How to Keep Food on the Table in a Changing Climate

Tools for adding value (quality control and safe storage)

engineering FOR CHANGE

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Tools for Smart Production

By Michael Dunford

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Although there is enough food to feed the world's 7 billion people, some 800 million people around the world are trapped in a life of poverty and hunger. In recent years, global food production has reached a record high, but one-third of all food produced for human consumption is lost or wasted.

Post-harvest food loss is one of the largest contributing factors to food insecurity, under-nutrition, and hunger across the developing world, directly impacting the lives of millions of poor, smallholder farming families. Food losses happen at every stage of the supply chain, as commodities become damaged, spoiled or lost while harvested, handled, processed, stored, and transported. These losses are most significant in developing countries. Within the first three months of harvest, farmers in these regions lose up to 40 percent of their crops to insects, pests, mould, and moisture. Most of that loss is due to inadequate handling and storage practices at the household level.

The lesson seems to be lost on many of us, however. A large amount of work has been done over the past 30 years investigating the causes of food losses in developing countries, yet the world has continued to apply a disproportionate level of attention to pre-harvest inputs, and an almost exclusive focus on improvements in farmer productivity. The issue with increasing production is that it requires more resources such as land, water, seeds and agricultural inputs, while the prevention of post-harvest losses can substantially increase the availability of food worldwide without requiring more inputs or placing an additional burden on the environment.

Figure 3: Farmers' increased sales due to the reduction in post-harvest losses

Tools for Smart Production

For rural families in developing countries, many of which already live on the edge of hunger, these losses can be devastating. Losses of 30-40 percent force these families to make difficult choices such as cutting meals or deciding which children should attend school.

The most common coping mechanism typically employed by most farmers to minimize post-harvest losses is to sell their crops right after harvest. This allows them to cover immediate post-harvest expenses and loans but at the same time leads them to accept low prices for their crops. In the following weeks and months, these very farmers are forced to buy grain for their own consumption from the retail market at considerably higher prices, ultimately creating a cycle of poverty.

Post-harvest losses have significant nutritional, health, and financial impacts for both consumers and farmers. They disproportionately affect women, who are largely responsible for managing post-harvest drying, cleaning, and storage. The potential impact on women from reducing post-harvest losses is significant. With less demand on the food supply for the family, women have more time to pursue other income-generating activities.

Unfortunately, reducing post-harvest losses in the developing world does not have a simple, universal solution. Each culture and region is unique and brings with it its own barriers to preventing post-harvest losses such as a lack of sufficient storage facilities, varying moisture levels or treacherous road conditions.

Tools for Smart Production

At the forefront in the fight against post-harvest losses are some of the most innovative minds working hand-in-hand with the communities themselves. The goal is to develop, reasonable, simple and, most importantly, sustainable solutions to the challenge of preventing post-harvest losses. The solutions also need to be replicable, efficient and cost effective, yet capable of having a dramatic effect on the livelihoods of rural farmers.

One such example is the United Nations World Food Programme's (WFP) project to reduce post-harvest losses in Uganda from 2014-16. In the project, WFP engaged almost 113,000 smallholder farmers from different regions throughout the country. By design, the project not only emphasized simple and affordable technologies, but also thorough trainings on post-harvest losses, harvesting, drying, threshing and on-farm storage. At the trainings, farmers were given practical demonstrations of new handling and storage equipment. No obligation was placed on farmers to purchase the new equipment, yet over 90 percent of workshop participants ordered one of the new hermetic home storage technologies. The options included multi-layer polyethylene storage bags, plastic PVC silos and metal silos. After purchasing these new technologies, the farmers received field support in the form of refresher trainings in an attempt to maximize retention and utilization of the new knowledge.

Michael Dunford

Michael Dunford is the United Nations World Food Programme (WFP) Country Representative for Tanzania.

Mud Brick and Wood Storehouses Save Grain After the Harvest

Mud Brick and Wood Storehouses Save Grain After the Harvest

There are a lot of good ways to coax more crops out of plot of farm land. Irrigation, pest control and fertilizer are the basics, and they work. But it does not make sense to increase crop production without stemming the high loss of food after the harvest, according to Sam McNeill, an associate professor of agricultural engineering at the University of Kentucky, and his colleagues who wrote a report on grain storage in Ghana for the U.S. Department of Agriculture-Foreign Agricultural Service.

