

Using Solar-Powered Adsorptive Driven Icemaker in Rural Areas: A Case Study of Northern Nigeria

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ABSTRACT

Rural areas in Northern Nigerian need refrigeration to preserve water and milk, for cold drinks, and for other needs. Because of the increasing cost and scarcity of conventional energy sources and because a large percentage of the rural population does not have access to this conventional energy service, they cannot solely depend upon electricity for refrigeration. It is becoming more imperative to make use of alternative energy sources. The solar-powered icemaker and its application to milk preservation in rural areas of the Northern Nigeria. Many Marketeters have increased their income by increased ability to market their milk.

Keywords: Energy, refrigeration, icemaker, rural area, milk.

1. INTRODUCTION

As a type of environmental benign and energy saving technology, adsorption refrigeration, which is driven by the low grade heat and uses refrigerants with zero ozone depletion potential (ODP) and zero global warming potential (GWP), is a promising way for the environmental protection and energy conservation. Meanwhile, solar energy exists abundant in the environment and no restriction of the usage. Combining the adsorption refrigeration technology with solar energy may further improve the energy utilization efficiency, and it attracted numerous studies both experimentally and numerically. Especially for the places with high insulation, where usually have a large demand for cooling or ice making to preserve food, drugs and vaccines. Considerable researches have been devoted to develop refrigeration machines that could employ solar energy efficiently [1-3].

So also, the silica gel-water adsorption chillers for the air conditioning had already been commercialized. Therefore, many researches focused on the technologies for freezing conditions with evaporation temperatures below 0°C. Generally, natural refrigerants for the freezing conditions are methanol and ammonia, in which ammonia is more popularly utilized for that it works at pressure above the ambient. The manufacturing process of the machine with positive working pressure would be easier than that with negative working pressure (vacuum). Common adsorbents for ammonia are activated carbon and metal chlorides [4]. The system [fig.1 and 2] operates in a day mode when ammonia refrigerant is generated by capturing solar energy, and the night mode when the refrigerant is cycled back to the generator and ice is made. The system is operated by repositioning the control valves each morning and evening [5].

The system produces up to 60 kg of ice per sunny day. Milk is chilled by making an ice bath and immersing milk cans into the ice bath. sixty kilograms of ice is sufficient to chill 1050 of milk for a day. Although this is a small amount of refrigeration, it is a useful and valuable for rural communities. Solar Ice firm

promoted the business of solar icemaker to rural development organizations.

The Northern Nigeria has rapidly growing urban areas and so has a strong market for milk. Most of the farming is small-scale subsistence farming. There is a lot of unemployment and wages are low. Their main crops are maize, rice and g/corn which they grow for their own consumption and sell the excess for income. They also produce cashews, charcoal, a variety of vegetables, bananas, mangoes, goats, chickens, etc. Much of the produce is sent to the market by individual farmers on the public buses that serve the area.

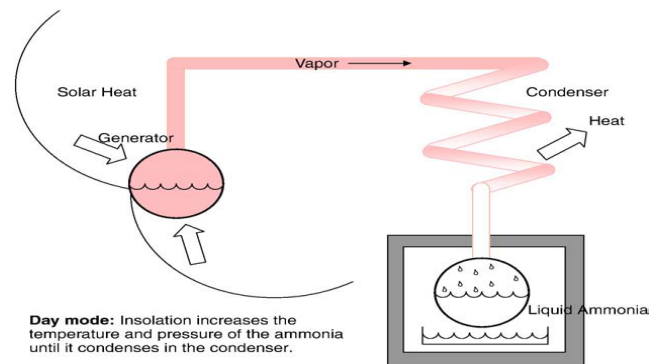


Fig 1: Schematic of day mode

This business has been working in the northern part of Nigeria for several years to alleviate poverty by teaching and promoting dairying. The farmers like dairying because it produces milk for their own families and it can generate daily income. Heifer has been successful in increasing milk production. Many of the farmers have increased milk production beyond what they can consume within their own families or sell to their neighbors. The average farmer may have only a few liters per day of extra milk, but selling it would bring important additional income. Although there is strong market in the

urban area, the distance to market makes it difficult for the individual farmer to sell there. With a dairy co-operative, milk can be bulked for transportation. Refrigeration is needed to allow more time for the process of collection and transportation.

