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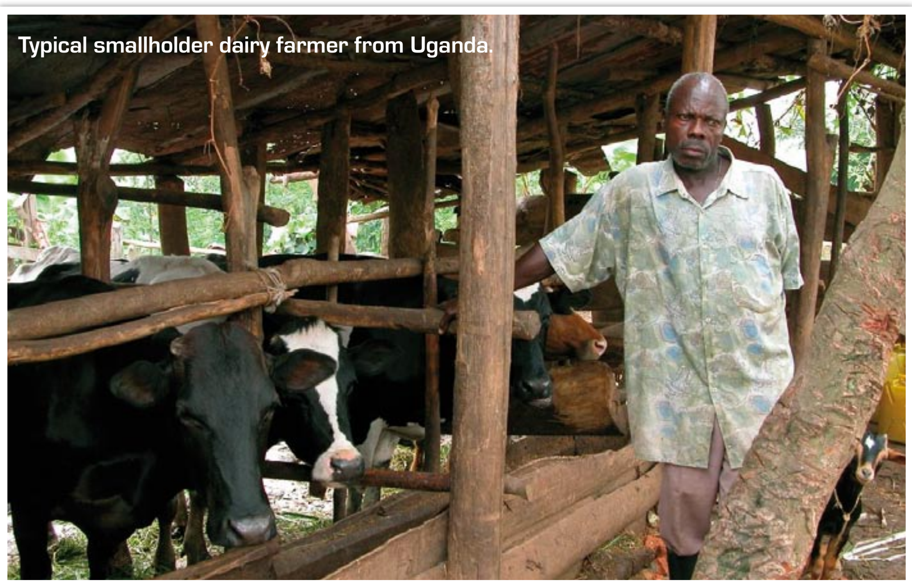
Smallholder farmers are rural producers, predominantly found in developing countries. They farm using mainly family labor and the farm provides the principal source of income. Two-thirds of the sub-Saharan region's 615 million people are smallholder (2-5 hectare) farmers and dairy farming (2-5 milking cows) is one of their significant source of income. Figure 1 shows a typical Ugandan smallholder dairy farmer.

Dairy in sub-Saharan Africa

The dairy market in sub-Saharan African countries is separated into two main channels: an informal channel and a formal channel. The formal channel includes milk collected from the farmers, cooled at a collection center and then transported to central processing facilities (private or public), where it is processed, packaged and marketed locally or exported to neighboring countries. The informal channel includes milk that is marketed directly from the farms, usually without any processing. In Uganda, the informal channel commands nearly three quarters of the market. In the informal channel, most of the morning milk collected on the farm is either sold to local or peri-urban markets or private collection centers that in turn sell directly to the urban public. Transportation to collection centers or urban markets is often done on foot, on the back of a bicycle (See Figure 2) and by public means. Once the milk reaches the market, it is sold as is to the consumer. The morning milk can be taken to markets because it is daytime and people can safely travel on roads. Since traveling at night might be unsafe and milk is highly perishable and cannot be kept till the next day without preservation, the evening milk is used for the farmers' families and the surplus is either sold where a local market exists, processed into low value products like ghee, or wasted. The refrigeration option is not available to most smallholders, as they do not have access to grid electricity and kerosene refrigerators are not economical and difficult to maintain. The high postharvest losses, especially during the rainy season present an opportunity.

The CoolChurn

Two approaches toward solving this problem have been tried. Middlemen have added hydrogen peroxide to the milk to lengthen its life. Unfortunately, this approach does not meet international standards and excludes the treated milk from the export markets. Also, if used in large quantities, hydrogen peroxide can cause health problems. The Uganda Government has banned the practice. A second approach involved producing ice using solar energy, but it has not been adopted due to the high initial cost. Recently, through a collaboration with researchers at the University of Georgia, Cool System of Germany (www.coolchurn.com) has taken an existing evaporative cooling technology developed for affluent European/Asian beer consumers and reengineered it to meet the needs of a milk cooling at a smallholder scale (See Figure 3). CoolChurn comes ready for the job, once filled with milk, all is needed is a flick of a switch and the cooling begins. Once the cooling is over, CoolChurn is regenerated to be ready for the next batch of milk. The regeneration involves heating the whole container to a suitable temperature. Electrical or natural gas heating is predominantly used in



Typical smallholder dairy farmer from Uganda.