After the harvest, anywhere from 10 to 40 percent of the rice, maize and other grains grown worldwide spoils or falls prey to insects, rodents and other pests. By curbing that loss, we will take a long step toward feeding the growing population.The world needs to increase food production by 70 percent by the year 2050 to feed an extra 2.3 billion people, the UN estimates. [See the infographic: E4C visualized | How to boost global food production]

Since 2009, McNeill and his team have led workshops in Ghana and Nigeria to show how to improve storage facilities. Good storage preserves more of the harvest, and it is also a good sales tactic. It allows farmers to wait out the market glut that follows a harvest so they can sell their grain later when the price is right for them.

Something as simple as the right grain silo can make a difference in developing countries. Using McNeill's report as a case study in Ghana, the country's economy is agrarian in which crops account for more than half of the value of goods

Storage silos in Nigeria. Photos courtesy of Sam McNeill

Here's an Alternative!

Purdue Improved Cowpea Storage (PICS) Bags

Minimizes mold growth and accumulation of mycotoxins , controls storage insect pests and prevents gastrointestinal issues.

Suitable in these areas: West and Central African Countries.

Mud Brick and Wood Storehouses Save Grain After the Harvest

in which crops account for more than half of the value of goods produced nationwide. Most farms are small. Nearly 80 percent of the crops produced nation wide are grown on smallholder farms. Post-harvest losses on those small farms runs from 30 to 50 percent.

With those numbers, it is easy to see how targeting losses on small farms could dramatically boost the amount of food available in Ghana.

McNeill and his colleagues are working with farmers, grain buyers and stored-grain engineers and managers from public and private food mills, feed mills and distilleries in Ghana and Nigeria. They tailor their talks to each region, taking into account climatic conditions and the materials that are locally available for storage.

"We generally discuss the pros and cons of each type and let them decide. Research is on-going to determine the best designs, methods and materials, but we do encourage farmers there to dry the crop as soon as possible to preserve grain quality and food/market value," McNeill told E4C.

"They were eager students, enthusiastic participants during the workshops, and gracious hosts," McNeill says.
For more information, please see the Web site for the ADM Institute for the Prevention of Postharvest Loss at the University of Illinois at Urbana-Champaigne. And consider subscribing to their informative newsletter.

Here's an Alternative!

Wakati One

Keeps the quality of the crops to expand both local markets and highly profitable export markets, and prevents gastrointestinal issues.

Suitable in these areas:
Tanzania, Ethiopia, Kenya, Uganda, India and Indonesia.

"We generally discuss the pros and cons of each type and let them decide. Research is on-going to determine the best designs, methods and materials, but we do encourage farmers there to dry the crop as soon as possible to preserve grain quality and food/market value.

- McNeill

Mud Brick and Wood Storehouses Save Grain After the Harvest

The knowledge dispensed in these talks might include this kind of silo advice:

The narrow cribs in the top row of pictures store de-husked maize. Sometimes farmers leave the corn in the cribs for too long and grain borers and other insects infest it. The stored corn is also vulnerable to theft, and the structures are not practical for farms larger than 40 acres.

The mud silos pictured in the bottom row also store dried maize. Because they are mud, they work better in dry climates. Moisture can build on their walls, but cooking near them warms the walls and keeps them dry. Anecdotally, they prevent insect infestations.

Special thanks to the American Society of Agricultural and Biological Engineers for bringing the issue of grain storage to our attention.

