University of California
Division of Agricultural Sciences

PROJECT PLAN/RESEARCH GRANT PROPOSAL

Project Year 2009 Anticipated Duration of Project 4 months

Project Leader Zhongli Pan Location USDA-ARS-WRRC, Albany, California and UC Davis.

Cooperating Personnel James F. Thompson, Ron Haff, Don Osias

Project Title

Improving processing and energy efficiencies of walnut drying

Keywords

Commodity(s) Walnut, drying, sorting, quality Relevant AES/CE Project No.

Problem and its Significance:

California produces almost 99% of walnuts in the U.S. with about 346,000 tons of production, 5,300 walnut growers and 55 walnut processors as reported by the USDA in 2006. The California Energy Commission (CEC) (2008) estimates that California's food processing industry generates over $50 billion in gross annual revenues and consumes over 3,700 million kilowatt hours of electricity. This makes food processing the third largest industrial energy user in the state. The CEC also recommends that the California Food Processing Industry should improve energy and productivity efficiencies and reduce water usage by implementation of novel technologies. Improved methods and technologies for the drying process would help the industry to meet these recommendations.

At harvest the moisture content of individual walnuts varies significantly. Nuts that have fallen to the ground before harvest are much dryer than nuts that are less mature and must be shaken from the tree. Existing dryers commingle all nuts and as a consequence there are large differences in nut moisture as the batch nears the acceptable 8% average nut moisture content. The wettest nuts must be dried to a safe moisture content of perhaps 10% to prevent mold development and the potential for fire hazard. This requires the batch as a whole to be overdried to insure the wettest nuts have reached acceptable moisture content. Unpublished tests by Thompson and Grant showed that at moistures near 8%, typical driers require 3 to 4 hours to remove a single point of moisture content. Over drying to 6% lot average moisture content is common and results in 6 to 8 hours of additional drying. Depending on the initial moisture content of a batch, the overdrying period can represent 25% to 50% of total drying time.

Most of the walnut drying capacity in the state was built when there was a balanced mix of early and late season varieties, allowing the crop to be dried over a six to eight week harvest season. However the California industry now has a large acreage of Chandler variety. This causes a great need for drying capacity during the two-week harvest of this variety. Much of the industry needs additional drying capacity during the Chandler harvest.

One method of speeding drying is to increase the temperature of the drying air. Lowe et al, 1961, showed that in-shell walnuts can be rapidly dried with temperatures up to 200°F with no detectable loss in kernel quality after 8 days of storage. Unpublished data from the files of Robert Parsons confirmed that increasing air temperature reduced drying time but had significantly lower quality after one year of storage compared with conventionally dried walnuts. Sibbett et al., showed that kernel temperatures above 104°F result in reduced kernel color quality. Drying air temperature is generally limited to 110°F to prevent kernel temperatures from exceeding critical

levels during the final stages of drying when evaporative cooling effects are small and kernel temperatures are close to drying air temperatures. If nuts were more uniform in initial temperature it may be possible to use elevated temperatures during the first part of the drying process when rapid loss of moisture causes the kernel temperature to be significantly cooler than drying air temperature. Rumsey and Lu, 1991 showed that walnuts can be predried with 300°F air for 4 minutes, reducing their moisture content by 5 percentage points. Higher air temperatures or longer drying times caused the shells to crack. Variable air temperature drying has been demonstrated with in batch hop dehydrators and reduced drying time by one third with no quality loss (Thompson et al, 1985).

Whether combined with a high temperature drying step or drying at a constant 110°F, sorting nuts by their moisture content will reduce gas and electricity use by minimizing overdrying. Final drying of walnuts is often accomplished during the early morning hours when outside air temperatures are near daily minimum. This means that preventing over drying results in reduced gas use exceeding the percentage decrease in drying time.

To increase drying capacity, reduce energy use, and moisture content uniformity, we propose to sort individual walnuts based on their moisture content before the drying operation. Nuts with similar moisture content will be dried together. This will reduce the amount of overdrying needed to insure wettest nuts have reached a safe moisture content. It is expected that high moisture walnuts can be dried with a higher temperature at the beginning of the drying cycle compared to the current drying practice, which will significantly reduce the drying time.

Commercial application of this approach will require modification of the dryer. One implementation could be to divert the wetter nuts to a high temperature continuous-flow dryer as is used with pistachios. This unit would be used for initial drying and the nuts would finish drying in an existing bin dryer at conventional drying air temperature. Another option would be to direct the wetter nuts to separate bins in the dryer. Bins for the high moisture nuts would be fitted with auxiliary heaters to increase air temperature above 110°F. Air temperature would be ramped down based on the average nut moisture measured by an in-bin moisture content sensor. A third implementation would be to dry the wetter nuts at 110°F. This option would not reduce drying times as much as the other two options but would still result in significant increases in drying capacity and reduced energy use because the initially dryer nuts would not be overdried.

Objectives:

1. Determine the moisture distribution and surface color characteristics of individual walnuts of selected varieties.
2. Evaluate various moisture detection methods for individual walnuts.
3. Study the drying times, rates and quality of sorted walnuts with different moisture contents under various drying temperatures and times.

Plans and Procedures:

The most popular variety of walnuts in California will be used for this study. The walnut samples will be obtained at the beginning, peak and late harvest periods. The samples should be used as soon as they are collected. Some samples may be stored in a freezer for later use.

