Walnut Drying Tool

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GAS EMERGING TECHOLOGIES PROGRAM (GET)

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Executive Summary

Walnut infrared (IR) pre-drying offers a promising energy efficient solution by rapidly removing moisture through high heat flux, potentially reducing drying time and overall energy use without compromising product quality.

• **Key objectives:**

This project aims to review previous research on walnut IR pre-drying, understand system parameters of bin drying, summarize a prior pilot study insights, gather cost data for IR dryer equipment and installation, and develop a spreadsheet-based tool to calculate energy savings and payback periods for walnut IR pre-drying technology adoption.

• **Challenges in conventional bin drying process:**

The process of drying walnuts is an energy intensive process. Walnut dryers typically use natural gas for heating and electricity for fan operation. In a typical process, walnuts are conveyed into an air dryer or conventional drying bins and are heated using natural gas. The drying time could be up to 24 hours for each batch to achieve safe storage moisture. The current method mixes walnuts with varying moisture levels, leading to over-drying some nuts to ensure safe storage moisture, increasing overall drying time and associated natural gas usage.

• **IR nut drying benefits and project outcomes:**

Walnut IR pre-drying can quickly pre-dry walnuts, especially those with higher moisture, by applying elevated temperatures to knock off moisture efficiently before conventional bin drying, reducing overall drying time and natural gas consumption without affecting product quality. Previous research demonstrated that the sorting of walnuts into low and high moisture groups and IR pre-drying could result in energy savings up to 25%, compared to hot air bin drying of unsorted walnuts.

A spreadsheet-based energy savings calculator is developed to estimate energy saving and cost saving potential of IR drying of walnuts. Also, the tool has the capability to estimate payback period based on the total project costs and customer copay.

Introduction

Walnuts are an important crop in California. California produces 99% of the commercial walnut supply in the U.S. About one-third of the crop is exported, making it a crucial player in the global walnut market [1]. In 2025, California's walnut production is forecasted at 710,000 tons, marking about 18% increase in production compared to 2024. Most walnuts are now produced in the San Joaquin and Sacramento Valleys, with more than half of the acreage being in San Joaquin, Stanislaus, Tulare, Butte, and Sutter Counties [2]. The California walnut industry includes over 3,700 growers and approximately 70 handlers [3].

After harvesting, walnuts need to be dried quickly to avoid quality loss and food safety problems due to high moisture and moisture variation within individual walnuts. The process of drying walnuts is the most energy intensive process. In a typical process, walnuts are conveyed into an air dryer or conventional drying bins and are heated using natural gas with 43°C hot air supply. The drying time could be up to 24 hours to achieve the safe storage moisture of 8%. The average natural gas consumption for walnut drying is 12.16 therms of natural gas per ton and 23.6 kWh electricity per ton of walnuts produced [4].

Walnut infrared pre-drying (IR) achieves high and rapid heat flux to product surface in shorter times compared to hot air heating and therefore is suitable for initial pre-drying. IR heating can be used before conventional bin drying to heat the walnut quickly and remove a large amount of moisture within a short amount of time. Thus, this method can be used as a potential method for reducing overall drying time without affecting the product quality.

Assessment Objectives

The goal of this project is to conduct literature review of walnut IR pre-drying and develop an energy savings calculator to quantify energy savings.

The various objectives required to achieve the goal of the study are:

a) To understand the design and operational parameters of conventional bin drying and IR pre-drying.
b) To summarize the lessons learned from the previous research and key aspects of experimental methods.
c) To compile information about equipment and installation costs of natural gas catalyzed IR dryers.

d) To develop a spreadsheet-based tool for quantifying energy savings and payback period of IR drying technology.

Literature Review

a) Current walnut drying technology and associated process challenges

The current walnut drying method mixes all walnuts from the field during harvesting. Then, walnuts are separated from debris, washed, and conveyed to the drying bins. Hot air at 43°C (normally heated by natural gas) is used to dry walnuts from their initial moisture level to a safe moisture level of 8% on a wet basis in conventional bins. See Figures 1-4.

