 ^{0}C.

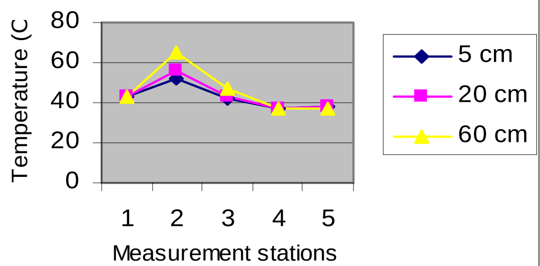

Figure 5: Temperature distribution with air vent fully open

The next set of measurements was taken within the drying chamber. As expected, temperature is expected to vary along the length, width and depth of the drying chamber. It was found that temperature variation along the width was of the order of 1 or 2 degrees. The variation is considered small, and therefore average values were used in the computation. The results are plotted in Figures 5-7 for three different vent openings. Each of these figures shows temperature distribution at three different depths, namely, 5 cm, 20 cm, and 60 cm. These depths correspond to the first (top), the second and the third wire mesh trays respectively. The first two can form the copra bed. The third wire mesh tray is intended for creating turbulence for greater uniformity of temperature within the dryer chamber.

Figure 5 shows the plot of temperature with air vent fully open. Apart from peak temperatures at station 2, the location of the burning husks, there is uniformity of temperature along the length of the dryer. The average temperature level is about 40 ^{0}C.

Figure 6 shows the temperature plot with air vent 50% open. This again shows uniform temperature along the length of the drying chamber. The average temperature is about 55 ^{0}C. This indicates a rise in temperature of 15 ^{0}C.

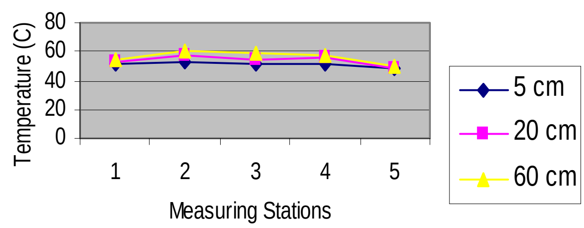

Figure 6: Temperature distribution w ith air vent 50% open

Figure 7 shows temperature plot for with air vent 95% closed. The temperature is generally uniform at about 80 ^{0}C. Thus, there is a further rise in temperature by about 25 ^{0}C.

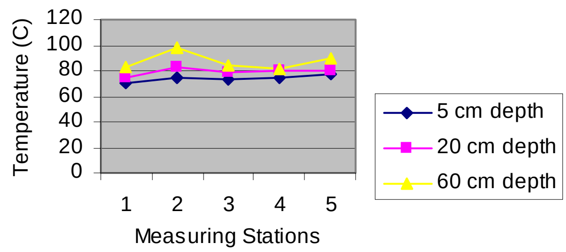

Figure 7: Temperature distribution with air vent 95% closed

6. DISCUSSIONS AND RECOMMENDATIONS

The paper has demonstrated that it is possible to design and develop a copra dryer for smallholders at a reasonable cost and with little operational and maintenance complexities. It is a clean hot air dryer that will not affect copra quality through smoke fouling. It is versatile in the sense that it can use any woody mass as fuel, and therefore superior to Ceylon dryer which is restricted to using dried shells only. The three tier temperature drying is expected to be superior to constant temperature drying because of shorter drying cycle time. The dryer is also more fuel efficient compared to Samoan dryers because of reduced heat loss. The current design also does away with the concept of forced draft dryers which entails unnecessary costs and complexity. The proposed dryer thus seems to be better than both the Samoan and Ceylon dryers. However, more work is planned to determine both the thermal efficiency and drying efficiency under field conditions.

7. ACKNOWLEDGMENTS

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9. APPENDIX-1

9.1 Copra properties

The average copra properties have been studied by several authors [2-5]. The results vary by about 6% depending on the grades of copra, but the following figures can be taken as the average values.

The average weight of an unhusked coconut = 1.4 kg

The average composition of a coconut: kernel = 30-33%,

Shell = 12-15%,

Husk = 30-37%, and

Water = 22-25% (all wet weight basis)

Moisture content of kernel (wet copra) = 50%,

Moisture content of dried copra = 6% (wb)

9.2 Fuel values

The model has been design to operate with any woody biomass fuel including coconut husks and shells.

Since coconut husks and shells are abundant at a coconut plantation where the model dryer is intended for use, we will restrict ourselves to these two fuels only. For each tonne of copra, there are 1.99 t fresh husks and 0.926 t of shells available to be used as fuels. The energy content of both husks and shells vary depending upon their moisture contents. According to [6], the gross specific energy (GSE) and net specific energy (NSE) contents of husks at 30% moisture content are 14 GJ/t and 12.3 GJ/t respectively. For shells the respective values are 14.6 GJ/t and 12.9 GJ/t. As mentioned, fresh copra contains 50% moisture and it is reduced to 6% in the dried state. In the drying process 887 kg is required to be removed per tonne of copra. The heat required to evaporate 887 kg of moisture at 30 ^{0}C is 2.15 GJ. So, it is evident that there is excess fuel energy available from either the coconut husk or shell of coconuts to dry their copra. The actual amount energy needed to dry a certain amount of copra will depend on the efficiency of the dryer used.