Determine the moisture distribution and surface color characteristics of individual walnuts of a selected variety

After the walnut samples are collected, they will be divided into two groups, one with husk and one without husk, and labeled individually. Then the spectral reflectivity (color characteristics) of each walnut will be measured using using a Minolta Spectrophotometer CM-508d (Minolta Co. Ltd, Japan) and expressed in CIE’s L*a*b* color space. The corresponding appearances and initial weights will be recorded.

To determine the moisture content of individual walnut, the samples will be further dried using an air oven to determine the moisture contents after the drying

tests. The initial moisture contents can be determined based on the initial weights, weight changes during drying and final moisture contents.

The moisture contents in different components, including husk, shell, and kernel of selected samples, will also be determined, which will provide basic information for developing rapid moisture detection methods.

The relationship between initial moisture content and surface color characteristics will be established to determine if the surface color of walnuts can be used for sorting walnuts with required moisture contents.

Explore different moisture detection methods for individual walnuts

Besides of the potential color sorting technique, it is important to explore other rapid moisture detection methods for individual walnuts.

Currently, the standard method for non-destructive moisture content analysis is near infrared reflectance (NIR), and many commercial products are available for this purpose. For the case of walnuts, these devices are unlikely to be effective due to the presence of a hard shell surrounding the nut. Some research has been reported using a microwave dielectric method to non-destructively determine the moisture content of unshelled peanuts (Trabelsi and Nelson, 2006). Radio Frequency (RF) impedance measurements of capacitance and phase angle have also been shown to be effective for determining moisture content of unshelled peanuts (Kandala and Butts, 2006). Either of these methods show promise for high speed non-destructive determination of moisture content in the interior of walnuts.

Another potential method to determine moisture content inside the walnut could be the use of x-ray sensing. While this technique has never been attempted, the basic principle is straightforward. An x-ray image is essentially a density map of the sample, and it is reasonable to hypothesize that the density of the walnut is correlated with the moisture content. This hypothesis can be tested using standard methods of density measurement and moisture content determination. Given that a relationship exists, then the potential for using x-ray imaging to determine moisture content can be investigated, initially using stationary film x-ray images then high speed real-time imaging.

In this research, therefore, we will first test the x-ray technique to determine its possibility for rapid moisture detection. RF technique will also be tested. At the end of the project, we should be able to provide the direction of the technologies that may be used for the walnut moisture measurement.

Study the drying times, drying rates and quality of sorted walnuts with different moisture contents under different drying temperatures

The labeled walnuts will be dried as a single layer to make sure that they experience the same drying temperature and air velocity. Fine thermocouples will be placed near the surface of the kernel. The drying temperature will be set at 110, 120, 130, and 140°F and drying will be stopped when the thermocouple measures a kernel temperature of 100, 107.5, or 115°F. The relative humidity of heated air will be recorded. The weight change will be determined by weighing the individual walnuts at different times during the drying. Then the drying rate curve will be developed. During the drying tests and at the end of drying, the appearance change and any cracks developed will be recorded. The information will be used for determining the critical drying parameters for high temperature drying. The moisture distribution of individual walnuts will be determined and reported.

Based on the drying test results of walnuts with different initial moisture contents and maximum kernel temperatures, walnuts with dried under selected conditions will be used to produce walnut samples that are used for a shelf-life study. The samples packaged in paper bags will be stored at 37°C in an incubator for 2 months. The storage behaviors related to the shelf-life of dried walnuts will be determined by measuring the changes in color, peroxide value, free fat acids, moisture content, and water activity during the storage period.

Based on the shelf-life study results, the highest drying temperatures will be determined for walnuts with different initial moisture contents.

Qualifications of research team and facilities

Dr. Zhongli Pan, Research Engineer at the USDA-ARS WRRC and Associate Adjunct Professor at UC Davis, has been conducting drying and shelf-life related research for more than 10 years. He currently carries drying related projects from the California Rice Research Board and Almond Board of California. His labs at WRRC and UC Davis have all necessary instruments and equipments for the drying and shelf-life study.

Mr. James Thompson has been working with walnut growers for many years and has extensive knowledge related walnut drying, production and processing.

Dr. Ron Haff, Research Agricultural Engineer at the USDA-ARS WRRC, has been conducting sorting related research for many years. His lab also has a well equipped x-ray facility for this proposed research.

Mr. Don Osias, an engineer at Applied Instrumentation, has developed various moisture meters for walnut bulk-drying. He has extensive knowledge about moisture meters.

Based on the high qualification of the research team and available facility, we are confident that we will achieve the proposed research goals.

References

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BUDGET REQUEST Budget Year

Funding Source			
Salaries and Benefits			
Postdocs/RA's	$16,000.00		
SRA's			
Lab/Field Assistance	$1,000.00		
Subtotal			Sub 2
Employee benefits	$4,000.00		Sub 6
TOTAL			
Supplies and Expenses	$7,000.00		Sub 3
Equipment			Sub 4
Travel	$1,500.00	Sub	5
	$29,500.00		
			TOTAL

Department account number

Budget justification:

1. The budget for the post-doc is for four month employment with 25% benefit rate.
2. Lab/Field Assistance fee is the budgeted consulting fee for Mr. Don Osias.
3. The supplies and expenses include $2,000 for drying and shelf-life study and $5,000 for x-ray and radio frequency research.
4. Travel is for field trip to collect samples.

_____ Date

Originator's Signature

COOPERATIVE EXTENSION County Director _____ Date _____

Program Director_____ Date _____

AGRICULTURAL EXPERIMENT STATION Department Chair_____ Date

LIAISON OFFICER _____ Date _____

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