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Parameters for Mango Glace´ Drying Simulation

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ABSTRACT

The objective of this research was to investigate parameters affecting drying rate of mango glace´, *i.e.*, diffusion coefficient, equilibrium moisture content, specific heat and density of mango glace´. The equilibrium moisture content was determined by static method at temperature of 45-70°C and relative humidity of 10-90%. Saturated salt solutions and an oven were used for controlling relative humidity and temperature, respectively. It was found that equilibrium moisture content decreased with temperature for relative humidity ranging from 10-60%. The BET equation was found accurate to describe the experimental results. The results obtained from drying experiment indicated that diffusion coefficient increased exponentially with drying temperature. It was further found that density and specific heat of mango glace´ decreased and increased linearly with moisture content, respectively.

Key words: BET equation, diffusion coefficient, fruit drying, mango glace´, saturated salt

INTRODUCTION

At present, there are many kinds of fruit in Thailand, which are high requirement for both domestic and export markets. However, there is still problem about fruit storage. Fruit drying is an important approach for solving the problem, as dried fruit can be stored in warehouse for long time. Fruit drying analysis is an important method to determine the suitable conditions for reducing drying cost and maintaining product qualities.

Achariyaviriya and Soponronnarit (1990) studied drying parameters and developed mathematical model of papaya glace´ drying. It was found that BET equation (Brunauer *et al*. 1938) was accurate to describe the experimental results of equilibrium moisture content of papaya glace´. A mathematical equation used for predicting diffusion coefficient was accurate to describe at temperature ranging from 40-80°C. From the experimental results of density and specific heat of papaya glace´, it was found that both of these increased linearly with moisture content. Nuimeem *et al*. (1993) studied the optimum strategy for pineapple glace´ drying. It was found that the appropriate operating parameters were as follows: drying air temperature of approximately 65°C, specific air flow rate of 11 kg-dry air/h kg-dry pineapple glace´ and air recycle of approximately of 75%. The product quality was good and energy consumption reduced. Teanchai and Soponronnarit (1991) studied parameters to evaluate and analyse pineapple glace´ drying. It was found that Iglesias equation (Iglesias *et al*., 1975) could describe in

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accordance with experimental results of equilibrium moisture content of pineapple glace´. The experimental conditions were as follows: drying temperature of 45-70°C and moisture content of 10-80% dry basis. It indicated that diffusion coefficient increased exponentially with drying temperature. It was further found that density and specific heat of pineapple glace´ increased linearly with moisture content.

All fundamental properties such as equilibrium moisture content, diffusion coefficient, specific heat and densities of mango glace´ were therefore to investigate and determine in order to use for the mango glace´ drying simulation.

MATERIALS AND METHODS

To determine equilibrium moisture content of mango glace´, the samples were cut into thin pieces (thickness about 2-3 mm) and placed on wire net hanging in five bottles which contained saturated salt solution of KNO_3, NaCl, $Mg(NO_3)_2.6H_2O$, $MgCl_2.6H_2O$ and LiCl. After that, placed the five bottles of samples in an oven. The experimental conditions were as follows: oven temperature of 45-70°C and testing time was approximately 14 days. Finally, took the samples out of bottles to determine equilibrium moisture content.

To determine diffusion coefficient of mango glace´, the samples were cut into dimension of $1\times1\times0.5$ cm^3 and placed in a dryer which drying temperature and air flow rate could be controlled. The experimental conditions were as follows: drying temperature of 45-70°C, drying air velocity of 0.6 m/s and moisture content after drying was approximately 15% dry basis.

To determine specific heat of mango glace´, the samples were cut into thin pieces (thickness about of 3 - 4 mm). Measured the specific heat by calorimeter at moisture content of 10-60% dry basis.

To determine density of mango glace´, the samples were cut into small rectangular pieces. Weighed the samples and measured the dimension by a vernier to calculate volume and density. The moisture content of mango glace´ in this experiment was in range of 10-50% dry basis.

To determine moisture content of mango glace´, the samples were placed in an oven at constant temperature of 103°C for 72 hours. The temperature was measured by K-type thermocouple, connected to a data logger with an accuracy of ± 1° C.

