



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



FEED THE FUTURE INNOVATION LAB FOR HORTICULTURE WEBINAR

Dry Chain – A solution to dried commodity losses due to moisture and humidity



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The Dry Chain for Seed and Commodity Preservation

Kent J. Bradford



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1/3 of food produced is lost
before reaching the consumer

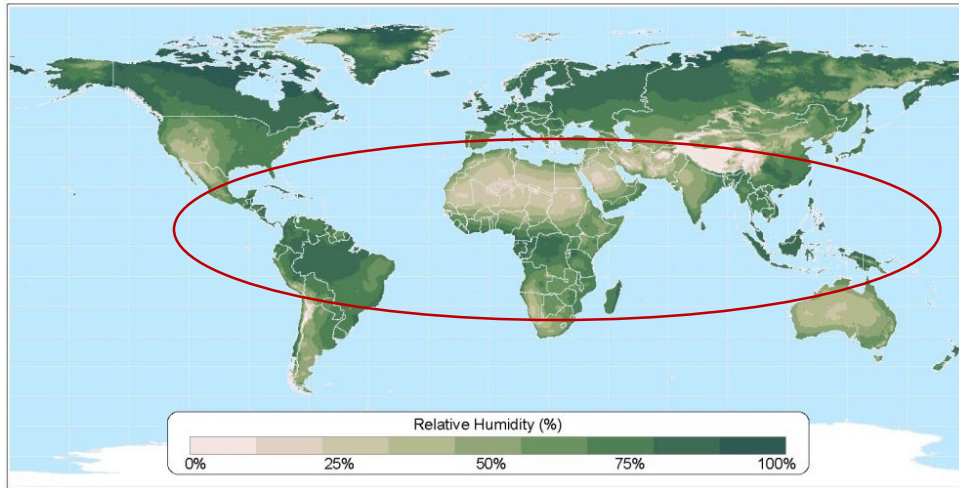


4.5 Billion

people have aflatoxin in their diet



Average Annual Relative Humidity

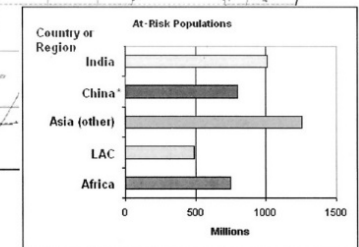
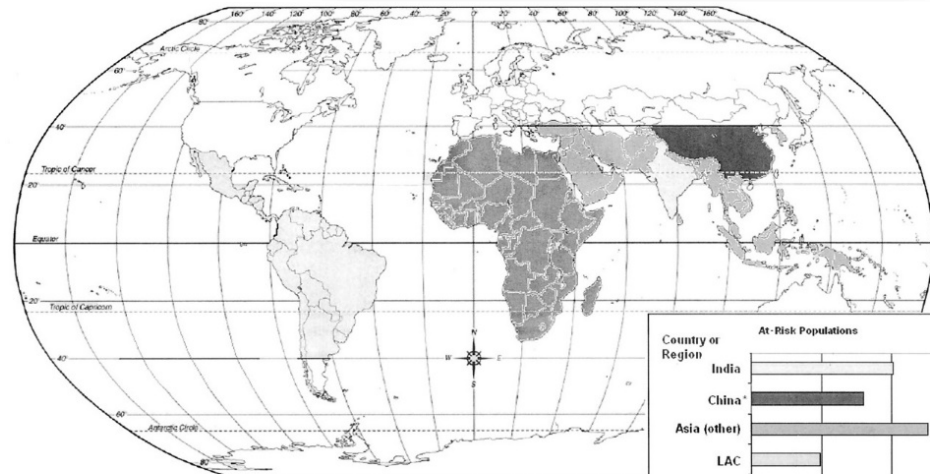


Data taken from: CRU 0.5 Degree Dataset (New, et al.)

Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

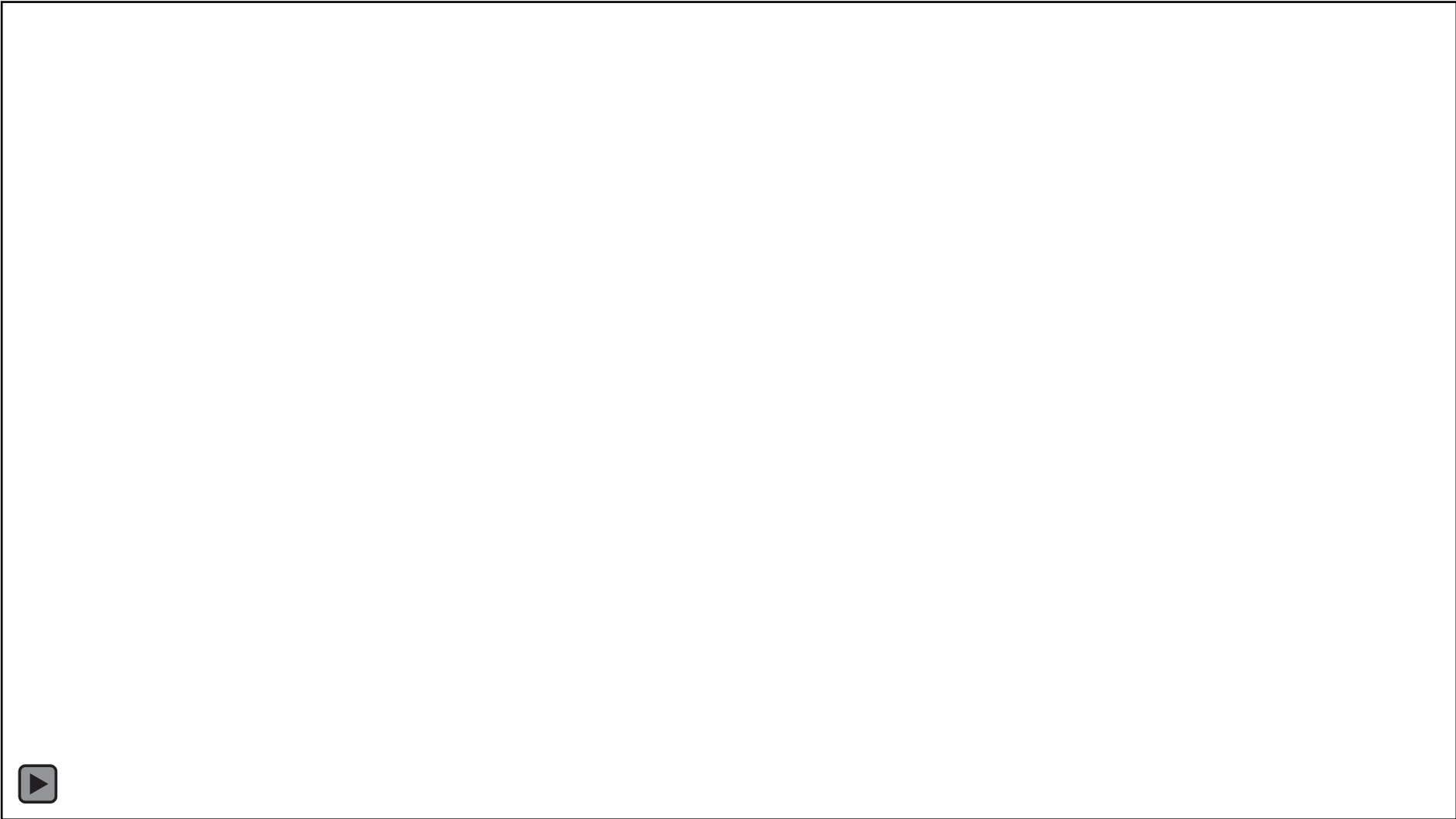


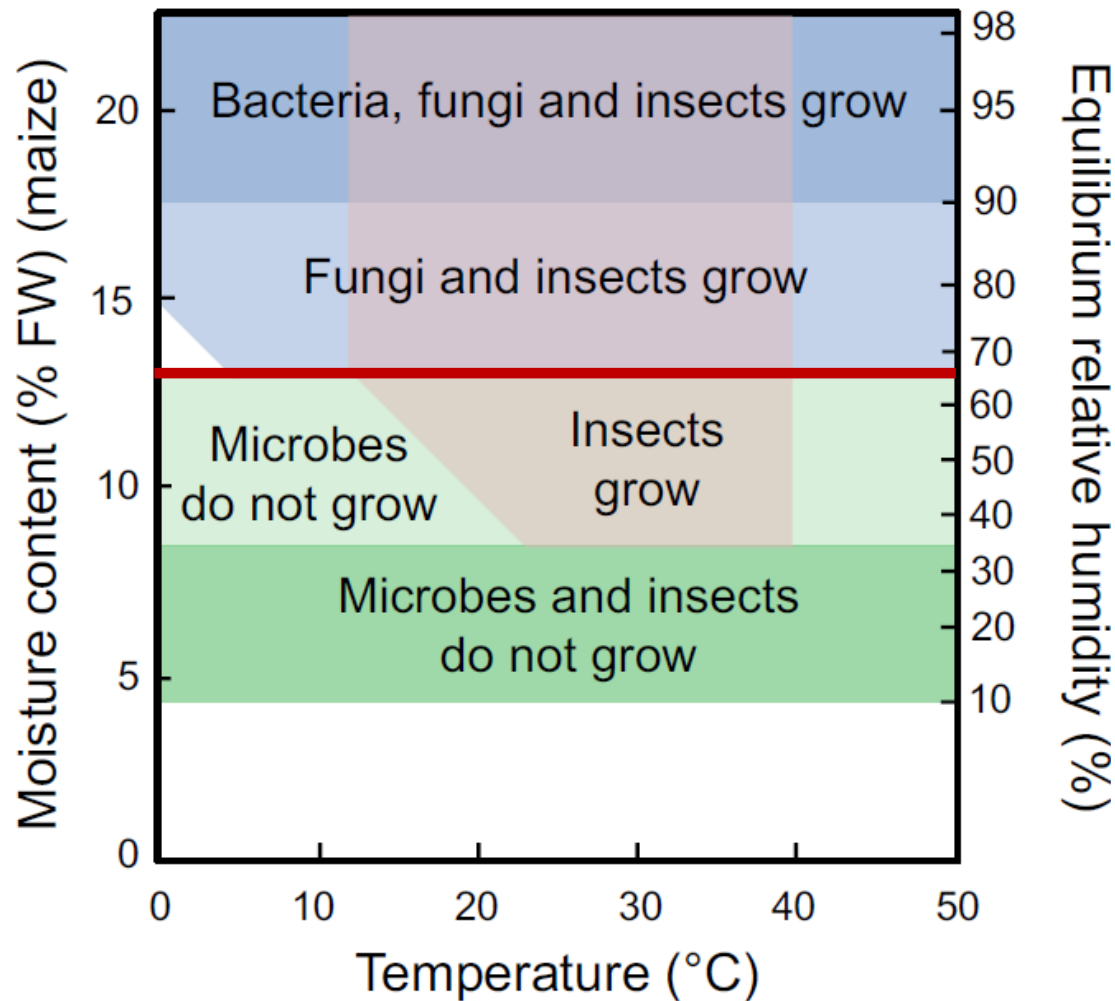
A large and increasing fraction of the world's population lives in areas where high humidity creates problems for seed and commodity storage.