The demonstration project is to install three strategic places in each of three communities, collect milk, chill it, and sell it to the urban areas for a profit. The buyers would make the arrangements with the villages and Solar Ice firm would provide the equipment, training and technical support. The project was funded in part by the World Bank's Development Marketplace program [6]. As a Development Marketplace winner, the project is recognized as being innovative and with potential for replication. The solar icemaker can also be used for artisan fishing, for cold drinks, and for vaccine preservation. This project enables many small-scale, environmentally sustainable rural businesses.

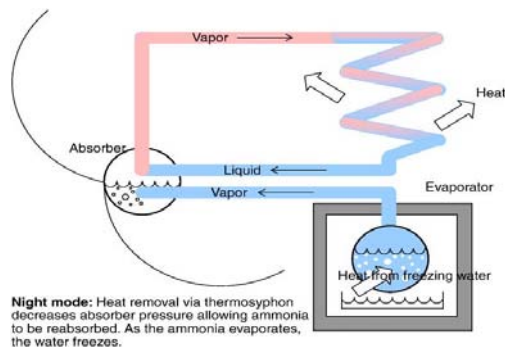


Fig 2: Schematic of night mode

The agreement with the villages was that SIC would install three solar icemakers in each of the villages, train the operators, and provide technical. The ministry arranged the project with the villages and would provide management support. The villages would:

- ❖ Form a farmers' society, select the management committee, and register with the state government.
- ❖ Rent office space and provide space for installation of the solar icemakers
- ❖ Select technicians to operate the solar icemakers
- ❖ Operate the dairy including collection, handling, and selling milk

The laws for the establishment of societies and has offices throughout the Northern part of the country to assist with the formation and management of societies. The Ministry of Commerce, Trade and Co-Operatives provided training and management assistance to the new societies. Each society formed a committee to select five people to be trained and be the operators of the solar icemakers. When the icemakers were installed, the establishment of cooperatives would collect, chill, and

market milk. From the income, they would pay the farmers, the technicians, and the other expenses of the co-operative.

2. INSTALLATION AND TRAINING

The icemakers were transported to Northern part of the country and installed by trained technicians from the ministry and other men from the village. Installation is a very straight forward process of preparing the foundation, putting components in position, piping components together, installing the collector, and charging with refrigerant. Installation is an important part of training the operators. After the equipment was installed, the operators were trained how to operate the icemakers. They learned how to operate the equipment quickly by demonstrating operation a few times and then having them operate the machine themselves. For additional information, the physical processes occurring were described. After a few days, the assessment of the operators is that the equipment is "easy to operate." Considering everything, the installation and training went smoothly and the icemakers are performing well. The solar icemakers were making up to 60 kg of ice per sunny day.



Fig 3: Three units were installed in Gwada District at Shiroro Dairy

3. DAIRY START-UP

After the solar icemakers were installed and operating, the societies proceeded with other preparations to start milk collection and sale. The societies needed to be licensed by the standard organization Nigeria (SON) and trained to test and handle milk by the ministry of Commerce, Trade and Co-operatives of various states. During training, they also learned how to make kiduruma and yogurt. (Like yogurt, kiduruma is made from fresh milk. Milk is heated to kill all bacteria then cooled and inoculated with specific organism which modifies flavor and extends shelf life. Kiduruma is similar in flavor to sour cream.) kiduruma and yogurt are important to dairy profits because they are sold at a higher price. The dairy operators learned how to package milk. All the necessary equipment and supplies were acquired. Ministry staff provided training on record keeping for a dairy.



Fig 4: On a good solar day, the icemaker makes 12 blocks. Each block is 2 by 10 by 40 inches, weighing 13.3 kg each.

For start-up, the spots must identify the specific customers for their milk. One option for the new spots was to sell their milk to the major dairy processors. The major processors pay about two thousand naira. The two new societies were planning to pay that amount to the farmers, so the societies and individuals itself would not be able to make money. The retail price for milk is four thousand naira and more for the value added products of kiduruma or yogurt. If the societies / individual choose to retail milk, they would get the higher price, but then they would have the additional tasks and expenses of transportation, distribution, and selling. Also, there is competition in the urban milk market from the major spots and from numerous “close-in” farms that sell milk directly. Both of the newly created dairies decided on direct sales to get the retail price. There is strong demand for milk and the urban buyers are ready to help farmer groups as much as they can, so hopefully the societies and individuals would be able to market successfully.