RESULTS AND DISCUSSION

The BET equation (Brunauer *et al.*, 1938) was employed for the regression analysis. It is written as follows:

$$RH/(1-RH)M_{eq} = 1/M_mC + [(C-1)/(M_mC)]RH \qquad (1)$$

Where RH = relative air humidity, fraction
M_{eq} = equilibrium moisture content of mango glace´, % dry basis

M_m and C were depended on drying air temperature (T) as follows:

M_m = 21.443 exp (-0.015175T)
C = 6738.6 exp (-0.13443T)

It was found that the BET equation could describe in accordance with experimental results, as shown in Figure 1. From the study on the effect of air temperature and relative humidity on equilibrium moisture content of mango glace´ as shown in Figure 2, it was found that if air temperature increased, equilibrium moisture content decreased at relative humidity from 10-60%. It was because when air temperature increased, vapour pressure of mango glace´ increased, causing equilibrium moisture content decrease. On the other hand, when relative humidity was higher than 60%, equilibrium moisture content increased. At higher range of relative humidity, the effect of sugar content was more significant. The vapour was absorbed more. Figure 3 shows the comparison among equilibrium moisture content of mango glace´ with sugar concentration of 60°Brix, papaya glace´(Achariyaviriya and Soponronnarit, 1990) and pineapple glace´ (Teanchai and Soporonnarit, 1991) with sugar concentration of 70°Brix. The BET equation was used to calculate equilibrium moisture contents of these fruit glace´. It was found that at air temperature of 45-70°C, equilibrium moisture isotherm lines of mango and papaya glace´ were nearly the same values, but those of mango and pineapple glace´ were different. It was because the internal structures of each kind of fruit were different.

From the experiment on the diffusion coefficient of mango glace´ at air temperature of 45-70°C, the regression equation technique was used to analyze experimental results. It was found that the relationship between diffusion coefficient and drying air temperature could be written as follows:

$$D = 5.2148\times10^{-10} \exp (0.079062T) \quad (2)$$

where D = diffusion coefficient of mango glace´, m^2/h
T = drying air temperature, °C

Figure 4 shows the comparison of diffusion coefficient of experimental and simulated results at various temperatures. It was found that the diffusion coefficient varied with air temperature. It was because when air temperature increased, the difference of internal and external vapour pressures also increased, causing moving rate of water from inside to the surface of mango glace´ increase.

Figure 5 shows the comparison of the diffusion coefficient of mango glace´ with sugar concentration of 60°Brix, papaya glace´ (Achariyaviriya and Soponronnarit, 1990) and pineapple glace´ (Teanchai and Soporonnarit, 1991) with sugar concentration of 70°Brix. It was found that the best moisture diffusion of the three fruit types at the same air temperature was pineapple, papaya, and mango glace´, respectively. It was because the internal structure of pineapple glace´ was more porous than those of mango and papaya glace´.

Figure 6 shows the mango glace´ densities at various moisture contents. It was found that density decreased linearly with increasing of moisture content. Using least square regression technique to determine the relationship between density and moisture content of mango glace´, the following equation was found.

$$\rho = 1419.8 - 3.8057M \quad (3)$$

where ρ = density of mango glace´, kg/m^3
M = moisture content of mango glace´, % dry basis

Figure 7 shows the comparison of the densities of mango glace´(sugar concentration of 60°Brix), papaya glace´(Achariyaviriya and Soponronnarit, 1990) and pineapple glace´ (Teanchai and Soporonnarit, 1991) at various moisture contents. The sugar concentration of the last two fruits was 70°Brix. It was found that when moisture content increased, density of mango glace´ decreased, but densities of papaya and pineapple glace´ increased. It was because the internal structure of mango glace´ had higher shrinkage than those of papaya and pineapple glace´.

Figure 8 shows the relationship between specific heat and moisture content of mango glace´.

It was found that specific heat increased linearly with moisture content. Least square regression technique was used to determine the relationship between specific heat and moisture content of mango glace´. The relation equation can be expressed as below:

$$C_S = 2.23 + 0.0205M \quad (4)$$

Where C_S = Specific heat of mango glace´, kJ/kg°C

M = Moisture content of mango glace´, % dry basis

Figure 9 shows the comparison of specific heat of mango glace´ (sugar concentration of 60° Brix) and pineapple glace´ (Teanchai and Soporonnarit, 1991) at various moisture contents. The sugar concentration of pineapple glace´ was 70°Brix. It was found that specific heats of these fruits varied linearly with moisture content. At moisture content ranging from 0-70% dry basis, specific heat of mango glace´ was higher than that of pineapple glace´.