* Estimated 66% of 1.2 billion people

Global Seasonal Humidity Patterns

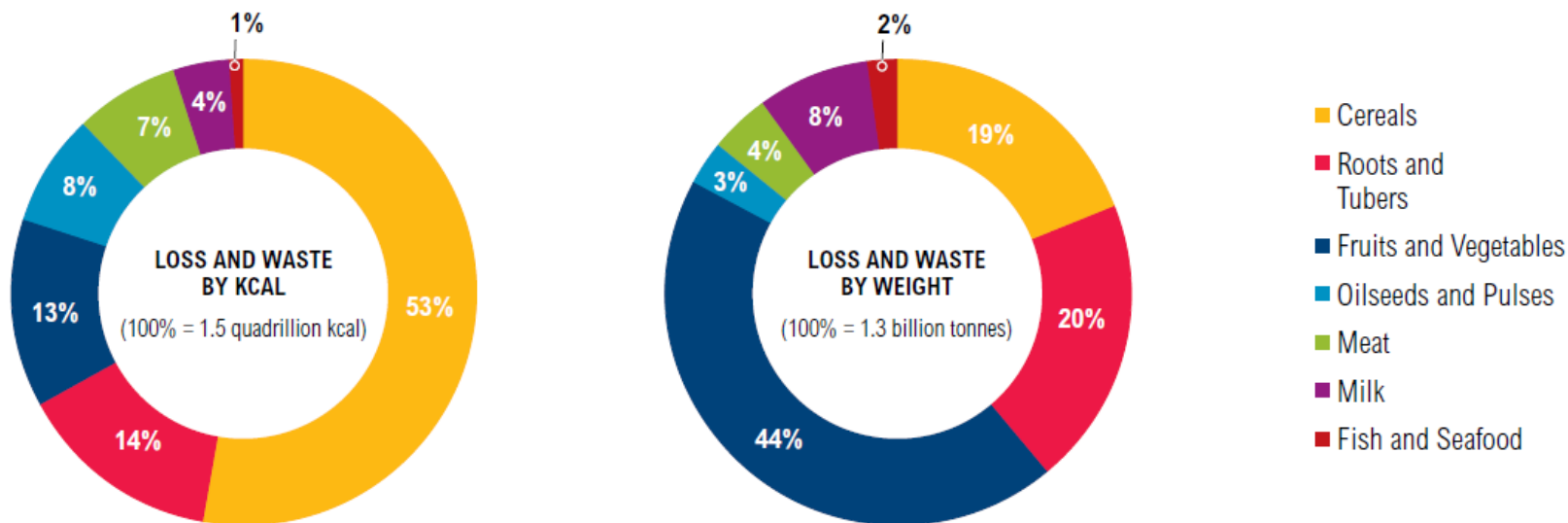




Above a critical moisture content (or equilibrium relative humidity), fungi and insects are able to grow on stored commodities.

Bradford et al. (2018) Trends in Food Science and Technology 71: 84-93.

Figure 1 | Share of Global Food Loss and Waste By Commodity, 2009

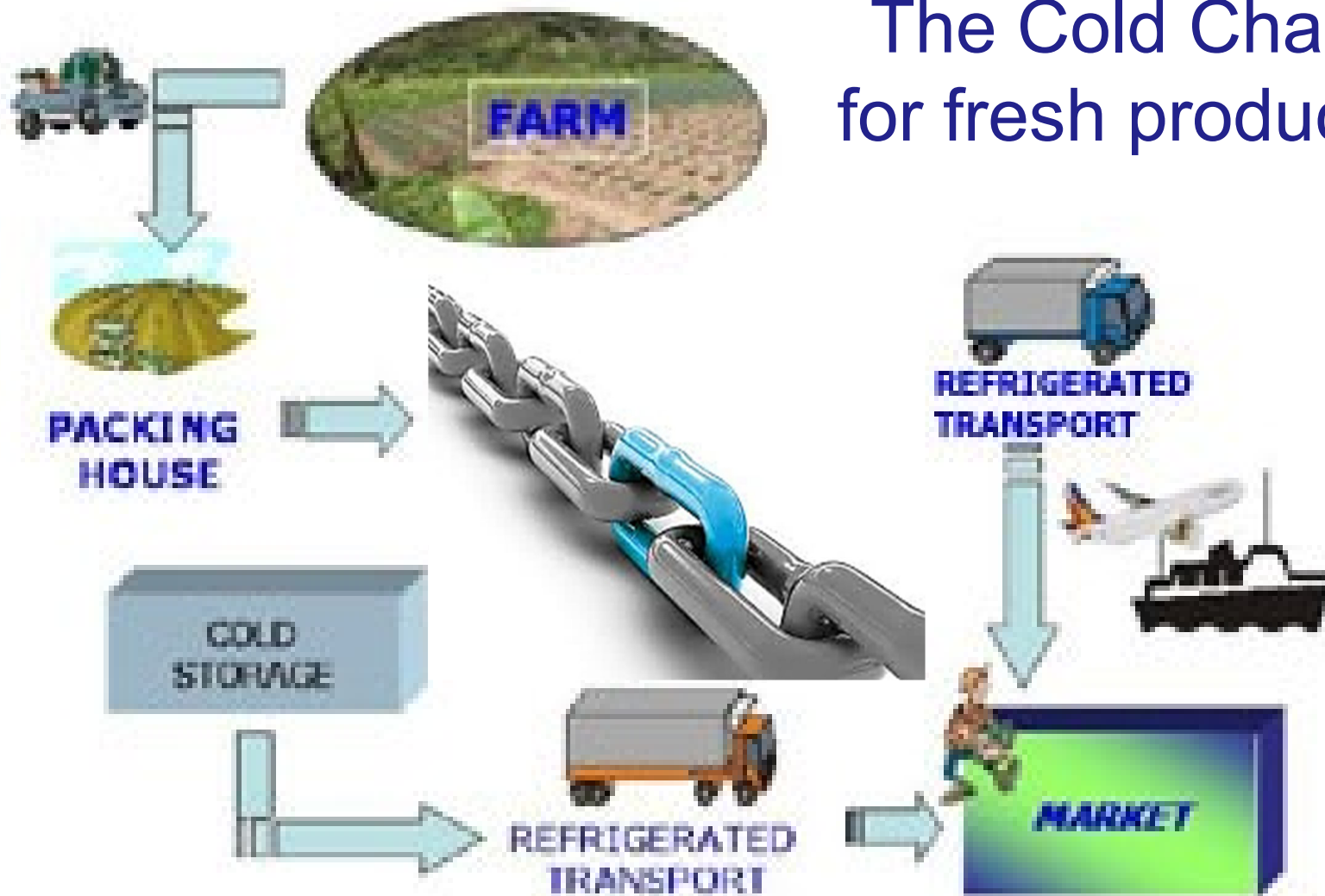


Source: WRI analysis based on FAO. 2011. *Global food losses and food waste—extent, causes and prevention*. Rome: UN FAO.

World Resources Institute, 2013

The largest fraction of food loss by weight is of fruits and vegetables, but in terms of calories, dry commodities (cereals, oilseeds and pulses) represent 61% of food loss and waste globally.

The Cold Chain for fresh produce.



Once dry and packaged, no further energy costs.

Dried products

DRY

Long-term storage

Excellent for seeds or germplasm storage.

GOOD

BEST

DRY CHAIN

WARM

COLD

COLD CHAIN

Fresh produce

Most foods begin wet and warm.

POOR

WET

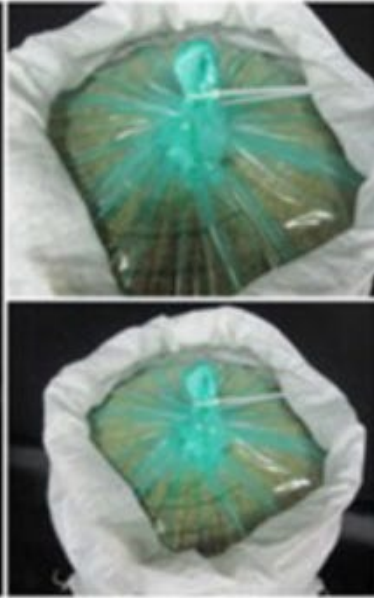
Infrastructure, refrigeration and energy costs.

Bradford et al. (2018) Trends in Food Science and Technology 71: 84-93.

Drying Methods



Hermetic Containers and Packaging



STORAGE OPTION 1

“PICS” bags
Purdue Improved Crop Storage



STORAGE OPTION 2

Plastic or metal bins



STORAGE OPTION 3



Superbags
GrainPro, Inc.

Dry Chain for Seed and Food Preservation

Use sun drying when possible.

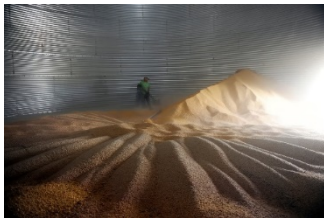
Use additional drying to <70% RH.

Package in moisture-proof containers.

Keep the containers sealed continuously.



Do not store moist bulk seeds/grains.



Do not use porous packaging.



Do not leave packages open.



Do not expose to humid air.



www.drychain.org



Desiccant-based Drying: Drying Beads



Demonstrated effective method for drying seeds and commodities.

Enclosing beads with the commodity transfers water to the beads.

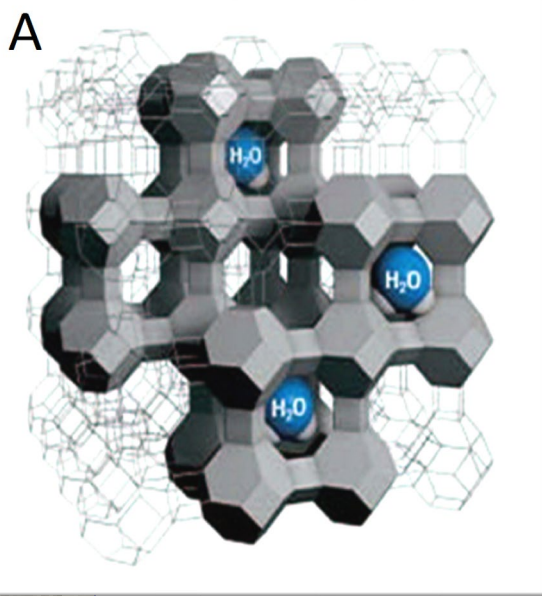
Beads can be heated to reactivate for reuse indefinitely.

www.rhino-research.com

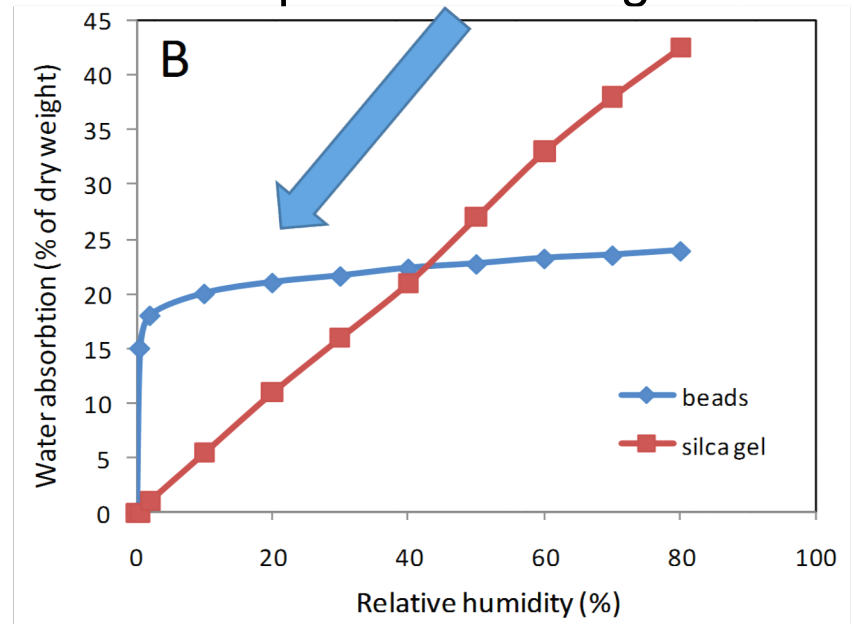
www.dryingbeads.org

www.drychainamerica.com

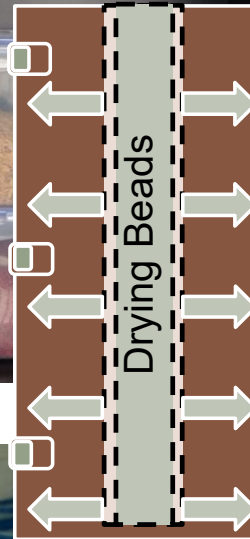
Zeolite desiccant beads absorb only water and bind it tightly until released by heating.



