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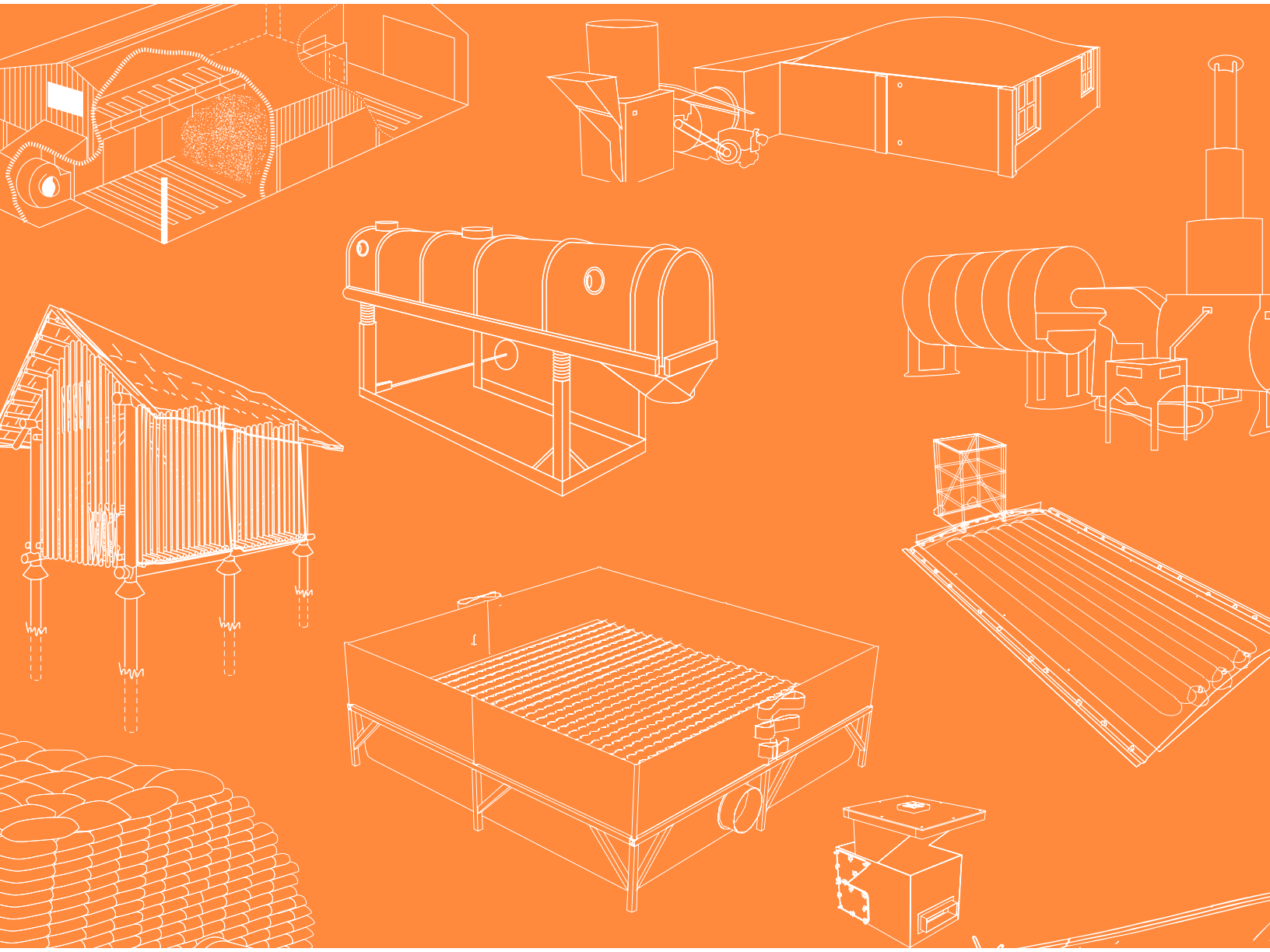

GRAIN DRYING SOURCEBOOK

Prepared by AflaSTOP: Storage and Drying for Aflatoxin Prevention

March, 2016

In partnership with:

CATAPULTDESIGN

Implemented / created by:

ACDI VOCA
Expanding Opportunities Worldwide

ASI
Make It Happen

Meridian Institute
Connecting People to Solve Problems

In support of:

PACA

Disclaimer

This sourcebook is a result of the partnership between Catapult Design and the AflaSTOP project to identify potential drying technologies suited to support post-harvest handling devices for grain farmers.

The technologies listed in this sourcebook are meant to provide a descriptive list of drying technologies currently available to grain farmers throughout the world. While the project strove to be inclusive, the list should not be considered exhaustive of any and all drying technologies.

The technologies inclusion, or lack thereof, in the sourcebook does not represent or imply endorsement.

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Executive Summary

The United States Agency for International Development (USAID) and the Bill and Melinda Gates Foundation (BMGF) partnered to co-fund the 5 year AflaSTOP: Storage and Drying for Aflatoxin Prevention project. AflaSTOP supports the objectives of the Partnership for Aflatoxin Control in Africa (PACA), and is jointly implemented by ACDI/VOCA and Agribusiness Systems International (ASI) under the direction of Meridian Institute.

The AflaSTOP project is identifying the most promising storage options for smallholders to arrest the growth of aflatoxin and designing viable drying technologies that will dry grain to safe storage levels. To implement effectively, AflaSTOP collaborates closely with researchers, appropriate-technology engineers and manufacturers (formal and informal), and government bodies (e.g. Kenya Ministry of Agriculture).

From the outset, AflaSTOP had an ambitious vision: widespread farmer adoption of technologies that impact aflatoxin development. The storage and drying technologies each have unique, although related, challenges and this sourcebook supported our activities to identify and design a viable drying technology for smallholder farmers.

In countless regions in tropical Africa smallholder farmers struggle to adequately dry their grain crops when rains follow soon after harvest. Grain is generally rushed into storage while the farmer shifts their attention and efforts to preparing their land for the next planting season. The traditional solution, common among smallholder farmers, is lying the crop of the ground to dry in the sun. This can often take weeks or days, depending on the weather, can results in post-harvest damage that is exacerbated by being stored at a higher than optimal moisture content.

For our vision to be realized, AflaSTOP must successfully improve or design a viable new drying technology, then transfer it to the commercial sector and facilitate going-to market and scale up – all within a few years and very limited market-distorting subsidies. As agricultural drying is a global issue being addressed by a diverse set of global and local stakeholders, the project's first step was to conduct an overall survey of currently available technologies to ensure we didn't repeat dead-end developments and/or not learn from new approaches. The technology development process takes years – we knew we had to aggressively research and collaborate with other stakeholders to jump start the process.

The following sourcebook was the first step in AflaSTOP's drying technology design endeavor. This document gave us the ability to identify promising designs and quickly compare and contrast differing elements and approaches. Each description gives an overview of the operating parameters, resource requirements, and positive and negative aspects of adoption.

Whether embarking on your own research and development, procuring a mechanized dryer for a cooperative or association, or simply trying to identify low-cost, in-field option for drying, I hope this sourcebook serves as a, similarly, effective first step.

Sophie Walker
Chief of Party, AflaSTOP
ACDI/VOCA & ASI

UNASSISTED AIR AND SUN

MOST SUITABLE FOR: On farm, low-cost, small batches, reliable weather

+

- Low-cost
- Works with limited material resources
- Little regular maintenance
- Some designs offer protection from environment

-

- Drying effectiveness dependent on climate
- Little to no protection from insects, soil and/or rain
- Some designs require additional labour (mixing and/or guarding)
- Slow and time-consuming

In-Field Drying

A drying method done when crops are first harvested. The maize remains on the stalk until dry enough for the next process.

AMBIENT

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Reliable weather, good security, minimal inputs

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	~30 days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	no cost
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	n/a
Footprint (m^2)	1 m^2 — 50 m^2	large

CHARACTERISTICS

Required Resources	Available field, security, climate conditions
Energy Input	Ambient environmental energy (sun, wind)
Form Factor	n/a
Mobile or Fixed	n/a
Integrated Drying Storage	n/a
Weather Dependent	Yes
Other Uses	None

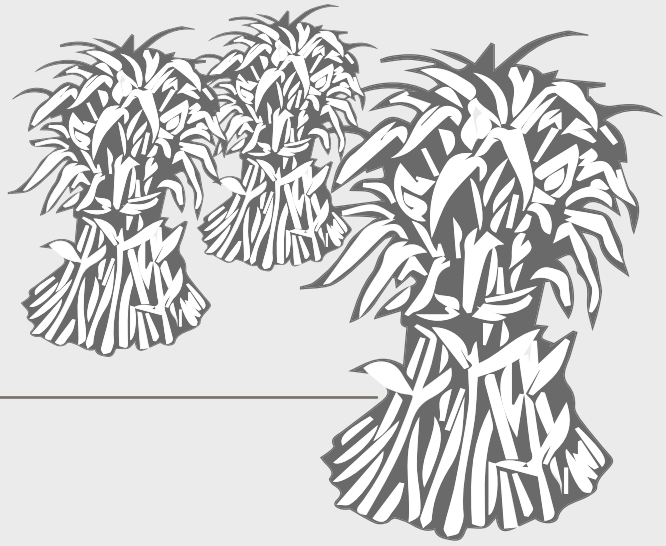
DETAILS

The longer maize can be left to dry on the stalk in the field (given ideal environmental conditions), the less time and energy is required for post-harvest drying. Minimum M/C that can be achieved from in-field drydown is 13.5 to 20 percent.

The rate of maize drydown in the field correlates closely to the maturation date of the crop and local weather conditions at maturity. Maize that reaches maturity during warmer, dryer weather will dry more quickly and completely than maize that matures later in the season, or during typically cooler, wetter periods. Drydown rates from 0.8 percentage points to 1.0 points per day can be expected during the warmest periods (24ºC), and less than 0.4 percentage points during cooler, damper weather (13ºC). Under good weather conditions, hybrids dry at similar rates. In less favorable conditions, the difference in hybrid maturation dates is more significant.

The crops are cut down and tied together creating a landscape of drying bundles in the field.

Bundles are composed of approximately 50 stalks.



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- Easiest, least expensive means to achieve initial drydown
- Requires no additional resources

-

- Delays field prep and planting of next crop
- Hiring a watchman for drying maize adds to cost
- Increased risk of contamination when maize can come into contact with soil

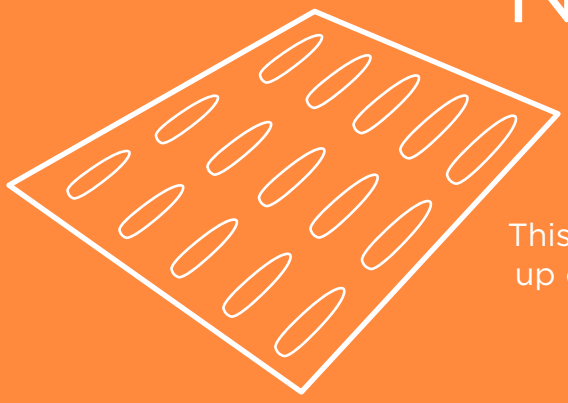
SOURCES

www.agry.purdue.edu/ext/corn/news/timeless/graindrying.html

cdn2.bigcommerce.com/n-biq04i/tqlla/products/3552/images/7213/J-84__33211.1379418043.380.500.gif

www.fao.org/docrep/005/x0530e/x0530e05.htm

Natural Drying Direct Sun



This is one of the most low-cost, easily set-up drying methods in which grains are laid out on a tarp and dried in the sun.

