FAIRTRADE AFRICA

DEVELOPMENT OF STANDARD SOLAR DRYERS FOR QUALITY COFFEE PROCESSING

TRAINERS MANUAL

JANUARY 2021

THE AFRICA FAIRTRADE NETWORK- GIZ FUNDED SOLARED COFFEE PROJECT

KALRO Kenya Agricultural & Livestock Research Organization

HASA HORT AGRO SOLUTIONS AGENCIES

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Developing standard solar coffee dryers for high quality coffee processing

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Preface

Preservation of agricultural produce is one of the central problems faced by developing countries due to poor post-harvest practices in coffee processing. These stages of operations affect the quality of the beans before milling, subsequent liquor strength, flavors and aromatic value. The use of solar dryers offers a cheaper, convenient, and environmentally friendly way to dry coffee.

Fairtrade Africa together with Hort Agro Solution Agencies (HASA) is working with coffee Cooperatives, Coffee researchers, and academic institutions to tailor make solar coffee dryers. The overall aim of the assignment is to develop a standard coffee dryer, trainers' manual and associated training materials for technicians and trainers.

Hort Agro Solution Agencies undertook a situational analysis which included a critical appraisal of constraints and opportunities; opportunities analysis focused on opportunities for use of alternative systems of drying coffee and prospects for enhancing cherry quality and labor effectiveness, based on adoption of a new technology.

Initially it involved reviewing the technical performance of three (3) existing solar driers designs in 3 Fairtrade certified producer organizations, located in Kirinyaga, Kericho and Nandi Counties namely Kibirigwi Farmers' Cooperative Society Limited –Nguguine Factory, Kabngetuny Farmers' Cooperative Society Limited-Kericho and Kapkiyai Multi-Purpose Cooperative Society respectively.

To achieve this objective, HASA in collaboration with Fairtrade Africa developed and installed a standard coffee solar drier, developed a manual for design, installation and maintenance of solar driers, facilitated and moderated trainings on designing, installation and maintenance of coffee driers among targeted technicians and Trainers of Trainers.

The desire is to guide small scale coffee farmers and processors in Kenya to optimize their yields and quality of processed coffee by offering technical support throughout the project to enable the commercialization of the driers to select Fairtrade certified producer organizations in Kenya.

Acronyms

BBC	Bacterial Blight of Coffee
CAN	Calcium Ammonium Nitrate
CBD	Coffee Berry Disease
CLR	Coffee Leaf Rust
CRS	Coffee Research Institute
FT	Fairtrade East Africa
FTA	Fairtrade Africa
GAP	Good Agricultural Practices
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
Ha	Hectare
HASA	Hort Agro Solution Agencies
IPM	Integrated Pest Management
K	Potassium
KALRO	Kenya Agriculture and Livestock Research Organization
MC	Moisture Content
Mg	Magnesium
N	Nitrogen
P	Phosphorus
PL	Parchment grade classified as lights
PPE	Personal protective equipment

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UNIT 1.0 COFFEE SOLAR DRYING

Solar dryers were designed to provide efficient drying even in hazy or partially cloudy conditions. Construction of this dryer is simple since its materials are available in the local markets and nearby shops. This solar dryer allows air to continuously flow around the coffee product which enables fast drying. The moisture content of a fresh coffee bean is between 50 and 75 percent of its total weight, depending on the variety and condition of the bean. Dry coffee beans usually contain 15 and 25 percent moisture but the recommended moisture content for storage and sale is 12 percent.

A low moisture content is the most important factor in maintaining the quality of the beans during storage as moist beans provide an ideal environment for insects and for the development of microorganisms. A solar dryer helps to minimize the moisture content in coffee beans as high moisture content during storage is certain to ruin the taste and appearance of coffee.

What is a solar dryer?
This is a structure used for drying agricultural produce eg coffee, cassava and other crop parts used as raw material majorly by food processing industries.

- The dryer is built like a greenhouse consisting mainly of metallic frame covered by durable greenhouse uv-polythene, developed to withstand varying weather extremeties.
- The structure allows solar energy to accumulate in the enclosure, hence considerably raising the micro-climate temperatures within the structure. The coffee shelfs are designed to allow efficient circulation of air in the beans. The structure has a vent approximately 30cm at the roof that allows escape of hot air generated within the structure. The walls are made of satandard nets approximately 50 to 70cm hieght that allows adequate cool external air to flow in the structure. The vent and the wall nets ensures there is made with materials and desibeds areThe hot dry air circulates around the proper circulation of air hence reducing accumulation of high moisture content in the structure. The high temperatures and adequate air circulation ensures the coffee beans dry evenly at a much faster and convenient rate.
- Shelfs made of metal, wire mesh and nets are constructed inside the dryer structure for spreading out the beans. Depending on the size of the structure, you can have 2 to 3 rows of the coffee beds at a spacing of 50cm between them with each having 2 layers of shelfs.

Figure 1: External view of a solar dryer.

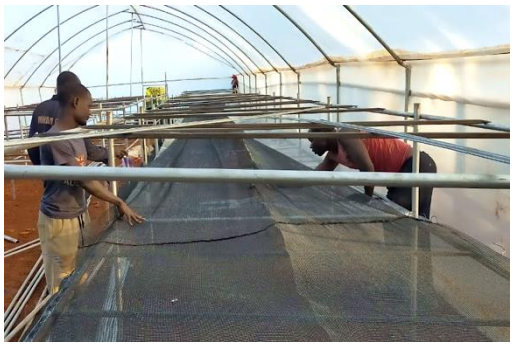

Figure 2: Interior view of a solar dryer

Figure 3: coffee beans on the shelfs

Materials needed: A solar drying structure with all the materials necessary for coffee harvesting, storage and processing - moisture metres, raised beds, and parchments.
Duration: 60-90 minutes
Preparations: Familiarize yourself with the national and internal best practises in coffee processing.