Photos courtesy of Sam McNeill

Microfluidic diagnostics for Kenyan Dairy Farms

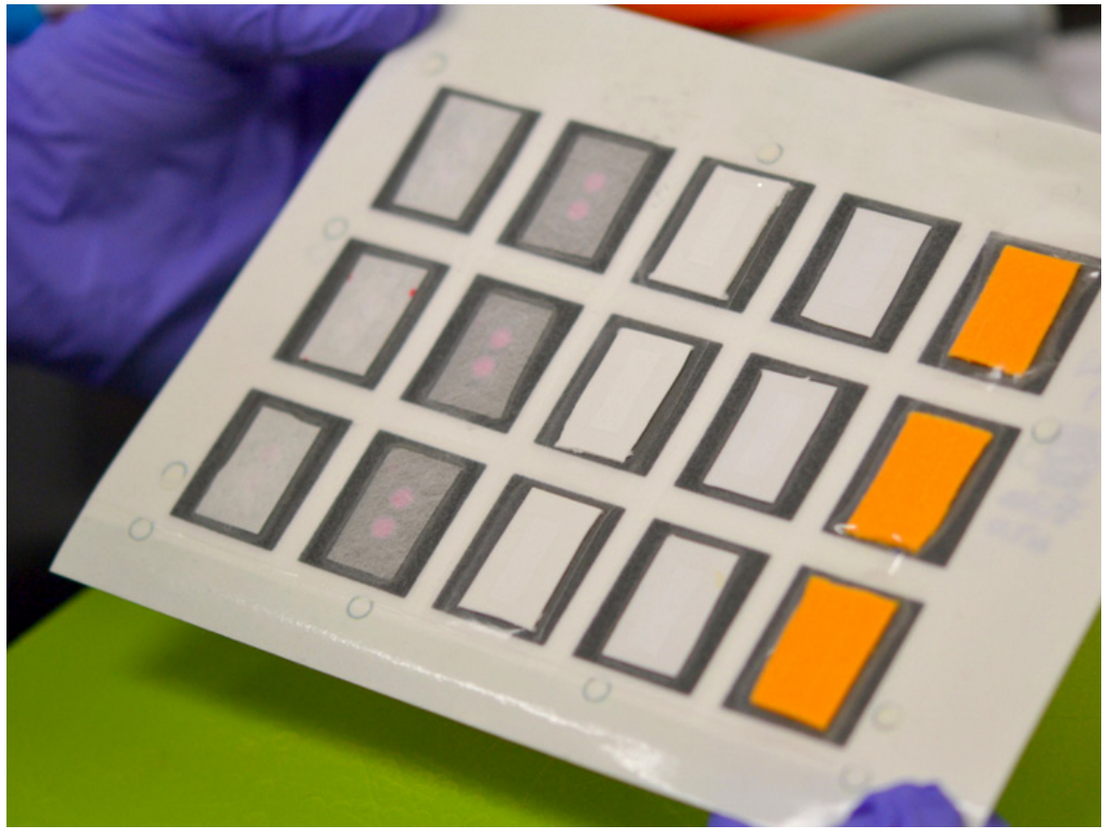
Microfluidic diagnostics for Kenyan Dairy Farms

Each square on this sheet is a test for aflatoxin, a compound produced by fungi that contaminate grains and milk. The different colors are each separate pad materials that DFA is testing for their wicking properties.

Tests for milk on Kenyan dairy farms may soon be ultra cheap, printed onto paper sheets and delivered to farmers and milk processing plants. Diagnostics for All (DFA), a US non-profit biotech firm, is designing tests for milk spoilage and estrus in cows (to detect when the cow is ovulating).

The tiny, coin-sized microfluidic chips are made mostly from thin strips of paper printed with wax. They do not require electricity or the storage of liquid samples. And they are simple enough for farmers to read, or to read with a mobile device app.

These tests, and others coming online after them, could streamline the dairy industry in Kenya and other developing regions. They may also boost profits on family-owned farms.



The BioD team builds a prototype of their biodigester.
Photo by Hatch International

Microfluidic diagnostics for Kenyan Dairy Farms

"I think it will have great impact," Patrick Beattie, Director of Operations at DFA, told E4C. "What it's doing is enabling farmers and veterinary workers to better manage their herds, and in some cases to improve their quality and access better markets that they wouldn't be able to access otherwise. All of that goes to a bottom line of improved farmer incomes," Beattie says.

