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|  |  |
| <b>KEY WORDS:</b> Drying, Fluidized bed, Infrared waves, Heat carrier particles, Potato. |  |
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+ E-mail: dmowla@shirazu.ac.ir

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() Mathlab

کنترل کننده دما

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![](_page_3_Figure_0.jpeg)

cm

|   | ( <b>W</b> / <b>m</b> <sup>3</sup> ) |     |        |                   |     |     |
|---|--------------------------------------|-----|--------|-------------------|-----|-----|
|   |                                      |     | T= °C  |                   |     |     |
|   | Dia= / mm L= / mm                    |     | Dia= / | Dia= / mm L= / mm |     |     |
|   |                                      |     |        |                   |     |     |
| Q | , ×                                  | , × | , ×    | , ×               | , × | , × |
| Q | , ×                                  | , × | , ×    | , ×               | , × | / × |
| Q | , ×                                  | , × | , ×    | , ×               | , × | , × |
|   |                                      |     | T= °C  |                   | ·   |     |
|   | Dia= / mm L= / mm                    |     |        | Dia= / mm L= / mm |     |     |
|   |                                      |     |        |                   |     |     |
| Q | , ×                                  | / × | , ×    | , ×               | , × | , × |
| Q | , ×                                  | , × | , ×    | , ×               | , × | / × |
| Q | / ×                                  | / × | , ×    | / ×               | , × | / × |
|   |                                      | 1   |        |                   | 1   |     |

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| (                      |   |   |
|------------------------|---|---|
| C <sub>P</sub>         | / X'/ + / ( -X')/   | ASHAR guide and Data book   |
| K p(j/m.s)             | K p = / X' / + / (-X') /  | R.L.Earle (unit Operations in food<br>processing above freezing page) |
| λp(kj/kg)              | λp= Χ'/   | R.L.Earle (unit Operations in food processing above freezing page)    |
| $A_{w}$                | $\begin{array}{cccccccccccccccccccccccccccccccccccc$                                  | Chou et al  |
| H <sub>w</sub> (kj/kg) | $H_{w} = E X_{m} + / E X_{m}$ $- E X_{m} + / E X_{m}$ $+ E ; ( / \leq X_{m} \leq / )$ | Keey  |

![](_page_4_Picture_2.jpeg)

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![](_page_4_Figure_3.jpeg)

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$$\frac{\partial \left(\rho_{p}C_{pg}T_{p}\right)}{\partial t} = \frac{1}{r} \left[\frac{\partial \left(rk_{p}\right)}{\partial r}\frac{\partial T_{p}}{\partial r}\right] + Q_{r} \qquad ()$$

. :

 $\pm k_{P}A_{P}\frac{\partial T_{P}}{\partial r} = h_{t}A_{P}(T_{g} - T_{P}) + k_{m}(Y_{e} - Y_{\infty})\Delta H^{evp}$ 

()

 $t = \circ \qquad \circ < r < R_P \qquad T = T_\circ$ 

 $t>\circ \qquad r=\circ \qquad \frac{\partial T_P}{\partial r}=\circ$ 

.

 $L_p/d_{p>}$ 

.

.

()

$$\frac{\partial(\rho_{p}X)}{\partial t} = \frac{1}{r} \left( \frac{\partial}{\partial r} \left( \rho_{p}rD_{eff} \frac{\partial X}{\partial r} \right) \right)$$
()

:

at 
$$t=0$$
  $0 < r < R_P$   $X = X$  ()  
at  $t > 0$   $r = 0$   $\frac{\partial X}{\partial r} = 0$   
at  $t > 0$   $r = R_P$   $D_{eff} \frac{\partial X}{\partial r} = k_m(Y_s - Y_e)$ 

$$X_{avg}(t) = \frac{\Psi_{\mu}}{v_{p}} \int_{\cdot}^{R} r^{\Upsilon} X(r, t) dr \qquad ()$$

.

$$Sh = \frac{k_m L}{D_{eff}} = \cdot / \mathcal{F} \mathfrak{N} R e^{\cdot / \mathfrak{d} \mathfrak{N}^{\mathfrak{r}}} S c^{\cdot / \mathfrak{N} \mathfrak{r}} \qquad ()$$

$$T_{avg}(t) = \frac{\pi}{V_p} \int_{0}^{R} r^{v} T(r, T) dr$$

$$() ()$$

$$h_t$$

$$I = \frac{hl}{K_g} = \cdot/\pi A r^{\cdot/\pi v} R e^{\cdot/.5\pi}$$

$$Ar Re$$

 $Ar = \frac{gd_p^r(\rho_p - \rho_g)\rho_g}{\mu_g^r}$ 

 $Re = \frac{\rho_g V d_p}{\mu_g}$ 

![](_page_6_Figure_0.jpeg)