SOLAR

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Ultra low-cost, small batches, spacious farms

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	low
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	11
Footprint (m^2)	1 m^2 — 50 m^2	25 m^2

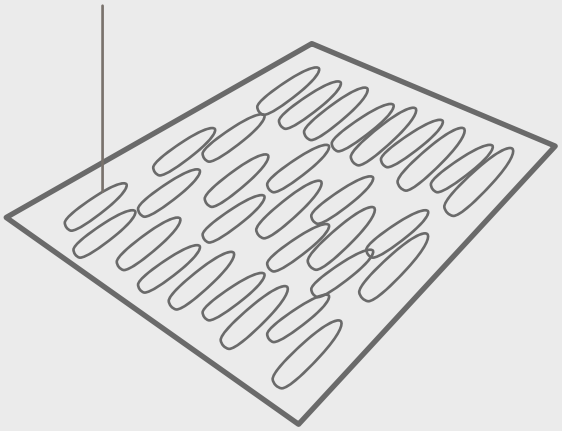
CHARACTERISTICS

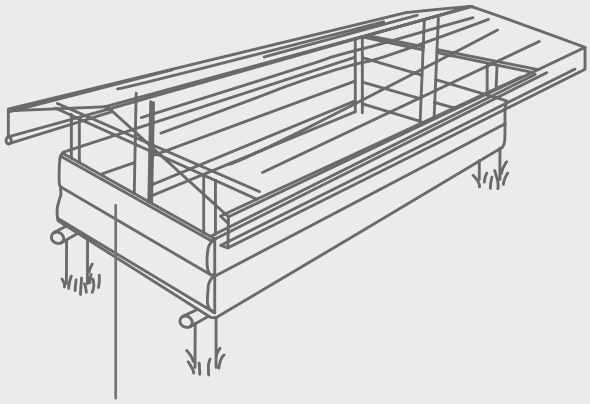
Required Resources	Surface cover or shallow bed; sufficiently arid conditions
Energy Input	Environmental
Form Factor	Flat surface
Mobile or Fixed	Surface cover: mobile; concrete slab: fixed
Integrated Drying Storage	No
Weather Dependent	Yes
Other Uses	Tarps may be repurposed

DETAILS

- Requires the grain be maintained in a shallow layer and mixed frequently
- A clean ground cover (e.g. taurpaulins, concrete slabs) should be used to maintain hygienic grain
- Harvested crop is spread on hard surface ground, roofs, or specially built platforms or trays
- Exposed to the sun, the crop will dry fairly quick depending on the humidity of the ambient air
- Crop has to be brought in or covered every evening or before rain
- Labor may be reduced considerably by placing crop on a plastic or tarpaulin sheet for easy handling
- Can dry cobs and shelled maize
- Performance can be significantly increased if the drying surface is black or constructed of elevated mesh trays
- Additional perfomance might be gained in arid conditions using purpose-built mesh trays and tranparent roof

Cobs are laid or bundled on the tarp and dried in the sun.





Alternatively, an elevated, shallow bed may be used for greater efficiency.

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- Low cost
- Low skill
- Tarpaulin is mobile
- Concrete slab is durable
- No maintentance required
- Local materials

-

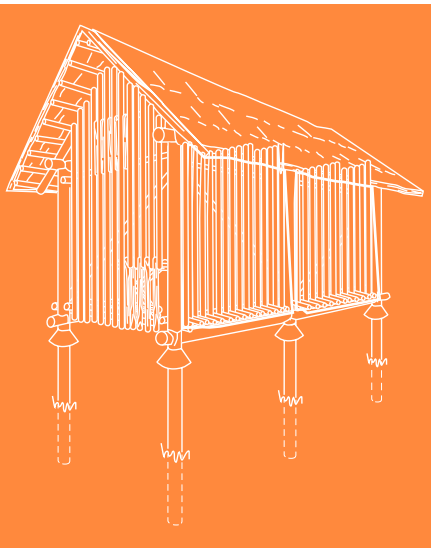
- Slow and low capacity
- Labor intensive
- Dependent on weather
- Concrete slab requires construction
- Concrete slab is fixed and requires permanent use of land
- Requires supervision to prevent consumption by animals
- Requires rapid gathering if rain threatens

SOURCES

www.fao.org/docrep/015/i2433e/i2433e10.pdf

www.fao.org/docrep/s1250e/S1250E0v.htm#Natural Drying

www.acdivoca.org/site/Lookup/CropConditioningHandbook/$file/CropConditioningHandbook.pdf



Grain Crib

Improved grain cribs increase ventilation over traditional designs. Designed for the drying and storage of maize on the cob. Expensive to build, prone to termite damage and losses to vermin.

AMBIENT

NATURAL CIRCULATION

STORAGE

MOST SUITABLE FOR: Short-term cob storage in arid environments

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	weeks
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med-high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	9.3-44.8
Footprint (m^2)	1 m^2 — 50 m^2	to 9 m^2

CHARACTERISTICS

Required Resources	Construction materials, appropriate climate
Energy Input	Ambient environmental energy (sun, wind)
Form Factor	Round (traditional) or rectangular (improved) enclosure
Mobile or Fixed	Fixed
Integrated Drying Storage	Yes
Weather Dependent	Yes
Other Uses	Storage of dried, bagged kernels; other materials

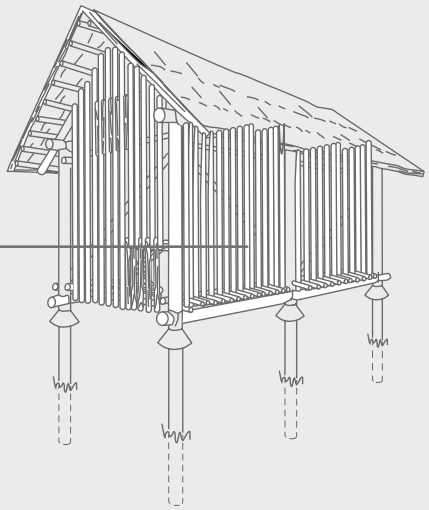
DETAILS

- Consists of wooden construction with chickenwire mesh for ventilation
- Designed for holding maize cobs in humid environments
- Improves upon more traditional designs in that it is longer and thinner to increase ventilation
- Expensive to build and prone to termite damage
- Where rain is possible at the time of harvest, tarpaulins may be needed to cover grain during rainfall

Traditional circular granaries may still be used with some modifications:

- The basket is more loosely woven, or the wall can be slatted with at least 40 percent air space.
- Granary diameter can vary up to 150 cm depending on ambient humidity.
- Rectangular granaries are more economical when production exceeds five to nine bags.
- Rectangular structure illustrated is called a ventilated maize crib.
- Design is intended for drying of maize on the cob without the husk, but it can be used with small modifications for any crop that needs ventilation.

Ventilated grain crib for drying maize on the cob:
The structure has slatted walls and should be placed with the long wall facing the prevailing wind.
In some areas, farmers reduce the ventilation gaps and close the structure more to prevent people from seeing the volume of maize in order to prevent theft and demands for food.



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- Can be built with local materials and knowledge
- Minimal maintenance
- Culturally familiar to small farmers
- Capacity can be adjusted according to need
- Cribbing allows farmers to harvest maize as soon as it is ripe

-

- Construction costs can be significant
- Drying effectiveness dependent on climate
- Does not protect against insects and little protection from vermin; rat guards are often needed
- Requires a dedicated space

SOURCES

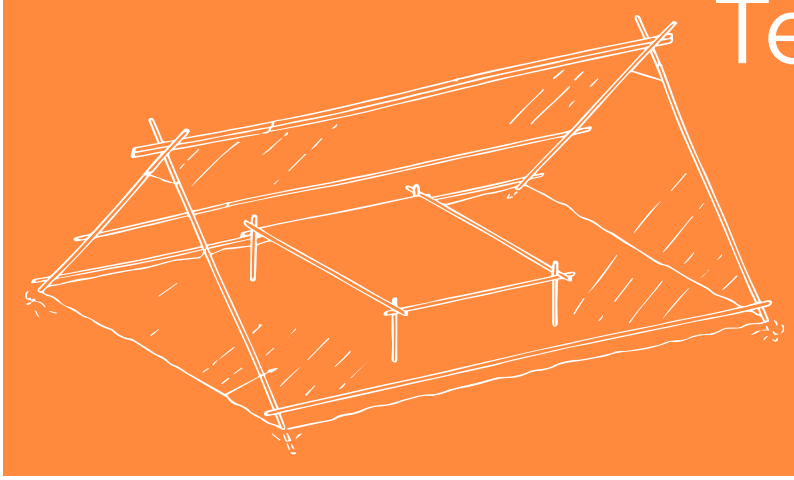
www.fao.org/docrep/015/i2433e/i2433e10.pdf

www.fao.org/docrep/s1250e/S1250E0v.htm#Natural Drying

www.fao.org/docrep/t1838e/T1838E0V.HTM

www.postcosecha.net

Tent Dryer



A clear plastic tent protects grain and captures heat from the sun.

SOLAR

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Low-cost and small batches

RELATIVE DATA

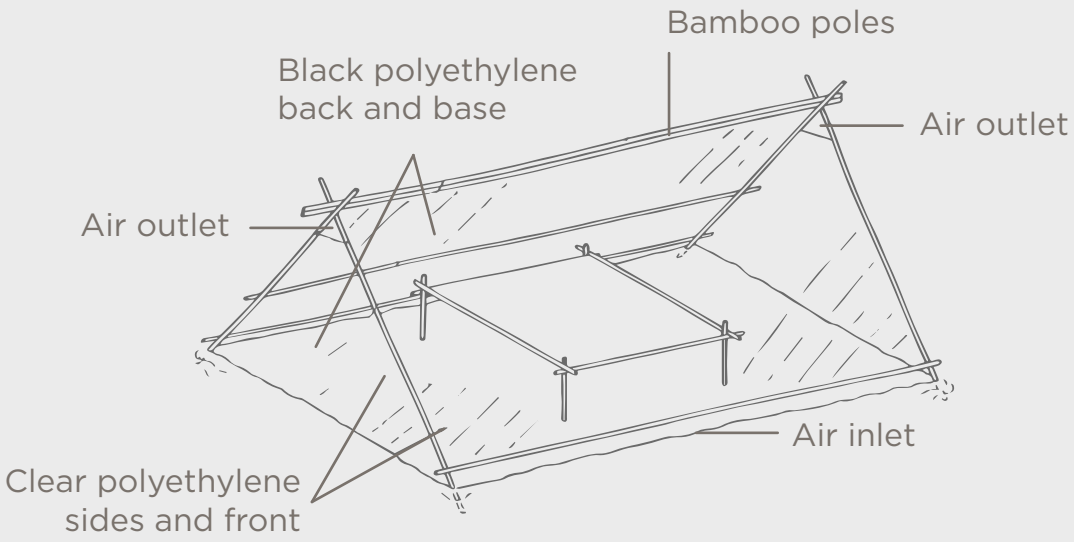
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	low
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	n/a
Footprint (m^2)	1 m^2 — 50 m^2	n/a

CHARACTERISTICS

Required Resources	Availability of construction materials
Energy Input	Environmental
Form Factor	Tent
Mobile or Fixed	Fixed
Integrated Drying Storage	No
Weather Dependent	Yes
Other Uses	Tarps may be repurposed (though risk damage)

DETAILS

- Similar to a greenhouse and constructed to protect grain and capture heat
- Airflow up and through the tent is encouraged using vents
- Grain may be lifted off the ground on mesh trays to enhance airflow and circulation
- Tent dryers are primarily used for small-scale fruits/vegetables and fish processing; it's estimated that drying time would take two to three days per batch of >20 percent MC grain



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- Low cost
- Mobile
- Protected from environment

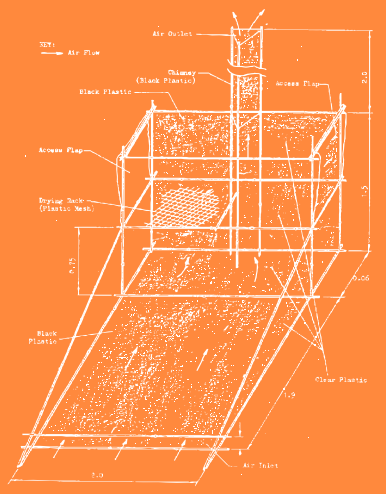
-

- Slow and low capacity
- Some skill required
- Dependent on weather
- Labor intensive
- Increased difficulty in stirring grain bed frequently

SOURCES

www.fao.org/docrep/X5018e/x5018E0h.htm#4.10

practicalaction.org/small-scale-drying-technologies



Solar Chimney Dryer

Simple components — a solar collector, a drying bin, and a solar chimney — make this dryer appropriate for on-farm use.