Figure 1: Waste removal, cleaning and dehulling of walnuts

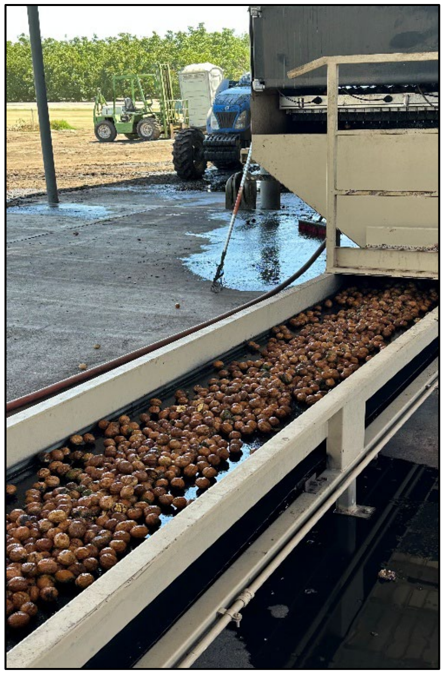


Figure 2: Wet walnuts on the conveyor belt

Figure 3: Bin drying

Figure 4: Natural gas burners and fan units

At harvest, walnuts with and without hulls are collected from the ground with harvesters and then transported to a facility for dehulling, washing and drying. The current walnut drying method has the following major problems resulting in inefficient drying in terms of energy usage and time.

The walnuts pick up 4% moisture on average when they are washed and are kept 2-3 hours in drying bins before drying. During this period, the water is soaked into their shells, which further increases the drying time.

Next, the existing process mixes all walnuts irrespective of the moisture content, which leads to huge variability in moisture content.

Then, the batch of walnuts is overdried to ensure the wettest walnuts are dried to a storage safe moisture level (8% on wet basis).

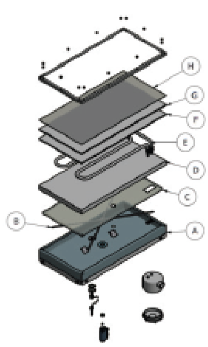
Thus, this over-drying of walnuts increases the natural gas energy consumption and overall drying time. Simultaneous over-drying and under-drying of walnuts leads to poor product quality as well as high energy consumption per ton of walnuts produced.

Walnuts with high initial moisture content may be dried at an elevated temperature during the first part of the drying process. The elevated temperatures could be used to knock off most of the moisture in the shell of high moisture containing nuts without affecting the product quality. Using high temperature pre-drying (such as IR pre-drying) followed by conventional bin drying at lower temperatures can be useful to rapidly removing moisture, thereby reducing the overall drying times and energy consumption.

b) Fundamentals of IR radiation and drying technology

IR radiation releases energy in electromagnetic wave form in the spectrum from 0.75 to 1000 µm. The medium and far-IR radiation can be efficiently used for thermal processing of foodstuffs. The use of IR pre-drying for partial dehydration has been investigated as a potential method for reducing drying time. Dr. Zhongli Pan and his research group at UC Davis conducted comprehensive tests to develop energy efficient drying technology using infrared heating after moisture-based sorting of walnuts. With the support from equipment manufacturers, walnut processing companies, and funding agencies, Dr. Zhongli Pan’s research group designed and developed a walnut IR pre-drying pilot system. In the first phase, a pilot system with a capacity of 1-2 tons per hour was built and in the second phase, the objective was to build and test two drying lines with a capacity of 10-15 tons per hour for each line [4].

IR radiation energy can be generated with various types of emitters such as catalytic emitters, electric emitters, carbon emitters, and ceramic emitters. The radiation first impinges on the surface of the material and then penetrates inside. It can be transferred from the heating element without heating the ambient air, which makes it more energy efficient. In the pilot study and demonstration project, natural gas catalyzed catalytic emitters were used as IR emitters. The working of catalytic emitters or catalytic heaters differs from the conventional heating by the introduction of catalyst which facilities flameless combustion. These catalytic emitters require both natural gas and electricity to operate. Electric power is required to pre-heat the heater. During the startup, the enclosed heating element is turned ON for about 15-20 minutes. This is termed as a pre-heat event. Once the catalyst is warmed up, natural gas can be introduced via the safety valve to begin the catalytic heating process. As long as natural gas and oxygen are supplied, the catalytic chemical reaction will continue without any flame, and the heater will emit infrared energy with the heater face temperature between 800-900 °F. Unlike conventional gas heaters or burners, the natural gas is burned at lower temperatures in catalytic heaters. Figure 5 shows the schematic diagram of catalytic IR heater.