Improved drying at low RH compared to silica gel.



Moisture Absorption and Bead Reactivation



The Dry Chain for Maintaining Seed Quality

- Harvest seeds and sun/air dry to the extent possible.
- Put in hermetic bag or container with drying beads.
- Dry commodity to low MC/RH for extended storage.
- Remove beads for reuse and keep product in hermetic containers or packaging during storage and transport.



Harvest



Air-dry



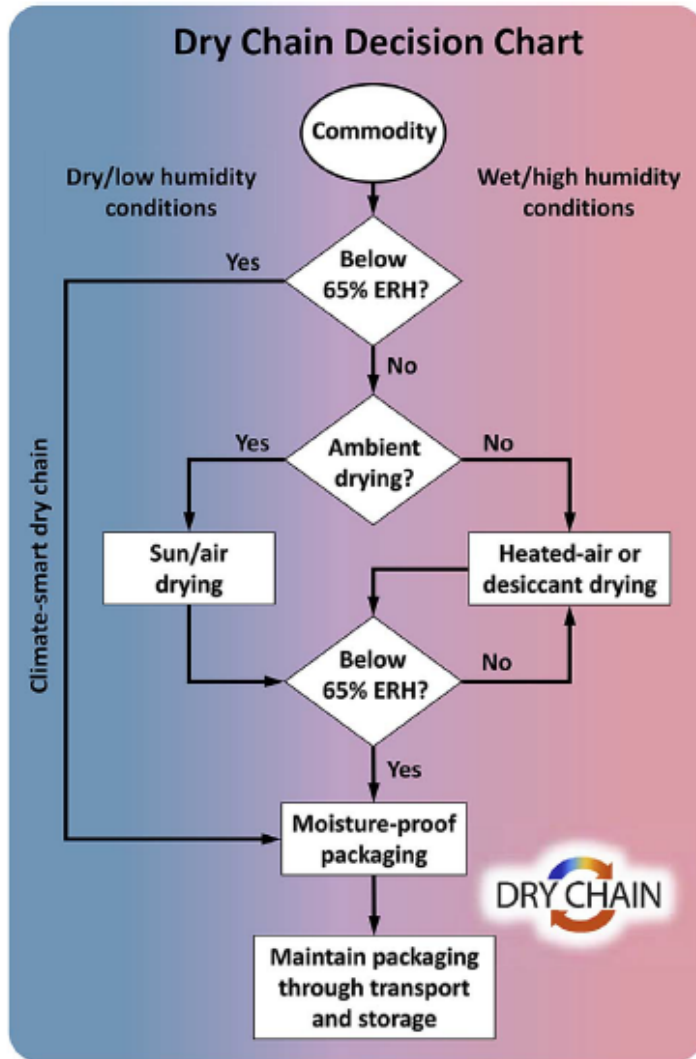
Bead-dry

Store in
water-proof
containers



<https://ag.purdue.edu/ipia/pics/>

Decision Chart for Seed and Commodity Drying



Seeds and food products should be dried at least to <65% eRH to prevent mold growth.

This can be achieved by air drying, but if not, additional drying is required.

Heated air or desiccant drying can lower commodity moisture to safe levels.

After drying, storage in sealed containers or in controlled RH facilities is necessary to prevent absorption of water from the air in humid climates.

Bradford, K.J., et al. 2018. Trends in Food Science & Technology 71: 84-93.

Opportunities for Local Germplasm Banks



Nepal



India



We worked with Bioversity International (CGIAR) to implement drying and hermetic storage systems with local community germplasm banks in India and Nepal.



10:00 am

Dr. Denise Costich, Head of Germplasm Conservation Lead at CIMMYT in Mexico, is using Drying Beads and DryCards to assist communities in Guatemala to better store their local maize seed.



11:00 am

A quick test indicates that these seeds are too moist and will lose viability rapidly and be attacked by insects and molds in storage.



 **CIMMYT**^{MR}



भाकृअनुप - भारतीय सब्जी अनुसंधान संस्थान

ICAR - Indian Institute of Vegetable Research

Indian Council of Agricultural Research

An ISO 9001:2008 Certified Institute



First Low-Energy Seed Gene Bank Inaugurated at ICAR-IIVR, Varanasi



Drying and packaging provides a low energy method for medium-term storage of germplasm and planting seeds, as refrigeration and dehumidification are not required.

<http://www.iivr.org.in/first-low-energy-seed-gene-bank-inaugurated-icar-iivr-varanasi.html>

Scaling-up Project in Bangladesh



Implementation program by Rhino Research supported by USAID

- Companies buy beads, equipment and containers
- Project provides in-depth training for employees on all aspects of use

Today, 3 companies are fully commercial:

- **Lal Teer** – drying capacity per season of 5,000 kg seed, expanding now to 25,000 kg
- **Getco** – drying capacity per season of 2,000 kg seeds
- **Metal Seeds** – drying capacity per season of 1,000 kg seeds

Several other companies and governmental agencies are starting:

- Malik Seeds – completed program – expected capacity of 10,000 kg
- ACI Seeds – completed program – expected capacity of 5000 kg
- BADC – completed program – expected capacity of 5,000 kg
- BARI – completed program – investigating possibilities
- BRR1 – germplasm storage – complete setup for breeder and foundation seed – supported by BMGF

Lal Teer Adopts Drying Bead Technology



“ ... Lal Teer tested this new technology, and concluded that these beads are drying our seeds faster and deeper, obtaining a better quality that results in a longer storage potential, and all this with lesser costs. Therefore Lal Teer made the executive decision to move ahead with implementing these beads for all our seeds and crops as soon as possible...”

Mr. Tabith M. Awal, DCEO, Lal Teer Seed Ltd, Bangladesh

Scaling-up Project 2016 / 2017

8 drying experts

100 trainers

800 seed farmers

100,000 farmers (indirect)



Water Activity and Fungal Growth

James Thompson



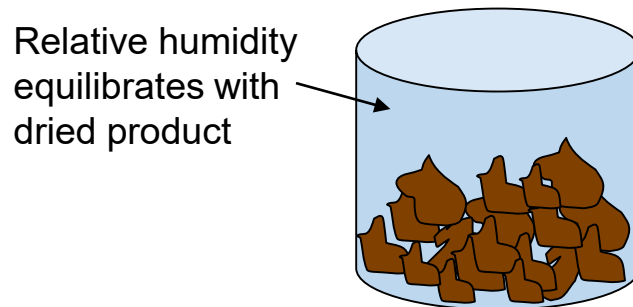
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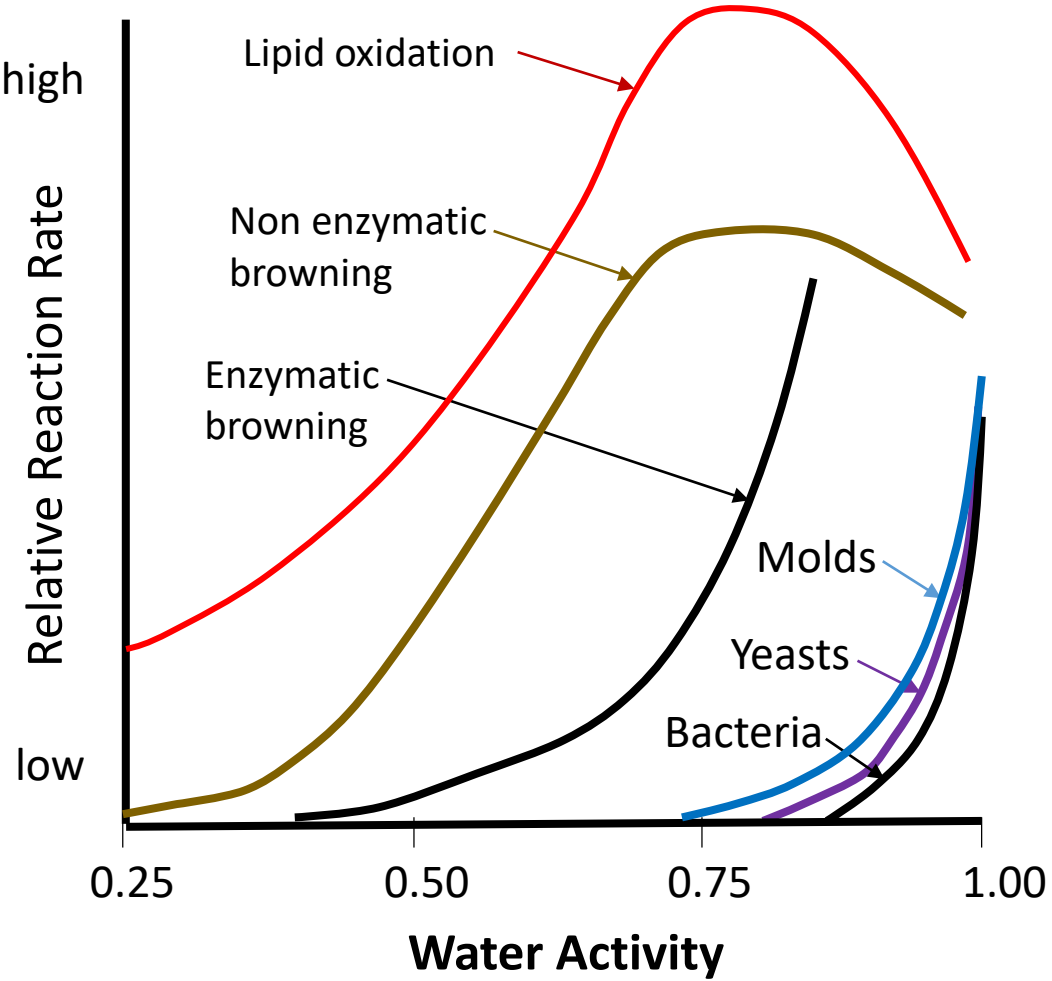
Equilibrium Relative Humidity & Water Activity

- Equilibrium relative humidity = headspace humidity above a product.