SOLAR

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Low-cost and small batches

RELATIVE DATA

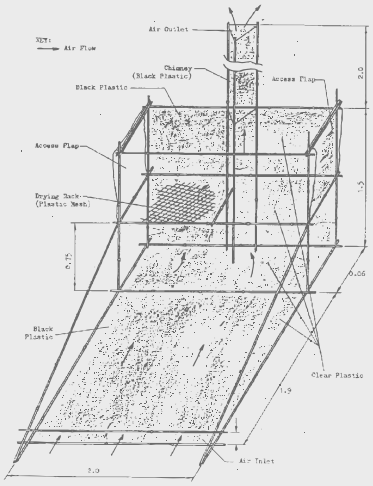
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	n/a
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	medium
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	low
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	11.1
Footprint (m^2)	1 m^2 — 50 m^2	38.5

CHARACTERISTICS

Required Resources	Availability of construction materials
Energy Input	Environmental
Form Factor	Rectangular
Mobile or Fixed	Fixed
Integrated Drying Storage	No
Weather Dependent	Yes
Other Uses	Drying fruits or vegetables

DETAILS

- Sized appropriately for on-farm use, but primarily used for rice paddies
- Design has undergone considerable development by the Asian Institute of Technology (AIT) in Bangkok, Thailand (Boothumjinda et al. 1983; Exell 1980)
- Consists of three components: a solar collector, a drying bin, and a solar chimney
- For a 1000 kg-capacity dryer, the collector is 4.5 m long and 7.0 m wide with the solar absorber base of burnt rice husks or black plastic sheet covered with a clear plastic sheet; the drying bin is 1.0 m long and 7.0 m wide with a base of perforated steel or bamboo matting
- Constructed of a bamboo frame covered with a black plastic sheet
- Grain quality is appreciably greater than that from sun-dried grain
- High structural profile poses stability problems in windy conditions
- Plastic sheet must be replaced every one to two years
- A smaller (100 kg capacity) and simpler version of this type of dryer has also been developed (Exell and Kornsakoo 1978; Oosthuizen and Sheriff 1988)



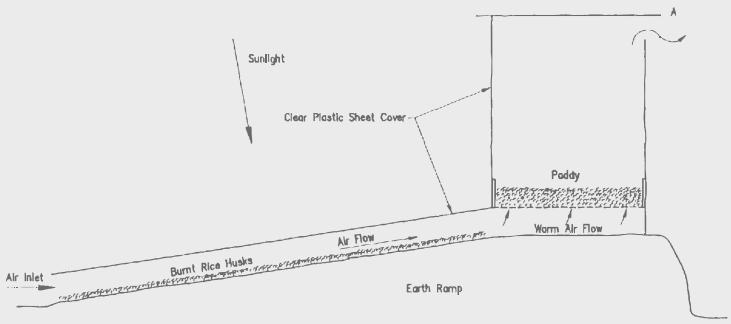


FIGURE 8: SMALL SCALE SOLAR PADDY DRYER (EXELL AND KORNSAKOO 1980)

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- Relatively low-cost
- High-quality grain
- Protected from environment

-

- Slow
- Low capacity
- Requires construction
- Nonmobile
- Dependent on weather
- Easily damaged
- Labor-intensive

SOURCES

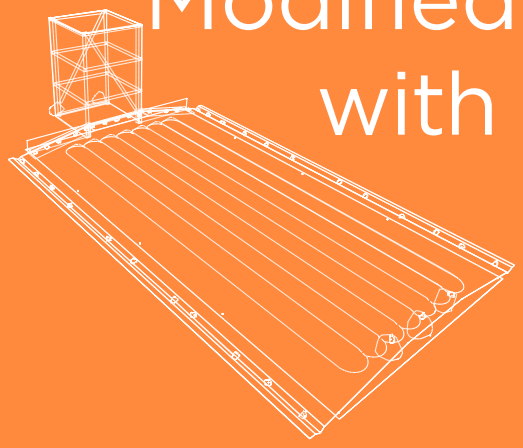
www.fao.org/docrep/X5018e/x5018E0h.htm#4.10

www.fao.org/docrep/t1838e/T1838E0V.HTM

practicalaction.org/small-scale-drying-technologies

www.fao.org/docrep/t1838e/T1838E1l.GIF

Modified Solar tarpaulin with Chimney Dryer



Solar chimney increases air speed over grain on tarpaulin and speeds up drying in dry conditions, protects grain from rain, suitable on farm use

SOLAR

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Best for low-cost, small batches

RELATIVE DATA

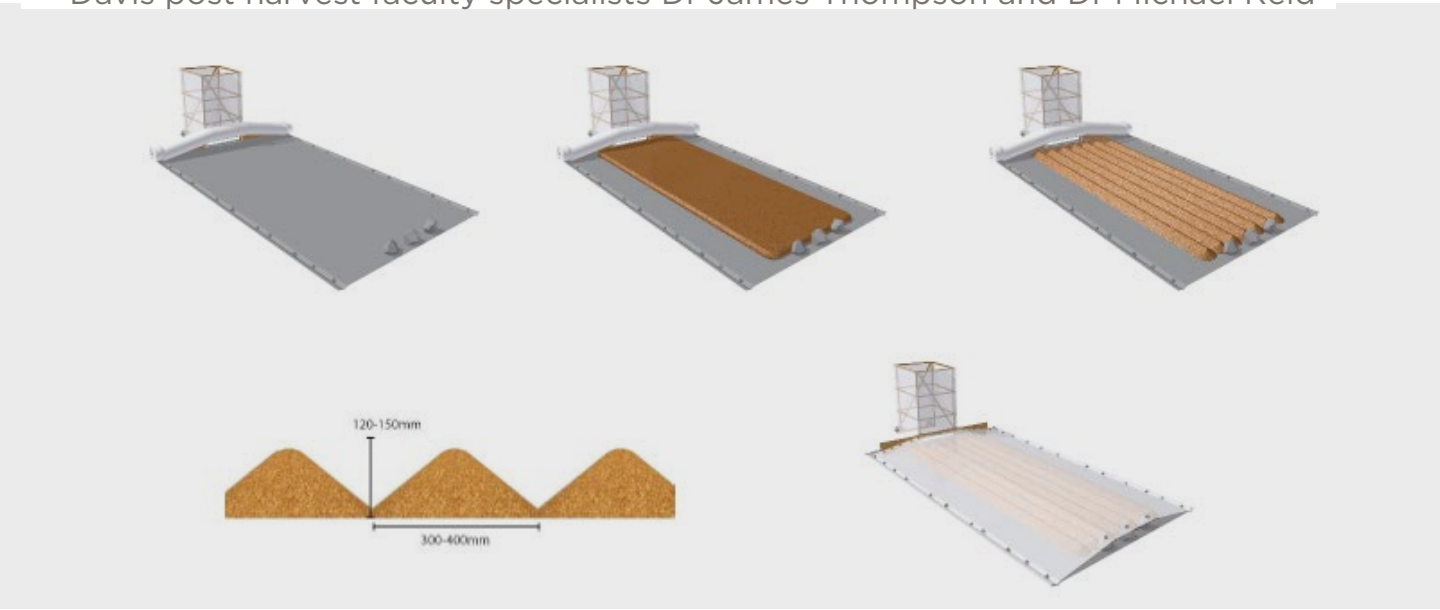
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	n/a
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	low
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	low
Footprint (m^2)	1 m^2 — 50 m^2	38.5

CHARACTERISTICS

Required Resources	Level surface, open area, unshelled or shelled maize
Energy Input	Solar/sun drying
Form Factor	7 m x 4.5 m sheet footprint
Mobile or Fixed	Fixed per batch; mobile in between batches
Integrated Drying Storage	No
Weather Dependent	Yes
Other Uses	Drying other grains, fruits, or vegetables

DETAILS

- Consists of three components: a solar collector, a duct structure, and a solar chimney
- Solar collector is constructed of a black plastic sheet placed on the ground with a clear plastic sheet suspended above it; the duct structure is constructed from plywood; and the solar chimney is constructed of a wood frame covered with clear plastic sheet
- Air is heated within the solar collector and drawn across the grain along the parallel rows due to the draft from the chimney
- Sized appropriately for on-farm use: for a 1 T capacity dryer, the collector is 4.5 m long and 7.0 m wide with grain bed spread 4.0 m long and 6.0 m wide in parallel rows on the black sheet
- Does not appreciably increase drying times in cloudy or raining conditions
- High profile of the chimney poses stability problems in windy conditions
- Protects grain from rain and animals reducing on farm labour
- The original high air velocity solar dryer for maize drying was designed by UC Davis post harvest faculty specialists Dr James Thompson and Dr Michael Reid



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- Relatively low cost
- High-quality grain
- Protected from environment

-

- Slow
- Low capacity
- Requires construction
- Nonmobile
- Dependent on weather
- Easily damaged
- Labor intensive
- Ineffective in high humidity

SOURCES

Data is based on prototyping and testing conducted by Catapult Design and ASI.

Concept based on the work of UC Davis.

FORCED AIR LOW-MECHANIZED

NON-SOLAR

FORCED AIR

NATURAL CIRCULATION

BATCH

STORAGE

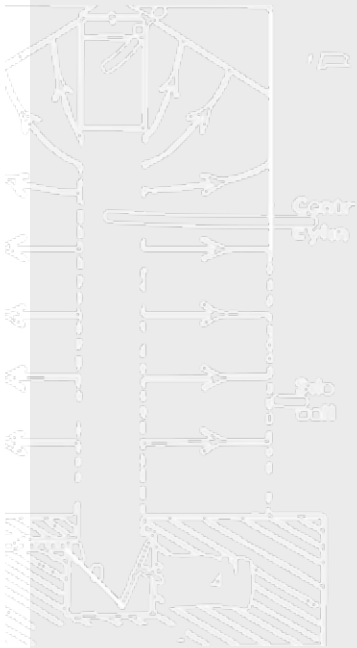
MOST SUITABLE FOR: Medium to large batch drying at faster speed

+

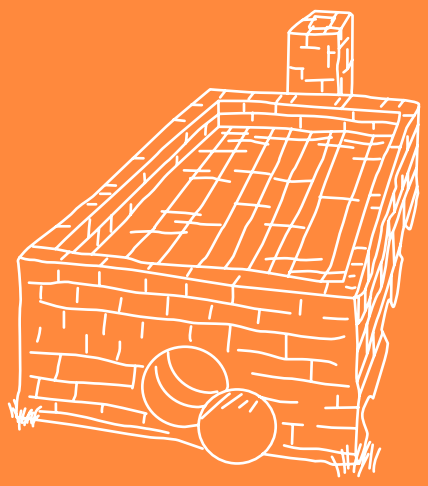
- Rapid and thorough drying
- Some solutions offer storage and drying
- Higher capacity per batch
- Protects grain quality

-

- More expensive than unassisted sun and air options
- Generally requires skilled design, fabrication and sometimes operation
- Energy (fuel or electricity) dependent
- Some solutions offer slow drying, some require additional protection from the elements



Wet grain
Drying zone
Dry grain



Thin Layer Dryer

This is simple to construct using available and inexpensive materials as well as easy to operate with unskilled labor.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Small- to medium-batch drying (less than 1MT)

RELATIVE DATA

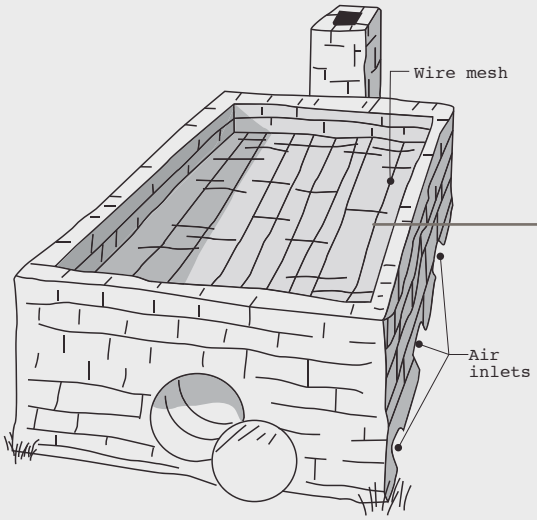
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	6-12 hours
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	med-high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med-high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	11-20
Footprint (m^2)	1 m^2 — 50 m^2	11m^2 (per 1 MT)

CHARACTERISTICS

Required Resources	Electricity or fuel for fan motor; biomass or hydrocarbon fuel
Energy Input	Electric or engine-driven fan; biomass or hydrocarbon heat source
Form Factor	Rectangular or round bin; grain bed depth <150 mm
Mobile or Fixed	Fixed for standard volumes; mobile possible for small volumes
Integrated Drying Storage	No
Weather Dependent	No, but must be covered in the case of rain
Other Uses	Drying other commodities

DETAILS

- Consists of a box enclosure with wire mesh tray top and a plenum below; a metal tube is run through the plenum and connects a firebox to a chimney
- Exhaust from a biomass fire is piped through a plenum below the grain, which rests on a mesh surface, and rises out of a chimney; the surrounding air in the plenum is heated by the exhaust and passively rises through the grain; additional plenum air is drawn from vents at the bottom of the dryer
- A hybrid-solar variation (i.e. McDowell Dryer) incorporates a glass roof and exposes the grain to direct solar radiation to accelerate drying
- Walls of the drying bin can be constructed of wood, brick, or metal
- Floor of the drying chamber is preferably made from suitably supported, fine wire mesh or perforated metal; if these are not available, sacking spread over a coarser but stronger wire mesh can be used
- Dimensions may be one to two meters wide and two to four meters long with the grain bed being very thin and requiring frequent stirring



The fan can be located anywhere close to the drying bed. The shorter the distance, the greater the efficiency.