Item	Description
A	HEATER PAN
B	DISPERSION TUBE ASSEMBLY
C	DISPERSION SCREEN
D	1" INSULATION
E	ELECTRIC HEATER ELEMENT
F	0.25" INSULATION
G	CATALYST
H	STAINLESS STEEL FACE SCREEN

Figure 5: Schematic diagram of catalytic heater

Figure 6 depicts the schematic and actual setup of IR dryer in the pilot study. The dryer consists of 5 major parts: feed conveyor, surge bin, IR dryer cabinet, inspection conveyor, and return elevator. The feed conveyor carries the wet walnuts and delivers them to surge bin. The surge bank acts as a bank to consistently feed the IR dryer at a controlled rate. The moisture-based sorting based on color of walnuts can be added here. The IR dryer cabinet contains catalytic infrared emitters and a variable speed metallic conveyor to convey the walnuts. The walnuts were conveyed under the emitters by conveyor belt placed 6 cm below the emitters. Based on the IR exposure time (which is up to 4 minutes), the speed of conveyor belt is adjusted accordingly. The inspection conveyor is used for collecting samples for quality inspection and the return elevator is used to carry the pre-dried walnuts to the main hot air-drying bins at the facility. The drying is stopped when the moisture content indicated by sensors reaches 8% on wet basis.

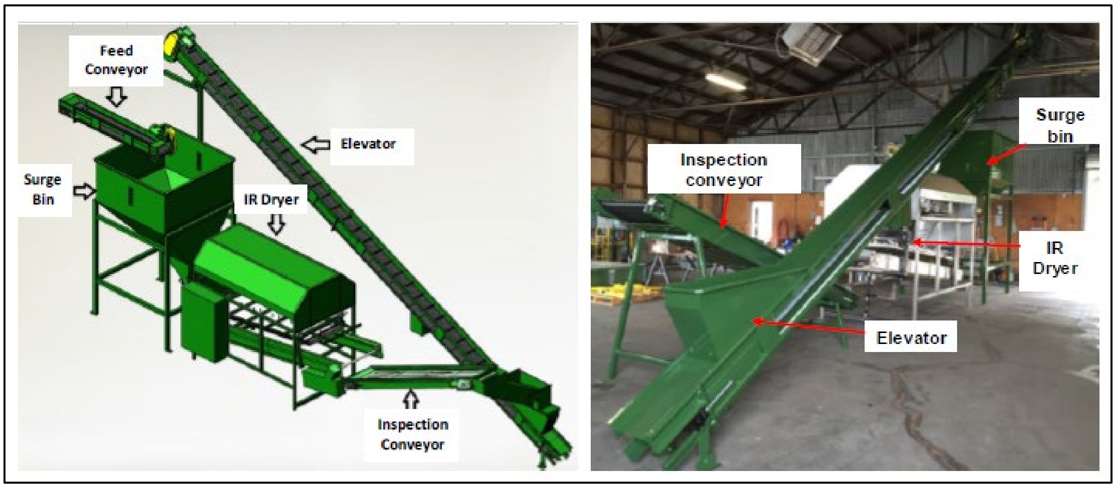


Figure 6: Components of pilot IR dryer [4]

c) Key results from the demonstration project and pilot study conducted by Dr. Zhongli Pan:

1) The new walnut drying technology has demonstrated drying time reduction and energy savings during pilot and field study implemented in 2018.

2) IR pre-drying after moisture-based sorting of walnuts led to average drying time reductions of 22% and 18% for low and high moisture walnuts respectively, compared to hot air bin drying alone.

3) The sorting of walnuts into low and high moisture groups and IR pre-drying for 3-4 minutes could result in energy savings up to 25%, compared to hot air bin drying of unsorted walnuts.

4) There was no significant difference in color of IR pre-dried and hot air-dried walnuts.

d) Airflow and blower horsepower considerations

Walnut dryers typically use natural gas for heating and electricity for fan operation. Selection of fans or sizing of fans is dependent on the airflow capacity and the static pressure that the fan must operate against. Total airflow to the drying bins is calculated by multiplying the dryer volume and the airflow per bin volume desired. Tables 1 and 2 indicate static pressure required and horsepower required per dry ton as a function of airflow and bin depth.