CONCLUSION

From the experimental results and discussion, it can be concluded as follows:

1. The BET equation was found accurate to describe the experimental results of equilibrium moisture isotherm at air temperature of 45-70°C and relative humidity of 10-90%. From the experimental results, it was found that equilibrium moisture content of mango glace´ decreased with air temperature at relative humidity ranging from 10-60%. The comparison of equilibrium moisture contents of mango, papaya and pineapple glace´ showed that the equilibrium moisture isotherms of mango and papaya glace´ were nearly the same.

2. Mathematical equation developed to

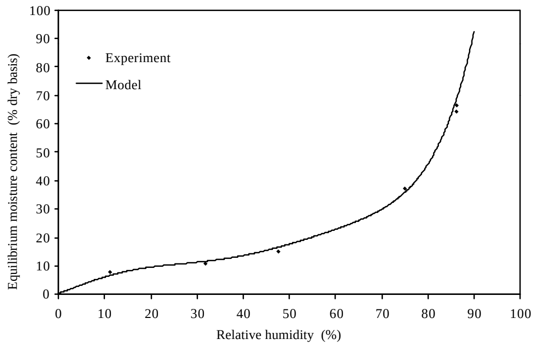

Figure 1 Comparison of predicted values of BET equation with the experimental data at air temperature of 45°C.

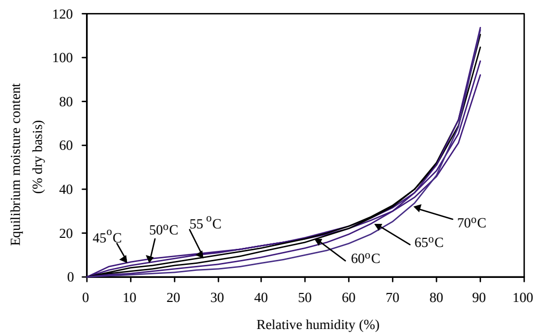

Figure 2 Relationship between equilibrium moisture content and relative humidity of BET equation at various temperatures.

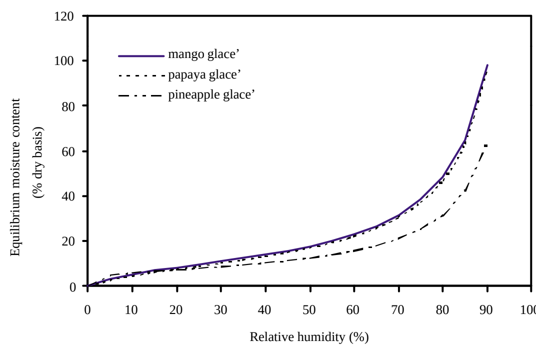

Figure 3 Comparison of equilibrium moisture content of fruit glace´ at air temperature of 50°C.

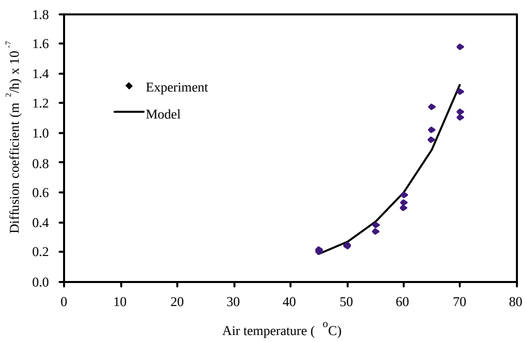

Figure 4 Relationship between diffusion coefficient and air temperature.

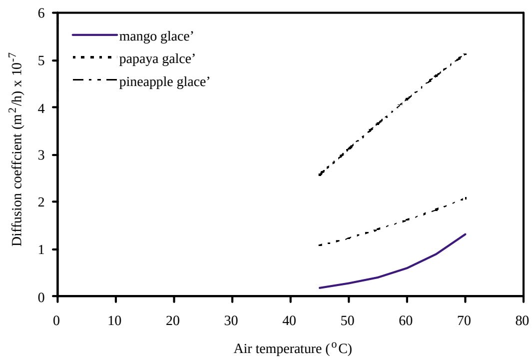

Figure 5 Comparison of diffusion coefficient of fruit glace´at various air temperatures.