Set up

- **Attention:** Ask learners to explain what happens to coffee beans once they deliver to factories till it is packaged for sale.
- **Introduction:** Introduce the title of the session on Good Manufacturing Practises (GMPs) for quality uncontaminated coffee beans.
- **Objectives:** To learn the best processing practises for quality coffee flavour and taste.
- **Benefits:** Observing GMPs will help farmers, cooperative societies, factories and processors to produce quality coffee beans. In return the processors will secure higher incomes that will trickle down to farmers.

Direction: Conduct a general lecture and practical lessons on GMPs in coffee processing including cherry harvesting, sorting, pulping, grading, fermenting, soaking and washing. The lesson will in detail cover the drying process where comparisons between the open sun drying process and the controlled solar drying process will be made.

- **Delivery:** Classroom lectures coupled with practical lessons where learners take part in coffee processing activities like weighing.

1.1 Introduction

Correct coffee processing is important in sustaining bean quality as it ensures better prices for growers. There are three principal methods of coffee processing in East Africa. These are:

- Fully washed process – the pulp and mucilage are removed by pulping, fermentation and washing. It is also called wet processing. This is the conventional form of Arabica coffee processing used in most parts of the world. It has the effect of producing high quality beans.
- Semi washed process - the fermentation step is skipped by use of de-mucilagers to remove pulp and some or all of the mucilage. This process is called pulped natural. It has the advantage of avoidance of over-fermentation that leads to low quality beans.
- Dry processing (natural) - no layers are removed - The pulp and the mucilage are dried with the beans. The additional time where there is contact of the bean with the sugary mucilage in the fruit which imparts sweetness on the bean. In East Africa, this is limited to robusta coffee.

1.2 Global innovations

Figure 4: Use of Greenhouses help achieve homogenous drying and shelter coffee beans from rains

Coffee producers are adopting various processing practices such as use of catalysts to speed up fermentation, ways of reducing environmental impact by cutting down the use of water and creation of more unique cup profiles. Various processing practices and innovations meant to improve bean quality to meet consumer demands for specialty coffees have been developed. These include:

- Honey processing – In this process, the skin and pulp are removed, but some or all of the mucilage (honey) remains. It is the mucilage with its honey-like tendency that gave birth to the name of the processing method.
- Use of green houses for coffee drying-This enables drying to be done throughout the day and shortens the coffee drying period. Drying can be done even in rainy weather. It is a practice that can be borrowed since it prevents re-wetting and saves on labor costs. However, care should be taken to avoid over-drying due to high temperatures experienced in the green house.
- Raised shade cover during the white stage of fully washed coffees- This ensures cool, slow drying leading to good quality beans that are not cracked. This can be borrowed and developed further to reduce the cost of establishing such shades.

Drying of coffee is a critical aspect of coffee processing since the quality and price of coffee beans depends on how dry they are and also on the way in which they have been dried. Even though coffee has been cultivated for decades, the technologies

used for solar drying are very limited. More than a dozen of drying methods are used in different areas ranging from a wooden dryer where the coffee is placed on boards and exposed to smoke, to the spreading of beans wherever there is space on: a straw mat, a sack or piece of canvas on the ground, an awning, under a bed or even in a rented courtyard in a nearby town. Coffee beans are sometimes dried in wood-burning ovens or in gas dryers.

In 2001, as part of a Master's degree programmed, El Colegio de la Frontera Sur (ECOSUR) initiated a participatory research process to develop a solar dryer with a group of organic coffee producers. A fundamental part of the process was the exchange of ideas and dialogue between disciplines and traditions. Other technologies of using solar dryers to dry agricultural produce were reviewed and similarities with coffee drying were identified.

The coffee drying process is when the moisture content in beans is reduced to just 10%-12% from 45%-50%. In washed processing, this will occur after the cherry flesh has already been removed: in dry processing this will happen while the seeds or beans are still in the fruit.

Coffee Fermentation Using commercial enzymes

Commercial enzymes are used to fasten the fermentation process. This is commonly practiced in Brazil to avoid long periods of fermentation. These can be used especially in cold areas to enhance fermentation. The enzymes include:

- Pectin lyase.
- Polygalacturonase which is the main enzyme involved in coffee fermentation.
- Pectin methyl esterase.
- In the East African region, the fully washed (wet processing) is the pre-dominant practice and involves a series of stages.

Figure 5: Open sun drying exposes coffee beans to dust, foreign matter and excess moisture during rainy weather.

1.3 Coffee Processing-Solar dried Coffee

Materials needed: A solar drying structure with all the materials necessary for coffee harvesting, storage and processing -moisture metres, raised beds and parchments.
Duration: 60-90 minutes

Preparations: Familiarize yourself with the national and internal best practises in coffee processing.

Set up

- **Attention:** Ask learners to explain what happens to coffee beans once they deliver to factories till it is packaged for sale.
- **Introduction:** Introduce the title of the session about Good Manufacturing Practises (GMP) for quality uncontaminated coffee beans.
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- **Direction:** We will have a general lecture and practical lessons on GMPs in coffee processing including cherry harvesting, sorting, pulping, grading, fermenting, soaking and washing. The lesson will cover in detail the drying process where we compare the open sun drying process to the controlled solar drying process.
- **Delivery:** Class room lectures coupled with practical lessons where leaners take part in coffee processing activities like weighing.