Table 1: Static pressure (in. of water) required for given airflows and bin depths [5]

Airflow (cfm/cu ft)	Bin depth (ft)			
	4	5	6	8
10	0.11	0.21	0.36	0.81
15	0.24	0.45	0.75	1.70
20	0.40	0.76	1.30	2.90
25	0.61	1.20	1.90	4.40
30	0.85	1.60	2.70	6.10
35	1.10	2.10	3.60	8.10
40	1.40	2.70	4.60	10.30

Table 2: Horsepower per ton required for given airflows and bin depths [5]

Airflow (cfm/cu ft)	Bin depth (ft)			
	4	5	6	8
10	0.022	0.042	0.070	0.16
15	0.070	0.13	0.22	0.50
20	0.16	0.30	0.50	1.10
25	0.30	0.56	0.95	2.10
30	0.50	0.95	1.60	3.60
35	0.78	1.50	2.50	5.60
40	1.10	2.10	3.60	8.10

Moisture sensors play a crucial role in the bin drying process of walnuts, ensuring that the drying process is controlled and monitored effectively. Automated moisture meters consist of series of devices that are installed in walnut drying bins and the moisture in each bin can be displayed at a central location. These systems use pneumatic controls for allowing the hot air into the bins to dry walnuts to a preset moisture limit (typically 8%). When the humidity or initial moisture of walnuts is high, the doors open wide for more airflow. As walnuts approach the target moisture or preset moisture limit, the doors modulate to restrict airflow. The doors are closed during the idle periods of operation.

Some systems also include automatic fill gate oversight along with moisture monitoring. This device closes the gate automatically when the fill point is reached. Thus, these systems control the operation of air doors and prevent over-drying.

The door modulation can be combined with fan speed control for higher energy efficiency gains. Variable frequency drives (VFD) use temperature and humidity sensors to modulate the fan speed. VFDs when installed on blower motor fans allow precise airflow control based on moisture content. Since fan power consumption is proportional to the cube of speed per affinity laws, the reduction in fan speed by 20% can reduce energy consumption by nearly 50%. Adjusting the airflow prevents over-drying of walnuts, which can improve walnut quality.

e) Equipment specifications and information about costs

The manufacturer recommended by Dr. Zhongli Pan's research group was interviewed to gather more information about the equipment specifications and product costs.

The equipment is proposed to be installed on the flat line conveyors. Tables 3 and 4 denote the dimensions of catalytic heaters and startup power options. The pilot study used 64 heaters of size 24 X 72 with 72,000 BTU/hour heating capacity. This heater model requires 480 V 3-phase power and 6.24 A per heater [4]. If the equipment is installed outdoors, no exhaust is required.

Table 3: Catalytic heater dimensions and sizing

HEATER SPECIFICATION

Heater Size	BTUH	CU FT/HR		Height		Width		Depth		Weight
		NG	LP	IN	MM	IN	MM	IN	MM	Lbs
12X36	18000	18.0	7.2	12.12	307.8	36.12	917.4	6.5	165.1	23
12X48	24000	24.0	9.6	12.12	307.8	48.12	1222.2	6.5	165.1	38
12X60	30000	30.0	12.0	12.12	307.8	60.12	1527.0	6.5	165.1	42
12X72	36000	36.0	14.4	12.10	307.3	77.25	1962.2	6.5	165.1	46
18X36	28000	28.0	11.2	18.12	460.2	36.12	917.4	6.5	165.1	40
18X48	37000	37.0	14.8	18.12	460.2	48.12	1222.2	6.5	165.1	50
18X60	45000	45.0	18.3	18.12	460.2	60.12	1527.0	6.5	165.1	55
24X48	50000	50.0	20.0	24.12	612.6	48.12	1222.2	6.5	165.1	62
24X60	60000	60.0	24.4	24.12	612.6	60.12	1527.0	6.5	165.1	68
24X72	72000	72.0	28.8	24.12	612.6	77.25	1962.2	6.5	165.1	89