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- Simple construction
- Good control over drying process
- Can dry rapidly and thoroughly

-

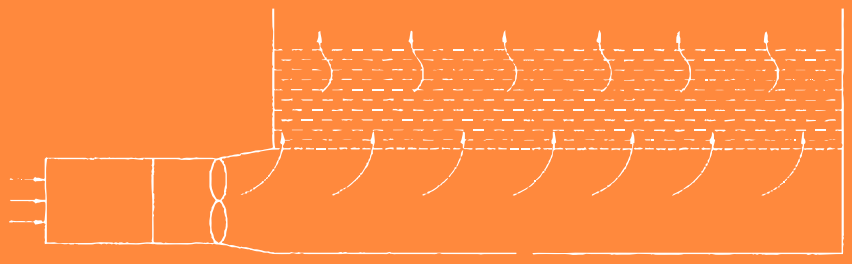
- Limited capacity
- Requires frequent attention during drying

SOURCES

www.fao.org/docrep/015/i2433e/i2433e10.pdf

practicalaction.org/small-scale-drying-technologies

Shallow Layer Dryer



Similar to the thin layer dryer, the grain is supported on a mesh tray.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Medium- to large-batch drying

RELATIVE DATA

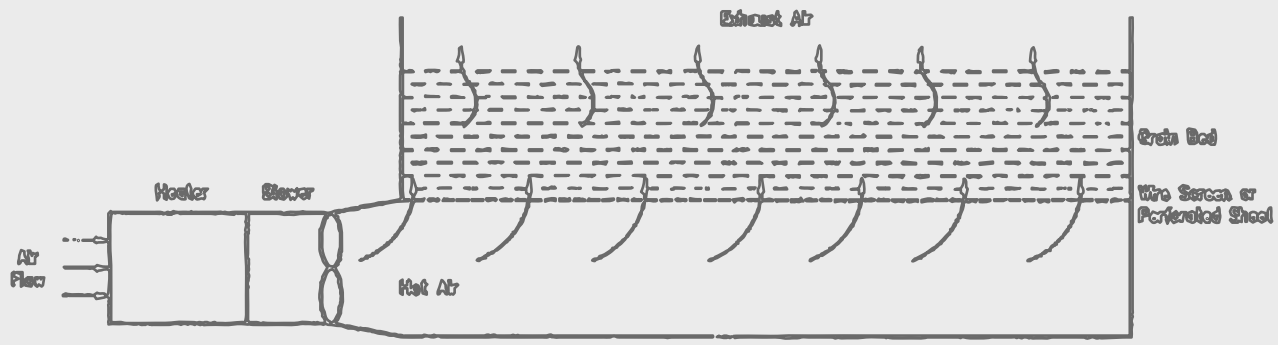
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	1-5 days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	med-high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med-high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	11-20
Footprint (m^2)	1 m^2 — 50 m^2	9 m^2 (per 2MT)

CHARACTERISTICS

Required Resources	Electricity or fuel for fan motor; biomass or hydrocarbon fuel
Energy Input	Electric or engine-driven fan; biomass or hydrocarbon heat source
Form Factor	Rectangular or round bin; grain bed depth 150-300mm
Mobile or Fixed	Fixed for standard volumes; mobile possible for small volumes
Integrated Drying Storage	Possible
Weather Dependent	No, but must be covered in the case of rain
Other Uses	Drying other commodities

DETAILS

- Simple to construct using available and inexpensive materials; easy to operate with unskilled labor
- Walls of the drying bin can be constructed of wood, brick, or metal
- Floor of the drying chamber is preferably made from suitably supported, fine wire mesh or perforated metal; if these are not available, sacking spread over a coarser but stronger wire mesh can be used; furnace fumes would be separated from the grain
- Consists of a box enclsoure with mesh tray top and an open airspace (plenum) blow; heated air is forced through the grain using an elecric blower
- Heat may be generated from any fuel source
- One to two meters wide and two to four meters long with a 150 - 300 millimeter-deep grain bed
- A stacked variation can also be built vertically with channels for both inlet and outlet air going through the grain (see alternate Figure - www.fao.org/docrep/s1250e/S1250E8Z.GIF); warmed air is blown into the plenum chamber beneath and then up through the grain



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- Effective drying of larger volumes of grain
- Good quality product

-

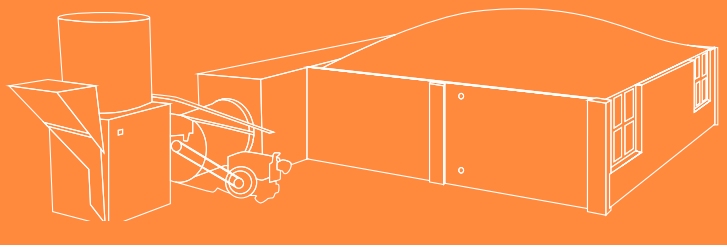
- Decreased efficiency compared to shallow-bed solutions
- Deep grain beds may result in inconsistent drying

SOURCES

www.fao.org/docrep/s1250e/S1250E0v.htm#Natural Drying

www.fao.org/docrep/t1838e/T1838E1L.GIF

Reversible-Air Flat-Bed Dryer



Offers more consistent and thorough drying than a unidirectional-flow shallow bed.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Batches with varying moisture content

RELATIVE DATA

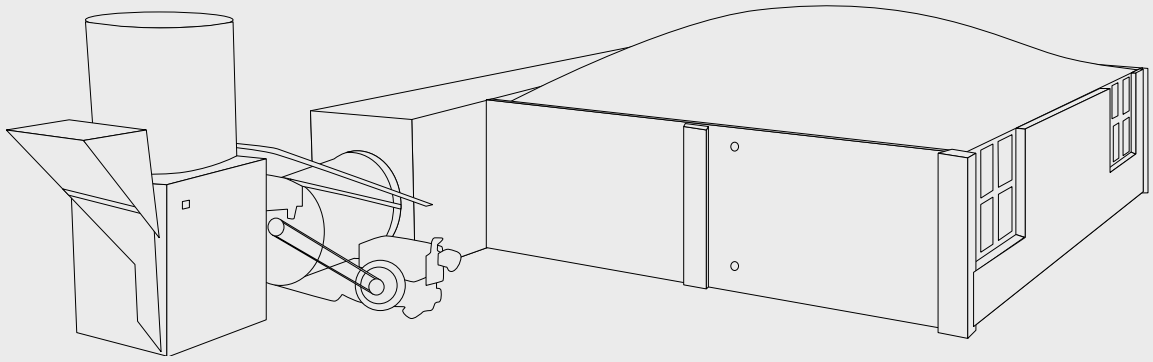
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour / 1 day / 1 month	day
Relative Operating Cost (% greater than current operating cost)	low <20% / medium 20-50% / high >50%	med-high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% / medium 100-300% / high >300%	high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags / 50 bags	11-30
Footprint (m^2)	1 m^2 / 50 m^2	n/a

CHARACTERISTICS

Required Resources	1.5-2 kw x ton for an engine-powered fan
Energy Input	Biomass or hydrocarbon heat source; potential for solar heating
Form Factor	Cylindrical or rectangular bin
Mobile or Fixed	Fixed for standard volumes; mobile possible for small volumes
Integrated Drying Storage	No
Weather Dependent	No
Other Uses	Drying other commodities

DETAILS

- Similar to a shallow layer dryer but with a deeper bed and additional capacity
- To facilitate even airflow, the length of the drying chamber should be two to three times the width
- Unloading ports can be fitted at intervals in the walls of the drying chamber
- To prevent excessive moisture gradients through the bed, the depth of grain in the bin is relatively shallow at 0.4 - 0.7 m and the air velocity is usually of the order of 0.08-0.15 m/s for maize; with these bed depths and air velocities, the pressure drop over the bed is relatively low at 250-500 Pa, and therefore simple and inexpensive axial-flow fans can be used
- Typically, power requirements are 1.5 - 2.5 kW per metric ton of grain for a belt-driven fan powered by a petrol or diesel engine
- Air temperature is selected according to the desired safe storage moisture content of the grain
- A “collapsible” variation may be constructed, though it requires considerable effort to collapse, transport, and reassemble in a new location
- Direction air passes through grain can be reversed so grain mixing not necessary



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- Saves labor compared to flat-bed dryers
- Uses half the area of a conventional flat-bed dryer for a given volume of grain
- Good uniformity of moisture content

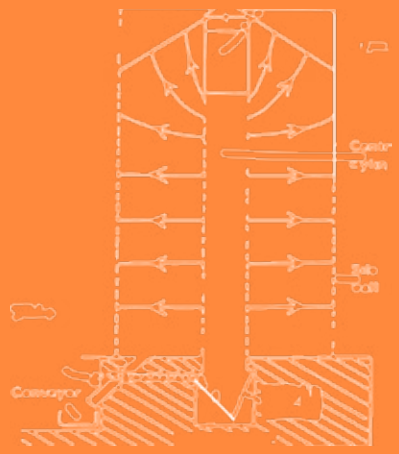
-

- Requires more sophisticated fan drive and plenum design

SOURCES

www.fao.org/docrep/t1838e/T1838E0w.htm

www.youtube.com/watch?v=sZvB8b6vPro



Radially Vented Bin

This dryer is appropriate for both mobile or on-farm applications.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Small batches of relatively dry grain

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	1 T
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low-med
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	11
Footprint (m^2)	1 m^2 — 50 m^2	n/a

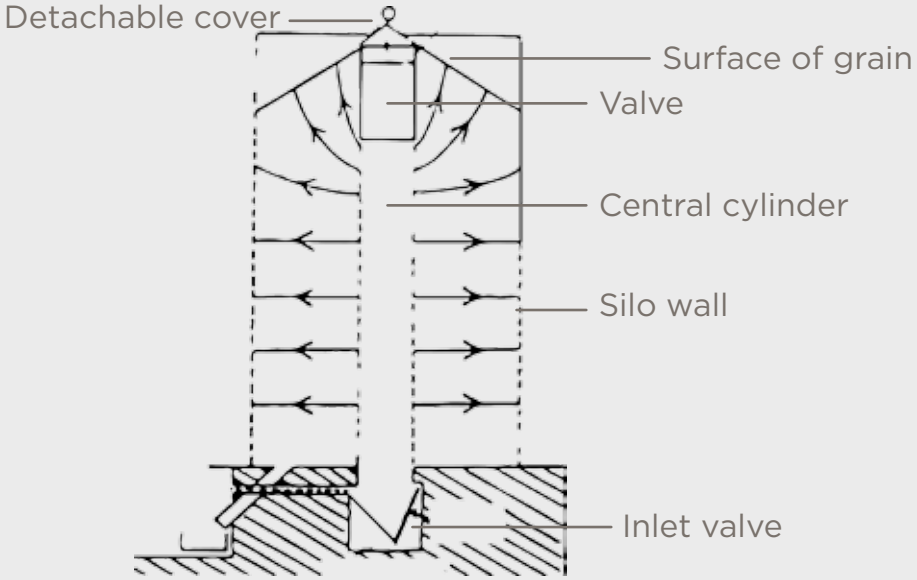
CHARACTERISTICS

Required Resources	Forced-air source; can use ambient or heated air
Energy Input	Power source for fan; can use ambient air or heated air source
Form Factor	Cylindrical
Mobile or Fixed	Either; design is appropriate for mobile applications
Integrated Drying Storage	Possibly
Weather Dependent	No
Other Uses	Drying other commodities

DETAILS

The bin wall is made of perforated steel or timber staves alternating with perforated steel strips. The distance between the duct and the bin wall is one to two meters, depending on bin size. The air path through the grain is thus limited to the radius of the bin. Air velocity will also decrease gradually towards the outer wall. They are normally used as a batch dryer with the grain then transferred to a store for either bulk or bag storage. When drying wet grain, the height in the bin should be decreased in order to increase the air velocity and eliminate high pressure on grain in the bottom of the bin.