Harvesting

Coffee harvesting in Kenya is done by selective picking of the ripe berries. This is a labour intensive exercise and involves most of the members of a family and hired labour. Transportation to the Factories is by Ox-drawn carts, pick-up vehicles, and sometimes Lorries. This is done immediately after harvesting.

Figure 6: The harvester carefully selects only the ripe berries at every harvesting cycle.

Cherry Sorting

The cherry is sorted out before pulping. This helps to remove the immature, diseased, insect damaged and dry berries as well as the leaves, twigs and other foreign matter. The sorted out berries are processed by the dry method.

Correct coffee processing is important in sustaining bean quality as it ensures better prices to growers. There are three principal methods of coffee processing in East Africa. These are:

- Fully washed process – the pulp and mucilage are removed by pulping, fermentation and washing. It is also called wet processing. This is the

conventional form of Arabica coffee processing used in most parts of the world. It has the effect of producing high quality beans.

- Semi washed process - The fermentation step is skipped by use of mucilage to remove the pulp and some or all of the mucilage. This process is called pulped natural. It has the advantage of minimizing chances of over-fermentation which leads to low quality beans.
- Dry processing (naturals) - no layers are removed - The pulp and the mucilage are dried with the beans. The additional time where there is contact between the bean and the sugary mucilage in the fruit imparts sweetness on the bean. In East Africa, this is limited to robusta coffee.

Figure 7: harvested berries being sorted to remove under/over ripe, dry, insect infested/diseased berries, twigs, leaves and other foreign materials.

Coffee Drying Stages

Freshly pulped coffee has a moisture content (mc) of about 55%, which has to be reduced by drying to 11%. This is the ideal level of moisture content required for proper storage, hulling and roasting. In Kenya, sun drying is predominantly used and mainly by the co-operatives and the coffee is spread on wire mesh tables for several days (normally about 14 days), until fully dry. When it rains, the coffee is covered by a polythene sheets to avoid re-wetting. Some big commercial estates use mechanical drying.

The following are the stages of parchment drying that are observed:

- **Stage 1: Skin Drying (55 - 45% mc)**-This stage involves the removal of surface water and that between the parchment and the bean. The parchment is spread on layers not exceeding 0.5 inches on wire mesh tables and turned frequently to encourage rapid evaporation and at the same time it is fully exposed to the sun. This stage is normally completed on the same day of final washing. While stirring the parchment to ensure uniform drying, discoloured and broken beans are sorted.
- **Stage 2: White Drying Stage (44-35% mc)**-At this stage, the parchment is white and it is easy to sort out the defective beans. Drying at this stage is made slow and controlled, and during very hot days, the coffee is covered during the hottest part of the day, (from 10.30 a.m. to 3.00 p.m.) in order to

avoid cracking of the parchment cover. This stage can be mechanized with well controlled temperatures to avoid cracking of the parchment.

- **Stage 3: Soft Black Stage (35 -25 % mc)**-At this stage the parchment attains is final black colour. In Kenya, it is recommended to only sun dry in this stage, for the coffee is said to be photosensitive and the sun light makes the coffee to acquire some preferred quality characteristics. The coffee is fully exposed to the sunlight for a period of 48 -50 hours. Mechanical drying is discouraged at this stage.
- **Stage 4: Hard Black Stage (25 -12 % mc)**-At this stage the parchment is hard dark in colour and can be done rapidly without any loss of quality.
- **Stage 5: Fully Dry and Conditioning (12 -11 % mc)**-This is done in ventilated stores or bins in order to even out the moisture of the coffee. At this moisture content, the coffee can be stored in well controlled environment without any effect on quality.

1.4 Pulping and pre-grading

Pulping is the mechanical removal of the pulp from the cherry to have parchment coffee. After pulping, the coffee is graded into three grades 1, 2 and lights. This is done by density and size of the coffee. Parchment 1 is conveyed to the fermentation tanks while grade 2 and lights are further processed again through another smaller pulper called a re-passer.

Figure 8: a display of a two-disc pulper

1.5 Fermentation

This is done to break down the mucilage into simple non sticky substances which are easily washed off from the coffee beans.

1.6 Intermediate washing

The fermentation procedure should be ‘dry’, followed by intermediate washing (after about 16 hours or so), then 4 to 6 hours of further dry fermentation if necessary, until the gritty feel is achieved.

1.7 Final washing and grading of parchment

Final washing is done to remove any adhering dirt or remains of mucilage sugars.

Figure 9: Under water soaking-the parchment is completely immersed in water

1.8 Under water soaking of parchment

This is the complete immersion of the fermented and fully washed parchment under clean water. It is done to improve the bean quality for a period of about 16 hours.

1.9 Parchment drying

Drying is the process of reducing the moisture content of the beans from about 55% moisture content to about 10.5 -11% which is safe for storage, hulling, and roasting. The process of drying goes through five distinct stages during which characteristic physical and chemical changes occur in the bean. Re-wetting should be avoided at all stages

1.10 Skin drying of parchment (55 – 45% MC)

This is the removal of surface water on the parchment. Place the parchment on drying beds lined with sisaltex, hessian cloth, tilder/shade net maintaining a parchment depth of about 2.5 cm (1 inch).

