Solar Specialty Crop Drying Research at the USDA – Agricultural Research Service

Western Regional Research Center

Solar thermal processing of specialty crops is a project that is part of the Processed Foods Research Unit (PFRU) at the USDA-ARS Western Regional Research Center in Albany, California.

Research Approach

The overall goal of ARS’s program in this area is to develop solar or solar-assisted cabinet dryer designs optimized for a given specialty crop and location. We will do this by addressing the three shortcomings of the current research, as described at left. Our target customers are small- and medium-sized specialty crop processors in the American West who currently dry their crops using natural gas-fired cabinet dryers. In our experiments, we will:

- Test dryer designs using multiphysics modeling software, then construct prototypes. We will develop a multiphysics computer model of a single drier using the software package COMSOL Multiphysics. We will then validate the model against experimental runs in a physical version of the drier, and use the model to direct design of solar collectors, modifications to the cabinet, and possible addition of a fan to create an active (forced convection) system.
- Employ dynamic feedback and feedforward control of dryer configuration based on real-time measurements. We cannot control the weather. However, we can measure ambient temperature, humidity, insulation, etc. as well as the mass, temperature, etc. of the product and use this information to adapt product location within the dryer, orientation of the solar collector, fan speed, etc. This will enable the most efficient use of the solar energy that is available at any given time.
- Select “smart” dryer construction materials to minimize drying time and improve product quality. Current dryer construction materials have suboptimal optical properties. Improving these properties, while keeping an eye on material costs, will shorten drying time and improve product quality. We will also consider incorporating a thermal energy storage unit in the design to enable drying outside of daylight hours.
  * Specialty crops include fruits, vegetables, nuts and other horticultural crops defined by the USDA – Agricultural Marketing Service.

Motivations

Solar dehydration (“drying”) of crops is an ancient food preservation technology that is gaining new interest worldwide due to the increasing cost of energy from fossil fuels. In the recent past, research in this area has been performed primarily by academics in Africa and South Asia. These studies have three common characteristics:

- Time-consuming prototyping of cabinet and solar air heating unit
- Researchers physically construct a cabinet drier and then determine the drying times of various crops and locations
- Construction materials selected for convenience

Challenge 1: Multi-physics Modeling of the Food/Dryer/Environment System

Our goal is to develop a robust, 3-dimensional model of the entire drying system, including the food material, the dryer, and the environment immediately surrounding the dryer. Once validated against experimental data, this model could be used to perform virtual experiments and test out refinements in dryer design outside of the harvest season for a given specialty crop.

Progress To Date

- Modeled temperature and air flow through a bench-scale connection drier
- Constructed solar dryer cabinet with geometry that mirrors lab dehydrator
- Conducted lab sponge-drying experiments with solar dryer
- Determined spatial variation in drying rate
- Conducted preliminary sponge-drying experiments with solar drying cabinet
- Measured multiphysics model with experimental data from lab dehydrator

Next Steps

- Validate multiphysics model with experimental data from lab dehydrator (Winter 2012)
- Add time-varying insulation to multiphysics model
- Collect additional data on sponge drying in solar drying cabinet (Summer 2012)
- Extend multiphysics model with experimental data from field cabinet (Fall 2012)

Challenge 2: Design a Feedback/Feedforward Dryer Control System

Solar thermal drying of food crops is, fundamentally, a food processing and operation. Unit operations produce the final results where they are controlled by an appropriate feedback and/or feedforward algorithm. Our team aims to develop modern control systems that will enable the most efficient use of the solar energy that is available at any given time. Feedback control involves measurement of the system state (product moisture content and product temperature, for example) and adjustment of independent variables to maintain, solar collector conditions, and so on to bring the system state closer to a desired endpoint. Feedforward control involves measurement of external disturbances (temperature, humidity, etc. for example) and similar adjustment of independent variables to compensate for these disturbances.

Progress To Date

- Measured 2 years of micrometeor data for the Albany, California soybean drying test area
- Setup temperature data logging system for interior of solar dryer cabinet.

Next Steps

- Setup humidity data logging system for interior of solar dryer cabinet (Winter 2012)
- Configure lab drier for dynamic feedback control. Determine appropriate feedback and feedforward control algorithms for implementation (Spring 2012)
- Optimize solar dryer cabinet with auxiliary fan and heater (Spring 2012)
- Configure solar dryer cabinet for dynamic feedback control. Determine appropriate feedback and feedforward algorithms and software for implementation (Summer 2012)

Collaborations

USDA-ARS is eager to collaborate with UC Solar faculty, staff, and students on projects of mutual interest. If you are interested in collaborating, please contact Dr. Rebecca Miltzareff, USDA-ARS-ARC.

USDA-ARS
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- 1,200 research projects within 14 National Programs
- 3,100 scientists
- $1.1 billion fiscal year 2009 budget
- 100 research locations including a few in other countries.

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Readings from Thermocouples

• Determine spatial variation in drying rate.

Researcher patiently fills in the blanks.

Agricultural Research Service
Summer 2012
Challenge 3: Determine Optimal Dryer Construction Materials

To date, very few attempts have been made to optimize the optical characteristics of solar dryer cabinet construction materials. Previous research of the USDA-ARS and elsewhere has shown that laboratory-generated light in various parts of the solar spectrum can aid in dehydrating and can increase certain nutritional components of specialty crops. However, exposure in sunlight is also known to degrade the quality of some fruit and vegetable products. Our team will test multiple solar spectrum-transparent materials for their effects on drying time and product nutritional quality.

Progress To Date

- Conducted laboratory experiments of various parts of the solar spectrum on fruit and vegetable crops.

Next Steps

- Incorporate transparent materials into solar drying cabinet (Spring 2012)
- Conduct side-by-side comparisons of fruit dried under different microclimate environments (Summer 2012)