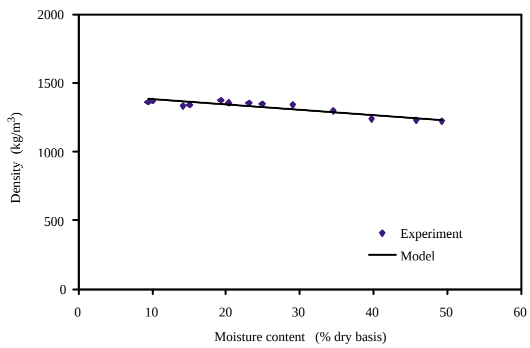

Figure 6 Relationship between density and moisture content of mango glace´.

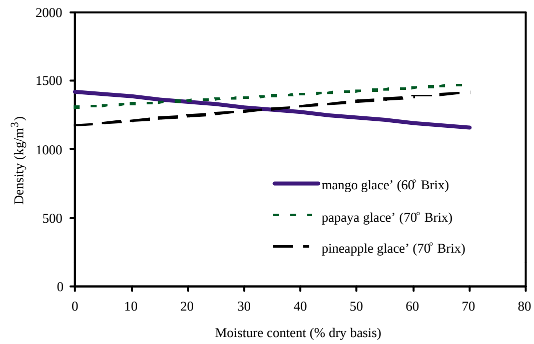

Figure 7 Comparison of density of fruit glace´at various moisture contents.

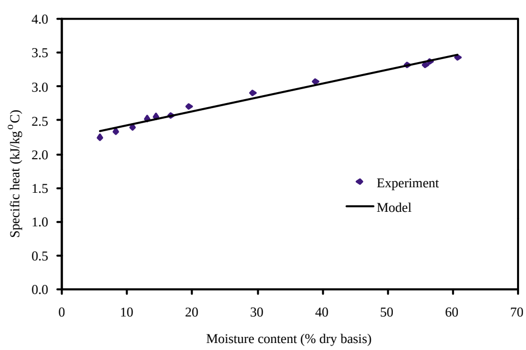

Figure 8 Relationship between specific heat and moisture content of mango glace´.

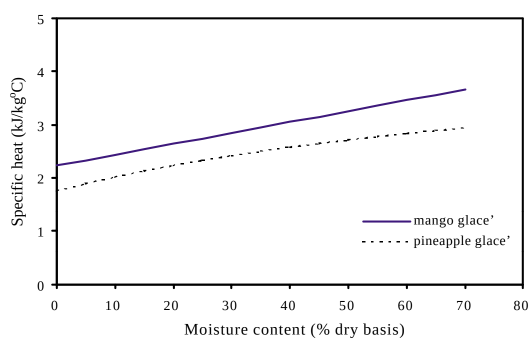

Figure 9 Comparison of specific heat of fruit glace´at various moisture contents.

predict the diffusion coefficient of mango glace´ was good prediction with air temperature ranging from 45-70°C. From the experimental results, it was found that diffusion coefficient increased exponentially with air temperature. The best moisture diffusion of the three fruit glace´ types was mango glace´, papaya glace´ and pineapple glace´, respectively.

3. Mathematical equation developed to predict the density of mango glace´ was good prediction at all of moisture content levels. From the experimental results, it was found that when moisture content increased, density of mango glace´decreased, but densities of papaya and pineapple glace´ increased.

4. Mathematical equation developed to predict the specific heat of mango glace´ was good prediction at all of moisture content levels. It was further found that at moisture content range of 0-70% dry basis, specific heat of mango glace´ is higher than that of pineapple glace´.

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LITERATURE CITED

Achariyaviriya, S. and S. Soponronnarit. 1990. Study of parameters for papaya glace´ drying analysis. Kasetsart J. (Nat. Sci.) 24 : 196-207. (In Thai)

Brunauer, S., P.H. Emmett, and E. Teller. 1938. Adsorption of gases in multi-molecular layers. J. of American Chem. Soc. 60 : 309-319.

Iglesias, H.A., J. Chirife, and J.L. Lombardi. 1975. Compression of water vapor sorption by sugar beet root components. Int. J. of Food Tech. 10 : 385.

Nuineem, M., S. Soponronnarit, and B. Bunnag. 1993. Optimum strategies for pineapple glace´. Kasetsart J. (Nat. Sci.) 27 : 79-90. (In Thai)

Teanchai, A. and S. Soponronnarit. 1991. Study of parameters for pineapple glace´ drying analysis. Kasetsart J. (Nat. Sci.) 25 : 206-218. (In Thai)

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