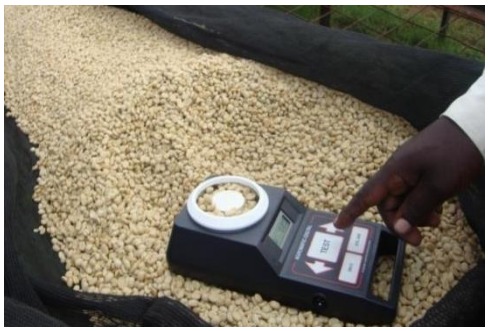

Figure 10: Moisture meter for measuring Moisture content of the beans at The drying tables.

Figure 11: Beans dried on top of raised clean tables.

1.11 Dry Method of Coffee Processing (Naturals)

Dry processing method for Arabica coffee

In East Africa, this method is primarily applied to Arabica coffee which is sorted out from the good cherry, commonly referred to as buni in Kenya. It is thus used to dry the over-ripe, under-ripe, stripped cherries after the harvest and in situations where wet processing facilities are not available. The coffee is dried to attain the required moisture content of 12% and then stored. It is later hulled where the dry pulp and parchment are removed in a single operation.

- **Step1:** Start drying the cherry on a clean and well drained surface after harvesting. e.g. on a concrete surface.

- **Step 2:** Dry cherries on raised surfaces or drying tables and cover with rain proof materials when there is rain to avoid re-wetting. This prevents mold growth.

Avoid mixing freshly picked or sorted out cherry with the drying ones. Each batch of cherries should be dried separately to avoid mixed drying

- **Step 3:** Ensure cherries are properly dried to a moisture content of 12%
- **Step 4:** Naturals received from farmers should be inspected, sorted and the moisture content determined before weighing and storage

Figure 12: A photo of well dried coffee beans

Figure 13: Poorly dried beans with moulds

1.12 Storage of parchment

Proper storage aims at preserving coffee quality by maintaining the right moisture content, protecting coffee from damage by insects or molds and preventing contamination. It also facilitates identification and handling of coffee lots. When storage conditions are too humid, coffee beans acquire a darker color and a moldy, fermented flavor hence loss of quality.

Some important highlights in coffee storage are:

- Store bulk coffee in well ventilated bins or on wooden floors and stir regularly.
- Coffee stores should be constructed so as to allow ventilation and avoid re-wetting.
- High, insulated roofs with air vents minimize heat transfer to the storage area. Good ventilation should be put in place.
- The store should be sited away from chemicals and any other possible source of contamination.
- For parchment stored in bags, wooden pallets should be placed on the floor at a minimum distance of 6 inches away from the floor and the wall to facilitate good ventilation avoid re-wetting through condensation.
- Smoking should be avoided in the stores.
- Clean gunny bags should be used for storage. Preferably sisal or jute bags
- The coffee store must be well ventilated and the corrugated iron sheet roof adequately insulated to minimize heat transfer.
- Avoid pro-longed storage as this leads to quality loss.
- Moisture monitoring of stored coffee should be done regularly in order to take corrective action.
- Moisture meters should be calibrated regularly and at least once per year.

- In the event that sorting was not adequately done during the skin drying and white stage, it should be undertaken before delivery to mills.

Summary: Recap the key points that farmers, factory managers and workers must get from this lesson on cherry harvesting, sorting, grading, pulping, fermenting, washing and drying. Emphasize the merits of homogenous drying under standard greenhouses compared to the demerits of open sun drying.

Questions: Ask and respond to questions or comments from your audience.
Evaluation: Ask the learners some questions to gauge their understanding of the subject.

UNIT 2.0 Developing Standard Solar Coffee Dryers

Materials needed: A sample / pictures of quality and defect coffee beans.
Duration: 60-90 minutes
Preparations: Gather a sample of quality and defect coffee beans for use in your session.

Set up

- **Attention:** Probe learners to share instances they have drunk good and "bad" coffee. Try to get them share their opinions on the reasons affecting taste and flavour of coffee.
- **Introduction:** Introduce the title of the session about the common defects found in coffee production and processing.
- **Objectives:** To learn how to minimize causes of coffee defects to produce quality coffee in taste and flavour.
- **Benefits:** minimizing instances of coffee defects will help Farmer cooperative societies, factories and processors to produce quality coffee beans. In return the processors will secure premium prices and enjoy high demand. These benefits will trickle down to farmers benefiting the general society.

Directions: Have a hybrid lesson that combine lecture and practical lessons on sources and methods of mitigating coffee beans defects whether on the farm, in primary or secondary processing.

- **Delivery:** Class room lectures coupled with practical lessons where learners can inspect and comment on quality of coffee beans.

2.1 Lessons Learnt

The solar drier is very simple to build and to operate, it is low-cost, it uses local or easily obtainable materials and incorporates the local knowledge of farmers. The technology has therefore been accepted and adopted and the farmers have used their creativity in developing innovative alternative uses.

During the process of developing the solar coffee dryer, we discovered that alternative technologies not only have to suit the social and economic conditions, but they must also fulfil a number of other requirements: they should build on and incorporate local knowledge; they should not contaminate the environment or be harmful to people's health; they should be simple to build and use easily obtainable materials; and they should be simple to operate – repairs and maintenance work should not pose a problem.

To ensure that all these criteria were fulfilled in the design of the solar dryer, it was important to involve the farmers throughout the whole process. The farmers were involved from the very start and their organization and decision-making methods were respected. Besides, the startup and evaluation of the technology was left in the hands of the farmers, with the use of the farmers' own methods to transfer the technology.

