A NATURAL CONVECTION GRAIN DRYER FOR HUMID DEVELOPING COUNTRIES
A NATURAL CONVECTION GRAIN DRYER FOR HUMID DEVELOPING COUNTRIES

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A type of natural convection grain dryer was designed for application in humid areas of the developing countries. This report deals with construction and operation of the designed grain dryers. They were built and tested in Peru and Belize. This type of dryer does not need any electro-mechanical device.
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SECTION I

INTRODUCTION

This paper presents a "how-to" guide related to construction and operation of a natural convection grain dryer for humid developing countries using only locally available resources. The dryer can be built from either concrete or mud blocks. Experimental dryers were built at the Universidad Nacional Agraria de la Selva and the Tulumayo Research Station of the upper Huallaga region of Peru and at the Big Falls, Toledo, Belize Marketing Board Rice Complex in Belize.

The dryers do not need any electro-mechanical device for their operation, are modular in design (single unit capacity 300 kg of paddy per 12 hr a day operation on a 6 percent moisture removal basis and 3 mt per day for a 10-unit size) and operate on a wide range of fuels such as wood, rice husks, and other agricultural by-products. A 10-unit dryer could be handled by 2-3 persons. The small length and width of the dryer make it possible to make a fire uniformly over its cross section which results in uniform grain drying.

Experiments conducted with the dryers in Peru and Belize demonstrated the feasibility of attaining a wide range of drying air temperatures (40°C to 75°C under the grain bed) by controlling the fuel and combustion rate. Rough rice from 20 percent initial moisture was dried to 14 percent in about 1 hour which was an undesirably high drying rate for rice. However, it clearly demonstrates the capability of the dryer for application to humid tropics of developing countries where labor and fuel such as wood, straw, rice husks, etc. are cheap.
SECTION II

BACKGROUND

The upper Huallaga region of Peru is located northeast of Lima in the high jungle. The city of Tingo Maria and the Tuluymayo Agricultural Research Station are located in this region. The region has a high rainfall. The Servicio Nacional de Meteorologia e Hidrologia (SENMHI) 1980 data for the Tuluymayo station indicated an average monthly rainfall of 242 mm with a range of 113-400 mm and monthly average humidity range of 81-88 percent (SENMHI, 1980). Figure 1 shows the monthly rainfall range for 1977-79 and mean monthly rainfall for 1970-79. The main harvest of the grain crops extend from May to September with a negligible harvest in July. Even though harvest months are relatively dry, heavy rainfalls occur periodically. Grain samples examined from farmer's stock and several local warehouses in the region indicated heavy insect and mold infestations.

Belize, a Central American country, also has a very high yearly rainfall. The Toledo district, a rice producing area, has an annual rainfall of about 5,000 mm a year. Heavy rainfall occurs during the paddy drying period, October to December.

Heavy rainfall during the harvest season makes it impossible to sun-dry the grains to a safe storage moisture level. Many researchers, including Chancellor (1968 and 1971), Ryu (1976), Bolduc (1978), and Guevarra (1979), developed grain dryers for developing countries but their application did not spread much beyond laboratory because of various practical reasons. Need for the development of acceptable on-farm grain dryers for the developing countries still exists and was stressed by various speakers of the 1987 Consultative Workshop on Grain Drying and Rice Milling in ASEAN countries.
FIGURE 1. Rainfall in Tingo Maria, Peru (Senamhi, Peru)

YEARLY AVERAGE RAINFALL: 3325 mm/YEAR

RANGE (1977-79)

MEAN MONTHLY RAINFALL (1970-79)
SECTION III
OBJECTIVE

The objective of this experimental study was to develop a suitable grain dryer for application to humid tropics of developing countries.
SECTION IV
DESIGN CRITERIA

The following design bases were considered appropriate:

1. The dryer must not require an engine or electricity. Grain drying should be accomplished by natural convection of air through the grain.