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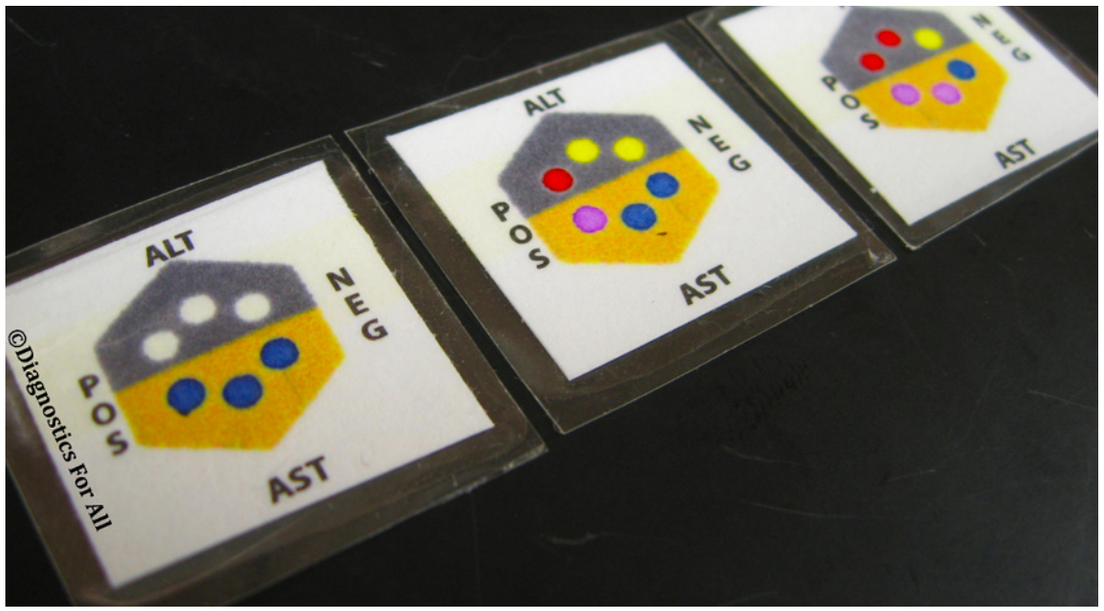
- Patrick Beattie,
Director of Operations at DFA

Wicking with Paper and Wax

The tests operate under capillary action, the same principle that allows plants to draw water from their roots up to their leaves, and the way a paper towel soaks up water when its edge is dipped in a glass. A drop of milk or a blood sample from a cow wicks through the paper along channels bounded by waxen barriers. It collects in wells that contain a chemical reactant.



These are human liver-function tests designed with the same basic paper and wax structure of the agricultural tests that DFA is developing now. Photo courtesy of DFA

Microfluidic diagnostics for Kenyan Dairy Farms

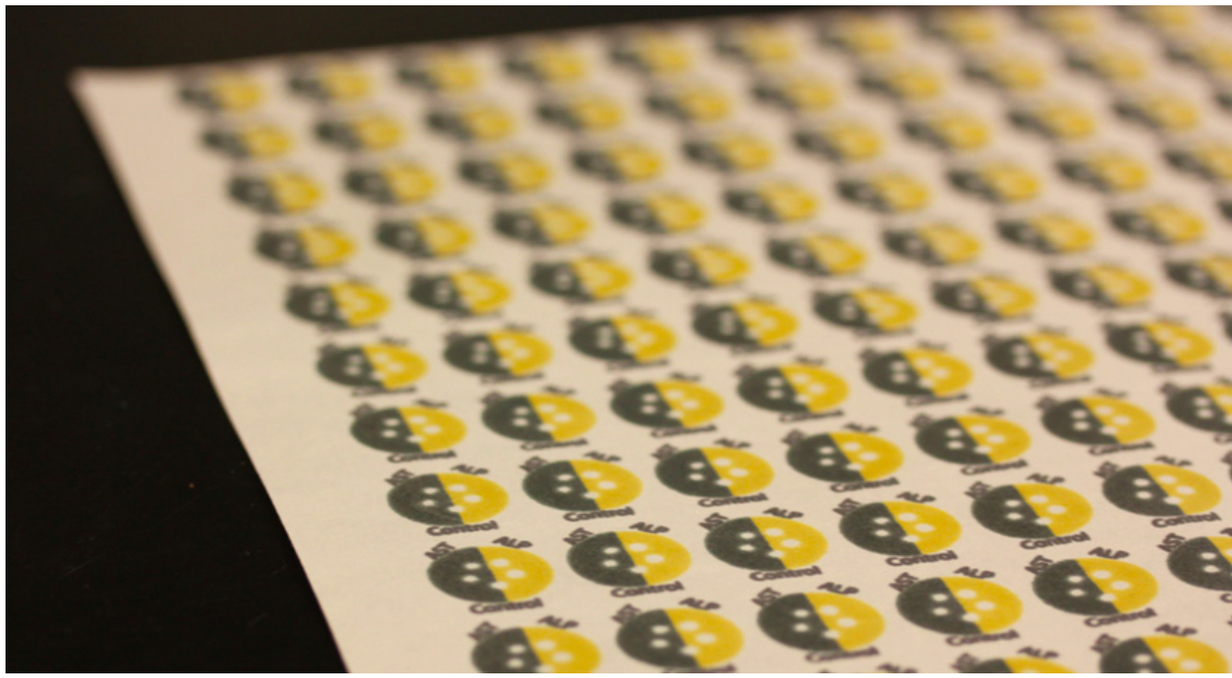
If the milk contains a threshold level of certain bacteria, a spot on the test will change color to indicate that the milk might be spoiling.

