IARI BEST PRACTICE

1. Title of the Practice

OFF-GRID, BATTERYLESS PUSA FARM SUNFRIDGE TECHNOLOGY

2. Objectives of the Practice

This is an innovative initiative to provide refrigerated storage of perishables for small holder farmers, even in areas lacking electricity supply. The requirement among farmers in India for community-level or on-farm cool structures for storage of perishables is immense, however their availability is limited. Postharvestlosses in India were 25% to 30% dueto lack of cold storage facilities and coldsupply chain, and that these losses havelowered the per capita availability of fruitsand vegetables in India. Only 10% to 11% of Indian fruits and vegetablesare provided cold storage and thatcapacity needs to be increased by 40%. Cold storages with goodcontrol of temperature and humidity are energyintensive and expensive, involve a largeinitial capital investment, and require anuninterrupted electrical grid supply, whichis not readily available in many farm communities. Cold storages operated by solar energy or renewable/ green energy is the need of the hour. InIndia alone, there are 136.8 million smalland family operated farms that have thepotential to benefit from on-farm or community coolers.

PUSA Farm SunFridge(FSF) is a specially designed off-grid batteryless green energy solar-refrigerated-evaporative cold storage structure that is effective and inexpensive and can enhance storability and help the grower control marketing of his high-value perishables. The FSF offers farmers an inexpensive access to "one's own" on-farm cold store that requires no utility-based electricity, and can improve control over marketing crops to fetch better prices and enhance their income.

3. The Context

High post-harvest losses especially due to high ambient temperatures in summer season; lack of sufficient cold storages and unreliable erratic electricity supply on farmers' fields are some of the challenges faced by small holder farmers in India. The lack of cold chain infrastructure waslinked to an estimated INR 92,561 crore(US$12.1 billion) annually and also many ofthe existing resources are inefficiently usedby being dedicated to single commodities(NITI Aayog, 2018).

The Pusa Farm SunFridge meets these challenges successfully, because the Sunfridge is cooled by solar energy (green or renewable energy) during the day and cold water in water battery (thermal storage) during nighttime. The2-tonne Sunfridge can be easily built as on-farm structure and can help farmer store or precoolhis produce, which will enable reduction in post-harvest losses causing his enhanced income. Decreased post-harvest losses will increase per capita availability of fruits and vegetables. After installation of Pusa Farm SunFridge the challenging issues are washing of solar panels, keeping the fabric wet, checking the running of the submersible pump for water battery and the refrigeration system for cooling.

4. The Practice

The Farm SunFridge(FSF) is asolar-refrigerated evaporatively-cooled off-grid, batteryless, on-farm cold store for storage of perishables. The evaporative cooling component reduces heat load on the structure, enabling the use of a smaller solar panel array and smaller capacity refrigeration system. TheFSF has been tested extensively for storage of amaranth - a model plant to evaluate imperfect storages. These 2-tonne FSFs can be self-built by farmers in two stages: initially as a evaporatively cooled store at 1st stage and then installing insulation and refrigeration system as add-on in the 2nd stage.

The first of its kind concrete/FSF(inner size 3 x 3 x 3 m), built at the Division of Agricultural Engineering, IARI in 2017, was made of reinforced cement concrete (RCC) roof, supported on 4 concrete columns. The columns were sheethed in autoclaved aerated concrete (AAC) blocks and built on a concrete foundation. The roof had 6" thick styrofoam underneath it. Solar panels were placed on a frame on theRCC roof.The floor was insulated with layer of AAC blocks, upon whichwas placed 4" thick styrofoam panel insulation. The walls were made of nylon felt (450 g/m^2) over a wire mesh (given for support) with styrofoam panels on the inside. Various composite wall designs and the mathematical model have been discussed and it was found thata mesh-supported fabric (MSF) surfaced as the best option for rapid and effective evaporative cooling. Two additional concrete/FSFs were built in village Picholiya, Ajmer, Rajasthan and at Ranjit farms at village Chamrara, Panipat, Haryana in 2020.