Table 4: Catalytic heater- startup voltage and amperage

HEATER STARTUP POWER OPTIONS

Heater Model	Voltage (AC)/Amperage per Heater						
	120	208	240	380	415	480	575
12X36	3.13	3.60	3.12	N/A	N/A	1.56	N/A
12X48	8.33	4.80	4.16	2.38	2.60	2.08	1.73
12X60	10.41	6.00	5.20	2.96	3.01	2.60	2.17
12X72	12.50	7.21	6.25	3.55	3.85	3.12	2.60
18X36	10.00	5.76	5.00	N/A	N/A	2.50	N/A
18X48	12.50	7.20	6.24	3.56	3.85	3.32	2.60
18X60	15.82	9.12	7.90	4.47	4.93	3.94	3.30
24X48	16.66	9.60	8.32	4.76	5.20	4.16	3.46
24X60	20.82	12.00	10.40	5.92	6.02	5.20	4.34
24X72	25.00	14.42	12.50	7.10	7.78	6.24	5.20

The estimated equipment costs are around $5,000 per IR heater and equipment installation costs are approximately around $8,000. The estimated costs of upgrading the existing setup of the conveyor lines are approximately around $50,000, which is a site-specific incremental cost [6].

Energy Savings Calculator Tool Development

This section summarizes the key remarks and assumptions made during the tool development. A spreadsheet-based energy savings calculator is developed to estimate energy savings potential of walnut IR pre-drying. Also, the tool has the capability to estimate payback period based on the total project costs and customer copay.

The tool uses a color combination which denotes that the cells in 'green' are user input, the cells in 'grey' are the engineering assumptions or constants, and the cells in 'orange' are calculated outputs or values.

The tool has inputs for following site specific parameters (baseline condition) including type of walnuts, length of season, information about number of conveyor lines and associated operating hours, information about number of burners and existing heat output, operating hours of drying bins, and specifics about operation of blower motor fans. See Figure 7. Note that the operating hours of the conveyor lines and drying bins can be significantly different. The conventional bin drying takes place usually for 20-24 hours per day throughout the typical season of 2 months. However, the operation of conveyor lines for feeding in the walnuts into the drying bins would be for maximum of 8-10 hours per day, depending on the production levels.

Site Specific Input Parameters and Baseline Condition

Parameter	Unit	Value
Type of Walnuts		Low moisture walnuts
Length of season	days	60
Number of existing conveyor lines		1
Operating hours of conveyor lines per day	hours	8
Operating hours of bin drying per day	hours	20
Production rate of walnuts	tons/hour	10
Heating output of existing burner	MMBTU/hr	10
Number of burners (bin drying)		3
Number of blower motors		4
Wattage of blower motor	HP	75
Efficiency of blower motor		0.95
Total operating hours of conveyor lines in season	hours	480
Total annual operating hours- bin drying	hours	1,200
Total output of burners (bin drying)	MMTBU/hr	30
Assumption for load factor on blower motor		0.5
Assumption for load factor on burners		0.3

Figure 7: Site Specific Input Parameters and Baseline Condition

The tool has inputs for following parameters associated with the proposed case of IR pre-drying including number of zones or proposed conveyor lines, number of IR heaters per zone, and BTU/hour input. See Figure 8. The desired production output and available floor area at the site can affect the number of IR heaters or number of zones that can be installed at a specific site.

Infra-red (IR) Nut Drying System Parameters (Proposed Case)		
Parameter	**Unit**	**Value**
Number of proposed conveyor lines or zones		1
Number of IR heaters per zone		64
BTUH input per IR heater	BTU/hour	72,000
Production rate of walnuts	tons/hour	10
Operating hours of proposed conveyor lines per day	hours	16
System Power Requirement	V	480
System Amperage per heater	A	6.24
Estimated Reduction in burner runtime	%	18
Pre-heat startup time for IR heater	hours	0.5
Assumption of startup events for IR heater		120
Assumption for power factor		0.85

Figure 8: IR Nut Drying System Parameters (Proposed Case)

Following is the summary of key engineering assumptions:

1. The tool has built-in assumptions for load factors of blower motors and burners based upon empirical values and SME interviews. A load factor of 0.25-0.3 is common for burners, since they are typically over designed. A load factor of 0.5 is assumed for the electrically driven blower motors. Several of the blower motors are equipped with variable frequency drives (VFD) that automatically ramp down the motor as dryer bins reach moisture content and the individual bin doors begin closing.

2. Figure 8 (user input tab for IR nut drying) also contains typical electric voltage and amperage requirements for the IR heaters. This is based on the data from Tables 3 and 4.