Milk delivery to the collection center on bicycle

European/Asian beer applications. To be able to regenerate the cooler on the farm, researchers from the University of Georgia, Makerere University, and Uganda Industrial Research Institute have experimented with a charcoal-powered brick oven. But because of the potential to contribute to deforestation, they have changed from charcoal to biogas as the energy source (See Figure 4). Biogas contains combustible methane (approximately 60-70%) and carbon dioxide (approximately 30-40%). Biogas results from fermentation of organic matter, such as cow dung, in absence of oxygen. It is an ideal fuel on smallholder farms not only for milk cooling but for other applications, such as cooking and lighting. The spent waste from the fermentation plant is excellent organic manure that can improve soil fertility.

Performance study

A field performance pilot study of the CoolChurn, funded by the World Bank, through a 2008 Development Marketplace Grant (http://web.worldbank.org/WBSITE/OPPORTUNITIES/GRANTS/DEVMARKETPLAE) is in its second year in Uganda. The study is being conducted with Rukara Dairy Farmer Cooperative Society, which has over 445 farmer members in Rubindi Sub-county of the larger Mbarara area, three to four hours west of Kampala, the capital. Thirty units are being deployed with the first cohort of participants and an additional thirty will be deployed in the second half of the study. To ascertain performance, cooled milk has been tested with respect to temperature, microbial count, and microorganism biochemical activity, 24 hours after the initiation of the cooling. From an average temperature of 29 oC, milk has been cooled to an average of 11 oC, a drop of 18 centigrade degrees. The conventional plate count method was used to assess the effect of cooling on milk aerobic microbial content. The number of colonies per ml (N) was only computed if the count fell in the colony range of 25-250 as required in the conventional method. Cooling reduced N as expected; the fresh and cooled milk Ns ranged between 13,000-140,000 and 5,900-29,000, respectively. A more meaningful assessment of cooled milk quality has been accomplished with the Resuzurin Reduction Test. In all cases, the milk was either excellent (blue - no color change), or very good (light blue) or good (purple). To date, all the milk cooled in CoolChurn has passed quality measures and has been added to the rest of the milk cooled at the Rukaka Dairy Farmers


Biogas regenerator in construction. Biogas is introduced at the bottom via a burner. The cooler is placed in the inner chamber and the top is covered with a steal plate with a small exhaust hole and insulated with removable bricks. For a given burner, the temperature achieved in the regenerator depends on the ratio of the air inlet to the exhaust areas. The change in temperature of the cooled milk from coolers regenerated with biogas achieved so far in approximately 10 centigrade degrees. Optimization is ongoing to increase the regeneration temperature through burner improvements and air recirculation.

CoolChurn (left): Height = 560 cm; Diameter = 380 cm, Milk capacity = 15.5 liters; Wight, empty = 22.0 kg; Weight, full = 37.5 kg; Opening diameter = 9.0 cm. A pair of electric regenerator installed at the collection center (right). Each unit regenerates two stacked-up coolers.

Cooperative collection center (See Figure 5). The exceptions have been when the water content was too high, a measure unrelated to cooling.

Feedback from farmers

Feedback from farmers is suggesting a great interest in regeneration on the farm with biogas, which will ameliorate the transportation problem; some have found the CoolChurn too heavy for transportation on bicycles and others higher up on the smallholder production continuum have found the cooler capacity too small to meet their evening cooling needs. However, the extra income generated by the evening milk is expected to make microcredit borrowing for biogas plant construction attainable. As such, adding milk cooling to cooking and lighting makes an investment into a biogas plant very attractive. Anaerobically fermenting the cow dung and utilize methane for energy purposes reduces the global warming contribution from smallholder farms. The exact income potential from the saved evening milk is not yet known. The final capital cost will depend on the CoolChurn demand. Participating smallholder business data will be analyzed after a full year of operation.

Business model

The business model in the study is based on smallholders paying in kind (fraction of cooled milk) till the cooler is paid off. In this model, regeneration can be carried out on the farm (biogas) or at the collection center (grid electricity). An alternative model is for a milk processor or middleman to own the coolers and uses them to increase milk collected from the smallholders. In this model, the processor can regenerate the coolers at a central facility as is the case for beer applications in Europe and Asia. In conceptualizing the milk cooling application, the focus was on the evening milk. But some farmers with small capacities are using the cooler for both evening and morning milk. The morning milk is added to the evening milk in the cooler, which offers flexibility as to when the milk can be transported to the collection center.

The performance of the CoolChurn in terms of maintaining or improving milk quality has successfully been demonstrated. However, there is more room in improving the product with respect to capacity and individualized renewable energy-powered on-farm regeneration. Work is in progress to address some of these challenges, so more milk can enter the cold chain and smallholders can realized more income and possibly expand their business.

Rukaka Dairy Farmers Cooperative Society collection center (left) and view of the town it is located in. The building is out of view on further up on the side of the sign. The employee in front of the collection center is manually cleaning the CoolChurn before regeneration.