We believe that the results of this process will be sustainable as it has strengthened the farmer's situation in many different ways: culturally, as the use of traditional knowledge strengthens the farmer's identity; financially, as the improved quality of the beans means better prices; politically, as the farmer's organizational capacity has been strengthened through the self-managed process.

2.2 Solar Dryer Construction

Materials needed: A solar drying structure with all the materials necessary for coffee harvesting, storage and processing -moisture metres, raised beds and parchments.
Duration: 60-90 minutes
Preparations: Familiarize yourself with the national and internal best practises in coffee processing.

Set up

- **Attention:** Ask learners to explain what happens to coffee beans once they are delivered to factories up until they are packaged for sale.
- **Introduction:** Introduce the title of the session about Good Manufacturing Practises (GMP) for quality uncontaminated coffee beans.
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- **Direction:** Give a general lecture and practical lessons on GMPs in coffee processing including cherry harvesting, sorting, pulping, grading, fermenting, soaking and washing. The lesson will cover in detail the drying process where farmers will compare the open sun drying process to the controlled solar drying process.
- **Delivery:** Class room lectures coupled with practical lessons where leaners take part in coffee processing activities like weighing.

Solar dryer construction

Materials needed:

- Round tubes-Metallic
- Insect net.
- Ultra violet cover
- Nuts and bolts.
- Self-drilling screws.
- Profiles and locking wires

Duration: 60-90 minutes
Preparations: Videos and pictures of on-going greenhouse construction**.**

Set up

- **Attention:** Ask the learners to detail how they constructed their houses from start to occupying.
- **Introduction:** Inform learners that the session follows a similar pattern as in making a functional solar dryer.
- **Objectives:** To learn how to manage a greenhouse construction project from start to end.
- **Benefits:** Leaners will be equipped with knowledge and practical skills of making and running a functional greenhouse for various uses with special emphasis on coffee drying.
- **Direction:** Have a hybrid lesson that combines lectures and practical lessons on project management, procurement of materials, project supervision and deliverables management.

Delivery: Class room lectures coupled with practical lessons where learners can participate in managing a greenhouse construction project.

Materials needed: Videos and pictures an on-going greenhouse construction.
Duration: 60-90 minutes
Preparations: Videos and pictures of on-going greenhouse construction.

Set up

- **Attention:** Ask the learners to detail how they constructed their houses from start to occupying
- **Introduction:** Inform learners that the session follows a similar pattern as in making a functional solar dryer.
- **Objectives:** To learn how to manage a greenhouse construction project from start to end
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Directions: Have a hybrid lesson that combines lectures and practical lessons on project management, procurement of materials, project supervision and deliverable management.

- **Delivery:** Classroom lectures coupled with practical lessons where learners can participate in managing a greenhouse construction project.

2.3 Requirements

The first steps are making a sketch diagram of the greenhouse and develop the structure design or plan of the greenhouse.

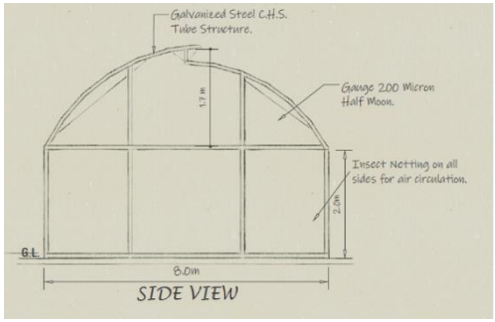


Figure 14: Side view of the greenhouse

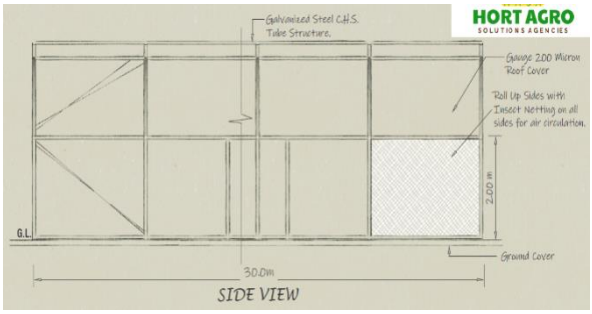


Figure 15: Side view (2) of the green house

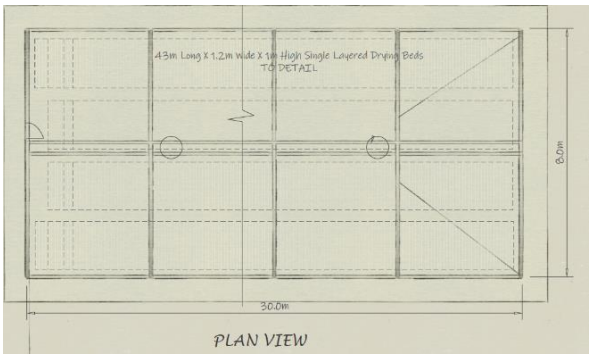


Figure 16: Plain view of the greenhouse

Material Specifications

a) 11stakes 42mm by 1.5mm round tubes.
b) 34 Pieces 38mm by 1.5mm round tubes (arches, braces and support).
c) 24pieces 32mm by 1.5mm round tubes (Running's).
d) 11 pieces 25mm by 1.5mm round tubes (roll ups).
e) 200m^2 insect net.
f) 610m^2 (200micron) UV cover.
g) Nuts and bolts.
h) Self-drilling screws.
i) Profiles and locking wires.