Milk sales also started slowly. For Gorzo at the beginning, they had one restaurant in the urban area that bought milk. The restaurant and super markets were requesting more milk from day to day but with the cost of transportation and the small volume of milk transported, the profits were low. Each day, more farmers would bring milk. As milk intake increased, the individuals needed to find more customers. Fortunately, there was a good market right in the vicinity of the individuals, so they started selling back to the local community. Milk was sold from the association office and bicycle or motorbike routes were run-through the surrounding community. The associations also started making kiduruwa and yogurt to keep profits up. When there was a holiday period, the urban customer stopped taking milk. After that, the associations had sufficient local market for the amount of milk being collected, so they continued with local sales only.



Fig 5: Milk, yogurt, and kiduruma are sold from distributed to the local community

The societies and individuals have built up local sales as much as possible. Eventually, they had to restrict the number of farmers delivering milk. The societies and individuals were working on urban sales again, but working out the details of transportation and sales was proving to be a challenge. For the time being, it was necessary to restrict collection. In December, 2012, the spots were able to start up urban sales again.

The Bame was selling 120 l/day to the city and Fuga is working on arrangements to sell 240 l/day to the city. Hopefully, they can keep expanding upon these urban sales and serve the needs of the many more farmers in the area. Having their own vehicles for transporting milk to town would possibly be a great help in marketing. But this would require collecting a larger quantity of milk. Also the capital was not available for a vehicle. However, evening milk collection has been minimal. Most of the farmers have local breed cows that produce only a few liters per day. The farmers are in the habit of milking only once per day, partly as a means of limiting production because of the difficulty of selling milk. As the dairy individuals and societies were able to collect more milk, the farmers will modify their dairying habits to produce more milk and make more money. This would include evening milking, increasing feed, and utilizing artificial insemination with exotic breeds. As evening milk collection increases, the need for refrigeration increases to keep milk through the night.

In figure 6, for valve control case, the valve will keep opening during the desorption stage. After the heating stage finished, the solenoid control valve would be closed and then the cooling water would be used to cool down the adsorbent bed. Opening the solenoid valve would start the synthetic reaction. Since the solenoid valve was closed when the adsorbent bed was cooled down, the evaporator pressure would be higher than the pressure of adsorbent bed before the valve was opened. So when the control valve was opened, the evaporating pressure would decrease while the adsorbent bed pressure would increase and finally these two pressures would become the same valve. This is done manually.

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Fig 6: Schematic of another made icemaker

Table 1: Game farm in Fuga district

Items	16/12/12 19/12/12	January 2012	Feb. 2012	March 2012	April 2012
Ice production (kg)		4897	4141	4894	1969
Farmers served		122	160	224	226
Milk collected (l)	4992	6199	8944	9942	9988
Daily average (l/day)	132	260	368	602	722
Milk sold (l)		62992	98601	99868	16288
Gross sales (N)	160,998	325,886	580,886	602,993	869,894
Payment to farmer (N)	156,893	123,453	249,439	581,440	453,842
Societies net income (N)	4,105	202,433	331,447	21,553	416,052

One method is for the societies and individuals to restrict milk collection when there is no ice, which is the day after a rainy or cloudy day. Another strategy is to store extra ice from sunny periods in an insulated box for rainy days. It is also possible to buy ice from where it is available. Another option is to have a diesel powered regular back-up ice making system. As the project progresses, the strategy for providing refrigeration during rainy or cloudy periods will evolve. On average, the location is sunny, so that over a full year, solar ice making is an advantage. The icemakers' performance was good in the beginning, making nearly 50 kg of ice on sunny days. The societies and individuals have sufficient ice for their modest beginning. The capacity of the icemaker is based upon a full sunny day. In December, the co-societies reported a increase in ice making capacity, This is most likely due to the reflective surface grading, inhibiting the performance of the solar collectors. It is planned to apply a new more durable reflective surface to re-establish the icemaker performance.

4. RECOMMENDATION

Additional solar icemakers are needed to serve more farmers in the area and to increase volume to make the urban sales profitable. It is important that a proper financial agreement is made for these installations to make the project economically viable and sustainable.

5. CONCLUSION

Two dairy farmer's societies have been established, Gwada in Shirorodistrict and Bame in Fuga district. The membership of Gwada is 404 and Bame 811.

These organizations operate as a for-profit business and generate income. A new type of adsorption icemaker driven, which uses a compound adsorbent and ammonia as working pair, integrated with sensible thermal storage tank, is designed and different working processes functioning excellently.

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