SOLAR ENERGY FOR QUALITY IMPROVEMENT IN FOOD-PROCESSING INDUSTRY

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ABSTRACT

Application of solar energy in food processing industry is mainly limited to drying operations. Solar vegetable-fruit dryers, operating below 55 degree centigrade, are used for the purpose. In recent years many solar gadgets have been developed for variety of applications. Different solar concentrators can provide excellent boiling, steaming, blanching and roasting capabilities while solar air dryers/heaters can effectively remove moisture. Efforts are required to integrate knowledge of food processing with capabilities of available solar thermal gadgets. Field trials on a variety of solar gadgets like 'Parabolic Concentrators', box ovens and solar dehydrators show not only huge fuel savings but also great value addition because of better quality of produce in terms of colour, aroma and taste. Because of excellent consistent quality, materials processed on these units can enjoy great market potential, in-house and for exports as well. Extremely low capital investment in this technology makes it financially viable.

Keywords: solar vegetable fruit dryer food-processing quality concentrator.

1. INTRODUCTION

Farmers in India have normally very small land holdings and most of them are not well educated. These farmers have to face the brunt of market uncertainties. Because of poor market rates for the produce many farmers have committed suicide in recent years because of high debt. As most of the farm produce is perishable, there is nothing a farmer can do if rates in the market fall. Processing of perishable farm produce to a processed food can be a very good alternative for such farmers, whereby shelf life of the product is increased. Farmers can earn extra money for value addition to the product. Solar dehydration is traditionally practiced for a few varieties of farm produce and fish. Development of new solar gadgets, like solar concentrators and ovens, open up many avenues for food processing. For small farmers, forming cooperative societies for food processing can be an excellent alternative.

2. BACKGROUND

Open sun drying is traditionally practiced for many vegetables, fruits and fishes. Dehydrated foodstuff has a higher shelf life, making it available throughout the year. The dehydrated fruits and vegetables have much smaller weight and hence are easy to transport. They cater to the needs of defence establishments, adventure expeditions, mountaineering, etc. These dehydrated products can be used in various preparations even in off-season. Drying vegetables, fruits and fishes by traditional open air sun drying is time consuming and less hygienic. In industrialised regions and sectors, mechanised dryers, with fans have now largely replaced open air-drying. Mechanised drying is faster than open-air drying and it uses much less land. But the equipment is expensive and requires higher energy cost with fuel or electricity to operate. With oil cost rocketing past $60 and electricity very uncertain in rural areas, a solar dryer is a good alternate option available in the market. Higher capital investment and lack of confidence in the technology are the main hurdles in popularizing this beautiful gadget. Applications of solar dryers are known to many. In recent years many solar gadgets have been developed for a variety of applications. Different solar concentrators and box ovens can provide excellent boiling, steaming, blanching and roasting capabilities while solar air dryers/heaters do the work of moisture removal. Combinations of such solar gadgets can take care of major energy needs in food processing industry. In spite of such developments, application of solar energy in food-processing industries has not picked up. There exists a big communication gap between solar

researchers and food technologists. Food technologists are not aware of capabilities of new breeds of solar gadgets like solar concentrators, ovens and dryers, while solar technologists are unaware of technical requirements of different processes followed in food processing. These gadgets have capabilities of bringing in revolutionary change in food processing technology. Developments for a few such food processing applications are being done at PRINCE. Apart from huge energy savings, in most of the cases there was big improvement in the quality of product with great value addition.

3. THIS PROJECT

At PRINCE center there are installations of a variety of renewable energy gadgets. Trials are conducted using these solar gadgets for different food processing applications as per requirement of the clients. Experiences of such trials using different solar gadgets are mentioned herewith.

3.1 Solar Concentrators

A parabolic dish concentrator of 2.3 m dia. was developed by the author[1] and Scheffler concentrators are being successfully used for variety of applications.

i. One parabolic dish concentrator of 2.3 m was successfully tried and tested at 'Ashtang Pharmacy' Dhule, where Indian traditional ayurvedic medicines are manufactured. This concentrator was used for boiling herbs and preparation of syrups (kadhas). Renowned ayurvedic doctor Mr. P.T. Joshi maintained separate records for the patients who were treated with medicines prepared on cooking gas and on solar concentrators. He reported that potency of the medicines prepared on the solar gadget is much higher than those prepared on cooking gas. His investment in a solar concentrator, costing Rs. 12000/- ($ 275), was paid back in less than 6 months. The solar dish concentrator has been in use for the last two and one-half years.

Photograph 1: Dr. P.T. Joshi with 2.3 m dia. Parabolic dish concentrator, preparing ayurvedic syrups.