2.4 Bill of Quantities for one drier

The second step is to make a budget or a bill of quantities of all materials needed to construct the drier. According to this plan you will need Ksh 0.8 million as detailed below. This is the market price in Kenya as of October 2020.

Table 1 Sample Bill of quantities

S/n	Description	Unit price (sh)	Quantity	Subtotal (Ksh)
1	GI Metal pipes 1.5”	1,800	100	180,000
2	GI Metal pipes 1”	1,500	100	150,000
3	P.E. Film (UV treated)	12,000	10	120,000
4	Digital Thermometer	5,400	2	10,800
5	Locking profile	700	100	70,000
6	Mesh (Metallic light gauge)	10,000	10	100,000
7	Mesh (Plastic)	11,500	10	115,000
8	Cement	700	4	2,800
9	Ballast	400	3	1,200
10	Sand	300	3	900
11	Welding rods	1,800	2	3,600
12	Rivets	1,596	1	1,596
13	Paint	2,500	2	5,000
14	Labor and logistics	138,000	1	138,000
	Totals			898,896.00

2.5 Material preparation

a) Cut the foundation metals (stakes) to 2.5m long and join a u-shaped metal onto it on one side and a wall pass on the opposite side. 22 stakes are required for the 8m by 30m greenhouse.
b) Cut the arches; 5.3m long for the top vent and 5.0m long for the lower vent.
c) Gently bend the arches to give-to-give a smooth curve. A total of 22 arches required.

Figure 17 Assortment of greenhouse materials

d) Cut a 50cm long round tube from a 38mm metal, flatten its ends by hammering and make holes on both ends using a drill. This metal is used in connecting the upper and lower vent. A total of 11pcs are used**.**

e) From the 38mm round tubes, cut 6pcs of 4.5m long metals, flatten one end and drill a hole on them and on the other side put a wall pass. These are the structure support for the greenhouse**.**

f) From the 38mm round tubes, cut 4pcs of 3.6m and 4pcs of 3.4m length. These are the braces for the greenhouse both upper and lower respectively**.**

Figure 18 Additional material requirement for greenhouse

2.6 Site Preparation

For the dryer construction, the following things have to be considered:

a) Choose a south or north (depending on location) facing area.The main element required for a greenhouse is good consistent sunlight.
b) Give preference to locations that have morning sun over afternoon sun: Although all day sun is the best option, opening up the area to morning light will increase the temperatures.
c) Choose a well-drained area: This is to avoid dampness that will encourage growth of molds.
d) Site slope: the site for the construction has to be gently sloping to a flat surface, where the slope is very steep. Soil leveling has to be done before the actual construction is undertaken.
e) Wind direction: the direction of the wind year round determines how the dryer should be oriented. The dryer should be constructed along the wind direction and not against it.

2.7 Construction

a) Identify a corner location.
b) Measure the location.
c) Ensure that the 8m by 30m area is level and clear of any obstacles.
d) On the corner locations, wrap a string around the pegs as shown below.
e) Using pegs, mark the length from one stake to the next at exactly 3meters.

Figure 19: Level the ground to construct the greenhouse on a flat ground

2.7.1 Hole digging

a) Dig holes 10cm wide and 50cm deep.
b) Ensure that each hole is greater than the width of each stake
c) Ensure that all holes are correct distance apart (3m) and on a straight line.

2.7.2 Frame construction

Once the site for the construction is identified and meets the basic requirements, the dryer is constructed as follows:

a) On a level ground, map out an area of 240m^2 (8m by 30m) using wooden pegs. Space the pegs 3m apart along the 30m length and 8m wide.

b) Place the corner stakes vertically into the holes, pour the mortar into the holes with the stakes and compress it using a wooden frame or a metallic piece. Allow it to settle for about 5 minutes then wrap a string one on the top of corner stakes and the other on the sides to ensure uniform heights(2m) and the straightness of the stakes on the line. Add the mortar until all holes are filled up.

c) In the dug up holes, put in the stakes (foundation posts) using mortar; ensure the posts are on a straight line along the 30m length and on the opposite side. Ensure that the above ground height of the posts is 2m and gently sloping for water flow whenever it rains.

d)Join the arches together using the 50cm long connecting metal using bolts and nuts and hung up the arches on the foundation posts. This is to be done once the posts have cured up, at least after two days. The arches are joined leaving a vent of 50 centimeters.

e)Put the top and lower vent running's side running's and both the braces into place using bolts and nuts, ensure the whole structure is well aligned and put the structure support in the middle of the dryer at a spacing of 6m apart. At this point, the entire structure is ready for covering.

f)Put the top and lower vent running's side running's and both the braces into place using bolts and nuts, ensure the whole structure is well aligned and put the structure support in the middle of the dryer at a spacing of 6m apart. At this point, the entire structure is ready for covering.

g)Start covering by putting the uv-cover on the half-moon ends and wide areas, followed by the top vent and vent screening, cover the lower vent and put in place the side roll ups.

Figure 20 installing the solar dryer structure. dryer.

Figure 21 covering the structure of the solar

Figure 22: Front view of a completed solar dryer.

2.8 Drying Shelves

The dryer has 3 shelves each measuring 2m wide by 28m long.
Each shelve has two layers to hold the coffee beans. The lower layer is 0.8m from the ground while the upper layer is 1.3m. The shelves are covered with a shed net to ensure that no coffee beans drops to the ground. Between the shelves, a passage of one meter wide is provided for easy movement within the dryer.