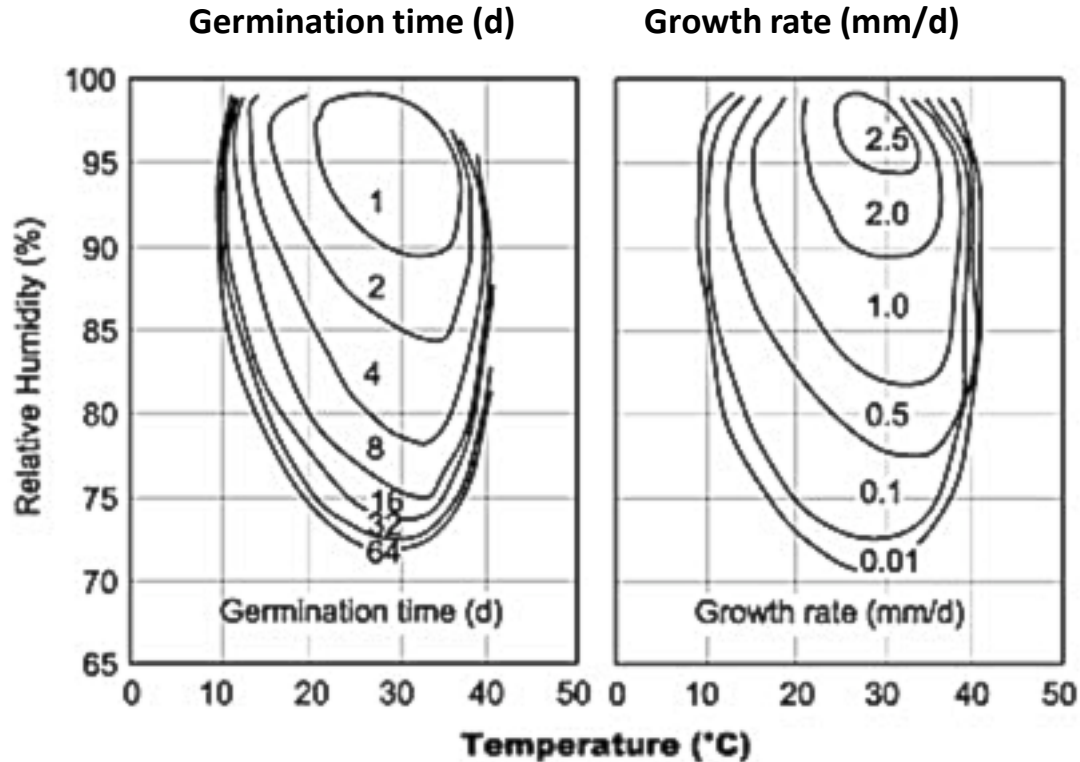


- Water activity = $ERH/100$
- $0.65 A_w = 65\% ERH$

Water Activity and Food Stability



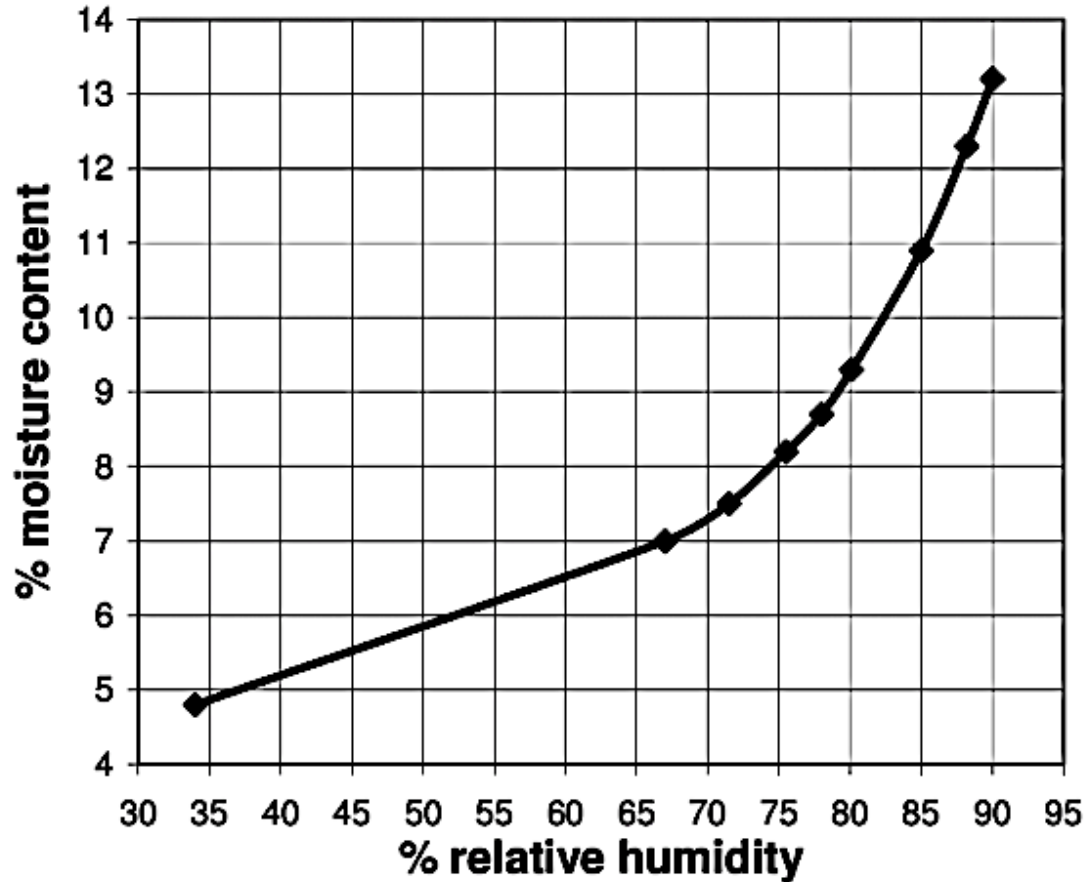
Fungal Growth



1. ERH below 75 – 80% allows more time for drying.
2. ERH below 65% allows safe long-term storage.

<http://www.wbdg.org/resources/indoor-air-quality-and-mold-prevention-building-envelope>

Equilibrium Moisture Content



Equilibrium moisture content of cocoa beans at 27° - 29°C (Gough, 1975).

ERH & Moisture Content

Relationship affected by:

- Product temperature
- Adsorption/desorption (hysteresis)
- Cultivar
- Growing conditions
- Drying, particularly high temperature exposure
- With an ERH/MC model determined for a particular grain sample, ERH will predict MC within $\pm 0.5\%$ ¹

¹Chen 2001

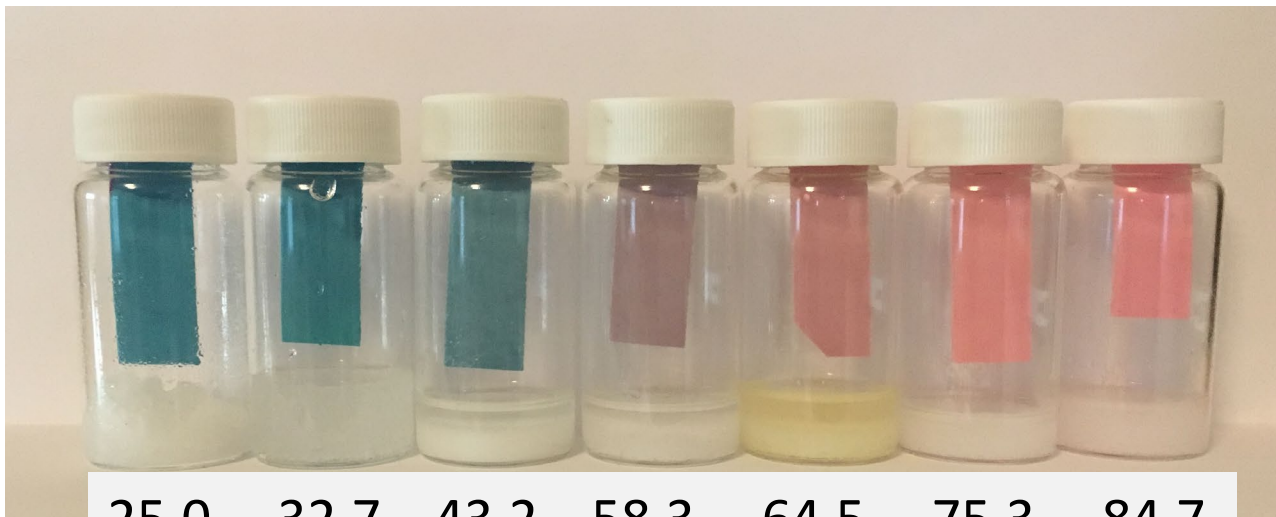
Measuring Moisture Content

- Fast measurement
- Low cost units, <\$300, have an accuracy of $\pm 0.5\%$ to $\pm 1.0\%$ MC.
- Bench top units \$2000 – \$5000 have an accuracy of $\pm 0.1\%$.
- Need separate calibration for each product and for each growing location.
- Important to obtain a representative sample.



DryCard

Equilibrium relative humidity calibration
with saturated salts



useful range

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DryCard™

Seal this card in a jar or bag with your dry product. Check the card after 30-60 min.

Wet
75 Molds grow
65 Molds don't grow
55
45 Dry
35

Is your product dry enough to store safely?

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Options for measuring ERH

DryCard



\$1 – 1.50

Hygrometer



\$3 - 10

Water activity meter



\$12,000

Measuring ERH

- Product has equilibrated after drying for 4 to 24 hr depending on particle size.
- Product has a uniform temperature.
- DryCard or hygrometer is exposed to product for 30 to 60 minutes for an approximate ERH determination.
- DryCard or hygrometer is exposed to product overnight for precise ERH determination.

DryCard



Hygrometer



Storage

A key link in the dry chain

Michael Reid and Jim Thompson



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Storage – a key link in the dry chain

- Proper storage maintains quality of grains and pulses, slows development of rancidity and kernel darkening in nuts, and maintains vitality of seeds
- Prevents mold
- Stops insect damage
- Prevents rodent and bird attack



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Poor storage!



Good storage?







Maintain the dry chain!

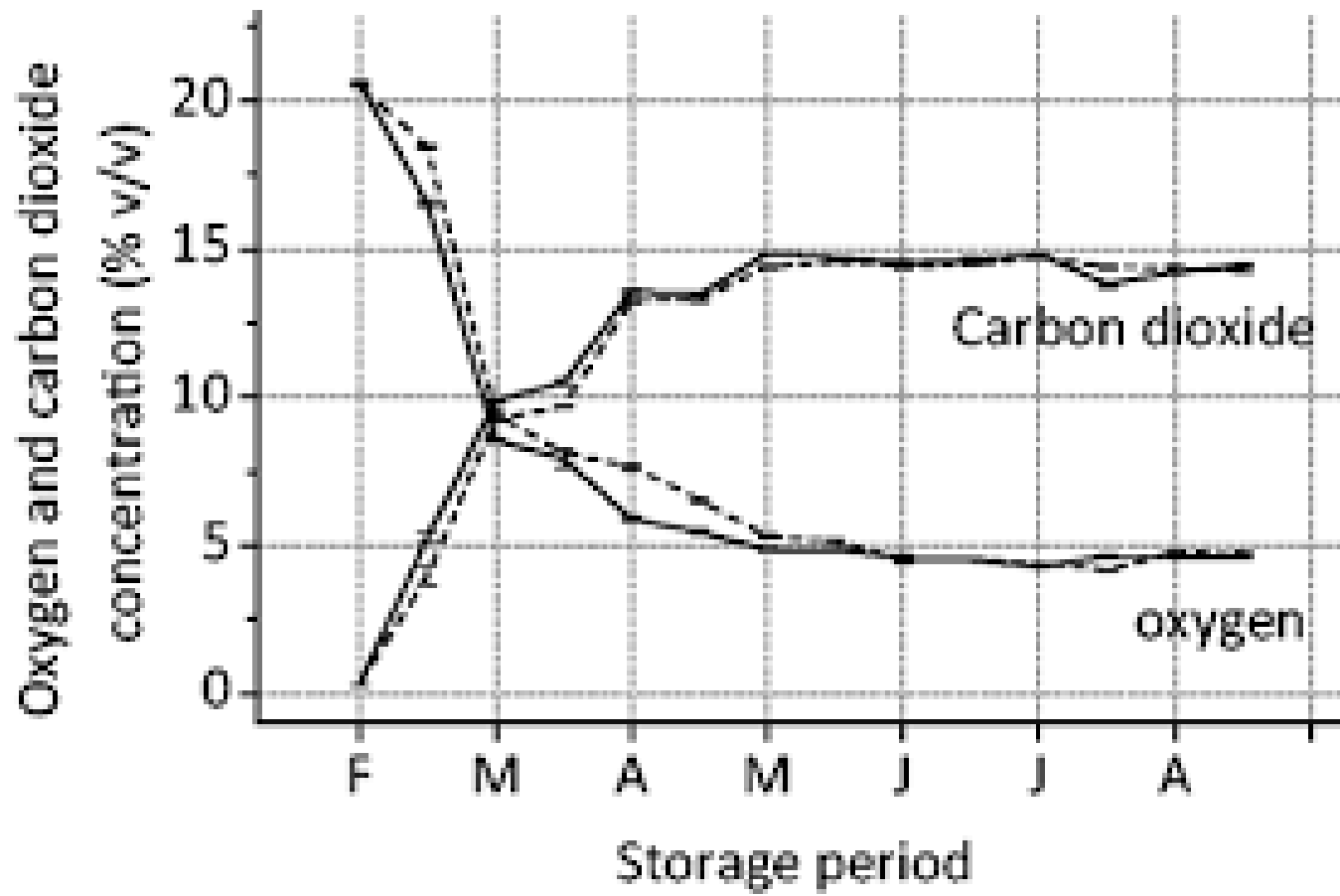
- Storage below 0.65 water activity reduces insect attack and prevents fungal infection
- To prevent rehydration, store in hermetic containers
 - Sealed
 - Plastic bags or drums
 - Steel canisters or silos

