# 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. Valunjakar & 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:

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

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

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 cji for Eq. (3.37) are listed in Table 3.1.

Topic: Coefficient Values for eq (ii) s for Eq. (3.37)

| $i$ | $c_{0i}$ | $c_{1i}$ | $c_{2i}$ |
|---|---|---|---|
| 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,

λ = 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, pg at 28oC is

| T (•C) | P (bars) |
|---|---|
| 26 | 0.03 |
| 27 | 0.04 |
| 28 | 0.04 |
| 29 | 0.04 |

Table: pressure of saturated vapor

Now,
pg = 0.04 bar = 40 mb
Ts = 1023.15 K (given in product catalogue of Elstine company)
Tg = 28 + 273.15 = 301.15 K
Lm = 0.2 m
λ = log (pgLm (Ts / Tg)) = 1.4342
Now,
τ = Ts / 1000 = 1.02315
So,

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

a0 = -3.4018
a1 = 1.6614
a2= -0.2369
Now, calculate ε using following equation

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

ln ε = a0 + (a1 + a2) * λ = -1.3587
ε = 0.257
Now, we have, Emissivity of the water vapor at 28 oC, ε = 0.257
The functional relationship for the emissivity and absorptivity of water vapor,

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

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

Given, Ts = 1023.15 K
Tg = 28 + 273.15 = 301.15 K
ε = 0.257
α = (301.15 / 1023.15)0.5 * 0.257 = 0.1394
Now, the spectral absorptivity, αλ, 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,

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

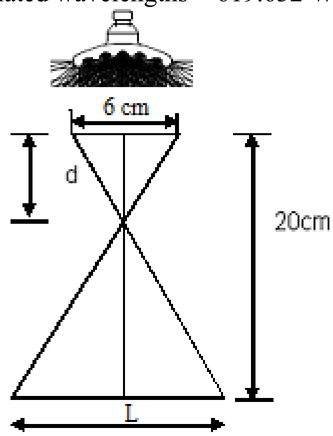
Where, T in Kelvin,

σ = 36.58072 x 10 -12 W/ in2 . °K

R = 0.9 * 36.58072 *10-12 * 1023.154

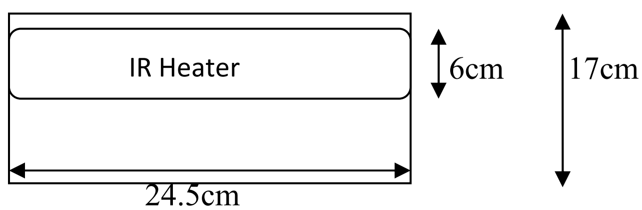
= 36.0788 W/ in2 = 10.058595 W/ m2

Area of Heating coil = 750 / 36.0788 = 20.7878 in2 .= 0.01341146 m2
Radiant efficiency of Ceramic source is 96%, 750 * 0.96 = 720W
Power per area = 720 * 0.01341146 = 9.6562512 W/ m2
Iλ(0) = 9.6562512 W/ m2
Iλ(0.2) = 8.310169783 W/ m2
Power after 0.2meter travelling = 8.310169783 / 0.01341146 =619.632 W
Now, Power at Grapes surface at all associated wavelengths = 619.632 W




d= 5.08 cm (as the source having curved shape) = radius

L = 17.2276 cm ≈17cm




So, Area covered under source = 17 * 24.5 = 416.5cm2
Area of grape berry = 3.14 * 0.752 = 1.766 cm2
No. of grapes = 416.5 / 1.766 = 236.
So, 236 grape berries covered under one selected IR source.
Weight of 236 grape berries = 236 * 2 = 472 gm
So, 619.632 W power spread over 472 gm grapes.
So, Power over one grape berry = 619.632 / 236 = 2.63 W
So, Watt per Grape surface area = 2.63W / (2*3.14*0.752) cm2
= 0.7445 W/cm2
Grapes, 80% water is present. Raisins having 14% water of its weight.
So, mass present inside one grape berry = 0.2 * 2 = 0.4gm
Therefore, (amount of water present inside raisins) / (0.4 + amount of water present inside raisins) = 0.14
Quantity of water present inside raisins = 0.0651gm
Water to evaporate from one grape berry = (2*0.8) – 0.0651 = 1.5349 gm
1.5349 gm = 0.003383841 lb
Now, Grape berry has spherical shape having diameter is 15 mm.
So, Surface area of Grape berry = 1.095077 inch2
Therefore,
lb. of water per square inch = 0.003383841 lb / 1.095077 inch2 = 3.09 * 10-3 lb/inch2