Summary: Recap the key points that learners must get from this lesson on project management and greenhouse construction.

Questions: Complete with an interactive session to ask and respond to questions or comments from your audience.

Evaluation: Ask the learners some questions to gauge their understanding of the

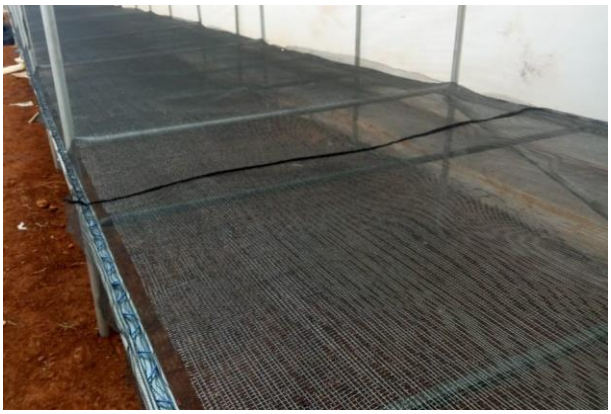


Figure 232 lower layer of the shelf

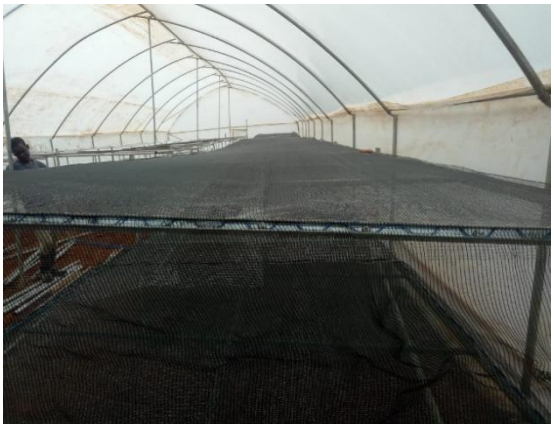
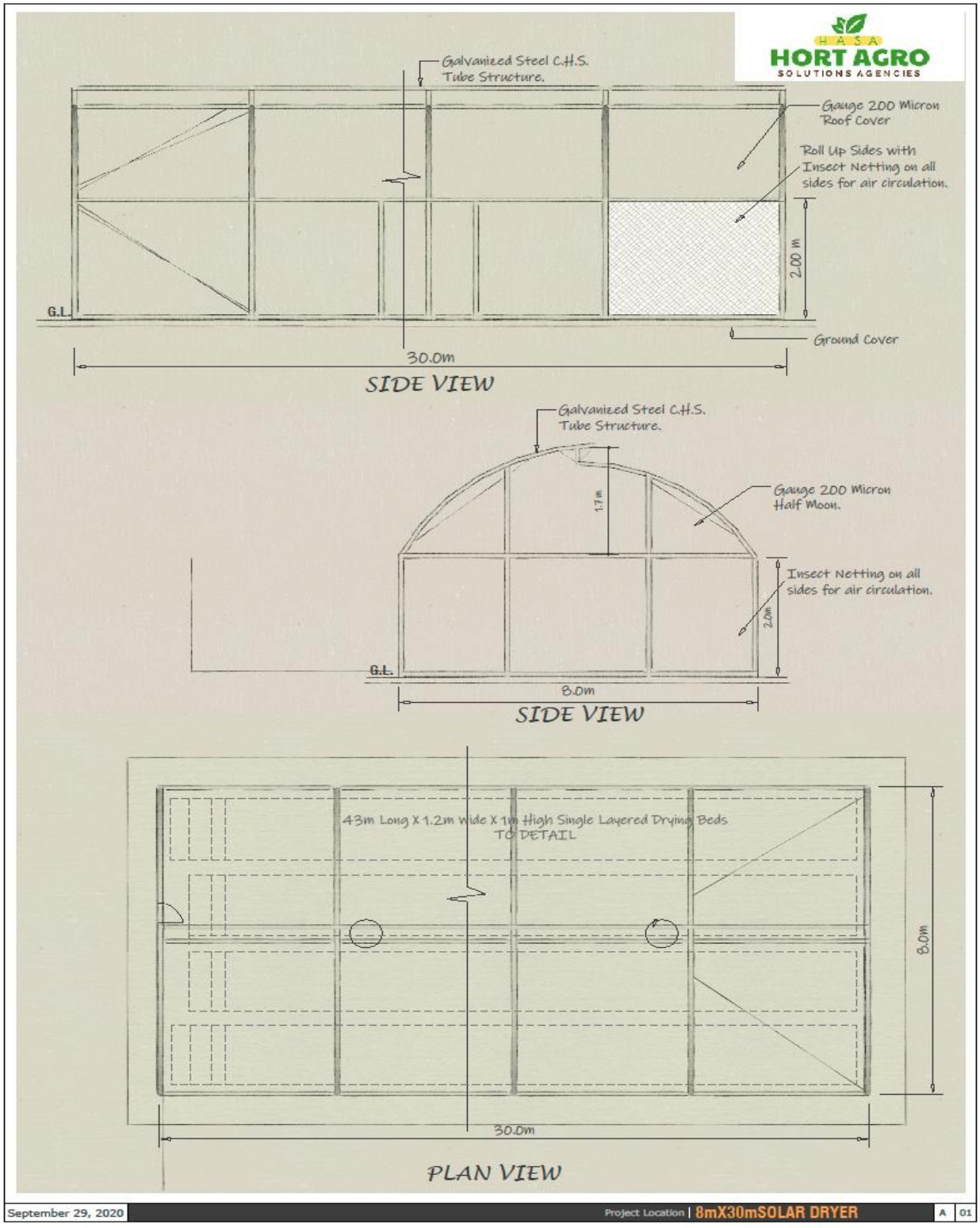
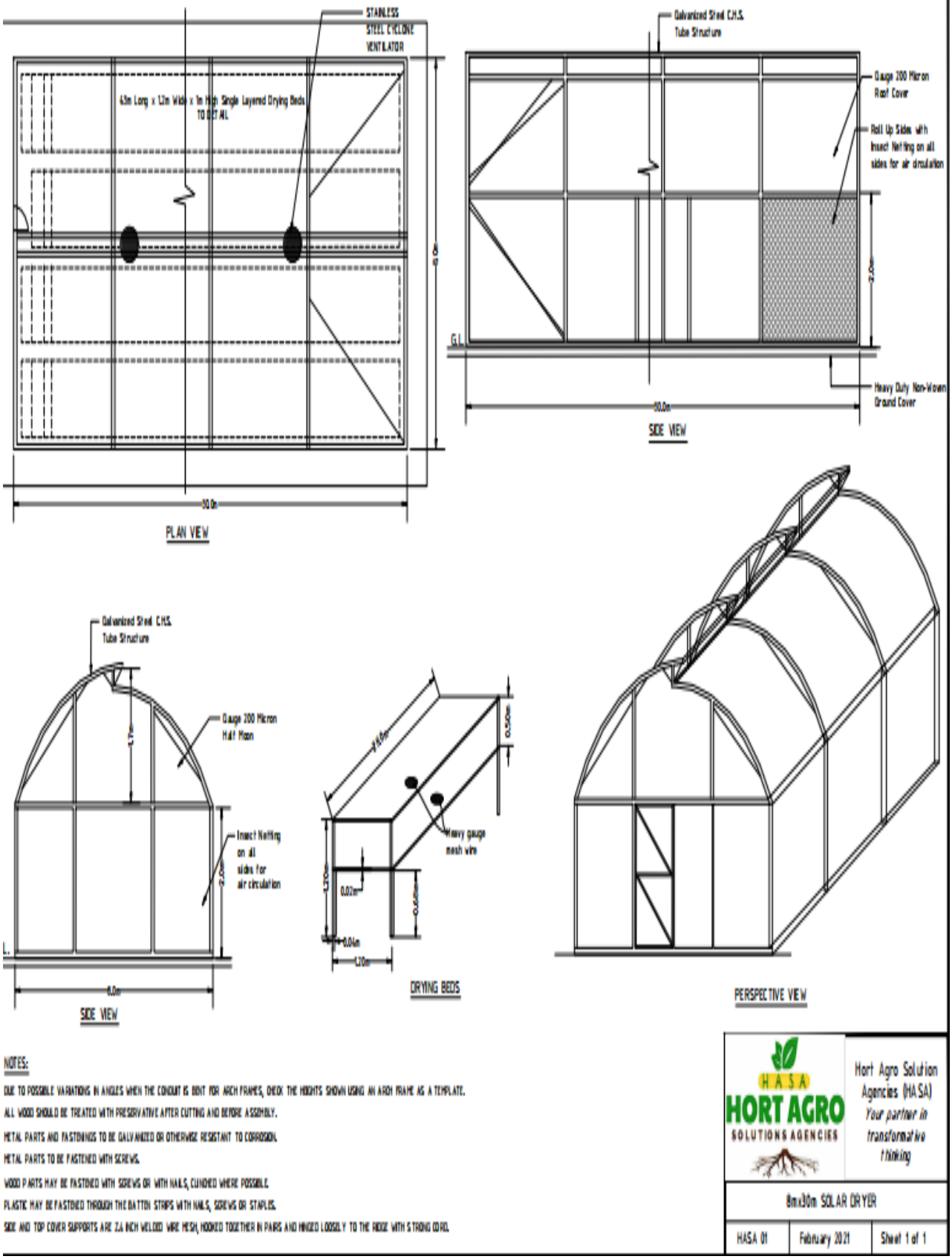


