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APPENDICES

Appendix A

Figures of Dryer Machine

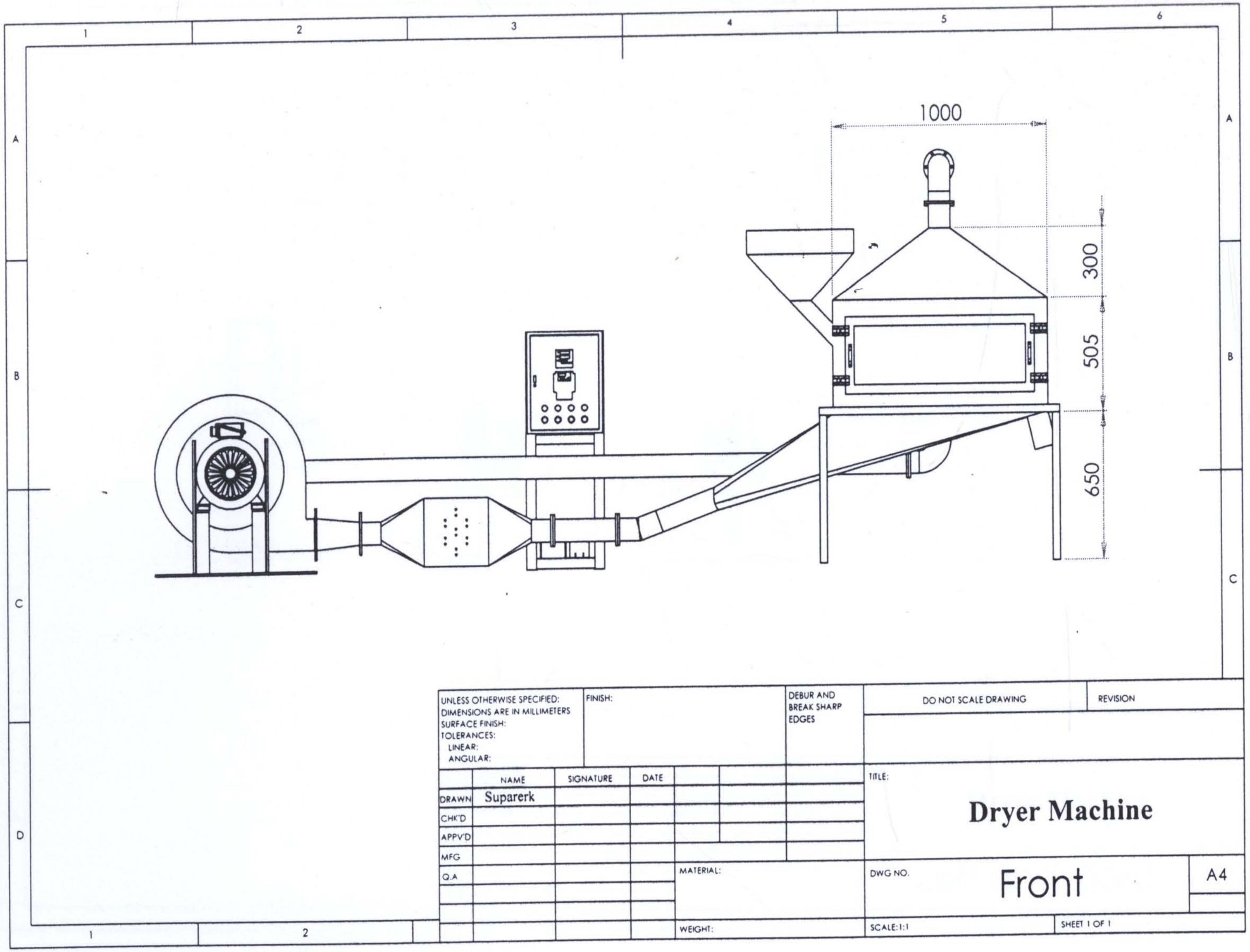