2. The dryer should run with a little (8 km/hr) or no wind velocity.

3. The dryer should run on locally available biomass sources such as wood, rice husks, and agricultural by-products.

4. Building materials not locally and easily available must not be used.

5. The building technique must be known to local builders and/or farmers.

6. The basic dryer unit should be a batch dryer that could be operated and maintained by the farm family. The batch size should be about 50 kg of high moisture rough rice.

7. The basic unit's drying capacity should be about 300 kg per day on the basis of 6 percent moisture removal.

8. The dryer should be modular such that the capacity could easily be increased to fit the larger farms. A ten-unit dryer should give about 3 mt per day capacity.

9. The cost of the dryer should be as low as possible.
SECTION V
DRYER CONSTRUCTION

Site Selection Criteria

1. Highest possible ground on the farm premise
2. Good drainage and no water logging on the building site
3. Closeness and convenience to get access to grain storage structure
4. Firm soil condition
5. Dryer located on the downstream direction of wind
6. Open space around the site
7. Closeness to an existing grain drying floor

Labor

1. One laborer with minimum or no skill as a mason
2. One helper

Tools

Use any available size. Suggested approximate specifications are given. One each is needed.

1. Hoe - 1.5 m long (5 ft)
2. Shovel - 1.5 m long (5 ft)
3. Carpenter's saw - 45.7 cm (18 in)
4. Trowel - 22.9 cm (9 in)
5. Level - 45.7 cm (18 in)
6. Machete - 61 cm (2 ft)
7. Strings - 15.3 m (50 ft)
8. Claw hammer - 680 g (1.5 lb)
9. Chisel - 15 cm (6 in)
10. Measuring tape - 4.6 m (15 ft)
11. Square - 45.7 cm x 45.7 (18 in x 18 in)

12. Five 19-liter (5 gallon) buckets

13. One 1 x 1 m (3 x 3 ft) wood or any hard surface

14. Tinsmith scissors - 31 cm (12 in)

15. Pencil and chalk

Materials (dimensions are approximate)

1. 75 concrete blocks - 40 x 20 x 15 cm (15 3/4 x 7 3/4 x 6 in) or 300 Adobe (mud blocks) - 24 x 18 x 10 cm (10 x 7 x 4 in)

2. Lumber
   a. 5 x 5 x 152.4 cm - 2 pcs
      (2 x 2 x 60 in)
   b. 2.5 x 30.5 x 76.2 - 2 pcs
      (1 x 12 x 30 in)
   c. 2.5 x 30.5 x 94.0 cm - 2 pcs
      (1 x 12 x 37 in)
   d. 2.5 x 10.2 x 88.9 cm - 1 pc
      (1 x 4 x 35 in)

3. 208 liter (55 ga.) oil drum - 1 No.
   (83.8 cm (33 in) long cylinder)

4. Perforated metal - 81.3 x 94.3 cm x 1.55
   (32 x 37 1/1 in x 16 gage) thickness
   2.4 mm (3/32 in) dia perforations on 4 mm (5/32 in) center to center -1 pc

5. Wood plank
   a. 162.6 x 15.2 x 1.3 cm - 2 pcs
      (64 x 6 x 1/2 in)
   b. 160.0 x 15.2 x 1.3 cm - 2 pcs
      (63 x 6 x 1/2 in)

6. Cement - 4 bags (46 kg (100 lb each))

7. Sand - 8 bags (46 kg (100 lb each))

8. Gravel - 12 bags of same volume size as sand bags

For adobe construction cement, sand, and gravel will not be needed.
Procedures

1. Select the site according to site selection criteria given above.

2. Flue opening should be positioned so as to face the prevailing wind direction during grain drying season.

3. Make water drainage arrangement in the site.

4. Remove the loose top soil if there is any.

5. Compact the soil after removing the top soil.

6. Dig about 8 cm (3 in) to 10 cm (4 in) into the ground covering 164 x 164 cm (64 1/2 x 64 1/2 in) area to position the slab made of concrete or adobe. Compact the soil firmly and level it. Lay four wood planks, item 5 of "materials", to form the 162.6 x 162.6 cm (64 x 64 in) slab in it.

