

Drying of Grape with an Infrared Radiation heating Mechanism

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Abstract: In this paper, Considered grapes type for drying was Thompson seedless grapes using laboratory flatbed dryer. Effect of environmental factors (like humidity and temperature), Infrared energy exposer and pretreatment on grapes at constant air velocity were studied. Ethyl oleate (2%), Potassium Carbonate (2.5%) and water (95.5%) were considered for pretreatment of grapes to get non-sticky and soft texture. A Standard cold dip emulsion pretreatment was used. Pretreatment increases drying rate because of cracks developed on pretreated grape's surface. Constant, controlled and concentrated Infrared energy gives great appearance as well as taste within 9 hours to 12 hours. Drying rate was predicted by calculation and observed practically at 20cm distances between Infrared energy source and grapes in flatbed dryer. For calculation of Drying rate, here considered only its water content and no other factors which are include in biomass structure of grape is consider. Energy intensity modeled using Özişik(1977) equation and polynomial expressions of Leckner (1972) to obtain the vapor emissivity. This work was done under the guidance of Dr. V. N. Walivadekar, Sci. S. Valunjkar & Sci. D. Ramarao in NIELIT (Formerly DOEACC Centre), Aurangabad as a project work.

I. INTRODUCTION

Grape is a seasonal crop and gets spoiled fast, therefore all the grapes of a season must be utilized within a short span of four to five days of harvest to produce raisins. Present natural drying process requires 12 to 15 days and the season is of 4 to 5 months. Hence, the investment on space and infrastructure are large and cannot be afforded by a farmer.

There are also locations where the ambient conditions are good for grape growing but adverse for raisin producing. Therefore, we designed and fabricated an experimental drying chamber which simulates the climatic conditions and also a microcontroller based control was developed to provide flexibility in varying simulated climatic conditions.

A controlled environment suitable for raisin producing is simulated within the closed chamber and is a three step process. Firstly, infrared source is used to internally heat the pretreated grapes to speedily remove the water content inside the grape for fast drying. Secondly, Fresh air as per environmental temperature is blown inside the chamber to remove humid air in between energy source and grapes which is developed inside the chamber, because of evaporation and moisture present on pretreated grapes surface and exhaust the humid air out of the chamber and finally the microcontroller goes to idle mode disconnecting the power to the chamber after the weight of the grapes reduce to about 25% of the original weight activating a buzzer for a duration of 10 seconds to indicate the end of the raisin producing process.

This Grape dryer has been designed and developed with IR Heater as an energy source. The said work has been undertaken as the project work in NIELIT (formerly DOEACC Centre, A'bad) under the guidance of Dr. V. N. Walivadekar (Director), Mr. S. T. Valunjkar & Mr. D. Ramarao.

II. DRYING RATE OF ONE BERRY HAVING WEIGHT 2GM

Given:

- 1) Ceramic IR source: 750W/230V
- 2) Size : 245mm length ,60mm breadth
- 3) Grape berry diameter (spherical shape) = 15(in mm)
- 4) Weight of grape berry = 2 gm
- 5) Distance from source to target=200mm(experimentally defined)

III. EXPERIMENTAL OBSERVED DATA

Atmospheric conditions (in experiment):

Temp =28oC, Humidity = 74%RH

At 20 cm distance between source and grape berry, Drying of one Grape berry (6gm weight) to make raisin takes place in 11 Hrs. And skin color of dried grape is light Brown.

(Blackening of skin of Grape Berry happened at 15cm distance between source and target.)

IV. CALCULATED DATA

Emissivity of the water vapor:

$$\ln \epsilon = a_0 + \sum_{i=1}^2 a_i \lambda^i \text{ -----(i)}$$

$$a_i = c_{0i} + \sum_{j=1}^2 c_{ji} \tau^j \text{ -----(ii)}$$

The variable λ and τ are defined as

$$\lambda = \log p_g L_m$$

$$\tau = T_g / 1000$$

Nonetheless, $pgLm$ and Tg were replaced by $pgLm(Ts / Tg)$ and Ts , respectively, to obtain the vapor absorptivity. The values of coefficients c_{ji} for Eq. (3.37) are listed in Table 3.1.

Topic: Coefficient Values for eq (ii)

s for Eq. (3.37)

<i>i</i>	<i>c</i> _{0<i>i</i>}	<i>c</i> _{1<i>i</i>}	<i>c</i> _{2<i>i</i>}
0	-2.2118	-1.1987	0.035596
1	0.85667	0.93048	-0.14391
2	-0.10838	-0.17156	0.045915

Source: Leckner, 1972.