3. As discussed in the Literature Review section, catalytic IR heaters require electric current only during the startup. The specifications indicate a startup time of around 15-20 minutes. However, the tool has built-in assumption of 30 minutes for one event. It is assumed that there would be 2 startup events per day- one during the

start of the shift and one after the break or production halt. This tab also includes an assumption of electric power factor of 0.85.

4. The production rate of walnuts (tons per hour) in the proposed case is assumed same as the baseline case.

5. The estimated reduction in drying of walnuts or runtime of burners and fans is dependent on existing moisture of walnuts and is assumed to be the same as the experimental results of Dr. Zhongli Pan's study - 22% and 18% reduction for low and high moisture walnuts respectively. The tool assumes a lower estimate (15% reduction) for unsorted walnuts. See sub-section (c) in Literature Review.

6. Figure 9 shows the assumptions for electric and gas utility rates. However, those are kept as user inputs and can be changed to estimate cost savings and payback period for a particular location in California. This also shows the unit conversion factors used in the calculations.

Electric and Gas Utility Rate Assumptions		
Average electric utility rate	$/kWh	0.39
Average gas utility rate	$/therm	1.22
MMBTU to Therm Unit Conversion Factor		10
Therm to BTU Unit Conversion Factor		100,000
HP to kW Conversion Factor		0.746

Figure 9: Utility rates and unit conversions

7. The assumptions regarding the equipment cost per IR heater, installation costs, and costs for modifications of existing conveyor lines are made per the description sub-section (e) of the Literature Review. See Figure 10. Note that the cost of modifications of existing conveyor lines is site specific and is kept as a user input in the tool. The total equipment and installation cost is calculated from the estimated

cost per IR heater, number of IR heaters, and modification cost of existing conveyor lines.

The estimated payback is calculated differently based on both the total project costs and customer copay. Note that the payback periods are primarily constrained by the typical length of walnut season, which is only about 2-3 months.

Energy Economics		
Parameter	**Unit**	**Value**
Equipment Cost Estimate per IR heater	$	5,000
Equipment Installation Cost Estimate	$	8,000
Modifications of Existing Conveyor Lines Estimate	$	50,000
Total Equipment and Installation Cost Estimate	$	218,000
Funding from utility programs	$	180,000
Estimated Customer Copay	$	38,000
Estimated Payback Period based on Total Project Cost	years	10.98
Estimated Payback Period based on Customer Copay	years	1.91

Figure 10: Energy Economics Tab

Following are the primary equations used in calculation procedures and tool development:

Refer to Table 5 for symbolic notation.

Baseline Energy Consumption: Conventional bin drying

$$Annual\ production\ rate\ of\ walnuts, A\ (tons/yr) = d * nc * tc * p \qquad (1)$$

$$Total\ gas\ consumption\ of\ existing\ burners,\ T_{g-pre}(therms/yr) = nb * hb * lb * Tb * C1 \qquad (2)$$

$$Total\ electric\ consumption\ of\ hot\ air\ blower\ motors,\ T_{e-pre}(kWh/yr) = \frac{nm * hm * lm * Tc * C2}{em} \qquad (3)$$

$$Total\ annual\ utility\ costs,\ T_{c\text{-}pre}\ (\$) = T_{g-pre} * Rg + T_{e-pre} * Rel \qquad (4)$$

$$Normalized\ energy\ consumption,\ N_{pre}\ (therms/ton) = \frac{T_{g-pre}}{A} \qquad (5)$$

Note: Formulae (1) and (5) are similar for both baseline and proposed case energy consumption. ‘pre’ and ‘post’ subscripts are used for baseline and proposed cases. ‘g’ and ‘e’ are used for natural gas and electric consumption.

Proposed Energy Consumption: IR Nut Drying followed by conventional bin drying

$$Total\ gas\ consumption\ of\ existing\ burners,\ T_{p1}\ (therms/yr) = T_{g-pre} * (1 - m/100) \quad (6)$$

$$Total\ gas\ consumption\ of\ IR\ heaters, T_{p2}\ \left(\frac{therms}{yr}\right) = \frac{Tc*nr*hr*lb}{C3} \quad (7)$$

$$Total\ annual\ gas\ consumption, T_{g-post} = T_{p1} + T_{p2} \quad (8)$$

$$Total\ electric\ consumption\ of\ IR\ heaters, T_{p3}\ (kWh/yr) = \frac{1.73*Ir*Vr*Ns*Is*pf*nc*nr}{1000} \quad (9)$$

