ECHO® Development Notes

Edited by Dawn Berkelaar and Tim Motis | January 2020 | Issue 146

Low Oxygen Methods for Insect Control in Seeds

by Tim Motis

This article summarizes several methods with which I have experimented to control various types of weevils in stored seed. Seed containers can range in size from small jars to barrels/drums, but must be airtight for these techniques to work. The techniques are relevant for seeds being stored for household planting or grain consumption, and can also be applied by community seed banks looking for low-cost control alternatives to chemical protectants and toxic fumigants.

Significance of insect damage in stored seeds

Seeds are typically stored for a time before being planted or consumed. Any insects present in that seed, if not controlled, can quickly multiply and cause significant damage (Figure 1).

Many storage pests originate in the field. Seeds may appear to be free of insects at the point of harvest, but eggs and larvae from the field may still be present. Insects can also be introduced when seeds are put into previously infested seed containers or grain bins. Insect damage reduces seed germination and quality and is a major cause of post-harvest seed loss. Most insect-related postharvest seed loss is caused by various species of beetles (Order Coleoptera) and larvae of moths and butterflies (Order Lepidoptera). This article focuses on weevils, which are a specific kind of beetle.

PRINCIPLES TO REMEMBER

Insects die with low oxygen (O_2) and high carbon dioxide (CO_2)

Without enough O_2, insects stop feeding and die. Insect mortality occurs at or below 5% O_2 (Njoroge *et al.*, 2019). Insects also die with high levels of CO_2. According to

Figure 1. Maize seeds damaged by lesser grain borer weevils (*Rhyzopertha dominica*). *Source:* Tim Motis

Navarro *et al.* (2012), rapid mortality of a broad spectrum of insect pests occurs with 60% CO_2. With elevated CO_2, it is not as critical to reduce O_2 all the way down to 5%.

Respiration depletes O_2

As seeds and insects respire, they take in O_2 and release CO_2. Microbes on seed surfaces also respire; this is true, for example, of mold growth under high humidity. Respiration is an important concept behind **hermetic storage**, which is the practice of keeping seeds in a sealed container. With no air coming in from the outside, the O_2 in a sealed bag or container declines until insect activity slows down and/or the insects die.

The rate of O_2 depletion varies with seed moisture content (moist seeds respire faster than dry seeds), temperature (heat favors faster respiration), seed volume (the more seeds in a container, the less O_2 there will be to start with), and presence of insects (the more there are, the faster respiration occurs). Looking at two reports, it took anywhere from <1 (Bbosa *et al.*, 2017) to 22 (Anankware and Bonu-Ire, 2013) days for O_2 in a seed-filled container to decline from 21% (the percent of O_2 in the atmosphere) to 5%.

Hermetic storage can be combined with other methods

Hermetic storage is the simplest method for controlling insects in stored seed, and is appropriate for many situations. However, combining hermetic storage with other approaches can be helpful, as in the following scenarios:

1. There are not enough seeds to completely fill a bag or container. As mentioned earlier, a partially-filled container has more air space—and thus more O_2—than a full container.
2. You have high-value seeds and want to control insects before any seed damage occurs.
3. You plan to share seeds with farmers and want to take extra precautions to avoid spreading insect pests.
4. You find it difficult to control insects by only excluding air. Insects' sensitivity to low O_2 can vary with life stage (Mbata

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et al. 2005). Eggs or pupae that might otherwise survive for a long time in a sealed container are more likely to die quickly when hermetic sealing is combined with other methods.

One approach that is related to hermetic storage is to withdraw air from a sealed container, creating a vacuum. The stronger the vacuum, the more air—and O_2—will be removed.

Another approach is to displace O_2 by allowing air to escape while introducing another gas into the container. In this article, we describe the use of biogas and CO_2 to accomplish this; both are alternatives to chemical insecticides.

Low O_2 extends the life of dry seeds

In addition to controlling insects, low O_2 prolongs the life of stored seeds (Groot *et al.*, 2015). Respiration is slowed by low O_2 and low seed moisture, preserving seeds' energy reserves. Low O_2 also slows the accumulation of unstable O_2-containing molecules that contribute to seed aging and deterioration (Jeevan Kumar *et al.*, 2015). **As long as they are dry, orthodox seeds will not die under low O_2.** (Orthodox seeds can survive drying or freezing, unlike recalcitrant seeds like avocado that will die if they dry out or freeze.)

Low O_2 can be accomplished with local resources

Mason jars, jerry cans, used vegetable oil containers, and drums/barrels are all suitable containers, provided they have airtight lids or caps and are not punctured. As another option, Purdue Improved Crop Storage (PICS) bags are promoted for hermetic storage of grain; for details on PICS bags, see a publication by Uys (2017) entitled "Using airtight bags to prevent post-harvest crop loss." PICS bags are made with high density polyethylene (HDPE), which is thicker and better than low density polyethylene bags for preventing air from diffusing in or out.

Many technologies can be used to create a vacuum, ranging from commercial vacuum sealers to low-cost devices such as brake bleeder pumps or modified bicycle pumps. *ECHO TN 93* explains how to modify bicycle pumps, brake bleeder pumps, and syringes to remove at least some of the air from seed containers.