So,

$$\lambda = \log (pgLm (Ts / Tg))$$

where,

- pg is the pressure of the saturated vapor at the temperature in mb

- The temperatures Tg and Ts , are the temperatures of the water vapor and an external blackbody heat source surface, respectively

- L is distance between Source & Target

Now,

The pressure of saturated vapor, p_g at 28°C is

T (°C)	P (bars)
26	0.03
27	0.04
28	0.04
29	0.04

Table: pressure of saturated vapor

Now,

$$p_g = 0.04 \text{ bar} = 40 \text{ mb}$$

$$T_s = 1023.15 \text{ K (given in product catalogue of Elstine company)}$$

$$T_g = 28 + 273.15 = 301.15 \text{ K}$$

$$L_m = 0.2 \text{ m}$$

$$\lambda = \log(p_g L_m (T_s / T_g)) = 1.4342$$

Now,

$$\tau = T_s / 1000 = 1.02315$$

So,

$$a_i = c_{0i} + \sum_{j=1}^2 c_{ji} \tau^j$$

$$a_0 = -3.4018$$

$$a_1 = 1.6614$$

$$a_2 = -0.2369$$

Now, calculate ε using following equation

$$\ln \varepsilon = a_0 + \sum_{i=1}^2 a_i \lambda^i$$

$$\ln \varepsilon = a_0 + (a_1 + a_2) * \lambda = -1.3587$$

$$\varepsilon = 0.257$$

Now, we have, Emissivity of the water vapor at 28 °C, $\varepsilon = 0.257$

The functional relationship for the emissivity and absorptivity of water vapor,

$$\varepsilon = \varepsilon(p_g L_m, p, T_g)$$

$$\alpha = \alpha(p_g L_m, p, T_g, T_s) \approx \left(\frac{T_g}{T_s}\right)^{0.5} \varepsilon\left(p_g L_m \frac{T_s}{T_g}, p, T_s\right)$$

$$\text{Given, } T_s = 1023.15 \text{ K}$$

$$T_g = 28 + 273.15 = 301.15 \text{ K}$$

$$\varepsilon = 0.257$$

$$\alpha = (301.15 / 1023.15)^{0.5} * 0.257 = 0.1394$$

Now, the spectral absorptivity, α_λ , of the gas layer = 0.1394

Now we know,

$$I_\lambda(0) - I_\lambda(L) = I_{\lambda 0}(1 - e^{-\kappa_\lambda L})$$

And

$$\alpha_\lambda \equiv 1 - e^{-\kappa_\lambda L}$$

Now,

For selected Ceramic IR source having emissivity 0.9,

Power (at all associated wavelengths) = 750W

By Stefan-Boltzmann Law,

$$R = (\varepsilon) \times (\sigma) \times (T^4) \quad \text{Watts/ in}^2$$

Where, T in Kelvin,

$$\sigma = 36.58072 \times 10^{-12} \text{ W/in}^2 \cdot \text{°K}$$

$$R = 0.9 \times 36.58072 \times 10^{-12} \times 1023.154$$

$$= 36.0788 \text{ W/in}^2 = 10.058595 \text{ W/m}^2$$

$$\text{Area of Heating coil} = 750 / 36.0788 = 20.7878 \text{ in}^2 = 0.01341146 \text{ m}^2$$

$$\text{Radiant efficiency of Ceramic source is 96\%, } 750 \times 0.96 = 720 \text{ W}$$

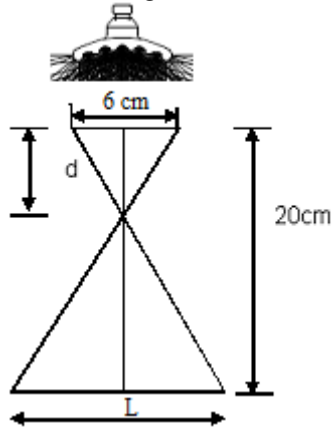
$$\text{Power per area} = 720 \times 0.01341146 = 9.6562512 \text{ W/m}^2$$

$$I\lambda(0) = 9.6562512 \text{ W/m}^2$$

$$I\lambda(0.2) = 8.310169783 \text{ W/m}^2$$

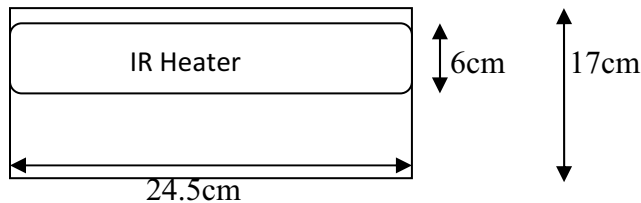
$$\text{Power after 0.2meter travelling} = 8.310169783 / 0.01341146 = 619.632 \text{ W}$$

$$\text{Now, Power at Grapes surface at all associated wavelengths} = 619.632 \text{ W}$$



$d = 5.08 \text{ cm}$ (as the source having curved shape) = radius

$$L = 17.2276 \text{ cm} \approx 17 \text{ cm}$$



$$\text{So, Area covered under source} = 17 \times 24.5 = 416.5 \text{ cm}^2$$

$$\text{Area of grape berry} = 3.14 \times 0.752 = 1.766 \text{ cm}^2$$

$$\text{No. of grapes} = 416.5 / 1.766 = 236.$$

So, 236 grape berries covered under one selected IR source.

$$\text{Weight of 236 grape berries} = 236 \times 2 = 472 \text{ gm}$$

So, 619.632 W power spread over 472 gm grapes.