Figure A.1 Shows front side of dryer machine

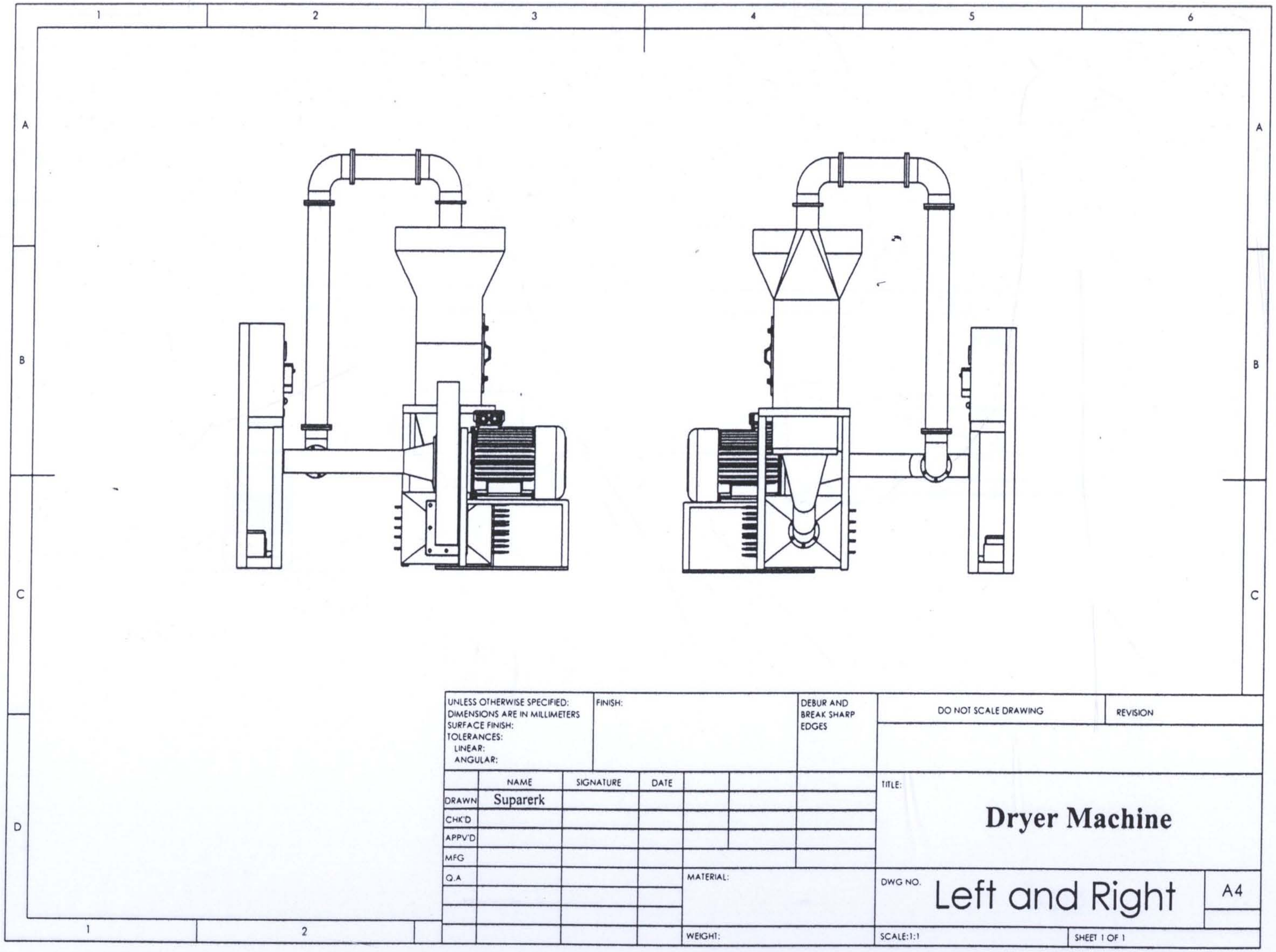