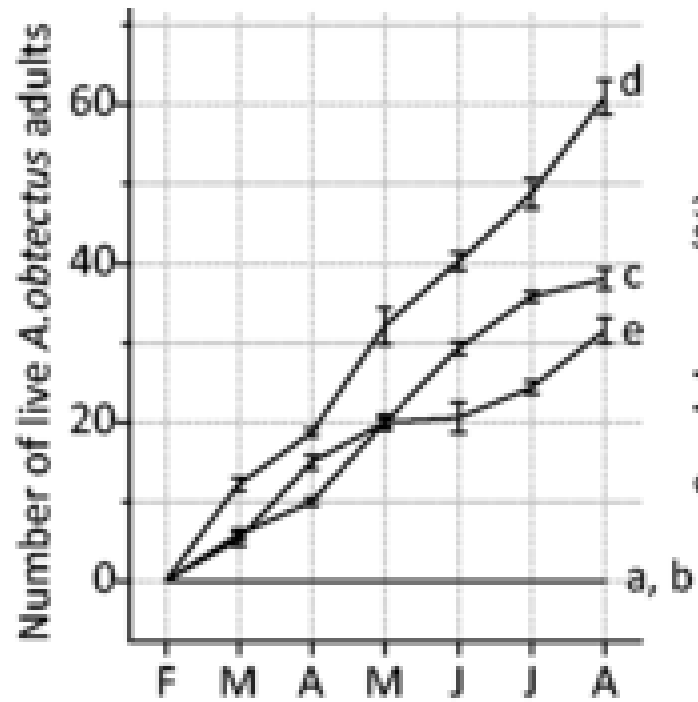


Benefits of hermetic storage

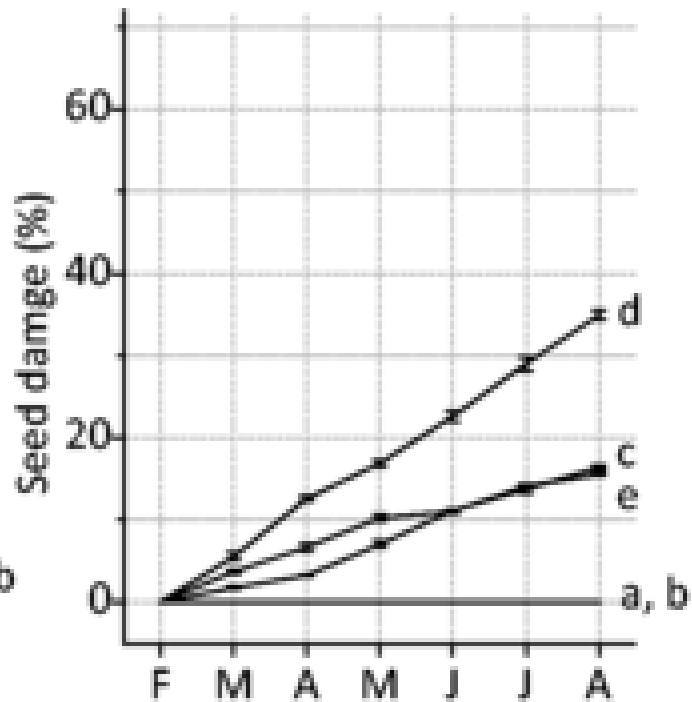
- Hermetic storage bags, like the inner polyethylene liner of the Purdue PICS bags, are sealed
- Infesting insects rapidly deplete the available oxygen
- Low oxygen prevents additional insect damage and may reduce mold growth too
- The insects kill themselves!







Storage period (February - August)



- a: non-infested PICS
- b: infested PICS
- c: non-infested PP
- d: infested PP
- e: actellic-treated infested PP



Key Concepts

- Storing products below 0.65 WA slows quality loss and prevents insect and decay damage.
- Hermetic storage can prevent insect infestation and mold growth by maintaining low WA and reducing the oxygen concentration
- Hermetic storage containers are an essential link in the dry chain



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Drying technologies

Michael Reid

Leader, Technology and Innovation

Horticulture Innovation Lab

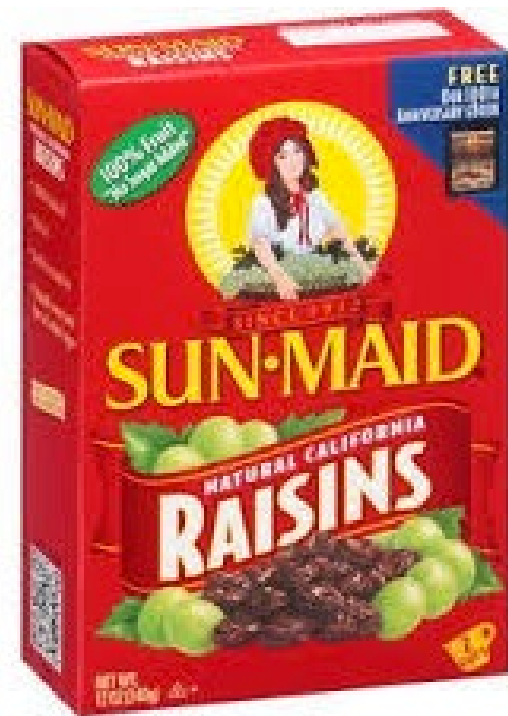


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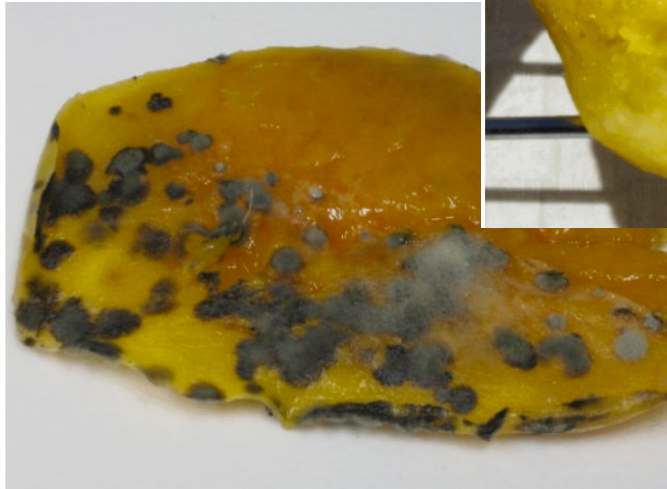
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Open air drying is widely used