- Heat may be generated from any fuel source
- A low-cost variant is the SRR Low Cost Dryer developed in Vietnam (US$100, 1 MT capacity)
- Radially vented bin dryers are normally fixed (nonmobile) solutions



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- Inexpensive: can be made using cheap local materials
- Compact: save floor area compared to standard batch dryers

-

- Inefficient: create higher moisture gradients than flat-bed dryers
- May not dry consistently or thoroughly

SOURCES

www.fao.org/docrep/015/i2433e/i2433e10.pdf

www.kongskilde.com/~/media/DLG/Kongskilde/DownloadLib/Brochures/Grain%20Handling/Storage%20Equipment/Wooden%20Silos%20-%20KCT%20KC/121001514%20GC%20GB%20KCT%20BRO%200401.pdf

Deep Layer Dryer

A combined drying and storage solution appropriate for cooperatively-owned systems

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Drying and storage of large batches

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	days to weeks
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med-high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	1000+
Footprint (m^2)	1 m^2 — 50 m^2	12 m^2 for 2T capacity

CHARACTERISTICS

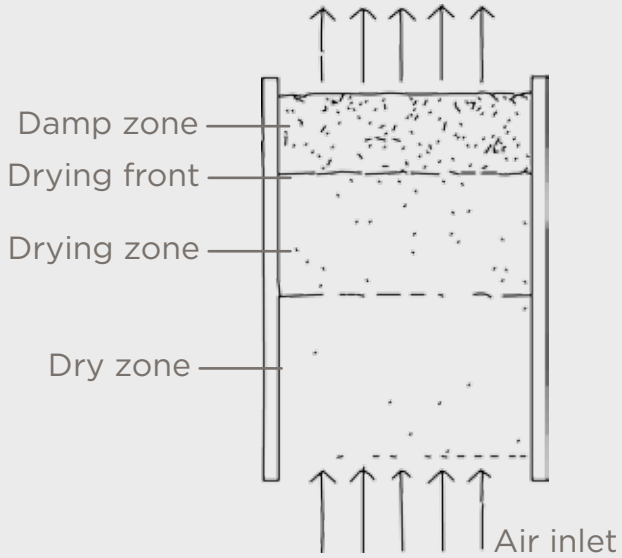
Required Resources	Fan and ambient or heated air; skilled labor
Energy Input	Electric or motor-driven fan; biomass or hydrocarbon heat source
Form Factor	Cylindrical or rectangular bin
Mobile or Fixed	Mobile is possible for small volumes
Integrated Drying Storage	Yes
Weather Dependent	No
Other Uses	Drying other commodities

DETAILS

These consist of beds, bins, silos, or rectangular warehouses equipped with ducting or false floor through which air is distributed and blown through the grain. The depth of the grain layer may be from 30 cm and up to 350 cm.

In deep layer dryers, unheated or slightly heated air (less than 6° C) is forced through the grain by a mechanical fan. The grain dries first at the point where the air enters. Next, a drying front passes through the mass in the direction of air movement, and then the grain at the air discharge location dries last. Most of the drying occurs just below the drying front in a layer called the drying zone, which develops and then moves through the bulk. The depth and rate of progress of the drying zone depends largely on the dampness of the grain and the air speed. A low ventilation rate results in a shallow, slow-moving zone whilst a higher rate produces a deeper zone which progresses more quickly.

Management and skilled operation of the drying zone is critical to prevent mold.



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- Simple design
- Combines drying with long-term storage
- High capacity but also adaptable as a mobile service
- Dryer design can be simple or require qualified design/engineering for larger capacities

-

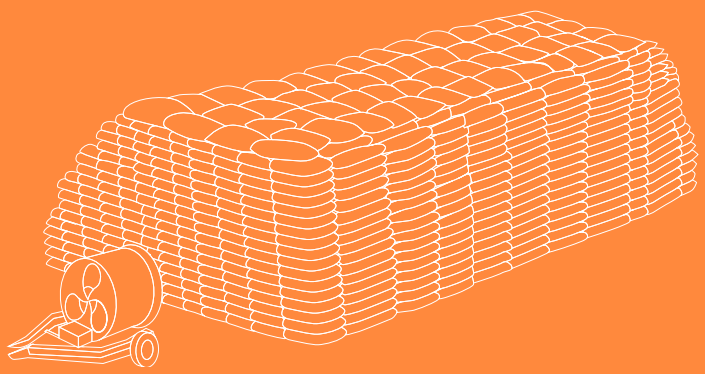
- Slow drying: risk of mold if not carefully managed
- Less effective in humid environments

SOURCES

www.fao.org/docrep/s1250e/S1250E0v.htm#Natural Drying

www.agridry.com.au/products/mobilegrain_dryers/PredatorSeries.html

Sack Drying System



This is a simple system suitable for high-capacity applications.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: High capacity drying and storage of bagged grain

RELATIVE DATA

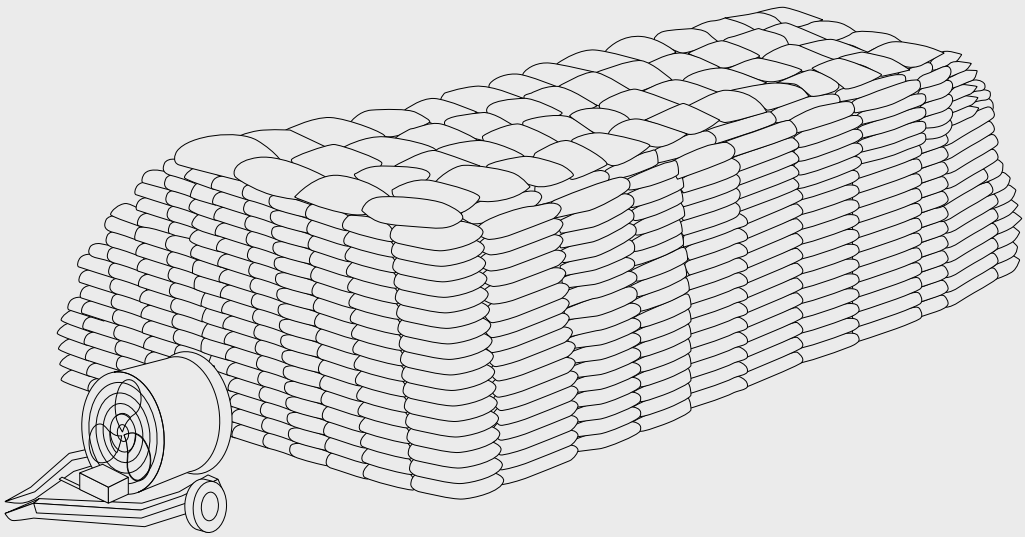
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	med
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	low-med
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	500
Footprint (m^2)	1 m^2 — 50 m^2	n/a

CHARACTERISTICS

Required Resources	Forced air and heated air source (biomass or hydrocarbon)
Energy Input	Electric or motor-driven fan; biomass or hydrocarbon heat source
Form Factor	Sacked grain is stacked around a longitudinal plenum
Mobile or Fixed	Fixed
Integrated Drying Storage	Possible with continuous air circulation
Weather Dependent	Yes
Other Uses	No

DETAILS

- Consists of a plenum with an open top of mesh, bamboo, or other means of supporting two to three layers of sacks; heated air is forced into the plenum chamber and up through the sacks of grain
- Requires an airflow rate of 0.1 m/s per meter of platform area
- Air heated to about 14°C above ambient will reduce the moisture content of the grain by 0.5 percent/hr; however, a temperature increase of 6°C to 10°C is more usual
- Heat may be generated from any fuel source
- Grain in sacks can be dried in a stack, or the sacks may be laid as one or two layers on a platform dryer
- In the stack variation, a perforated plenum tunnel is used to form the base of the stack and to distribute the air uniformly; the initial moisture content determines how large the stack can be: eight sacks high for an initial mc of 25 percent and 12 to 13 sacks high for an initial mc of 18 percent; a fan is used to blow air through the stack, and this is normally diesel powered



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- Simple, inexpensive design
- Does not require a dedicated structure
- Minimum supervision required during operation

-

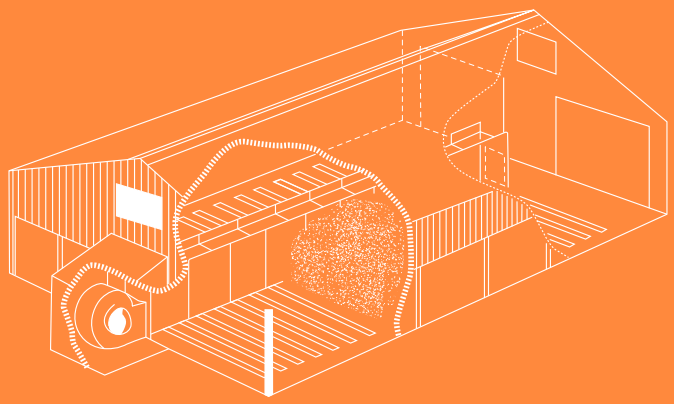
- Inconsistent drying: affected by consistency and level of initial moisture content
- Maize must be bagged (shelled or on-the-cob) before drying
- Requires sufficient room for grain stack
- Since the drying floor is typically wire mesh, smoke can pass through the grains

SOURCES

www.fao.org/docrep/s1250e/S1250E0v.htm#Natural Drying

www.fao.org/docrep/s1250e/S1250E8W.GIF

Floor Drying System



This is similar in concept and performance to a sack drying system.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: High-capacity drying and storage

RELATIVE DATA

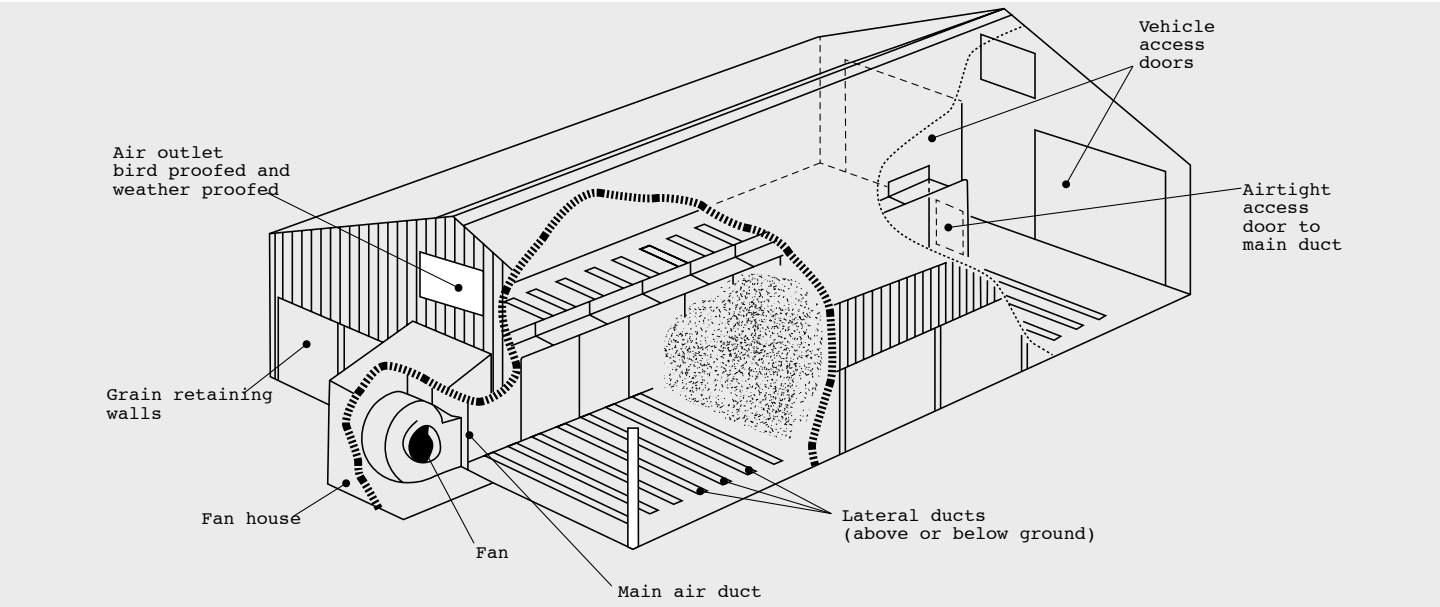
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	low-med
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	500
Footprint (m^2)	1 m^2 — 50 m^2	n/a