7. For the dryer made of concrete blocks, mix concrete in the approximate volume proportion 1:4:6 (cement: sand: gravel). This mixture is somewhat lean on cement but will keep the expenditure low.

8. For the dryer made of mud blocks, select clay soil (yellowish clay good for adobe making). Beat the soil after adding the proper amounts of water and some reinforcing materials such as fibers, straw, rice husk, etc. by repeatedly stamping on it to make the soil and water mixture into a dough-like consistency, so that it could be formed into bricks. For brick forming use a 25 x 18 x 10 cm (10 x 7 x 4 in) box with the two 25 x 18 cm (10 x 7 in) surfaces removed, which will allow easy charging of mud into the form and discharging of the formed mud brick. About 300 mud bricks will be required. Lay the formed adobe under a shed for slow air drying. Quick drying in the sun could result in cracks. Turn the bricks at about 12 hour intervals which will assure uniformity of drying. Suggested drying time is 1-2 weeks depending on the weather.

9. Pour concrete as prepared in item 7 to form a 162.6 x 162.6 cm (64 x 64 in) slab 10 cm (4 in) to 15 cm (6 in) thickness (Figure 2) or lay adobe as prepared in item 8. Ram concrete properly to remove air bubbles and level the surface. For adobe construction use grouting made of the same type of clay as used for the mud brick.

10. Let the concrete slab cure for a day covering the surface with moist cloths, gunny sacks, etc. A curing period of 1-2 days is also suggested for adobe slab.

11. Lay the concrete or mud blocks such that the center of the slab and the center of the dryer coincide and the chimney has an internal dimension of 95.9 x 82.6 cm (37 3/4 in x 32 1/2 in) size opening (Figure 2). The external dimensions are not critical. Lay one layer of concrete blocks or two layers of mud blocks. Use soil and sand to fill in the pocket A, created on the foundation slab by the four walls formed by the blocks (Figure 2). Flash the soil and sand surface with the brick surface.

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12. Remove the top and bottom circular covers of the oil drum, item 3 of "materials". Now split the drum in half along the length. Use chisel and hammer. Each semi-cylindrical dome will serve as a flue for making fire underneath.

13. Position any one of the two flues like a dome such that length of the flue is parallel to the 82.6 cm (32 1/2 in) dimension of the chimney opening and perpendicular to the 95.9 cm (37 3/4 in) dimension (Figure 3). The flue should be positioned exactly in the middle such that it will rest on the front and back walls.

14. Complete the construction as shown in Figures 4 and 5.

15. Make a grain holding basket as shown in Figures 6, 7, and 8.

16. Make two semi-circular baffles by splitting the oil barrel bottom lid in half.

17. Make, over the dryer, a thatched roof supported on 6 vertical wooden posts about 15 cm (6 in) diameter and 3 m (10 ft) long with about 61 cm (2 ft) in the ground covering an approximate area 3.66 m (12 ft) x 3.66 cm (12 ft). Two horizontal cross posts supported over the 6 vertical posts should have about the same diameter. The structures will have no walls. The roof will allow grain drying during rainy days.

18. Let the dryer dry for about a week before starting grain drying.
Figure 2. Foundation slab and first layer of concrete block.
CONCRETE BLOCK

CONCRETE SLAB

FLUE MADE OF 55 GAL OIL DRUM

95.9 cm (37 3/4 in)

FLUE IS TO BE POSITIONED SYMMETRICALLY IN THE DRYER

162.6 cm (64 in)

162.6 cm (64 in)

10 to 15 cm (4 to 6 in)

82.6 cm (32 1/2 in)
FIGURE 4. Front View of Dryer

- Curved Wall
- Air Entry: Open Area 5 cm (2 in) Wide
- Flue Made of 55 Gal Oil Drum
- Ground Level: 10 to 15 cm, (4 to 6 in.) Thick Slab
FIGURE 5. Back View of Dryer

144.8 cm (57 in.)
123.8 cm (48 3/4 in.)

R 27.3 cm (10 3/4 in.)