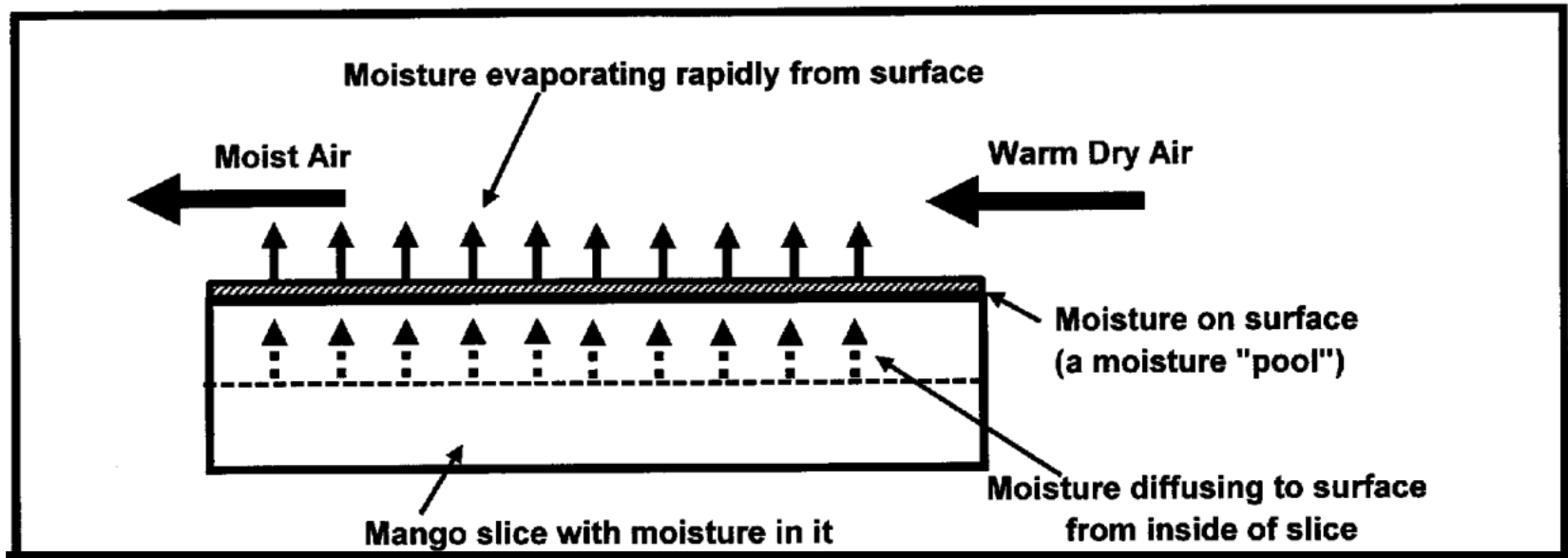


Problems with open air drying

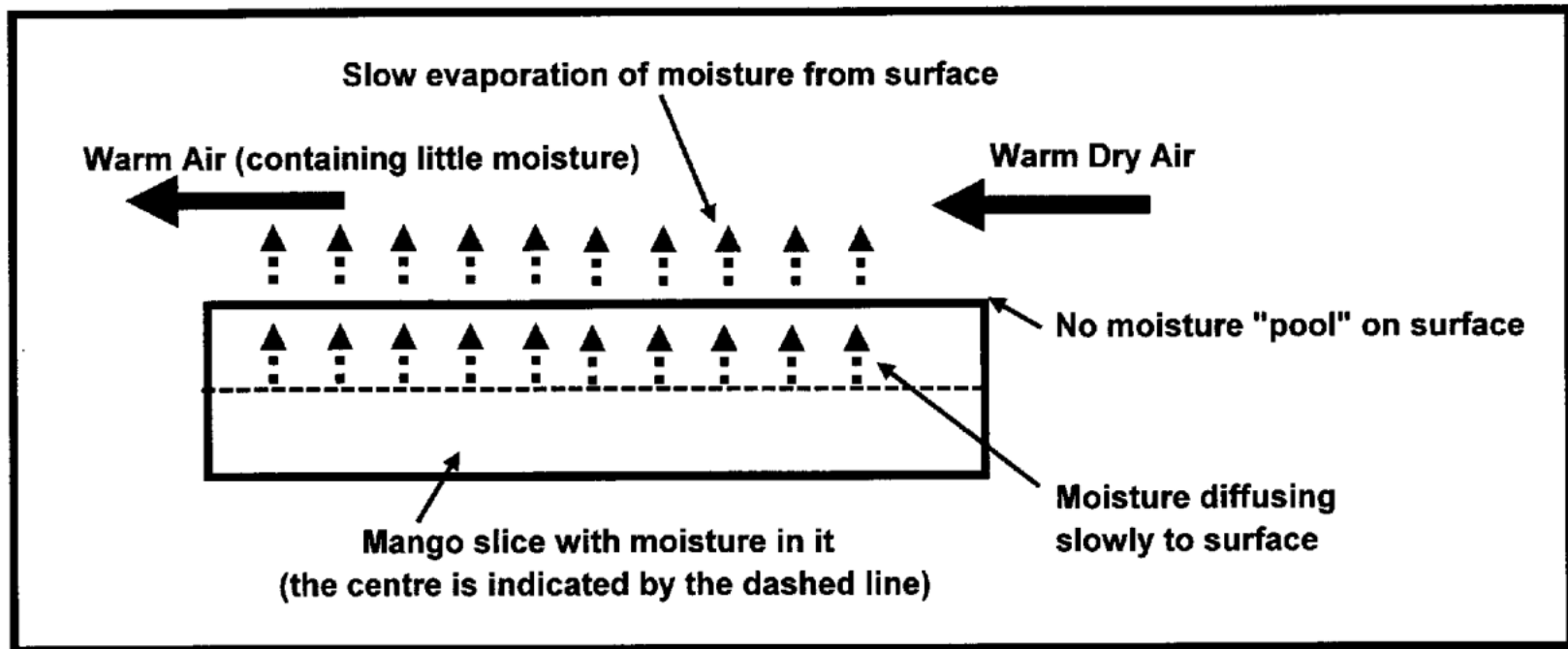
- Rain – requires covering when rain threatens
- Birds, ducks, hens, RATS, mice
- Flies, wasps
- Dust, dirt, leaves
- Wind?
- Thieves?



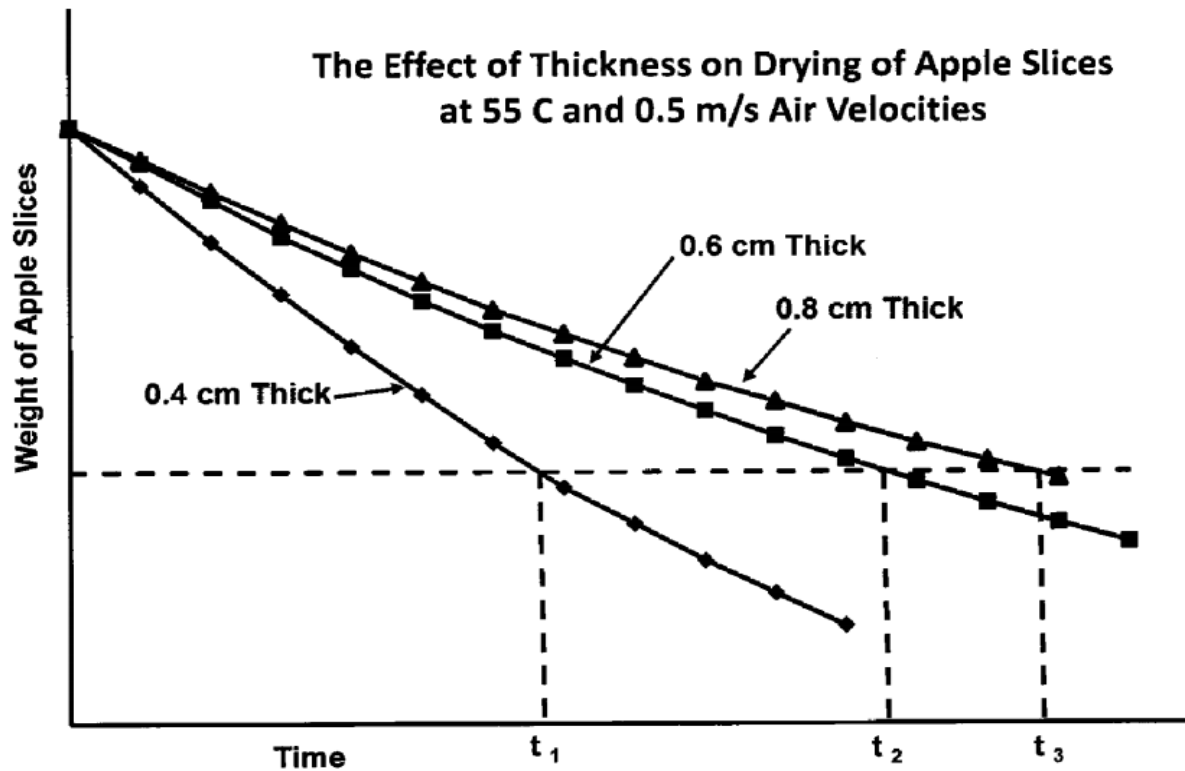
Initial drying of a fruit slice



Late in the drying process

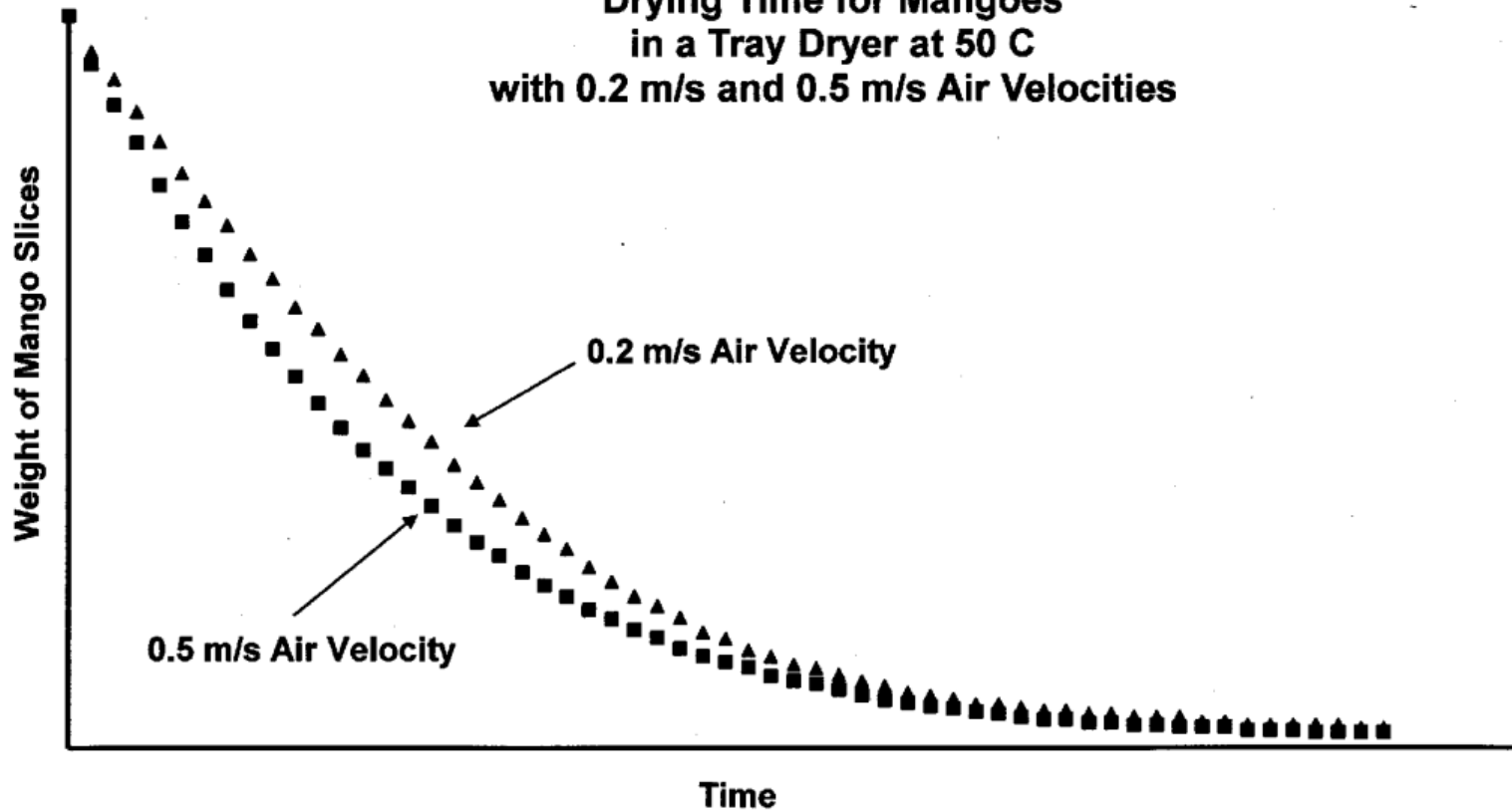


Effect of slice thickness

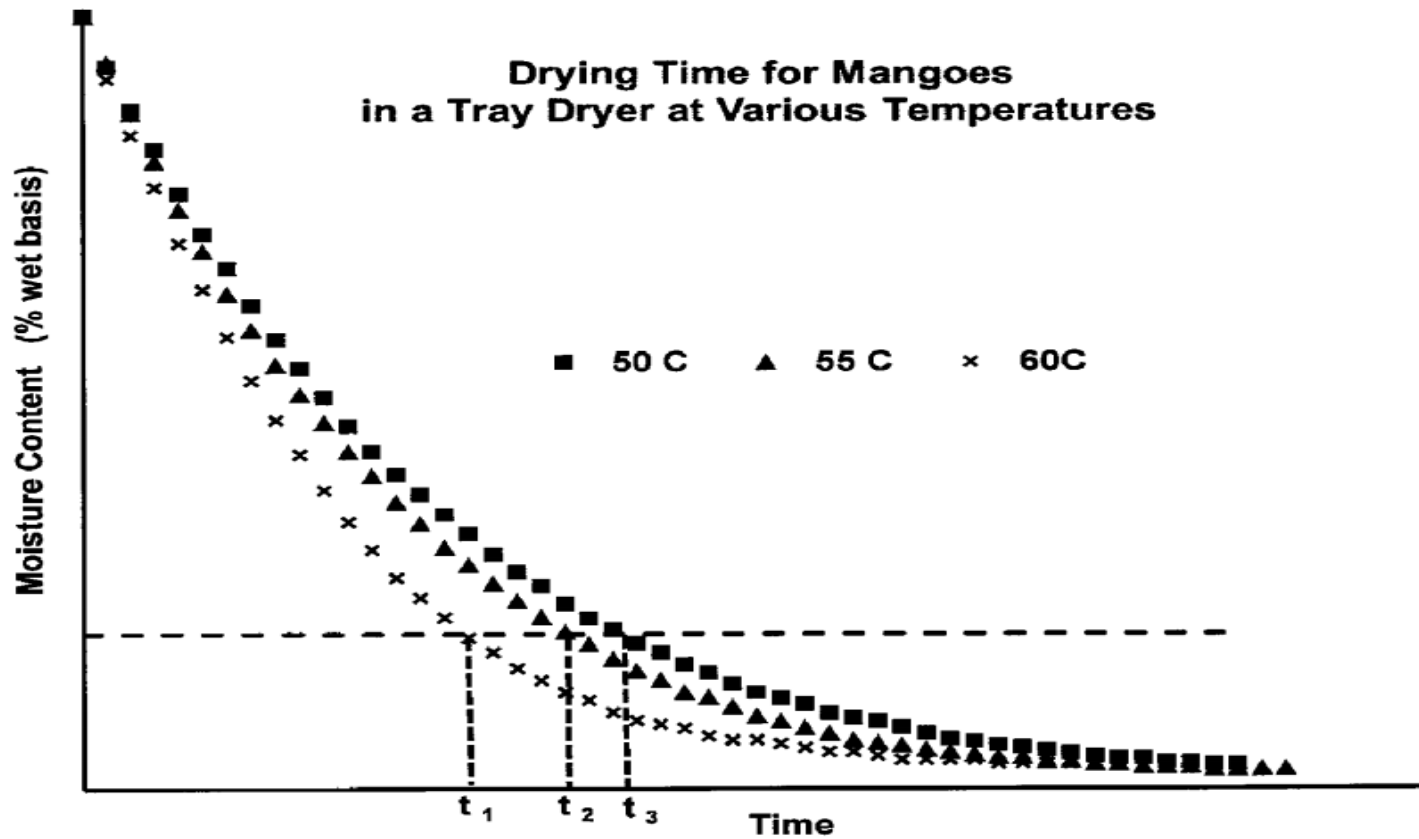


Effect of air speed

Drying Time for Mangoes
in a Tray Dryer at 50 C
with 0.2 m/s and 0.5 m/s Air Velocities