Biogas, comprised primarily of methane (CH_4) and CO_2, can be produced with kitchen scraps or animal manure in household-level anaerobic digesters. CO_2 can be produced with materials such as organic waste, sugar, and yeast.

You can implement the methods described below with widely available materials. Use approaches that work best for your situation.

METHODS TRIALED AT ECHO

Vacuum sealing

Lawrence *et al.* (2017) controlled bruchids (*Callosobruchus maculatus*) in cowpea seeds with 600 mm Hg (mercury) of vacuum drawn with a commercial vacuum sealer. The vacuum did not adversely affect seed germination.

Building on that trial, I carried out a small experiment to find out if weevils could be controlled with a vacuum drawn by a brake bleeder pump (Figure 2). I placed maize weevils (*Sitophilus zeamais*) in 5 ml of maize grain into three sealed 225 ml jars under 500 mm Hg vacuum. I set up a similar treatment in another jar that was sealed but not under a vacuum. I repeated these steps with red flour beetles (*Tribolium castaneum*) in bird seed (mix of various grains used for this and other experiments presented in this article) and flour. Within three days, all of the maize weevils under vacuum died. Between the second and fifth week, all the red flour beetles under vacuum also died. At five weeks (present time), both types of weevils in sealed jars with no vacuum are still alive. Results suggest that, in partially-filled containers, a vacuum drawn with low-cost devices can kill insects faster than hermetic sealing alone; however, insect species vary in the time it takes them to reach 100% mortality.

Figure 2. Brake bleeder vacuum pump modified as explained in ECHO *TN* 93. *Source:* Tim Motis

How would you know if you have drawn enough vacuum to reduce O_2 down to 5% or less? Percent of container volume occupied by O_2 can be calculated as explained in an ECHO Research Update. With a container filled three-fourths full of maize seed, I calculated an O_2 level of 3.7% with a gauge reading of 500 mm mercury.

Note that pulling air out of a partially-filled plastic bucket or similar container causes the sides to collapse inwards. That would not be an issue with "gas-assisted" hermetic sealing, where O_2 is displaced by another gas. Below are some ideas for using biogas and CO_2.

Biogas

In a trial done in 2017, a colleague (Stacy Swartz) and I killed sawtoothed grain beetles (*Oryzaephilus surinamensis*) using biogas fed into an inner tube from a floating drum anaerobic digester (see *ECHO TN* 44) that was filled with animal manure. Squeezing the inner tube forced the gas into a 2-L plastic bottle filled with insect-infested maize seed (Figure 3). The beetles stopped moving within a few hours. Weeks later, we saw no live insects in the container; if eggs or larvae were originally present, they did not survive.

Researchers in India have already experimented with biogas for control of

Figure 3. Seed container modified with tire stems at the bottom and top of the seed container. The inner tube was connected to the bottom tire stem, which has its valve core removed to allow gas to flow into the container. The valve core was retained in the tire stem at the top of the bottle so that the valve-core pin could be pressed down (to allow air to escape while the container is being filled with biogas) and then released (to trap the biogas in the container once full). *Source:* Tim Motis

grain weevils (*Sitophilus granarius*), red flour beetles, and rice weevils (*Sitophilus oryzae*) that commonly infest stored rice and wheat. Based on a review of the literature and their experimental findings, Hoysall *et al.* (2015) drew some positive conclusions about using biogas to control weevils. First, more and more Indian farmers are using HDPE (high density polyethylene) bags/containers for seed storage, in place of traditional bamboo and adobe structures; this shift lends itself to gas-assisted hermetic storage. Second, household-level biogas systems have potential to control insects, even in partially-filled seed containers. Third, biogas does not reduce seed germination.

Some cautions are in order when working with biogas. For one thing, biogas is flammable. Be sure to monitor the tubing and connections, since gas leaks could lead to fires. For another, biogas can contain hydrogen sulfide (H_2S), which is heavier than air and could conceivably accumulate in a biogas-treated seed container. At low concentrations (0.01-1.5 ppm), humans can detect the rotten egg smell of H_2S (OSHA, 2020). At concentrations of 100-150 ppm, levels of H_2S are high enough to cause respiratory and other problems, but H_2S will be undetectable by smell--so caution is warranted at all times. H_2S is dispersed by wind, so when you open a container of seeds treated with biogas, do so in a well-ventilated space with air blowing away from you. Also, consider reducing H_2S by filtering your biogas through an iron oxide-containing scrubber, such as a rusty iron sponge (Vögeli *et al.*, 2014; see pg 55).

Carbon dioxide

Below are a few simple ways to make your own CO_2. If you experiment with these techniques, do so in a well-ventilated space to avoid breathing in unsafe amounts of CO_2.

From fruit waste

Fruits release CO_2 as they ripen and decay. With this in mind, I filled a 19-L bucket two-thirds full with star fruit (*Averrhoa carambola*) that had fallen to the ground underneath our trees (Figure 4). The bucket lid had a flexible rubber ring, making the bucket airtight when closed. I used a flexible plastic tube to connect the bucket of fruit to a bucket partially filled with bird seed. Within the bucket of bird seed, I placed a CO_2 sensor and a cloth-covered mason jar filled with a mix of flour, bird seed, and red flour beetles. By puncturing the lid with a thumbtack, I created a small hole through which air could escape as CO_2 flowed in. With CO_2 being heavier than air, the air is flushed out as CO_2 flows in (Saour and Yameogo, 1993). A buildup of pressure, indicated by the sides or lid of either bucket being pushed outwards, would show restricted flow.