CHARACTERISTICS

Required Resources	Forced air and heated air source (biomass or hydrocarbon)
Energy Input	Electric or motor-driven fan; biomass or hydrocarbon heat source
Form Factor	Grain is spread to dry across a heated floor
Mobile or Fixed	Fixed
Integrated Drying Storage	Possible with continuous air circulation
Weather Dependent	No
Other Uses	No

DETAILS

- Consists of a warehouse with a vented floor integrating lateral ducts fed with air from a main duct
- The main duct is often large enough for a man to walk inside in order to close off lateral ducts where the grain is already dry.
- Lateral ducts can be installed above or below floor level: above-ground laterals are cheaper but will have to be removed during unloading the store; below-ground laterals are left in place and can be driven over
- Grain is piled over the lateral ducts, which are fed with warm air from a main duct
- Heat may be generated from any fuel source
- If the grain is piled deeply enough, drying fronts may develop and the principles of deep layer dryers will apply



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- Drying floor is sheltered from rain and weather
- Capable of drying large volumes of grain
- May incorporate drying with long-term grain storage
- With a permeable floor, becomes an effective sack dryer

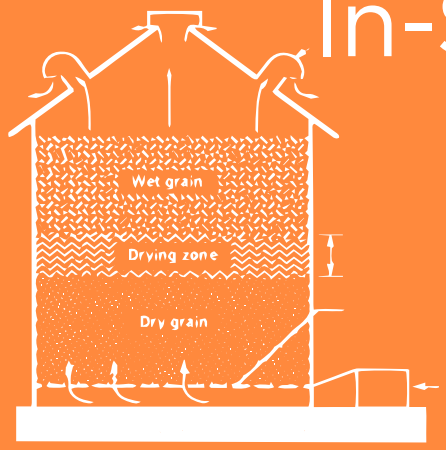
-

- Grain must be frequently raked to ensure even drying
- Requires a dedicated, well-engineered structure
- Requires large fans and heat sources for large grain volumes

SOURCES

www.fao.org/docrep/s1250e/S1250E0v.htm#Natural Drying

In-Storage Natural Air Drying



This consists of a well-ventilated structure (e.g. bin, store, silo) with a full perforated floor, one or more high-capacity fans, a grain distributor, and stairs.

AMBIENT

FORCED AIR

STORAGE

MOST SUITABLE FOR:

RELATIVE DATA

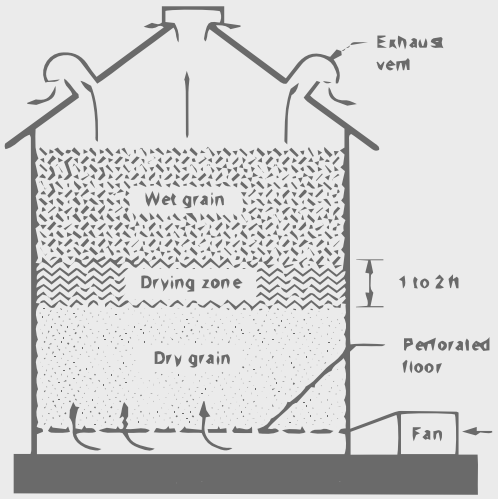
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	4-8 weeks
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	med
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med-high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	variable See details
Footprint (m^2)	1 m^2 — 50 m^2	large 169-263 m^2

CHARACTERISTICS

Required Resources	Source of forced air; non-permeable grain bin
Energy Input	Forced air (electric or engine-powered fan)
Form Factor	Cylindrical bin
Mobile or Fixed	Fixed
Integrated Drying Storage	Yes
Weather Dependent	No
Other Uses	Drying and storage of other grains

DETAILS

- Drying process is slow, generally requiring four to eight weeks
- Initial moisture content is normally limited to 22 percent to 24 percent
- Drying results from forcing unheated air through grain at airflow rates of one to two cfm/bu
- Drying and storage occur in the same bin, minimizing grain handling
- Bin is equipped with a full perforated floor, one or more high-capacity fans, a grain distributor, and stairs
- Cleaning equipment is used to remove broken kernels and fines
- May be advantageous to partially dry grain in a previous drying stage if grain is particularly wet or if faster drying times are required
- Solar collectors could be used to increase the temperature of the incoming air
- Minimum recommended grain bed dimensions: 24’ diameter x 12’ deep (110,800kg)
- Maximum recommended grain bed dimensions: 30’ diameter x 18’ deep (259,000kg)



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- Drying and storage in the same bin
- Does not require attention during drying
- Requires 25 percent to 40 percent of the energy of high temperature drying systems
- Produces superior quality product

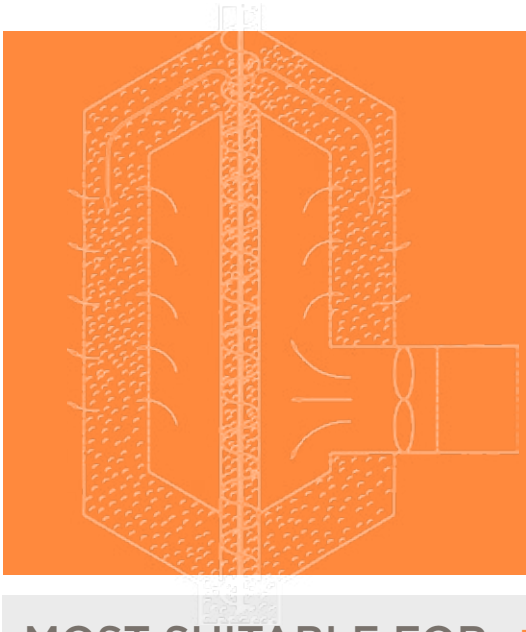
-

- Ineffective in high-humidity regions (maximum 22-24 percent moisture content)
- High cost for commercial solutions
- Slow drying time (four to six weeks)
- Less efficient for small volumes

SOURCES

ohioline.osu.edu/aex-fact/0202.html

https://www.evernote.com/shard/s202/share/5980-s202/res/c97902ef-9c7e-42d9-afcf-e53514ac75cb.gif?resizeSmall&width=1280



Recirculating Batch Dryers

Most dryers of this type are portable and can be moved relatively easily from farm to farm.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Rapid, medium-volume, on-farm drying

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	3-6 hrs/ batch
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	100+
Footprint (m^2)	1 m^2 — 50 m^2	n/a

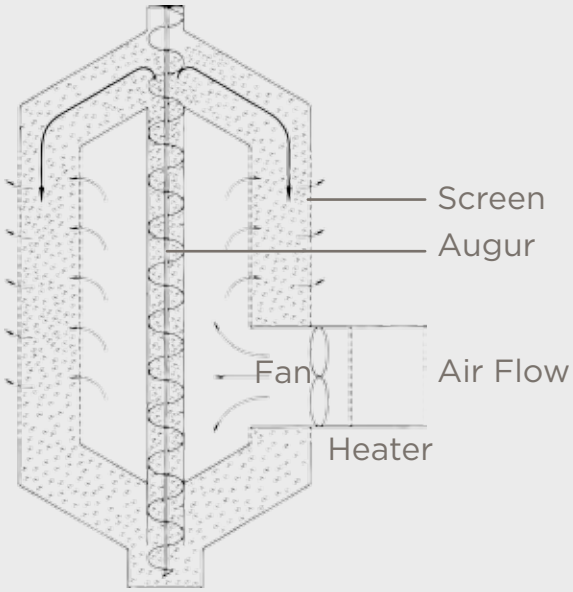
CHARACTERISTICS

Required Resource	Skilled operator, high energy inputs for forced air and heating
Energy Input	Hydrocarbon (liquid or gas) or biomass fuel required
Form Factor	Mobile dryers or cylindrical; fixed dryers are rectangular
Mobile or Fixed	Fixed or mobile
Integrated Drying Storage	No
Weather Dependent	Less so than other solutions
Other Uses	No

DETAILS

Consists of a self-contained unit comprising a cylindrical bin made of perforated steel; central airspace (plenum); vertical auger for moving grain from bottom to top; fan; and heater. Heated air is blown into the plenum space and out through the grain as the grain is continually mixed, lifted, and recirculated through the bin via the auger. Once drying is complete, cool air is passed through the grain to temper it.

This type of dryer avoids the problems of moisture gradients experienced with bin dryers by recirculating the grain during drying. The dryer is a self-contained unit with an annular drying chamber, which is 500 mm thick and around a central plenum chamber; a fan; a heater; and a central auger for transporting grain from bottom to top. When drying is complete, the grain is discharged from the top. Most dryers of this type are portable and can be moved relatively easily from farm to farm.



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- High drying efficiency and capacity, especially for wet grain
- Dries grain to consistent MC
- Portablility

-

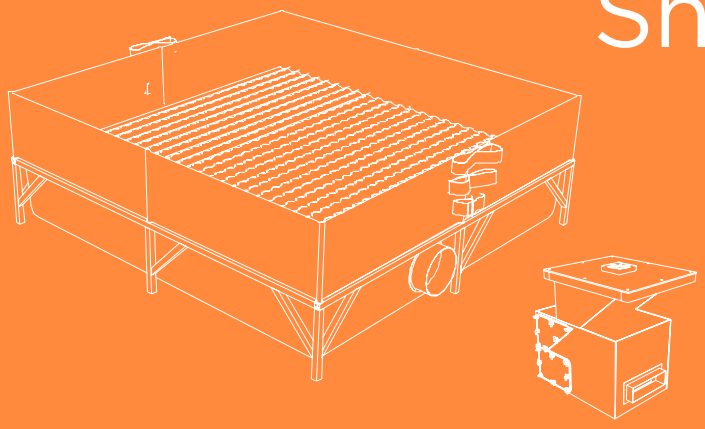
- High purchase and operating costs
- Requires skilled design, fabrication, and operation
- Requires specialized components to operate effectively
- Grain easily overdried and damaged
- Relatively high center of gravity and difficult to move over rough roads

SOURCES

www.fao.org/docrep/t1838e/T1838E0W.HTM

www.fao.org/docrep/t1838e/T1838E1N.GIF

Shallow Bed Dryer



NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: Small-batch drying

RELATIVE DATA

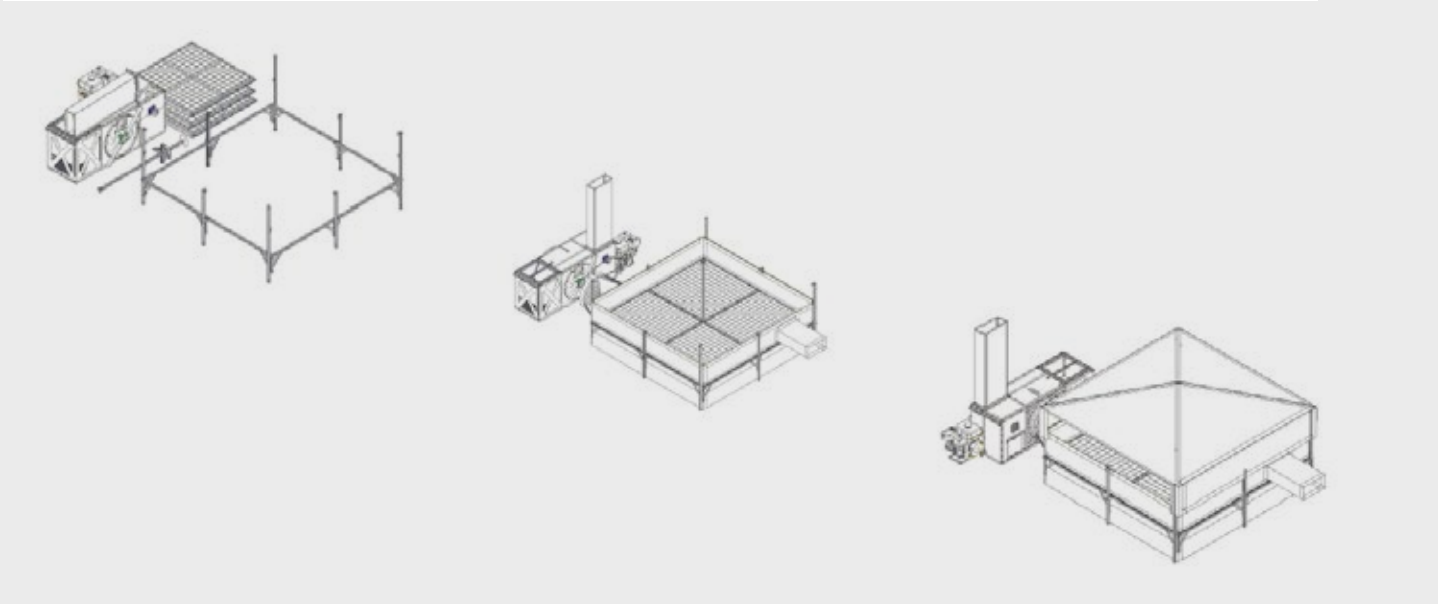
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	hours
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	med-high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med-high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	5-6
Footprint (m^2)	1 m^2 — 50 m^2	7.5 for 500 kg