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 lb * 1.0 BTU/lb./°F * (212 °F – 82 °F)}/ 3.412
= 0.1289
Surface area of grape = 1.095077 inch2
Watt-Hour/inch2 = 0.1289 W-Hour / 1.095077 inch2
= 0.1177
Heat for vaporization = (965 Btu / lb. * 3.09 * 10-3 lb/inch2) / 3.412
= 0.8739 Watt. Hour/in2
Total Energy required = 0.1177 + 0.8739
= 0.9916 Watt. Hour/in2
So, total energy required to evaporate 1.5439 gm = 0.9916 Watt. Hour/in2 * 1.095077 inch2
= 1.0859 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.
So, Power over one grape berry (2.9 µm - 3.1 µm) = 2.63 W * 0.04586
= 0.12 Watt
Time Required to Dry One Grape berry (or 1.5439 gm of water )
= Total energy required to evaporate 1.5439 gm / Power over one grape berry (2.9 µm - 3.1 µm)
= 1.0859 Watt. Hour / 0.12 Watt
= 9.05 Hours ≈ 9 Hours
Drying Rate = Quantity of water / Time Required to Dry 4.6gm of water
= 1.5439 gm / 9 Hours
= 0.1715 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.

## REFERENCES


[1] Dr. Taur (Assistant Professor - Food Technology), Parbhani Agriculture University
[2] Mr P.L. Satwadhar (PDE), Parbhani Agriculture University
[3] Dr Vasant Pawar , (HOD - Food Tradery and business management), Parbhani Agriculture University
[4] Molecular modeling (calculation for weak hydrogen bond page 231)
[5] Molecular Spectra & Molecular Structure – Infrared & Raman Spectra of Polyatomic Molecules by GERHARD HERZBERG, National Research Council of Canada
[6] Research Paper on Electrostatic deflection of the water molecule, a fundamental asymmetric rotor - Ramiro Moro, Jaap Bulthuis, Jonathon Heinrich, and Vitaly V. Kresin
[7] Fundamentals of Physics – Subhramanyam & Lal
[8] Food Chemistry, Dennis D. Miller
[9] Larousse Encyclopaedia of food
[10] Fundamental of Biochemistry- J.L. Jain
[11] Fruits and vegetable photochemical - laura A. d la Rosa
[12] S.S. Rangana, Analysis of Fruit & Vegetable products.
[13] The Grape – MPH
[14] www.madehow.com/Volume-4/Raisins.html
[15] www.chemistry-dictionary.com/dictionary.php?w=H
[16] iweb.tntech.edu/albu/teaching/CHEM3510-F06/Unit09.pdf (Resonance Energy)
[17] www.doitpoms.ac.uk/tlplib/stiffness-of-rubber/lennard-jones.php
[18] www.docstoc.com/docs/22705904/CHAPTER-10---MOLECULAR-SHAPE-AND-THEORY-OF-BONDING
[19] www.highpressurescience.com/onlinetools/conversion.html
[20] www.elstein.com
[21] www.engineeringtoolbox.com/water-vapor-saturation-pressure-air-d_689.html
[22] vinodiary.com/wp-content/uploads/2009/09/Anatomy-Components-of-the-Grape.pdf
[23] imagine.gsfc.nasa.gov/docs/science/know_l2/emspectrum.html
[24] www.astronomynotes.com/light/s6.html
[25] www.supertoinette.com/recettes/caramel_to.html
[26] www.food-info.net/uk/colour/caramel.html