The level of CO_2 in the seed bucket reached 80% one week after the start of the trial. One week later, when I opened the seed bucket, the level of CO_2 was still at 80% and all of the beetles were dead. This finding shows that it is possible, on a bucket scale, to kill red flour beetles within two weeks of exposure to CO_2 from rotting star fruit. A potential improvement on this method would be to mash the fruit in the bucket and then add water and some commercial yeast.

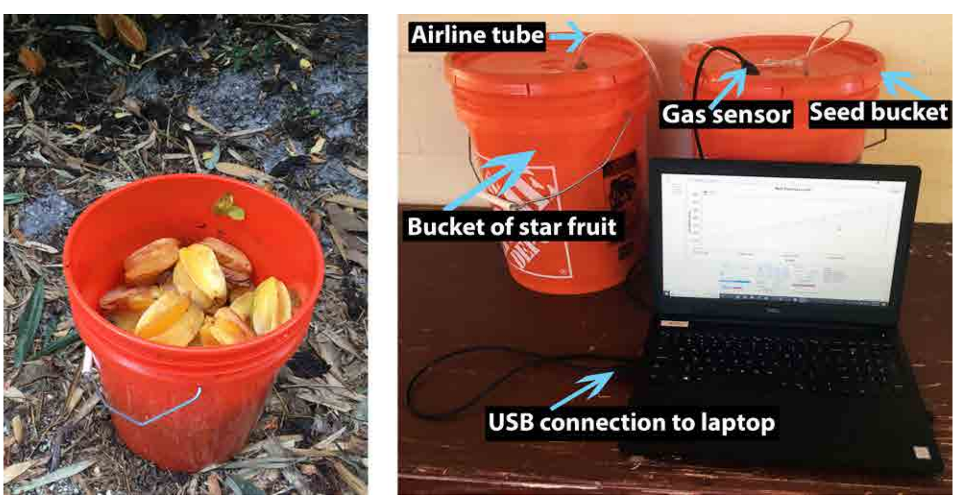

Figure 4. Bucket of star fruit (left) connected to a bucket of seeds (right), with a sensor for measuring CO_2 in the seed bucket. *Source*: Tim Motis

From yeast fermentation

Yeast added to sugar-water produces CO_2. Here are some basic steps for generating CO_2 this way:

1. Connect tubing to the lid of an airtight container. Vinyl tubing can be pressed into a hole drilled to a diameter that is slightly smaller than the tubing. I preferred to puncture the lid of a milk jug or bucket with a nail, and then use a pliers to push a barbed hose connector (like those shown here and in Figure 5) through the nail hole and into the lid. Use putty or superglue to make a leak-free connection between the connector and the lid.

Figure 5. Barbed hose connector on bucket lid. *Source:* Tim Motis

2. Mix sugar with water until it completely dissolves. The amount of sugar affects the length of time over which CO_2 will be generated. You need at least enough water to dissolve the sugar. I suggest filling a container anywhere from one-fourth to two-thirds of the way full. The empty space in the container minimizes liquid/water vapor from being pushed up into the tube as the yeast becomes active.

3. Add some yeast. I used a dry form of baker's yeast (*Saccharomyces cerevisiae*) shown in Figure 6 and commonly available in grocery stores in Florida, USA. The amount of yeast you use will influence the rate and duration of CO_2 production. Experiment to optimize the amounts of sugar and yeast that will adequately sustain a desired rate of CO_2 production for your needs. I suggest 1-1.5 ml of baker's yeast for treating small jars of seed; for buckets and drums, you will likely need 15-25 ml of yeast. To prevent liquid from pushing into the tube and entering the seed storage container, place the

Figure 6. Baker's yeast used to generate CO_2. *Source:* Tim Motis

containers so that the point at which CO_2 exits the yeast-containing vessel is lower than the point at which CO_2 enters the seed container (Figure 7).

4. Make a small hole, the size of a pin or thumbtack, in the lid of the seed container. This will prevent pressure build-up and allow air to escape as CO_2 enters.

With 2.5 ml of yeast and 0.5 L of sugar, CO_2 controlled cowpea weevils in a small jar (see 2017 ECHO poster). With 15 ml of yeast and 2 L of sugar, this method also controlled red flour beetles in a 114-L drum half full of maize seed (Figure 7). For the latter experiment, I placed beetles with a mix of flour and bird seed in two 50-ml plastic vials. One vial was placed at the bottom of the barrel, covered by maize grain, and the other half way up from the bottom of the drum. I opened the barrel 19 days after starting the experiment, at which time the beetles in both vials were dead. With more experimentation, the recipe could be adjusted to minimize the amount of sugar and time it takes to control weevils.