![](_page_6_Figure_1.jpeg)

() Hygroscopic

![](_page_7_Figure_0.jpeg)

 $D_{\text{eff}}$ 

)

(

![](_page_7_Figure_2.jpeg)

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![](_page_8_Figure_0.jpeg)

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![](_page_8_Figure_1.jpeg)

°C

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![](_page_8_Figure_3.jpeg)

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![](_page_9_Figure_0.jpeg)

![](_page_10_Figure_0.jpeg)

- Fasina, O. O., Tyler, R. T., Pickard, M. D., Modeling the Infrared Radiative Heating of Agriculture Crops, *Drying Technology-An International Journal*, 16 (9-10), p. 2065 (1998).
- [2] Afzal, M. T., Abe, T. and Hilida, Y., Energy and Quality Aspect During Combined FIR-Convection Drying of Barely, *Journal of Food Engineering*, 42, p. 177 (1999).
- [3] Izadifar, M., Mowla, D., Simulation of a Cross-Flow Continuous Fluidized Bed Dryer for Paddy Rice, *Journal of Food Engineering*, 58, p. 325 (2003).

- [4] Hatamippour, M. S., Mowla. D., Experimental and Theoretical Investigation of Drying of Carrots in a Fluidized Bed with Energy Carrier, *Drying Technology*, **21** (1), p. 83 (2003).
- [5] Sakai, N., Hazawa, T. Applications and Advances in Far-Infrared Heating in Japan, *Trends food*, *Sci Technol*, 5, p. 357 (1994).
- [6] Naret Meeso et al. Modeling of far-infrared irradiation in paddy drying process. Journal of Food Engineering, 78(4), p. 1248 (2006).
- [7] Ginzburg, A, S., "Application of Infrared Radiation in Food Processing" London; Leonard Hill Books (1969).
- [8] Ranjan, R., Irudayaraj, J., and Jun, S., Simulation of Infrared Drying Process, Drying Technology, 20(2), p. 363 (2002).
- [9] Isengard, H. D. and Prager, H., Water Determination in Products with High Suger Content by Infrared Drying, *Food Chemistry*, 82, p. 161 (2003).
- [10] Togrul, H., Suitable Drying Model for Infrared Drying of Carrot, *Journal of food engineering*, 77, p. 610 (2006).
- [11] Sharma, G. P., Verma, R. C., Pathare. P. B., Thin-Layer Infrared Radiation Drying of Onion Slices, *Journal of food engineering*, 67, p. 361 (2005a).
- [12] Hebber, U. H., Vishwanathan, K. H. and Ramesh, M. N., Development of Combined Infrared and Hot Air Dryer for Vegetables, *Journal of Food Engineering*, 65, p. 557 (2004).
- [13] Sharma, G. P., Verma, R. C. and Pathare, P. B., Mathematical Modelling of Infrared Radiation Thin Layer Drying of Onion Slices, *Journal of food engineering*, **71**, p. 282 (2005b).
- [14] Abbasi, B. and Mowla, D., Experimental and Theoretical Investigation of Drying Behaviour of Garlic in an Inert Medium Fluidized Bed Assisted by Microwave, *Journal of Food Engineering*, 88, p. 438 (2008).
- [15] Soojin Jun and Joseph Irudayaraj, Selective far Infrared Heating System-Design and Evaluation, Drying Technology, 21 (1), p. 51 (2003).
- [16] Yang, H. W. and Gunasekaran, S., Comparison of Temperature Distribution in Model Food Cylinders Based on Maxwell's Equations and Lamberts Law During Pulsed Microwave Heating, *Journal of Food Engineering*, 64, p. 445 (2004).
- [17] Mult, A., Berna, A., Borras, M. and pinaga, F., Effect of Air Flow Rate on Drying of Carrots, *Drying Technology*,5(2), p. 245 (1987).
- [18] Bak, Y. C., Son, J. E. and Kim, S. D., Heat Transfer Characteristics of a Vertical Tube in a Fludized Bed Combustor, *Int. chem. Eng.*, 29(1), p. 166 (1989).
- [19] Salagnac, P., Glouannec, P., and Lecharpentier, D., Numerical Modeling of Heat and Mass Transfer in Porous Medium During Combined Hot Air, Infrared and Microwave Heating, *International journal of heat and mass transfer*, **47**, p. 4479 (2004).
- [20] ASHRAE Guide and Data Books, "American Society of Heating, Refrigerating and Air Conditioning Engineering", New York (2005).
- [21] Earle, R. L.,"Unit Operation in Food Processing", 2<sup>nd</sup> ed., Pergamon Press, Oxford. (1992).
- [22] Keey, R. B., "Introduction to industrial drying operations", 1st, Pergamon, New York. (1978).