FLUE MADE OF 55 GAL OIL DRUM

10 to 15 cm. (4 to 6 in.) THICK SLAB

GROUND LEVEL
Figure 7. Front, top, and right view of drying basket

2.5×5×94 cm (1×2×37 in) wood 2 pcs on opposite sides

2.5×30.5×94 cm (1×12×37 in) wood 2 pcs on opposite sides

- Handle Bar

2.5×30.5×76.2 cm (1×12×30 in) wood 2 pcs. on opposite sides

2.5×10×88.9 cm (1×4×35 in) wood 1 pc.

Perforated metal 81.3×94 cm (32×37 in) with about 2.4 mm (3/32 in) dia, hole on 4 mm (5/32 in) center, approximate thickness 1.5 mm (0.061 in)
2.5X5X94 cm (1X2X37 in) WOOD 2 PCS ON OPPOSITE SIDES

PERFORATED METAL 2.4 mm (3/32 in)
HOLDS ON 4 mm (5/32 in) CENTER
1.5 mm (0.061 in) THICK 81.3X94 cm
(32X37 in)

12 5 cm (2 in) NAILS INTO 2.5 cm
X 10 cm X 88.9 cm (1X4X35 in) WOOD
5 X 5 cm (2X2 in) WOOD HANDLE BAR

2.5X30.5X76.2 cm (1X12X30 in) WOOD
2 PCS. ON OPPOSITE SIDES

3.8 cm (1 1/2 in) DIA. HANDLE

ALL PARTS ARE NAILED TOGETHER BY USING
2.5 AND 5 cm (1 AND
2 in) NAILS.
SECTION VI
DRYING METHOD

1. Two persons will be needed to dry grain.

2. Collect the fuel sources such as wood, rick husks, corn stalk, rice straw, etc. The weight of the fuel required should be 1/10th of the grain to be dried. Better fuel economy could be achieved by properly managing the combustion rate.

3. Make a fire underneath the dome shaped flue (Figure 9) such that the whole flue area is covered.

4. Use the two baffles, item 6, under "Dryer Construction" in the front and back of the flue to regulate combustion, fuel combustion rate, and the grain drying rate.

5. Put about 45.5 kg (100 lb) of wet rough rice into the grain holding basket, item 15, under "Dryer Construction". Level the grain surface in the basket (Figure 9).

6. Put the basket on the top of the dryer such that the basket closely fits inside the dryer chimney and the handles rest on the wall (Figure 9).

7. Stir grain in the basket at 15 min intervals to achieve uniform drying.

8. To remove about 6 percent moisture from paddy use no less than 1 1/2 hour drying time. Quick drying of paddy results in more breakage during milling. For grains such as corn, sorghum, etc., this rule does not apply.
Hc__GRAIN
WITHIN THIS DRYING BASKET

SEMI-CIRCULAR
FLUE MADE OF
208 l (55 GAL)
OIL DRUM

USE BAFFLE IN
FRONT & BACK OF
FLUE TO CONTROL
FIRE & DRYING
AIR TEMPERATURE

SEMI-ANNULAR OPEN
SPACE FOR DRYING
AIR ENTRY
Experiments conducted in Peru and Belize showed that a 6 percent moisture removal from paddy could be achieved in 1 hour 10 minutes. The drying rate could be slowed down by reducing the amount of fuel, using baffles and increasing the amount of grain in the basket. The drying capacity was about 23 kg/hr of paddy in a single unit model.
SECTION VIII
CONCLUSION

This modular design dryer could be used in humid developing countries for various grain drying needs at a rate of 23 kg/hr to 230 kg/hr of paddy for a single-module and a ten-module dryer respectively. During grain drying season, a daily paddy drying capacity of 300 and 3,000 kg could be attained for the respective units. Capacity is expected to be higher for other grains, such as corn and sorghum.

The dryer has the potential for use in other drying needs such as cacao, oil seeds, spices, and fish.


Servicio Nacional de Meteorologia e Hidrologia (SENAMHI), Tingo Maria, Peru, 1980, personal contact.