Figure 7. Carbon dioxide from a bucket flowing into a metal drum containing maize seed. Holes for tubing and air escape were drilled into a modified lid, made with PVC plumbing parts, to avoid puncturing the drum. *Source:* Tim Motis

Since keeping seeds dry is important for maintaining viability in storage, minimizing the time to control insects with this method is an important goal to consider. In the above-mentioned trial with the metal drum, relative humidity in the barrel stayed near 75%. I observed no mold, a finding consistent with that of Gupta *et al.* (2014) who found that high CO_2 levels (60%-80%) inhibited fungal growth; 80% CO_2 inhibited aflatoxin (*Aspergillus flavus*) in their research. Even so, with CO_2 generated in water or fruit waste (high in moisture), it seems best to disconnect the seed container from the CO_2 source as soon as possible. Then the lid of the seed container could be briefly opened to exhaust humidity before storing (with the lid closed once again) under dry conditions (less than 65% humidity to prevent mold growth) or with a desiccant. Minimum treatment time with CO_2 gas will depend on the insect species and how quickly CO_2 flows into the seed container.

A simple water displacement method works well for determining the flow rate of CO_2 or biogas. You will need a narrow bottle marked off in milliliters; I used a plastic graduated cylinder (Figure 8). Fill the cylinder with water and, with the palm of your hand over the top (to keep water in), invert the cylinder into a pan of water (4 or 5 cm deep). Keeping the open end of the cylinder under water, remove your hand. Water should stay in the cylinder. Keeping the cylinder upright, with the open end below the water level in the pan, place the end of the tube from the CO_2 or biogas generator under the opening of the cylinder. As gas bubbles into the cylinder, the water level in the cylinder will drop. Allow a minute or two for the rate of bubbling to stabilize underwater. Then record how many milliliters of water disappear after one minute. I found that, within three hours of mixing the ingredients, 15 ml of yeast with 0.5 L of sugar dissolved in 2 L of water produced 22 ml/min of gas. Two days later, the flow rate had declined to 7 ml/min, suggesting that more sugar would have been needed to maintain the maximum flow rate over a longer period of time. Since the process produces alcohol, which becomes detrimental to yeast as it accumulates, starting with more water might help sustain a desired flow rate by diluting the alcohol.

Candle burning

A burning candle consumes O_2 and releases CO_2 and water vapor. That made us wonder whether or not a burning candle in an enclosed, sealed space uses up enough O_2 to control insects.

With a lit candle placed at the bottom of a sealed and empty 19-L plastic bucket, Stacy Swartz and I measured the resulting O_2 concentration with an O_2 sensor. O_2 levels declined from 21% (normal for open air) when the lid was first closed to 17% when the flame went out (5 to 7 minutes depending on wick length; in a room with the lights turned off we could see when the flame went out). We repeated this three times with similar results each time. Our finding is consistent with a report by Dowell and Dowell (2017) who, likewise, found that candle burning only reduces O_2 by a few percentage points.

We found that the candle produced enough heat to melt a hole in the plastic lid. That much heat would kill at least some of the insects in a container. It seems likely that the heat could also adversely affect the viability of seeds near the candle; a germination test would confirm this.

Figure 8. Water displacement method for measuring flow rate of a gas. *Source:* Tim Motis

CONCLUSION

Our research results to date, combined with findings in scientific literature, indicate that low O_2 does control seed pests and can be achieved in creative ways without expensive equipment. Hermetic sealing is already widely promoted and practiced. Benefits of vacuum sealing have also been well documented. The CO_2 and biogas methods discussed in this article are not as well-tested. I was encouraged to find that red flour beetles can be controlled on a barrel scale with simple ingredients like sugar and yeast. I hope that this article will raise awareness of the benefits of low O_2 for seed storage, and that the information provides insights for further innovation. Always, when trying something new, experiment to make sure it works before promoting it to farmers.

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2019 ECHO International Agriculture Conference: Topic Summaries

by ECHO Staff

ECHO's 26th Annual International Agriculture Conference was held in November 2019. Below are brief summaries of a few of the plenary sessions and workshops. These and other talks, video, and slide presentations are available on ECHOcommunity.org.

CHE 25 Years Later

(Bibiana MacLeod)

Bibiana MacLeod, a physician from Argentina, has been involved in community development throughout Haiti for 25 years. Initially operating independently as a missionary, Dr. MacLeod was introduced to Medical Ambassadors International's "Community Health Evangelism" (CHE) program during a fated trip to the Dominican Republic. CHE is a holistic development approach that addresses people's physical, spiritual, emotional, and social needs. Having struggled to initiate change in the Haitian communities with which she served, Dr. MacLeod saw the chance for progress through the tenets of CHE.

CHE uses the acrostic, "METHOD", as one way to identify goals of its program:

M is for multiplication. Practitioners should seek to engage the community in question in such a way as to enable organic multiplication of CHE principles of health.

E is for equal dignity. Though herself a physician, Dr. Macleod did not consider herself more enlightened than the rural Haitians with whom she worked. She considered them to be equals, and themselves teachers from whom she could learn.

T is for tools. Community health cannot progress without providing the appropriate tools for education and application. These include participatory learning and action (PLA) and servant leadership methodologies.

H is for holistic understanding. CHE engages communities physically, spiritually, and emotionally. Each of these aspects of an individual's life affects their overall health.

O is for ownership by locals. Dr. MacLeod shared the need for an exit strategy; development practitioners should work themselves out of a job.