Effect of air temperature



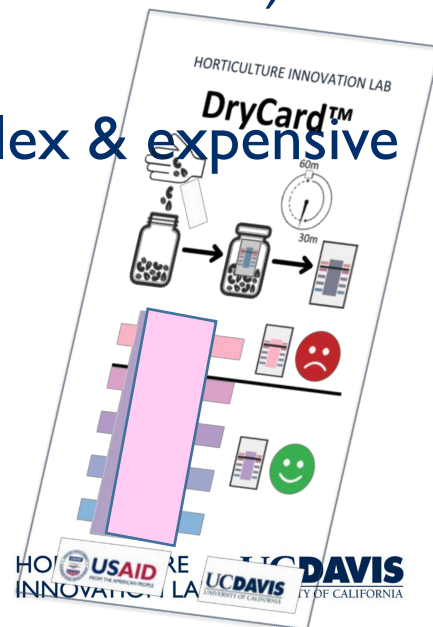
SO:

- Effective drying of high value commodities (fruit, vegetables, fish, meat) requires a system that provides:
- Thin layers
- Protection
- Air speed
- High temperature



Drying grains and pulses

- The problem
 - Frequently the DryCard shows farmers that their grain is insufficiently dry to be stored safely
 - How can they dry it?
 - On the ground (handling, rain, predation, contamination)
 - Chimney dryer (low capacity)
 - Current dryers (solar, gas, electric) are complex & expensive



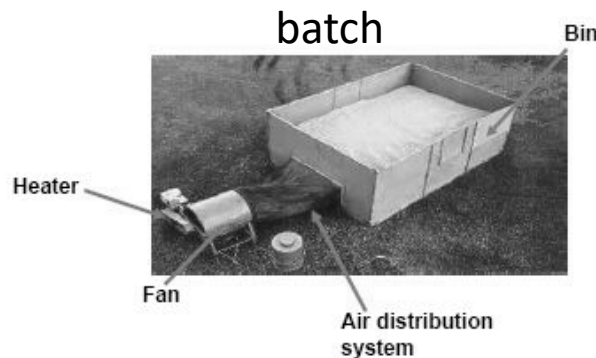
Dryer options (based on rice drying)

Dryer	Capacity	Dry time	Operation assumptions	Capacity (MT/day)
Sun dry	0.06 MT/m ³	2-4 days	17 m ³ area	0.25 – 0.5
Batch	1-10 MT	8-10 hrs	1 batch/day	1- 10
Recirculating batch	4-10 MT	8-10 hrs	1 batch/day	4-10
Column-continuous flow	10 MT/hr	5 passes	20 hrs/ day	40
Belt-continuous flow	10MT/hr	5 passes	20 hrs/day	40

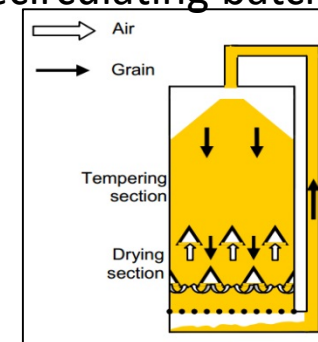
sun



batch

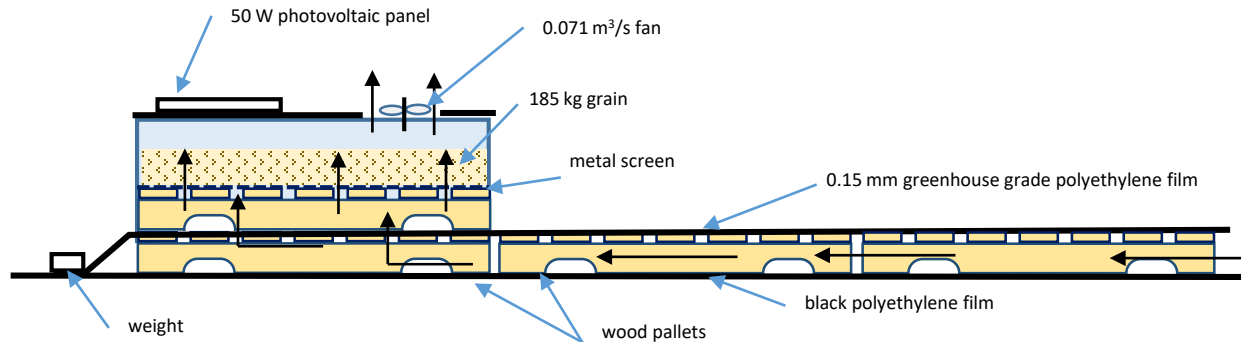


recirculating batch

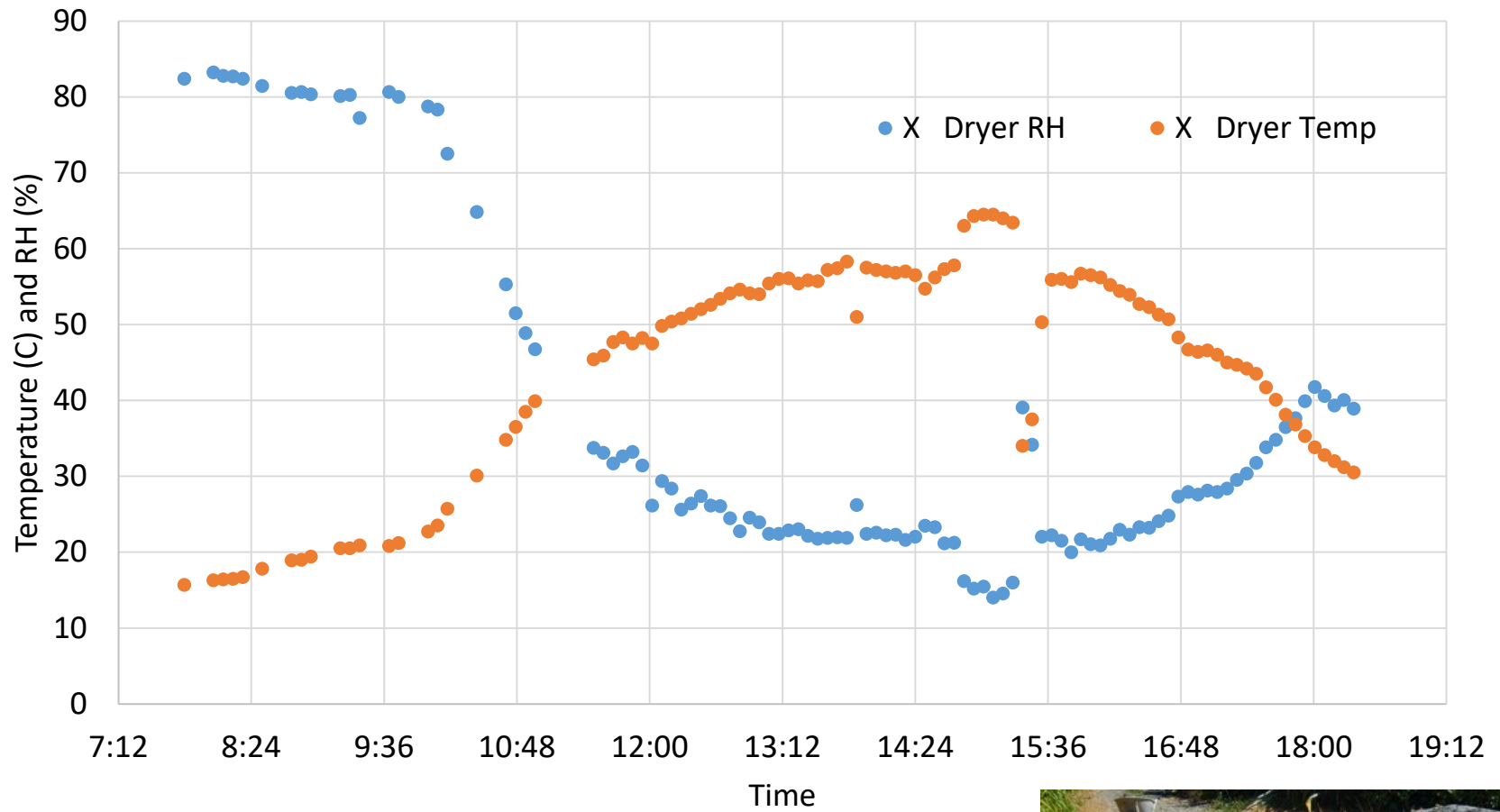


The UC Davis Pallet Dryer

- We have developed a simple solar dryer that uses inexpensive materials
 - discarded wooden pallets and a sheet of plywood
 - clear and black plastic
 - a small solar panel and fan
- Estimated cost <US\$100









DryCard Entrepreneur Program

Anthony Phan

Project Analyst

Horticulture Innovation Lab

aynphan@ucdavis



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Setting up DryCard Entrepreneurs



- 1) Identify suitable businesses or entrepreneurs for DryCard/Dry Chain
- 2) Review business plan for DryCard manufacturing and sales
- 3) If approved, establish agreement for production, reporting, and support
- 4) Send necessary resources including starter pack of materials (10,000 DryCards)
- 5) Begin in-country production and sales

We are looking to add more DryCard entrepreneurs!