The estrus test works in the same way. The farmer would prick a cow's ear to draw a blood sample and apply it to the paper where a chemical reaction reveals the absence of the hormone progesterone. When cows ovulate their progesterone levels drop.

Why Spoilage and Estrus?

In 2009, Beattie joined a team at the Meridian Institute, a Washington, DC-based consultancy, on a research trip to Ghana and Kenya funded by the Gates Foundation. The goal was to examine the ways that farmers practice their craft in those regions, and then to identify processes that new technologies could improve. Milk spoilage and artificial insemination were good fits.

Small-plot dairy farmers in Kenya gather their milk and deliver it to central milk chilling plants. The plants pool the milk from dozens or hundreds of farms so that even a few gallons of spoiled batches could contaminate many others. Milk spoilage tests already exist, but DFA's paper strip, when the design is complete, is likely to be less expensive and more accurate.



This is a sheet of liver-function tests. When the design is complete, the agricultural tests may look similar, printed on a sheet for easy distribution to farmers. Photo courtesy of DFA

Microfluidic diagnostics for Kenyan Dairy Farms

Estrus testing is important, also, because of how domesticated cattle reproduce. Most cows are artificially inseminated The practice is widespread (there is even a WikiHow guide for newbies) and practical because bull semen freezes and ships well. The best bulls are in demand for breeding worldwide and it is easier to ship their semen than to ship the bull. It is also cheaper for farmers to buy semen rather than raise bulls for breeding. (For more, please see this brief overview of artificial insemination.).

DFA's estrus test can take guesswork out of the insemination process and tell the farmer when the cow is ready. A cheap and widely available test can save the farmers' time and money.

Paper Microfluidics for Developing Countries

George Whitesides at Harvard University first invented the paper-and-wax technique with cheap medical diagnostics in mind. DFA has licensed the concept and is developing a range of agricultural and medical tests. The organization has a grant from the Gates Foundation for $3 million over two years to develop the agricultural diagnostic tests.

DFA is also developing tests for liver damage, which is common in HIV/AIDS patients, and for malaria, dengue fever and preeclampsia, a complication of pregnancy.

Next Steps

When the tests are ready for distribution, DFA plans to seek partners to manufacture and sell them. The idea is that selling them, rather than giving them away, could help the tests catch on. DFA's field research has shown that farmers can make more money by using the tests, so they have incentive to buy them. And they will be cheap to manufacture, so private companies could have incentive to make them. "There will be incentive all around," Beattie says.

For more information or to contact DFA, please see the organization's Web site. To learn more about paper microfluidics, please see George Whitesides' paper in the journal Analytical Chemistry, Diagnostics for the Developing World: Microfluidic Paper-Based Analytical Devices (there, you can also find a link to a podcast about the research).

Out of iSHOW: The BlumbangReksa Shrimp Pond Monitor and CreenCHILL's biogas-powered milk refrigerator

Out of iSHOW: The BlumbangReksa Shrimp Pond Monitor and CreenCHILL's biogas-powered milk refrigerator

A shrimp farm monitor and a biogas-powered milk chiller won India's leg of the world-traveling iShow hardware competition. The teams behind the inventions shared a part of $500,000 in prizes and expert design review. Here's a closer look at their food-production-improving innovations.

BlumbangReksa Shrimp Pond Monitor

The tiger prawns swimming in butter on your plate likely began life swimming in a shrimp hatchery. Raising crustaceans is big business in Asia and Indonesia vies with China for the title of number one shrimp producer in the world.

Before they get to the plate, though, the prawns have to navigate life in carefully controlled waters. Imaduddin Majid and his team created a device that automates the water testing process to make the job easier on the farmers.