D is for development instead of relief. CHE practitioners do not assist in ways that create dependency. Instead, the locals are fully the agents of change in CHE.

Perhaps the most compelling aspect of Dr. MacLeod's presentation was the narrative of various community members with whom she has worked. There were stories of adoption, health ownership, and physical and emotional nourishment.

Dr. MacLeod was also transparent with what did not work in her programs. She learned many lessons over her 25 years in Haiti, interacting with the complexities of culture and family dynamics, and she used some of them to inform and encourage the conference audience. For example, she highlighted the importance of both horizontal (across a community) and vertical (across generations) change, so that problems solved for one generation do not return in later generations.

As the presentation closed, we were left with the following, “When [community members] say, ‘We did it!,’ you know you’ve been successful.”

Unleashing the Value of Neglected and Underutilized Crop Diversity
(Nadezda Amaya)

Many members of ECHO’s network are working to introduce underutilized crops in their communities. Getting these crops to grow is one thing; trying to market small quantities of a relatively unknown crop is another thing altogether. In her plenary talk, Nadezda Amaya described a project that helped increase awareness of chaya in Guatemala, first by using a technique called Rapid Market Appraisal (RMA) to analyze chaya’s value chain, then by introducing a series of interventions based on the results. The project, sponsored by International Fund for Agricultural Development (IFAD), was implemented by Bioversity and partner organizations in Guatemala.

Thousands of neglected and underutilized species (NUS) exist around the world. They tend to grow even under difficult conditions, and also tend to be very nutritious. These crops can potentially fill a niche in the market, providing income for small-scale farmers. However, small-scale farmers often have limited access to markets.

NUS crops have some drawbacks. For example, they may be viewed as “poor people’s food.“ Market chains may not exist for these crops. Since little breeding and selection has been done on most NUS, they may not yield well.

Chaya’s resilience and nutritive properties have been recognized for decades, but it has not been widely promoted as a cash crop. Chaya is indigenous to Mexico, where it is widely grown and appreciated as an integral part of people’s traditions and culture. Chaya is less well-known in Guatemala.

In the project Amaya described, a value chain analysis was done in Guatemala to determine bottlenecks, identify market opportunities, learn about women’s involvement in production and use of chaya, and look for ways to empower women.

Figure 9. Chaya's value chain in Guatemala was short. *Source:* Cody Kiefer

Based on the results of the value chain analysis, efforts were made to improve market access and demand.

Using RMA, data was collected through a literature review, interviews with people at all points along chaya’s value chain, market visits, and an evaluation of chaya’s acceptability to consumers.

Chaya’s value chain in Guatemala was short (Figure 9).

Chaya leaves are perishable, and the value chain was not very organized; however, lack of demand was the biggest problem. On the positive side, the RMA revealed that chaya cost less than other greens.

Amaya described several interventions to promote chaya:

1. Chaya was incorporated into school feeding programs. The leaves were used in three of 20 dishes served at the school. One logistical difficulty was that the schools needed official receipts from farmers for their records, but few of the farmers were equipped to give receipts.

2. Chaya was used in dishes served at high-end restaurants (Figure 10). Amaya quoted a chef who was passionate about chaya and who helped increase its visibility: “We have to use the kitchen as a development tool.”

3. The program worked with the processing industry to use chaya to make value-added products. Amaya commented that now is a good time to take advantage of the private sector’s move to responsible sourcing. Many companies are looking for ways to invest in socially responsible practices.

Figure 10. Chaya plated in a high-end restaurant dish. *Source:* Nadezda Amaya

4. Promotion activities helped to spread the word about chaya through social media posts, a conference, press conferences, food samples in markets, and online videos.

Amaya concluded her talk with a cautionary story. Quinoa used to be a NUS. In recent decades, it has been in such high demand that most farmers who grow quinoa no longer eat it themselves; instead, they sell it for the income and purchase less-nutritious food for themselves. Amaya commented that farming families should be encouraged to eat better themselves first, and then to sell their surplus.

Breadfruit Products: Untapped Commercial Potential (Mary McLaughlin)

Mary McLaughlin is the chair and founder of Trees that Feed Foundation (TTFF), which helps plant trees to feed people, provide jobs, and benefit the environment.

Though TTFF works with many kinds of fruit trees, they most commonly distribute breadfruit trees. In her plenary talk at EIAC 2019, McLaughlin spoke about the untapped commercial potential behind products made from breadfruit.

Breadfruit trees grow along the equator, in many areas of great food insecurity. McLaughlin described breadfruit as a “potato on a tree,” known mostly as a source of carbohydrates, but shared that breadfruit also contains magnesium and important vitamins.

For those who have a breadfruit tree, the yield tends to be “feast or famine.” A mature tree can yield 300 large fruits per year, but they all ripen at the same time--too many fruits for one family to eat before they spoil. However, the flesh from a single fruit, dehydrated and ground, can yield a pound of flour that can be used to make porridge and other products. Breadfruit flour has a two-year shelf life and boasts many other advantages. For example, the flour is gluten-free, which is a selling point at a time when many customers are looking for alternatives to wheat and other grains that contain gluten.