CHARACTERISTICS

Required Resources	Fuel source for fans, biomass fuel for heat source, construction skills
Energy Input	Engine-driven fans and biomass heat source
Form Factor	2 m x 2 m square bed with grain bed depth of 180 - 200 mm
Mobile or Fixed	Fixed during drying
Integrated Drying Storage	No
Weather Dependent	No, as long as fuel source is dry enough to burn
Other Uses	Drying other commodities

DETAILS

- Similar to the shallow layer dryer but portable/mobile
- Consists of a drying air supply unit connected to a collapsible shallow bed (mesh tray top and an open airspace (canvas plenum) below)
- Heated air is forced into the plenum and up and through the grain bed, which is spread on the mesh tray, using a powered blower
- Heat is generated from burning biomass (maize cobs) in a furnace and performing convection heat exchange within a heat exchanger to remove combustion flue gas from the drying air
- Operating footprint is 3.0 m x 2.5 m with transportation dimensions being 1.4 m x 1.3 m x 0.9 m
- Grain bed for 500 kg batches is around 180 - 200 mm deep



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- Effective drying of low to medium volumes of grain
- Good quality product
- Weather independent
- Mobile
- Good control over drying process
- Can dry thoroughly to recommended 13.5 percent MC

-

- Limited capacity
- Requires frequent attention during drying

SOURCES

Data is based on prototyping and testing conducted by Catapult Design and ASI.

FORCED AIR HIGH-MECHANIZED

NON-SOLAR

FORCED AIR

CONTINUOUS

BATCH

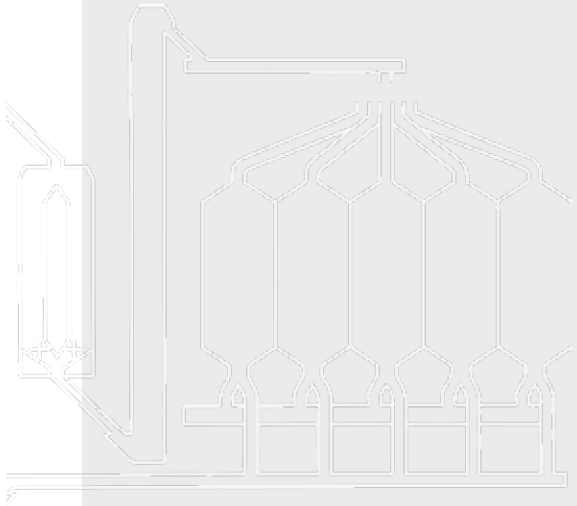
MOST SUITABLE FOR: Rapid drying larger volumes, located at highly commercial operations

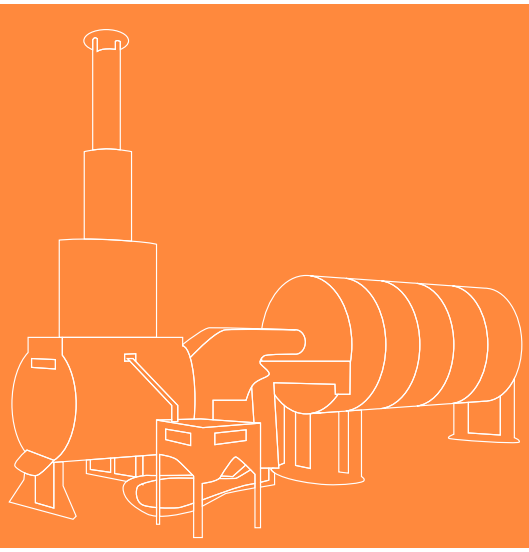
+

- Weather independent
- High speed, consistent, and thorough drying
- Capable of drying medium to large volumes of grain
- Some designs combine storage with drying

-

- Higher operating costs
- Generally requires highly skilled design, fabrication and sometimes operation
- Energy (fuel or electricity) dependent
- High investment cost





Rotary Drying

Consists of forced air, directly heated passed into a rotating drum.

NON-SOLAR

FORCED AIR

BATCH

MOST SUITABLE FOR: cooperatives or medium to large scale farms

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	See pros
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low-med
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	med
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	10-100
Footprint (m^2)	1 m^2 — 50 m^2	20 m^2 upwards

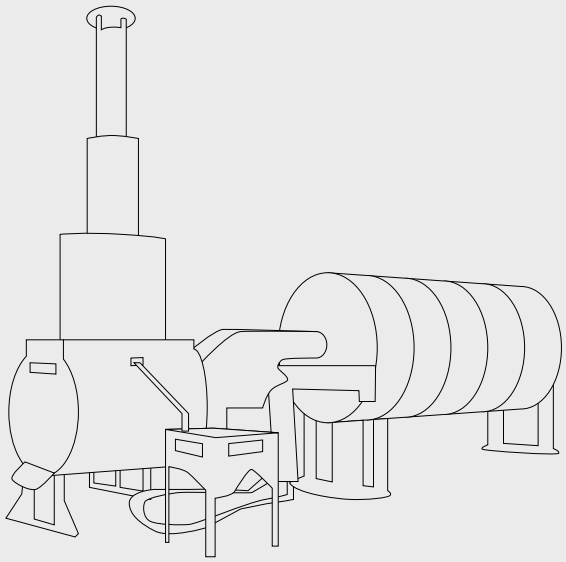
CHARACTERISTICS

Required Resources	Electricity or generator
Energy Input	Electricity or fuel, biomass or hydrocarbon heat source
Form Factor	Horizontal cylinder
Mobile or Fixed	Fixed
Integrated Drying Storage	No
Weather Dependent	No
Other Uses	Drying other commodities

DETAILS

Small scale rotary dryers are widespread and available from sellers in China, Brazil and India. They are fixed on solid deep concrete foundations, often including a loading area with a auger into the bin, and a pit under the cylinder for off loading by gravity, and an auger to lift the grain out. They are used for a wide range of commodities (maize, coffee, paddy) and can be used as seed dryers with the right calibration.

This type of dryer is relatively inexpensive to acquire and takes between 3 – 5 hours drying per batch. The air is heated and forced directly into the rotating cylinder therefore there can be smoke contamination. The bed continuously slowly rotates allowing the grain to fall through the hot air being pumped in.



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- High drying efficiency in smaller volumes
- Dies grain to consistent MC
- Suitable for small scale commercial operations (eg 3mt per day)
- Operational costs can be high if biomass not available
- Investment costs range from $3000 upwards

-

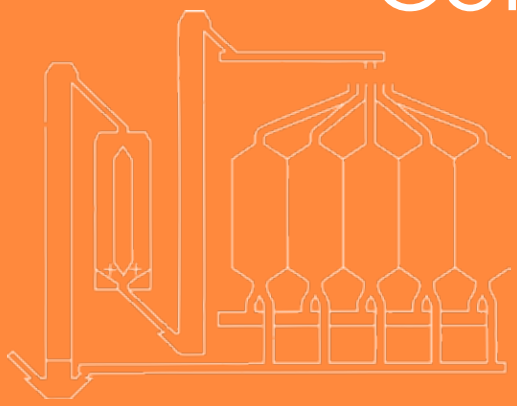
- Requires skill to install properly
- Relatively skilled operations
- Requires maintenance and specialized components
- Can damage grain if not used carefully
- Should not be overloaded

SOURCES

www.fao.org/docrep/t1838e/T1838E0y.htm

www.alibaba.com/showroom/grain-rotary-drum-dryer.html

Continuous-Flow Dryers



Relatively high in cost, continuous-flow dryers are applicable only in highly mechanized situations.

NON-SOLAR

FORCED AIR

CONTINUOUS

MOST SUITABLE FOR: Mobile drying or large-volume fixed operations

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	2-3 hrs / mt
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	med-high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	40
Footprint (m^2)	1 m^2 — 50 m^2	2 m^2

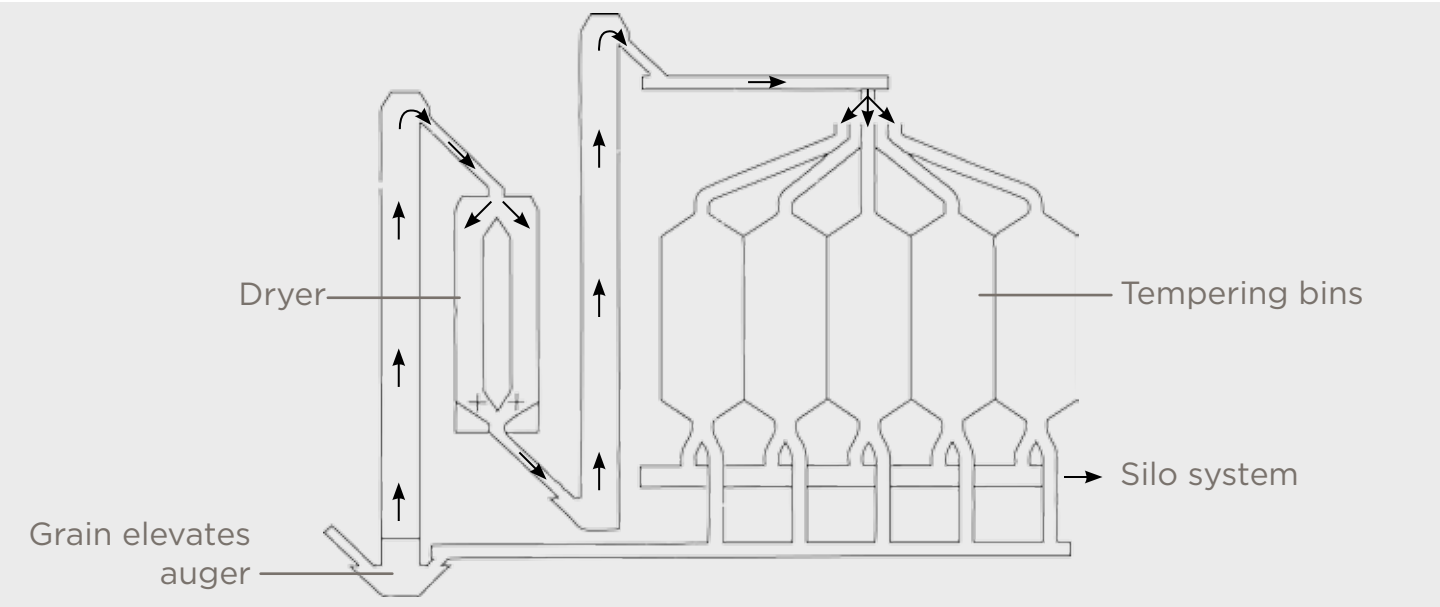
CHARACTERISTICS

Required Resource	Dedicated heat source, high-capacity fan, skilled operator
Energy Input	Biomass/liquid/gas fuel for furnace; electricity or motor for fan
Form Factor	Vertical columns or bins; other vertically oriented formats possible
Mobile or Fixed	Fixed or mobile
Integrated Drying Storage	No
Weather Dependent	No
Other Uses	No

DETAILS

The grain passes through these dryers in a continuous flow at a controlled rate. The grain falls between two metal sheets to approximately 100 to 150 mm deep, and hot air is blown through the crop. In this system, the air temperature can be substantially higher than in bulk dryers. The rate of throughput can be controlled and hence the length of time exposed to the hot air. This is adjusted according to the amount of moisture to be removed. The latter part of the path through the dryer is an ambient air section to cool the grain. Continuous-flow dryers are high in cost and are applicable only in highly mechanized situations.

Continuous-flow dryers can be considered as an extension of recirculating batch dryers. However, rather than grain recirculating from bottom to top, as in the latter, the grain is removed from the bottom, in some systems cooled, and then conveyed to tempering or storage bins. Additional drying occurs in cooling off period.