The iron frame FSF takes a quarter of that time to be completed and operational and would cost less in both materials and labor. This has been built in prefabricated and assemble-enabled iron frame at IARI exhibition ground. The frame columns were welded to mild steel plates which were bolted via J-bolts embedded in concrete footers at each corner. The roof, made of steel (metro) sheets, was supported on the iron frame with a southerly slope of 28° (almost equal to latitude of the place). Solar panels were secured to horizontal aluminium tubing attached directly on the metro sheet roof. The composite walls were composed of fabric-mesh-styrofoam panels in much the same way as the concrete FSF and were fitted to the frame to build a relatively air-tight structure. The ceiling was made of fibre sheets and insulated with 6” of styrofoam panels. The floor design and insulation was the same as the concrete FSF.

Both concrete and iron FSFs were refrigerated using a commercially available air conditioner of capacity 18000 BTU h^{-1}, which was modified to generate air temperatures as low as 5 °C. The evaporator of the AC was split made into a coil and put in a thermal reservoir, a drum of 250 L, placed on the floor of the FSF. The refrigerant R410 flowed through the heat exchanger (split evaporator coil) and cooled the water in the thermal reservoir. The rest of the evaporator coil in the indoor blower unit of the AC cooled the air in the FSF. The thermal reservoir was connected to a “water battery” made from 4” diameter PVC pipes and elbows suspended from the ceiling and holding around 800 – 900 kg of water. The water from the reservoir recirculated through the water battery making it cold during daytime. The cold water of the water battery kept the room cool at night time. The refrigeration system was run from a photovoltaic array of fourteen 330-W panels or twelve 420-W panels whose power was inverted to AC using a 5-kW inverter.

The indoor unit of the AC wasconnected to a solar adaptive controller, which was designed to change the demand of the AC in keeping with the solar insolation.

5. Evidence of Success

The FSF is operational at three semi-arid villages in states of Rajasthan, Haryana, and Delhi, and the fourth FSF is built as a demo unit at IARI Exhibition ground in Delhi. The latter has been visited by over 500 farmers/ policy makers since March 2021, covered extensively on various print (total circulation approx. 5 million) and social media platforms, and has stimulated intense interest among growers and policy makers. Around 68% of the visitors have expressed a desire to build FSF at their farms.

The latest FSF at Cullakpur, Delhi, is in operation since December 27, 2021, and temperature and RH data of FSF can be retrieved from the cloud at https://dashboard.hobolink.com/public/Farm%20SunFridge%20Cullakpur%20Delhi. The data from the Farm Sunfridge at IARI, Pusa is also uploaded to the cloud and can be seen at https://dashboard.hobolink.com/public/Farm%20SunFridge%20IARI%20PUSA%20Delhi.

The Cullakpur SunFridge differs from the previous Haryana and Rajasthan FSF installations in that it is built using prefabricated iron frames and was almost completely assembled by nuts and bolts at the farm itself. This enabled the construction work to be faster with higher efficiency and precision. This methodology of construction used detailed mechanical drawings for each structural element, which enabled more precise measurements and construction, leading to improved 'tightness' of the insulation and overall better fit and finish.

Expanding FSF usage will decrease post-harvest losses, improve food security, maintain a strong farm economy, reduce carbon footprint, and can impact ~130 million smallholder farmers in India. For example, one of our growers using FSF at Cullakpur demonstrated 4x surge in his income by storing red cabbage in the FSF for over 60 days.

6. Problems Encountered and Resources Required

The problems encountered are that the farmers and retailers need more than 2 tonnes capacity structure, so higher capacity FSFs need to be designed and built, for which more research is required too. More Farm SunFridges need to be built as demonstration units in different agro climatic zones in India for the farmers and retailers to have first-hand knowledge and hands on experience of the working of these off-grid batteryless cold stores. We would require 10 such FSFs in India for which the resources needed would be to the tune of 1 crore rupees.