Still, exporting breadfruit or breadfruit flour is not easy. You need to be able to provide

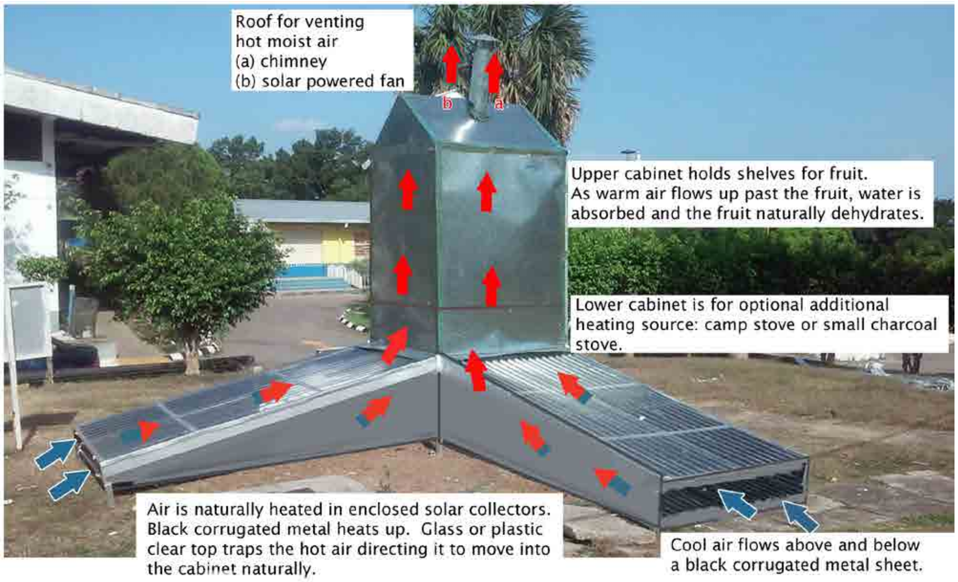

Figure 11. Hybrid solar dryer with arrows showing airflow and parts described. *Source:* Trees that Feed Foundation (https://www.treesthatfeed.org/resources/891-2).

large quantities of breadfruit that is of consistent quality. You need commercial equipment, labels, and packaging. You also need to figure out how to ship and market your product. Because of some of these hurdles, when TTFF helps establish a factory, it offers to buy breadfruit flour from them for two years.

TTFF has worked with producers and processors to see breadfruit developed into chips, flour, fries, and more. The organization maintains a contact list for people who grow breadfruit, including each grower's latitude, longitude and contact information. This makes it easy for companies looking for breadfruit to find and contact people near them who grow it for sale.

The way TTFF distributes trees is unique, and encourages local jobs. When an organization contacts TTFF about getting trees, they supply trees via a coupon system. TTFF contacts and pays a local supplier to provide the trees. (A minimum order is 500 trees if you are importing them from large scale growing houses in Europe and US. The easiest way to acquire trees is to obtain them from someone growing them in your own country, because import permits are needed to ship trees to a different country.)

TTFF recommends planting breadfruit at a spacing of 35 ft (11 m) between trees, with intercrop plants between. It generally takes three years before the first fruits are ready, and five years to reach full production.

TTFF has developed a hybrid solar dryer (Figure 11) to efficiently dry breadfruit and other fruits. McLaughlin commented that this dryer works well in a community situation. Community members who sign up to use the solar dryer bring their own metal trays (with holes in the bottom to facilitate air flow), and take turns using the dryer.

Black Soldier Fly Larvae Workshop (JC Barrios)

Providing livestock with protein is a vital part of animal nutrition management in the tropics. Finding feed ingredients that are high in protein and/or abundant can be a major obstacle.

Black soldier fly larvae (BSFL) are a protein-dense feed ingredient native to the Americas but now found in much of the tropics due to global trade. JC Barrios, Animal Manager at HEART, shared his failures, successes, and tips for constructing and maintaining an appropriate BSFL system for livestock feeds during his afternoon workshop presentation at the conference. For details about BSFL life cycle, pupation, and numerical data, see JC's presentation on ECHOcommunity.org.

BSFL systems vary in size, depending on how much material is available to feed the larvae and how much larvae you want to produce. Figure 12 shows a smaller, bucket-based system (Figure 12A) and a photo and drawing of a much larger design (Figure 12B, C). More photos of the larger design can be found in JC's presentation.

During his workshop, JC shared some of his failures and "lessons learned":

Feed for BSFL:

- <u>Good feedstock:</u> anything high in protein, carbohydrates/starches, or fats. These include kitchen scraps, dairy, fruit, coffee grounds, offal, and fermented foods; onion and garlic are okay to add in small proportions.
- <u>Don't feed:</u> diseased animals, seeds, cardboard, wood chips, paper shreds, things high in fiber, pesticide-contaminated items.
- Make sure to break up clumps of feed and to keep the feedstock aerated.
- Make sure the feeding bin drains well. The leachate can be used to fertilize plants.