DryCard Distribution Network



Email Anthony Phan
(aynphan@ucdavis.edu)
for contact information

- Set up DryCard manufacturing, marketing and sales in 10 countries
- 22,000+ DryCards sold (30,000+ distributed)
- Entrepreneurs incorporate related postharvest technologies into their business



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Dry Chain in Bangladesh

Mohd. Rezaul Islam ("Rana")



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Solar chimney drying in Bangladesh





Main dried products and how they dried in Bangladesh

1. Chili
2. Fish
3. Pulses
4. Cereals
5. Mango
6. Ground nuts
7. Sunflower



Traditional packing and storing



Dried fish awaiting packing



Dried fish is packing for transportation



Dried chilled stored for house hold usage

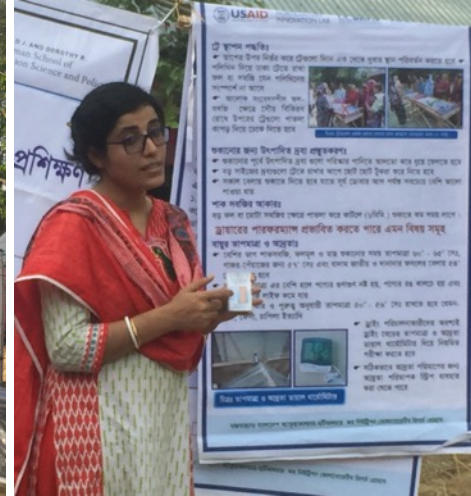
1. Color, scent and aroma are considered the primary determinant of proper drying
2. Palpability is also good indicator of drying for many products (chili,
3. Sometimes a sound (brittle sound when breaks) is also taken for a drying indicator

Project approach on introducing and implementing Solar Chimney Dryer

- 3 UC Davis Solar Chimney Dryers (1 for fish and 2 for fruit/vegetable drying)
- Shared by local communities of 3 upzilas of Barishal, Bangladesh



- Trained 40 people on building and drying in on chimney dryer
- Introduced dry card on determining proper drying



Perceived Benefits of Chimney Dryer

*“...is **easy to construct** with local materials, and **easy to maintain**, just need to change the plastics in few months time.”*

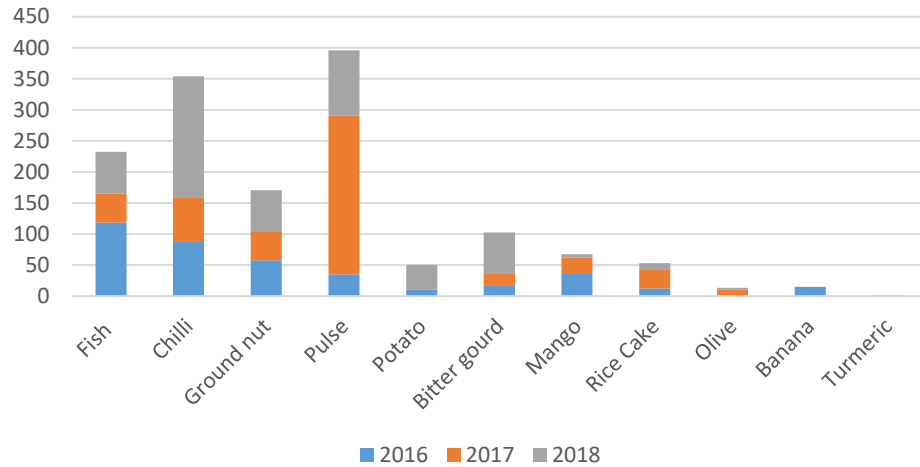
*“...can **dry faster** than traditional method. On clear sunny days, it used to take 5 days to dry, our fish, with chimney dryer, it takes 3 days.*

- *“...keeps food **safe, closed and protected** from dirt and dust, insects, rodents, dogs, cattle, mosquito eggs, etc.”*
- *“...gives **better color, smell and taste** of dried fish than the one dried using traditional method. No pesticides used during washing of vegetable products”*
- *“.....helps us get **better price**, almost double, for dried fish and vegetables. We **make good profit** selling vegetables and fish!”*

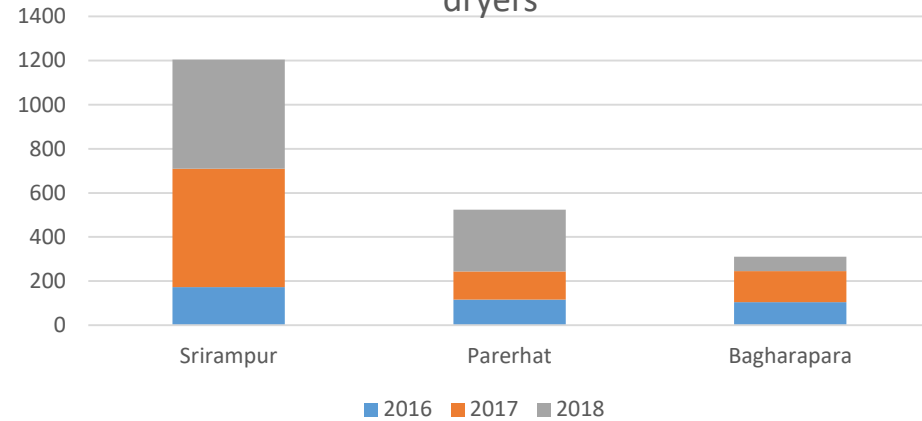


Total amount of product and price difference between fresh and chimney dried products

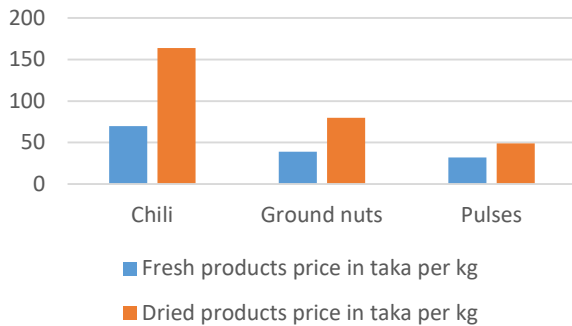
All products dried (Kg) in chimney dryers



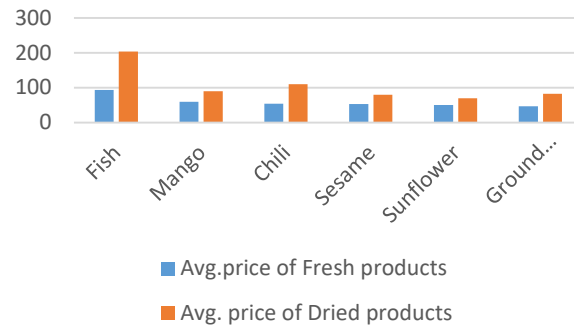
Site wise total products dried (Kg) in chimney dryers



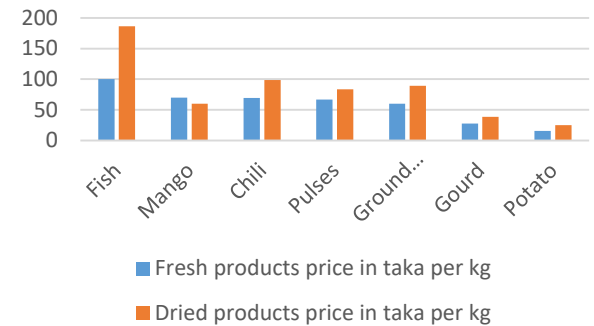
Market price in 2016



Market price in 2017



Market price in 2018



Challenges

Before implementing

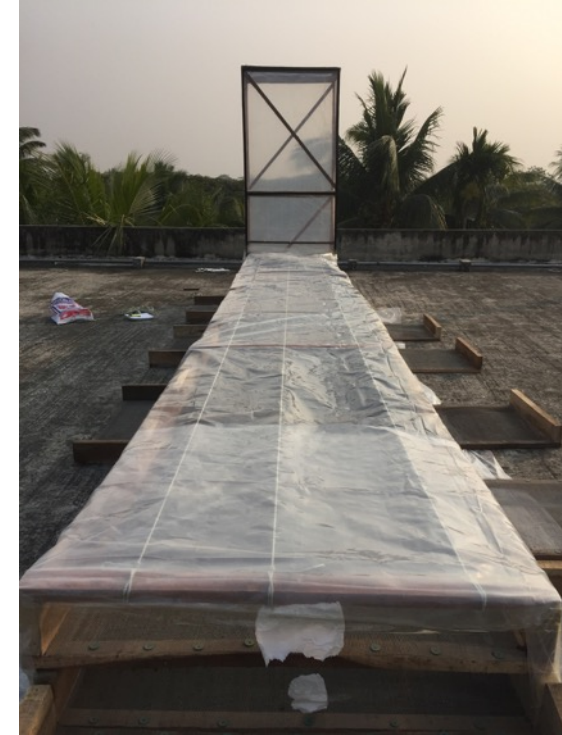
- Make people understand the technology
- Make carpenters/people understand the design (didn't have any handy manual back in 2015)
- Finding the sized and seasoned wood and good quality plastic

After implementing

- Food habit : no practice and demand of dried fruits (Banana, pineapple, jackfruit) vegetables (Tomato, Cabbage, Bitter gourd)
- Too much dependency on project support
- Shift back to alternate (traditional) easy way when it comes invest
- Lack of concern on food hygiene
- Unprecedented weather condition
- Periodic repairing
- Capacity for commercial drying

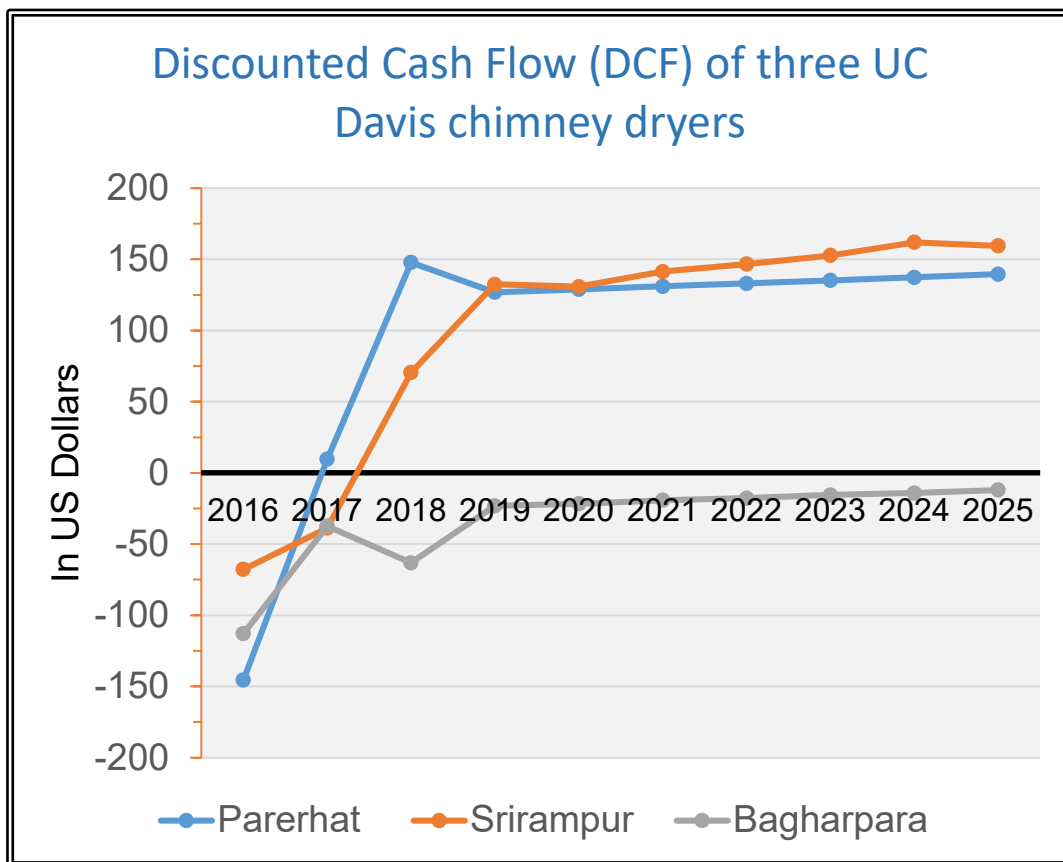
Successes & Opportunities

- One community built a second dryer for extra capacity by their own (started making and then completed with the project support)
- Prototype higher capacity for fish drying: PSTU and Hort. Innovation Lab team has tested higher capacity (40 kg) chimney dryer
- WorldFish scientists saw opportunities for fish drying and built 7 dryers in local communities near the sea
 - Technology scaling: 3 dryers built in Kolapara and 4 in Nidrachar (in 2017)
 - Trained farmers that built dryers have been hired by WorldFish to provide construction, repair service, and training
- Recently WorldFish secured fund a from WFP for making 26 dryer for the host community in Cozxsbazar to face the Rohingya crisis



Prototype higher capacity chimney dryer

ECONOMIC ANALYSIS - CHIMNEY DRYERS



- ❖ For dryers at Shrirampur and Parerhat, the revenue generated from dried products surpassed costs starting in the second year
- ❖ The dryer in Bagharpara was used to dry low value crops – cabbage, gourd, mango and banana. The revenue stream never surpassed the costs.
- ❖ ***Economic performance of technologies like the chimney dryer varies significantly depending on the products being dried (high vs low value crops, as well as the product unit prices.***



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