$$\text{So, Power over one grape berry} = 619.632 / 236 = 2.63 \text{ W}$$

$$\text{So, Watt per Grape surface area} = 2.63 \text{ W} / (2 \times 3.14 \times 0.752) \text{ cm}^2 = 0.7445 \text{ W/cm}^2$$

Grapes, 80% water is present. Raisins having 14% water of its weight.

$$\text{So, mass present inside one grape berry} = 0.2 \times 2 = 0.4 \text{ gm}$$

$$\text{Therefore, (amount of water present inside raisins) / (0.4 + amount of water present inside raisins)} = 0.14$$

$$\text{Quantity of water present inside raisins} = 0.0651 \text{ gm}$$

$$\text{Water to evaporate from one grape berry} = (2 \times 0.8) - 0.0651 = 1.5349 \text{ gm}$$

$$1.5349 \text{ gm} = 0.003383841 \text{ lb}$$

Now, Grape berry has spherical shape having diameter is 15 mm.

$$\text{So, Surface area of Grape berry} = 1.095077 \text{ inch}^2$$

Therefore,

$$\text{lb. of water per square inch} = 0.003383841 \text{ lb} / 1.095077 \text{ inch}^2 = 3.09 \times 10^{-3} \text{ lb/inch}^2$$

Emissivity of the infrared source (Heating Filament) = 0.90

Emissivity of Water = 0.93

Specific Heat of Water = 1.0 BTU / lb. / °F

Latent Heat of Vaporization = 965 Btu / lb.

Boiling Point of Water = 212 °F (100 °C)

Ambient Temperature = 82 °F (28 °C)

The energy required to heat the water is given by:

3412 BTU = 1 KW-HR

$$\text{Watt-Hour} = \frac{(\text{Weight})(\text{Specific Heat})(T_1 - T_2)}{3.412}$$

$$= \{0.003383841 \text{ lb} * 1.0 \text{ BTU/lb./}^\circ\text{F} * (212 \text{ }^\circ\text{F} - 82 \text{ }^\circ\text{F})\} / 3.412$$

$$= 0.1289$$

Surface area of grape = 1.095077 inch²

$$\text{Watt-Hour/inch}^2 = 0.1289 \text{ W-Hour} / 1.095077 \text{ inch}^2$$

$$= 0.1177$$

$$\text{Heat for vaporization} = (965 \text{ Btu} / \text{lb.} * 3.09 * 10^{-3} \text{ lb/inch}^2) / 3.412$$

$$= 0.8739 \text{ Watt. Hour/in}^2$$

$$\text{Total Energy required} = 0.1177 + 0.8739$$

$$= 0.9916 \text{ Watt. Hour/in}^2$$

$$\text{So, total energy required to evaporate } 1.5439 \text{ gm} = 0.9916 \text{ Watt. Hour/in}^2 * 1.095077 \text{ inch}^2$$

$$= 1.0859 \text{ Watt. Hour}$$

But, Power over one grape berry (at all associated wavelengths) = 2.63 W/grape berry

Now,

Power emitted by the source, at 1023.15 K, within the band of wavelength (2.9µm-3.1µm) which is useable during drying process is only 4.586% of Total emitted power.

$$\text{So, Power over one grape berry (2.9 } \mu\text{m} - 3.1 \mu\text{m)} = 2.63 \text{ W} * 0.04586$$

$$= 0.12 \text{ Watt}$$

Time Required to Dry One Grape berry (or 1.5439 gm of water)

$$= \text{Total energy required to evaporate } 1.5439 \text{ gm} / \text{Power over one grape berry (2.9 } \mu\text{m} - 3.1 \mu\text{m)}$$

$$= 1.0859 \text{ Watt. Hour} / 0.12 \text{ Watt}$$

$$= 9.05 \text{ Hours} \approx 9 \text{ Hours}$$

Drying Rate = Quantity of water / Time Required to Dry 4.6gm of water

$$= 1.5439 \text{ gm} / 9 \text{ Hours}$$

$$= 0.1715 \text{ gm/Hr}$$

Drying rate of one berry (2gm) is 0.1715 gm/Hr.

Parameters	Value
Atmospheric conditions	Temp =28oC, Humidity = 74%RH
Grape berry dimensions(spherical shape)	15 mm Diameter
Weight of one Grape berry	2gm
Power of IR Source	750W
Distance between Source to Target	20cm
Power over one grape berry	2.63 W
Power over one grape berry (2.9 µm - 3.1 µm)	0.12 W
Quantity of water inside Grape berry to dry	1.5439 gm
Time Required to Dry 1.5439 gm of water	9Hrs
Drying rate of 1kg grapes	85.75 gm/Hr.

V. CONCLUSION

From the above data, we conclude that, as we increase the Distance between source and target, getting more pleasant color of rasine, but increase the Drying time. To avoid blackening of skin of rasine, if the power of

IR is greater than 2.63W, it will burn the skin of grape berry. Experimental observed time to dry 1.5439gm water inside grape berry and calculated time to dry 1.5439gm water having 2 hours difference. This is because of grape's biomass structure. So, grape size is also a very important factor while drying. As the grape size increase drying time is also increases. Grape size also affects the drying rate graph.

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