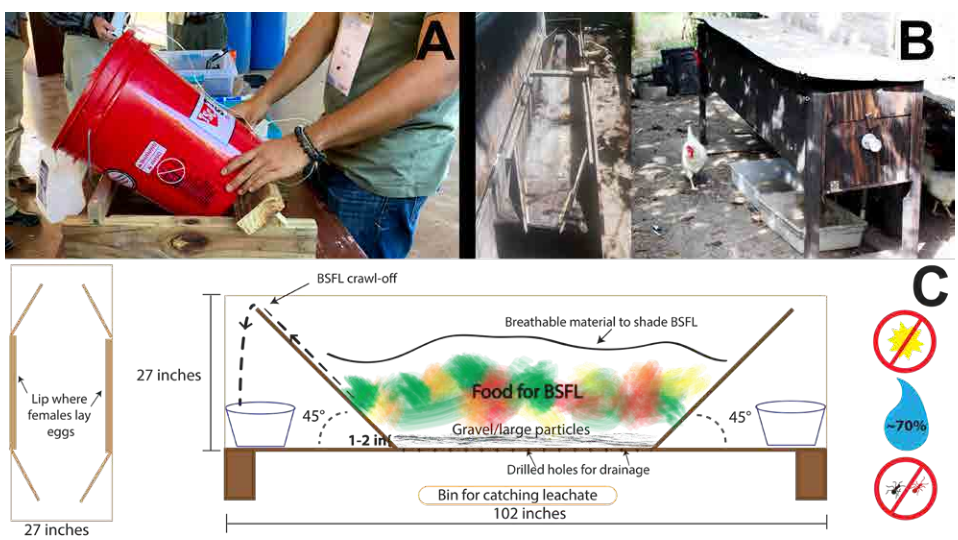

Figure 12. BSFL systems. A shows a smaller, bucket-based system, while B and C show a larger system that JC built and placed inside the chicken production area at HEART. *Sources:* JC Barrios and Stacy Swartz

Tips for success:

- To attract female black soldier flies to lay eggs in a newly-built system, place sour corn or cardboard in a jar (see presentation for photos). Females will lay their eggs in the cardboard or on the maize kernels.
- BSFL actively avoid light. Keep the catchment in the shade, out of direct sunlight. You can put shade cloth, a bag of feed, or a burlap sack over the feedstock to keep it shaded.
- A bad smell is a sign of a bad bin.
- When larvae are preparing to pupate, they crawl away from the feedstock area. In figure 12C, the angled ends of the bin are designed to funnel the larvae as they are preparing to pupate, so that they can be collected and fed to animals. If larvae do not crawl off, the feeding bed may be too dry and/or there may not be enough food. It is also a bad sign if larvae crawl off prematurely.
- To prevent ants from entering the system, put the legs of the feeder in containers filled with a mixture of water and liquid soap.

Feeding biochar to livestock

(Noah Elhardt)

Noah Elhardt lives in Senegal where he works with the Beer-Sheba Project, a training farm with a commercial livestock operation. In an evening talk at November's conference in Florida, he referred to a unique use of biochar that we asked him to elaborate on for EDN.

Charcoal and biochar are both terms describing carbonized chars derived from wood or other organic materials such as coconut fiber, bamboo, bones, or rice husks. Biochar has gained attention recently as a soil additive that can increase soil fertility and organic matter content. However, the labor involved in producing, dispersing, and incorporating biochar may discourage many farmers from using it. At the Beer-Sheba Project, we recently came across an innovative use of biochar that has cascading benefits across multiple areas of our farm.

Historically, charcoal has been used in medical treatment of humans and animals. More recently, some livestock farmers have begun using biochar as a regular feed supplement to improve livestock health and feed intake. A recent literature review (Schmidt *et al.* 2019) summarized the results of 112 scientific papers related to the use of biochar as a feed supplement for cattle, goats, pigs, poultry, or fish. In most of these studies, biochar had a positive effect: it improved animal digestion, reduced toxins, increased feed efficiency, improved meat quality, reduced odors from manure, and/or reduced vet costs. These benefits alone could make the use of biochar appealing and cost-effective in many contexts. (Rarely, biochar was found to bind with carotenoids or vitamin E, making them less available to livestock; this could limit its long-term use in some cases.) Biochar can be added to most feed rations. Typically, farmers add biochar at 0.5%-2% of the total dry matter feed weight.

When biochar passes through an animal's digestive tract, it binds with nutrients useful for plant growth. This is beneficial for two main reasons. First, the biochar is already pre-charged with nutrients when the animal excretes it in the manure. Second, some of these nutrients in manure are normally lost to the atmosphere (through volatilization) or to leaching; the presence of biochar helps keep those nutrients in place. Whether the manure is composted or applied directly to a field, its value is improved by the biochar it contains.

In Senegal, we intensively graze our livestock directly on pasture. During our rainy season, dung beetles are active. They incorporate the manure into tunnels below or near cow patties, where their young further decompose it. A study in Australia found that when biochar was fed to cattle, dung beetles incorporated it as far as 40 cm below the surface of their pasture (Joseph *et al.* 2015).

According to ongoing research, the benefits of biochar to plant production can vary widely depending on soil type, climate, and the biomass used to make the biochar (Kalus *et al.* 2019). However, when biochar is used as a feed supplement, improved soil health is only one of a series of cascading benefits throughout the farm. Apart from the biochar production, most of the work of charging, distributing, and integrating the biochar is done by animals or through existing uses of manure.

References and Further Reading

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Kalus, K., J.A. Koziel, and S. Opaliński, 2019. A review of biochar properties and their utilization in crop agriculture and livestock production. *Applied Sciences* 9:3494.