Figure 24 upper layer of the shelf

Figure 25 Internal view of a solar dryer complete with upper and lower shelves.

2.9 Design Sketch of the drier





NOTES:

DUE TO POSSIBLE VARIATIONS IN ANGLES WHEN THE CONDUIT IS BENT FOR ARCH FRAMES, CHECK THE HEIGHTS SHOWN USING AN ARCH FRAME AS A TEMPLATE.

ALL WOOD SHOULD BE TREATED WITH PRESERVATIVE AFTER CUTTING AND BEFORE ASSEMBLY.

METAL PARTS AND FASTENINGS TO BE GALVANIZED OR OTHERWISE RESISTANT TO CORROSION.

METAL PARTS TO BE FASTENED WITH SCREWS.

WOOD PARTS MAY BE FASTENED WITH SCREWS OR WITH NAILS, CLINCHED WHERE POSSIBLE.

PLASTIC MAY BE FASTENED THROUGH THE BATTEN STRIPS WITH NAILS, SCREWS OR STAPLES.

SIDE AND TOP COVER SUPPORTS ARE 2.4 INCH WELDED WIRE MESH, HOOKED TOGETHER IN PAIRS AND HINGED LOOSELY TO THE RIDGE WITH STRONG CORD.

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8mx30m SOLAR DRYER

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