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- High efficiency and speed
- Dried grain has consistent MC
- Effectively dries high MC grain
- Continuous-flow operation adapted for large-volume, automated drying

-

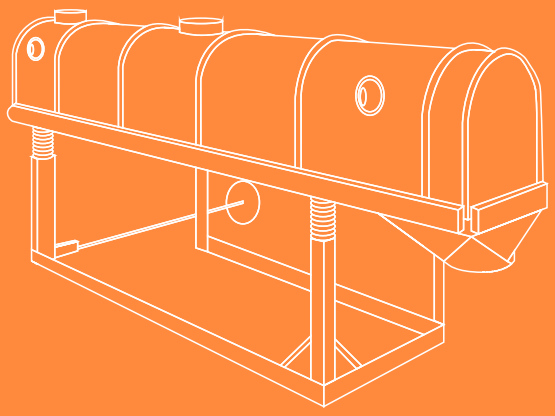
- Technically complex, requires expensive components
- May not be suitable for small batch drying
- Requires trained operator

SOURCES

www.fao.org/docrep/t1838e/T1838E0W.HTM

www.fao.org/docrep/t1838e/T1838E1P.GIF

www.fao.org/docrep/t1838e/T1838E1R.GIF



Fluid Bed Drying

Thoroughly tested on rice paddies, this dryer has limited performance inputs for its application with maize.

NON-SOLAR

FORCED AIR

CONTINUOUS

MOST SUITABLE FOR: Large-scale commercial or cooperative facilities

RELATIVE DATA

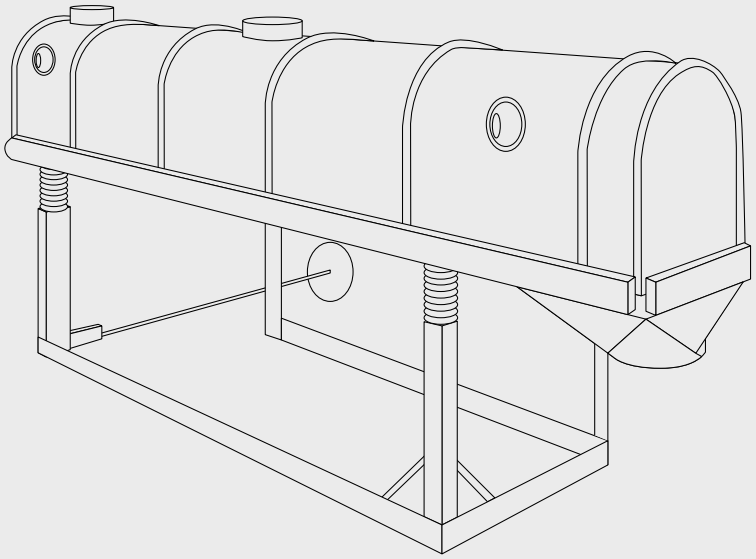
Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	n/a for maize
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	high
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	varies
Footprint (m^2)	1 m^2 — 50 m^2	varies

CHARACTERISTICS

Required Resource	Skilled operator, high BTU furnace, airflow of at least 2 m/s
Energy Input	Biomass or diesel furnace; electric or engine-driven fan
Form Factor	Vertically or horizontally oriented cylinder or rectangular enclosure
Mobile or Fixed	Fixed
Integrated Drying Storage	As part of a two-stage drying system
Weather Dependent	No
Other Uses	No

DETAILS

This type of dryer in which individual grains are suspended and sometimes transported by air moving at high velocity (2-3 m/s) can produce very evenly dried grain. Recent research in the Philippines (Sutherland and Ghaly 1990; Tumambing and Driscoll 1991) has indicated that the fluid bed dryer has promising potential for the rapid first-stage drying of paddy to 18 percent moisture in two-stage drying. Paddy at a bed depth of 100 mm can be dried from 24 percent to 18 percent moisture in 15 minutes with air at 100°C and a velocity of 2 m/s, with no adverse effects on quality. However, due to the high air velocities required to fluidize the paddy, power requirements for the fan are high, and the thermal efficiency is low compared to conventional (fixed bed) drying. Recycling exhaust air was identified as a potential means to improve thermal efficiency.



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- Very rapid, consistent drying
- Can dry high MC grain
- Efficient as part of two-stage drying system

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- Rapid drying damages grain
- Should only be used to dry to 18 percent MC to minimize grain damage
- Complex, expensive design
- Must be linked to another system in order to dry grain below 18 percent
- Low inherit energy efficiency
- Adopted primarily for paddy, less proven for maize

SOURCES

www.knowledgebank.irri.org/rkb/paddy-drying-methods/heated-air-drying.html

NON-ENVIRONMENT

NON-SOLAR

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Long-term storage and high-value grain (seed)

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- Simple to use
- Re-usable
- Adaptable to different solutions

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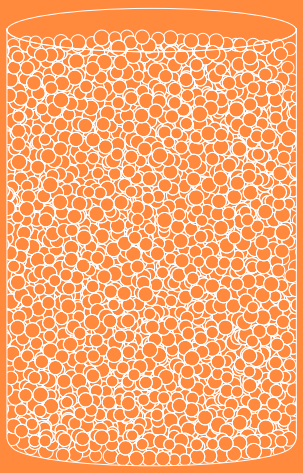
- Expensive up-front investment that increases proportionally with volume of grain



Desiccant Bead Drying

Modified aluminum silicates are capable of absorbing 20 to 25 percent of their initial weight in water.

NON-SOLAR

NATURAL CIRCULATION

BATCH

MOST SUITABLE FOR: Long-term storage and high-value maize (seed maize)

RELATIVE DATA

Processing Speed (time to dry x kg of maize from x%MC to y%MC)	1 hour — 1 day — 1 month	14 days
Relative Operating Cost (% greater than current operating cost)	low <20% — medium 20-50% — high >50%	low
Relative Acquisition Cost (% greater than current acquisition cost)	low <100% — medium 100-300% — high >300%	high
Capacity (# of 90 kg bags of dry shelled maize)	10 bags — 50 bags	infinite
Footprint (m^2)	1 m^2 — 50 m^2	n/a

CHARACTERISTICS

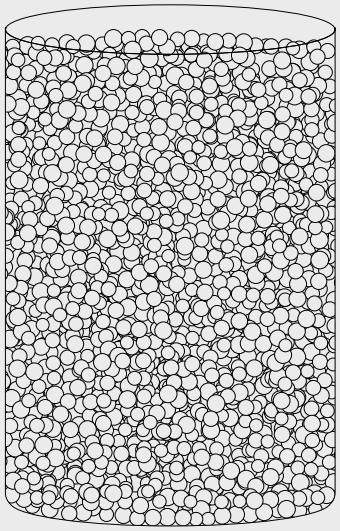
Required Resources	Hermetic enclosures, heat source >200ºC for regenerating beads
Energy Input	Pre-drying in sun to remove surface moisture; energy for regenerating beads
Form Factor	Approximately 12 mm diameter beads; any sealable container
Mobile or Fixed	Fixed
Integrated Drying Storage	Yes
Weather Dependent	No (assuming hermetic storage is available)
Other Uses	Heating other materials; insect control; drying other agricultural products (such as flowers, saved seeds, shrimp, fish, fruits, vegetables, etc.)

DETAILS

Ceramic desiccant beads are designed as a low-cost means to dry agricultural products to low moisture levels in high-humidity tropical environments. They are simple to use, reusable, and durable. When used in conjunction with hermetic containers, they help prevent losses due to rodents, insects, and molds.

Drying beads are modified aluminum silicates capable of absorbing 20 to 25 percent of their initial weight in water. When placed in an enclosed hermetic container, the beads will remove moisture from the atmosphere, creating a very low-humidity environment. Moisture in grain is transferred to the beads in an enclosed environment without the need for heating. Once the beads are saturated, they can be removed and regenerated (up to 10,000 cycles) by heating to >200ºC for three to four hours.

Desiccant bead drying can be scaled to dry small to large quantities of material. Small quantities (180-270 kg) may be economical to dry through direct contact between beads and maize. In larger quantities, they may use forced-air systems.



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- Very simple
- Effective to use (calculate required amounts based on maize RH)
- Re-usable (up to 10,000 cycles)
- Scalable
- Adaptable to multiple solutions (direct contact, remote air desiccation)
- Non-mechanical solution
- Requires minimum training

-

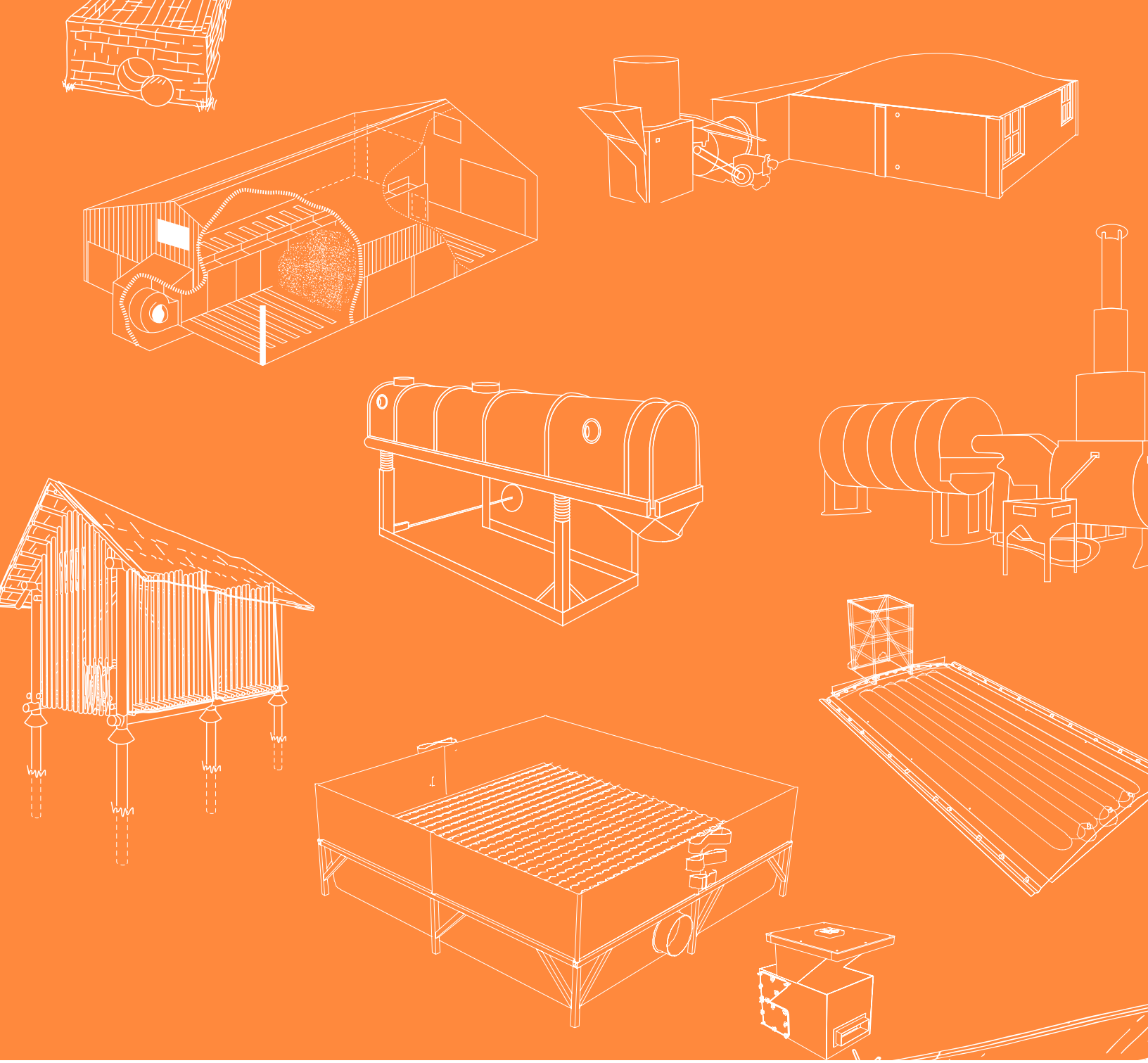
- High initial cost
- Requires high bead/material ratios to dry to low RH in a single stage
- Expensive: current cost $10/kg for zeolite beads; 1 kg of maize requires approximately 500 g of beads
- Requires sealed storage containers
- Beads must be separated from grain before consumption

SOURCES

www.dryingbeads.org

www.dryingbeads.org/?avada_portfolio=pest_control

AMBIENT
SOLAR
NON-SOLAR
NATURAL CIRCULATION
FORCED AIR
CONTINUOUS
BATCH
STORAGE



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