$$Total\ electric\ consumption\ of\ hot\ air\ blower\ motors, T_{p4}\ (kWh/yr) = T_{e-post} * (1 - m/100) \quad (10)$$

$$Total\ annual\ electric\ consumption, T_{e-post} = T_{p3} + T_{p4} \quad (11)$$

$$Total\ annual\ utility\ costs,\ T_{c\text{-}post}\ (\$) = T_{g-post} * Rg + T_{e-post} * Re \quad (12)$$

$$Normalized\ energy\ consumption,\ N_{post}\ (therms/ton) = \frac{T_{g-post}}{A} \quad (13)$$

Table 5: Symbolic Notation

Symbol	Unit	Description
d	days	Length of season
nc		Number of conveyor lines
tc	Hours/day	Operating hours of conveyor lines per day
Tc	Hours/season	Total operating hours of conveyor lines in season
Tb	Hours/year	Total annual operating hours of burners
p	Tons/hour	Hourly production rate of walnuts
nb		Number of burners (bin drying)
nm		Number of blower motors
hb	MMBTU/hour	Heat output of existing burner
hm	HP	Horsepower of blower motor
em	%	Efficiency of blower motor
lb		Load factor- burners
lm		Load factor- blower motors
C1	Therms/MMBTU	Conversion factor (MMBTU to Therms)
C2	kW/HP	Conversion factor (HP to kW)
C3	BTU/Therms	Conversion factor (Therms to BTU)
Rg	$/therm	Average gas utility rate
Rel	$/kWh	Average electric utility rate
m	%	Percentage reduction in runtime of burners
Ir	A	System amperage per IR heater
Vr	V	Voltage requirement
pf		Power factor
nr		Number of IR heaters per zone
hr	BTU/hour	BTU input per IR heater
Ns		Number of startup events- IR heater
ls	hours	Pre-heat startup time for IR heater

See Figures 11-13 for calculated values of baseline energy consumption, proposed energy consumption, and total energy savings. Normalized energy consumption is a metric added to compare energy consumption on the basis of tons of walnuts produced.

Baseline Energy Consumption		
Parameter	**Unit**	**Value**
Annual production of walnuts	tons	4,800
Total gas consumption of existing burners	therms	102,240
Total annual kWh consumption of hot air blowers	kWh	141,347
Total annual utility costs	$	179,858
Normalized energy consumption	therms/ton	21.3

Figure 11: Calculated Values- Baseline Energy Consumption

Proposed Energy Consumption		
Parameter	**Unit**	**Value**
Annual production of walnuts	tons	4,800
Total gas consumption of existing burners	therms	79,747
Total gas consumption of IR heaters	therms	3,141
Total annual kWh consumption of IR heaters	kWh	8,457
Total annual kWh consumption of hot air blowers	kWh	110,251
Total annual kWh consumption	kWh	118,707
Total annual gas consumption	therms	82,888
Total annual utility costs	$	147,419
Normalized energy consumption	therms/ton	17.3

Figure 12: Calculated Values- Baseline Energy Consumption

Total Annual Energy Savings and Cost Savings		
Parameter	**Unit**	**Value**
Total gas consumption savings	therms	19,352
Total kWh consumption savings	kWh	22,640
Total annual utility cost savings	$	32,439
% Energy Cost Savings	%	18.04

Figure 13: Calculated Values- Total Energy and Cost Savings

Conclusions

Walnut IR pre-drying offers a promising energy efficient solution by rapidly removing moisture through high heat flux, potentially reducing drying time and energy use without compromising product quality. Dr. Zhongli Pan's research group (UC Davis) conducted a pilot study in 2018 to demonstrate the energy efficient IR drying of walnuts. IR drying technology has demonstrated significant reduction in drying time of walnuts and energy savings during pilot and field study implemented by Dr. Zhongli Pan's research group. The sorting of walnuts into low and high moisture groups and IR pre-drying for 3-4 minutes could result in energy savings up to 25%, compared to hot air bin drying of unsorted walnuts.

The equipment and installation cost information is compiled from an interview with the equipment manufacturer for proposed project. A spreadsheet-based energy savings calculator was developed to estimate energy saving and cost saving potential of walnut IR pre-drying. Also, the tool has the capability to estimate payback period based on the total project costs and customer copay.

References

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