After successful application of solar concentrators, Dr. P.T. Joshi has now started using other solar gadgets like solar water heaters, solar dryers etc. He insists that improvement in potency of medicines is a major advantage with solar processing.

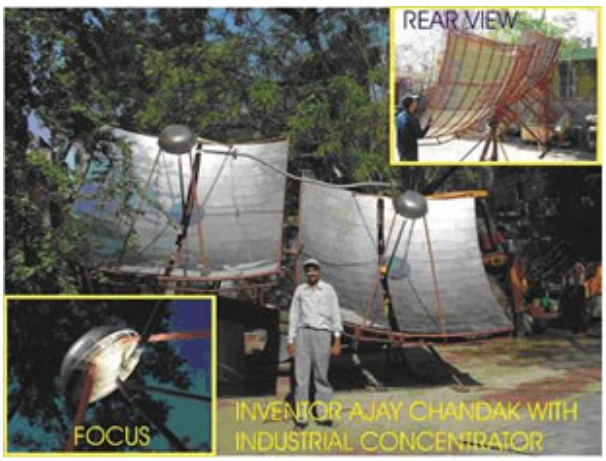
At Chandak Farm a similar 2.3 m dia. solar concentrator is used. Following applications were tried on this concentrator successfully with huge fuel saving and better quality of product.

- For boiling Amla (Indian Gooseberry) for different applications like Amla candy, Amla pickles etc. This results in huge fuel savings and better quality produce.
- For preparing hair oil from Amla and Aloe Vera.
- Roasting of cashew nuts was carried on a small scale for viability studies. The trials were successful and the concentrator can be a good substitution for conventional drum roasting and plate roasting processes, where firewood is used.
- Boiling, blanching, frying and roasting applications were successfully tried.

These parabolic concentrators are a good heat source for boiling and roasting applications, requiring temperatures less than 200^0C. One 2.3 m dia. concentrator works as a 2 kW heat source. For higher commercial requirements demanding medium temperatures, Scheffler concentrators of 12 and 16 sqm. are more suited.

3.2 Solar Concentrator for baking and roasting applications

A new industrial concentrator developed at PRINCE is capable of delivering hot air up to 200 degree centigrade. This concentrator is suited for oven-like applications for baking & roasting in high temperature ovens.



Photograph 2: 'Industrial Solar Concentrator' for hot air up to 200^{0}C

A Scheffler concentrator of 10-sqm was successfully tested for bakery applications. One concentrator could bake 180 loaves of 200 grams each in a day in the month of March. Quality of bread was excellent with uniform puffiness and colour.

Photograph 3: Oven used for bakery using Scheffler Concentrator.

3.3 Solar Dryers

Solar dryers are normally designed for use below 55^o C, assisted with airflow. The author[1] has designed a simplified, low cost version of solar dryer, which is affordable at rural levels.

Photograph 4: Low cost solar dryer for agro processing.

The following features were used in the new dryer to reduce the cost and improve the performance of the unit.

- Arrangement is proposed to install the cabinet for loading the material on a rooftop, while collector panels were laid on the south side towards the ground. This saved cost of a fabricated support structure. As the cabinet is placed at higher elevation than the collector panels, with uniform slope, natural draught assists the induced draught created by fan. Because of combined draught overall auxiliary power consumption for the fan is reduced.
- In case of power cuts natural draught maintains airflow and overall temperatures are maintained slightly above the set temperatures. This provision avoids overheating and spoilage of the material in the cabinet.
- Solar collectors were constructed in powder-coated mild steel sheets instead of aluminium sheets. This reduced the cost of solar collector panels by around 50%. The outer shell of the panel is constructed from a single sheet without any joints, which takes care of the possibility of hot air leakages.
- A cabinet for loading material was constructed with glass on three sides and a plywood door on the rear side. Cost of the cabinet contributes a lot in conventional solar or other mechanised dryers as it is to be constructed in stainless steel and needs to be properly insulated. Replacing this envelop by glass saves 80% of the cabinet cost. No insulation is required in this case.
- Use of glass for the cabinet permits trapping additional solar energy. In the current design glass cabinet contributes approximately 25% of the aperture area of the unit.

- Use of glass for the cabinet also permits better control on the process as the operator can see the material being processed, without opening the cabinet. Over drying can be avoided.
- Design of the cabinet permits even distribution of hot air throughout the cross section, which permits uniform drying rates. Control on maintaining moisture at the desired level is easily possible. Even an unskilled worker can operate the unit.
- Simple design permits manufacturing at the local level through local fabricators.
- Extremely low capital investment: Conventional mechanised units of CFTRI (Central Food Technology Research Institute, located at Mysore in India) costs around Rs. 200,000/- for 100 kg per day capacity mechanised unit while this design costs around Rs. 80,000/- for the same capacity. Further cost reduction is possible if plastic sheets are used instead of glass.
- Negligible running cost. A mechanised unit require 8 kWh of auxiliary power and 50 kg of coal per day for a 100-kg/day capacity while a solar dryer requires less than 2 kWh of auxiliary power for a fan, for the same capacity.