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ECHOES FROM OUR NETWORK

After reading the review of *Syntropic Farming Guide* in *EDN* 145, Roger Gietzen had some further thoughts to share on the topic of syntropic farming.

He began by sharing more about what he hopes to achieve with his design in Haiti. He commented, "One important advantage of the design I'm using in Haiti, is that it will produce an abundance of small pieces of wood that can be used for making charcoal or for building. And since it's coming from trees that can be pollarded, the yield will return every year without killing the trees. I got this idea from the Inga Foundation and integrated their alley cropping method into the design, [allowing for] more varieties of trees. I think this will be one of the most popular aspects of the design in Haiti and other tropical developing countries where wood is greatly needed. It is my biggest selling point to the farmers."

Gietzen also told us about some literature that expands on what was presented in *EDN* 145. First, he mentioned a book from World Agroforestry, *Agroforestry Systems for Ecological Restoration*, which was just recently translated from Portuguese (available online in English and in Portuguese). He wrote, "[This book] talks about the challenges of bringing the technology of agroforestry to developing countries." Gietzen highlighted a table in the book with a portion on page 38 (of the PDF file) that presents encouraging economic returns for successional agroforestry systems.

He added, "You might enjoy reading this article, too, written by one of Ernst's long-term students who has been doing research." The article explains experiments underway to grow grain crops between tree lines in a syntropic agriculture system. When asked for further perspective, Gietzen commented, "To continually grow cash crops or market garden crops is important to a lot of farmers. The people I first consulted with on syntropic systems [told me] that they need to evolve into forest systems to really get into that strong, self-sustaining abundant phase. That means the farm eventually becomes shaded and is not fitting for growing many annuals or market garden crops. You only get about four years of good sun exposure in the food forest and then it's shaded. That has bothered me from the beginning, because I know the annuals are the favorite crops for the farmers to grow in Haiti. I have been really wishing I can find some sort of compromise where I can use trees for soil regeneration, but prune them all so the farm stays sunny. That way the farmers can grow corn, beans, wheat, rice or whatever. I know it's possible, because I'm familiar with the inga alley cropping system. In fact, I started a couple inga systems this year in Haiti." The syntropic agriculture model offers an advantage to the inga alley cropping system in the sense that it incorporates many different kinds of trees rather than just one.

Syntropic agriculture is often advertised as needing no outside inputs. The article referred to above (and referenced below) mentioned some inputs. Gietzen commented, "I noticed that they do sometimes use manure or rock dust or other inputs. So depending on the soil condition, it may make sense to amend the soil, so you don't have to wait years for the fertility to improve. I may emphasize that when I revise my guidebook. It's great you can grow a system without inputs, but each case is different and farmers shouldn't limit themselves when they are capable of using organic fertilizers to give the system a boost."

Gietzen also responded to questions from our network about syntropic agriculture. That forum conversation can be found here.

References

Miccolis, A., F.M. Peneireiro, H.R. Marques, D.L.M. Vieira, M.F. Arcoverde, M.R. Hoffmann, T. Rehder, A.V.B. Pereira. 2016. *Agroforestry Systems for Ecological Restoration: How to reconcile conservation and production. Options for Brazil's Cerrado and Caatinga biomes*. Brasília: Instituto Sociedade, População e Natureza – ISPN/ World Agroforestry Centre – ICRAF.

Rebello, J.F.d.S. and D.G. Sakamoto. 2019. *Large-scale syntropic farming: results and challenges*. CEPEAS (Center for Research in Syntropic Farming).

BOOKS, WEB SITES AND OTHER RESOURCES

Vetiver Latrine

Many of our readers do not have access to good options for sanitation. One technology to consider is the pit latrine or "long drop"; there are many designs for constructing them. Dr. Roger Gietzen has presented an option using low cost materials that incorporates composting capabilities in his booklet "Vetiver Latrine Guide."

The design of this vetiver latrine boasts several advantages. For one thing, the materials are less expensive than those used to build more typical latrines. For another, vetiver grass, which provides the privacy screen, can also be cut for other uses; meanwhile, vetiver roots help reinforce the pit walls.

Gietzen's booklet is a very detailed and amply illustrated guide for constructing a vetiver latrine. The process includes choosing the site location, digging a pit, constructing the floor slab and supporting beams, and establishing the vetiver grass. The booklet also includes plans for incorporating a banana and papaya circle around the latrine.

A vetiver latrine is a good option for sanitation, as long as local laws allow for it, vetiver grass is available, and the design would be locally acceptable. The booklet is available from http://edn.link/vglatrin in multiple languages.

UPCOMING EVENTS

ECHO Florida Events:
Location: ECHO Global Farm, USA

Introduction to Tropical Agriculture Development
June 1-5, 2020

Small-scale Livestock Management
July 27-31, 2020

Introduction to Tropical Agriculture Development
September 14-18, 2020

ECHO Asia Events:

Seed Saving & Seed Banking Course
March 30-April 1, 2020
ECHO Asia Farm, Thailand

PLEASE NOTE: At ECHO we are always striving to be more effective. Do you have ideas that could help others, or have you experimented with an idea you read about in *EDN*? What did or did not work for you? Please let us know the results!