Majid and his team saw farmers in their hometown of Yogyakarta, Indonesia, testing their water periodically or, in some cases, just guessing about the conditions and going off of their intuition. Shrimp farms are expensive and a failed farm can bankrupt a family.

BlumbangReksa goes to work on a shrimp pond in Indonesia. Photo is a screen capture from a YouTube video.

To help their local farmers, Majid and team investigated the reasons behind farm failures.

Out of iSHOW: The BlumbangReksa Shrimp Pond Monitor and CreenCHILL's biogas-powered milk refrigerator

Shrimp and prawns species require specific ranges of salt and acidity at different stages of life. Maintaining the balance depends on changing factors such as the weather and ground runoff. A pond's salinity can climb during a run of hot dry days, for example, as the water evaporates.

> **We needed to know what make shrimp die and what we can do to make a change. And we found it. The cause behind these big problems is human error.**
>
> **- Imaduddin Majid**

To prevent mistakes, the team created BlumbangReksa, an automated testing system that alerts farmers when conditions dip into the danger zone. The device drops sensors into the pond and tests for six parameters: Dissolved oxygen, temperature, salinity, total dissolved solids, pH and the relative humidity of the air above the water. When a problem arises, farmers receive a text message or they can view data streamed to a Web site.

"Usual measurement devices are not enough. Shrimp farming runs very fast, so they need fast responses and real-time measurement to maintain the water quality to keep shrimp healthy. Also, the device must be connected to some database so they can have big data, and the device can do analysis so it can give information about what to do to keep the water quality high," Majid says.

"We do this thing because seeing the farmers' smiles are the strongest inspiration for us," Majid says.

Out of iSHOW: The BlumbangReksa Shrimp Pond Monitor and CreenCHILL's biogas-powered milk refrigerator

GreenCHILL Off-grid Biogas Milk Refrigerator

More than 20 percent of milk produced in developing countries is lost before a consumer lays hands on it. Waste stems from inefficiencies on the farm, postharvest, processing and distribution. But it doesn't have to be that way. In industrialized countries roughly 5 percent is lost before the consumer buys it, thanks in part to prompt refrigeration.

The lack of power and refrigeration on some Indian dairy farms has been a major cause of milk losses. Some farmers chill their milk with ice slabs, and others simply try to sell the milk as quickly as possible. But GreenCHILL burns fuel that the dairy farms have in abundance and preserves milk for longer. The savings in chilling expenses and milk loss prevented could add up to offset the cost of the system, says Akash Agarwal, the co-founder of New Leaf Dynamic Technologies which is developing the GreenCHILL. He explains the innovations folded into the design.

The GreenCHILL biogas-powered refrigeration system cools a 10 metric ton cold storage unit. Photo courtesy of GreenCHILL.

Out of iSHOW: The BlumbangReksa Shrimp Pond Monitor and CreenCHILL's biogas-powered milk refrigerator

"Our technology uses Ammonia gas as the refrigerant. We have engineered an ammonia absorbent and de-absorbent module. This module uses hot water at 110° C to compress the refrigerant (ammonia) which is then condensed in a condenser. A controlled release of the liquid ammonia from condenser through an expansion valve causes refrigeration to happen like any other refrigeration process. The refrigerant from evaporator (bulk milk cooler or air chiller in this case) is then circulated back to the other module where decompression takes place with water at ambient temperature. Using the pressure driven refrigerant cycle refrigeration takes place without requiring a compressor."

The system integrates with any industrial 500 to 1000 liter milk cooler or cold storage by replacing the unit's compressor. A full system with cold storage costs $19,000 and sales have begun. The design is versatile and 10 variants are under construction now that run off the waste heat generated by gasifiers. The gasifiers power telecommunications services in rural parts of the northern Indian states Rajasthan and Uttar Pradesh.

After two iterations, research and development continues in house and in tandem with the Indian Institute of Technology, Patna. The aims are to increase energy efficiency and reduce the ecological footprint, Agarwal says.

For more information please see www.newleafdynamic.com.

Here's an Alternative!

ChotuKool

CFC-free, fan-cooled thermo-electric cooling system intend-ed to conserve food and pre-vents gastrointestinal issues.

Suitable in these locations: West and Central African Countries.