Trials were successfully conducted on various agro products. Some of these are:

- Amla Candy is dried in these dryers. Commercial production has continued for the last two years.
- Trials were successful for green chilli, moringa leaves, asparagus, Aloe Vera, ladyfingers, tomato, onions and gourds for dehydrated products.
- In cashew nut, kernel is covered with testa. These kernels were successfully dried in solar dryers, which facilitates easy peeling off of testa.

3.4 Solar Box Ovens

Solar box ovens were tried for roasting and baking applications successfully. Some of these developments include:

- Roasting of 'Soyabean' for baby food.
- Roasting of 'Cashew Nut'.
- Roasting of ground-nut.
- Baking breads and cakes.

4. TRIALS AND RESULTS:

Following are the results and lessons learned during the trials on different solar gadgets used for food processing applications.

- Prior to use of solar gadgets, 'Amla Candy', Amla used to be boiled using conventional fossil fuels and then final produce dried in open sun. Colour of 'Amla Candy' used to be brown-black and maintaining moisture level of around 20% was difficult. Hence quality of the produce was not consistent. Same product on solar dryer gave excellent green-yellow colour with much natural and fresh looks (Photograph 5). Moisture retention is more uniform and quality is consistent. Value addition is great. The 'Amla candy' processed on solar dryers could fetch price of Rs. 200/- per kg against Rs. 140/- per kg of open sun dried one.
  No fossil fuels are required in this case. Boiling of Amla is carried out on solar concentrators, while drying of final product is done on solar dryers.

Open Sun Dried. Processed on Solar Dryer

Photograph 5: Amla Candy processed by 'Open Sun Drying' and on 'Solar Dryers'.

- Trials on green chilly, moringa leaves, asparagus, Aloe Vera, ladies finger & gourd showed excellent colour retention. The dehydrated produce meet higher quality norms in terms of colour, aroma and taste.
- Powders of green chilly, moringa leaves, wheat grass, tomato etc., were prepared after drying. These powders have approval from food product manufacturers.
- In cashew processing the shelled kernel is covered with the testa and, to facilitate removal, i.e. to peel in order to produce the blanched kernel, the shelled kernel is dried. The moisture content is approximately 6% before drying and 3% after. The same unit was used for drying shelled kernel successfully.
- In cashew nut processing, roasting of the nut in box ovens gives excellent quality nuts. Breakage of nuts was reduced by 50% and roasting was uniform. Nuts roasted in box ovens followed by drying kernels in solar dryers, not only save energy cost but also fetch handsome Rs. 50/- per kg more than the nuts produced by electrical boilers and dryers.
- Drying of juices takes more time. It was observed that instead of preparing juices, it is better to dry the stuff in sliced form. Dehydration rate was 2 to 4 times

faster when material is placed in sliced form than drying juices.

- Powdery material is more difficult to dry, than granular or sliced material.
- The solar dryer design, with natural draught assisted by induced draught created by fan saves auxiliary power. Specific energy consumption in forced draught solar dryer is in the range of 3 kWh for removal of 100 kg of water, while natural draught assisted with the induced draught dryer was consuming 2 kWh for the same moisture removal. Energy cost for 'Amla Candy' worked out to be Rs. 0.30 per kg of end product, which is negligible, compared to cost of finished goods, around Rs. 200/- per kg.
- Roasting with a solar concentrator requires great skill and there were incidences of food burning, especially with cashew nuts, soybean and groundnut. It is observed that solar ovens are better suited for baking and roasting applications than concentrators. Uniform baking and roasting are observed in solar ovens. Even an unskilled worker can work well with ovens, but not with the concentrators.
- The moisture removal rate was observed at around 3 kg per sq. mtr. area of panel in dry climate.
- Apart from fossil fuel savings, quality improvement of the food product and better process control are the main advantages.
- The economics of a solar dryer is justified if the finished product can fetch additional cost of Rs. 5/- per kg of moisture removal and for more than 100 days of operation per year.

5. CONCLUSION

For promoting solar energy application on a large scale in the food processing industry, it is very important to integrate knowledge of food processing with capabilities of different solar gadgets. Application of existing solar gadgets and developing new designs of solar gadgets based on case-to-case basis are key for adoption of this beautiful technology by the food processing industry. Great quality improvement in solar processed food was observed in terms of retention of color, aroma and taste. Solar processed products could fetch much higher prices in the market because of better quality of the product.