Figure A.2 Shows left and right side of dryer machine

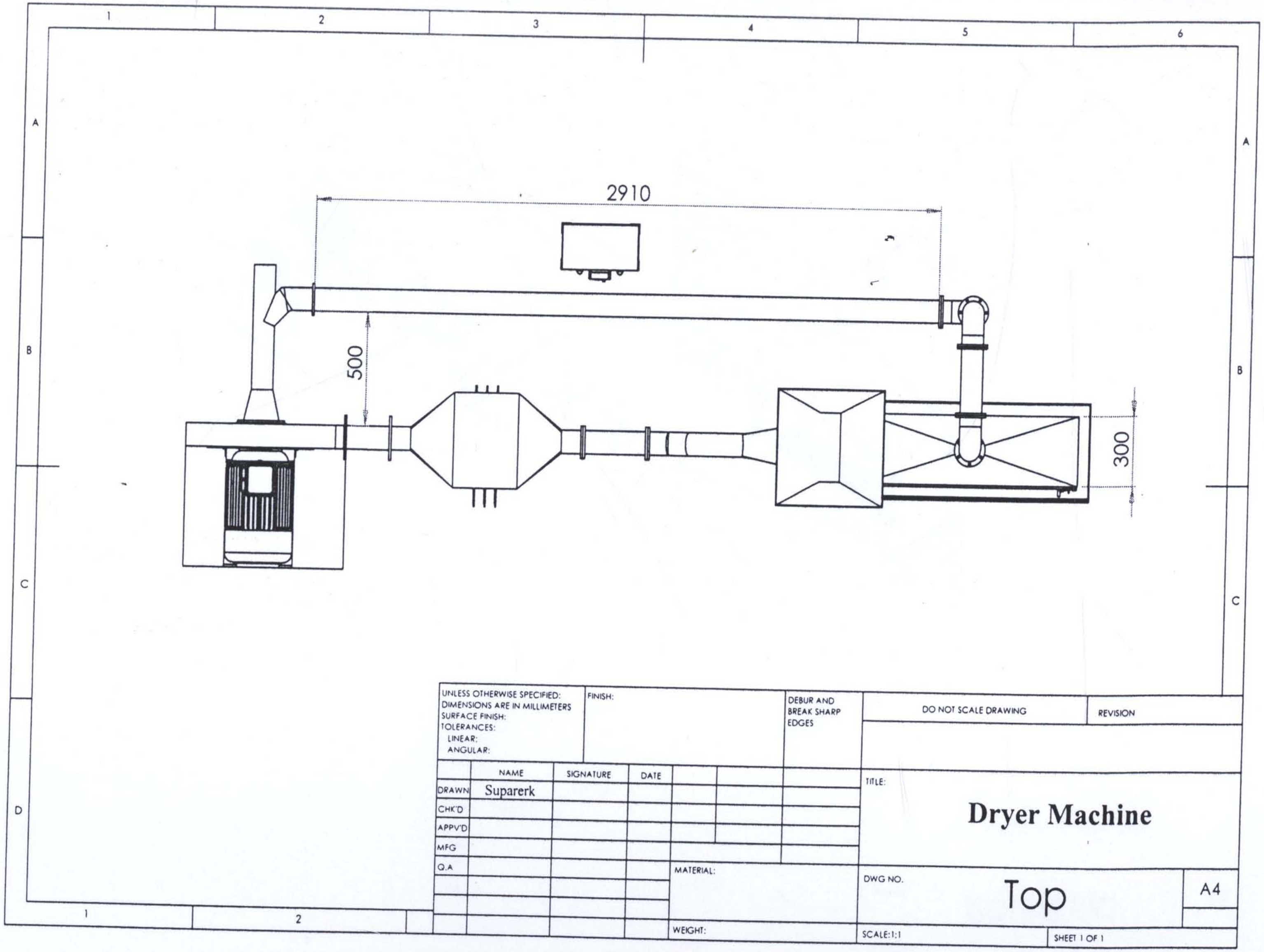

Figure A.3 Shows top side of dryer machine

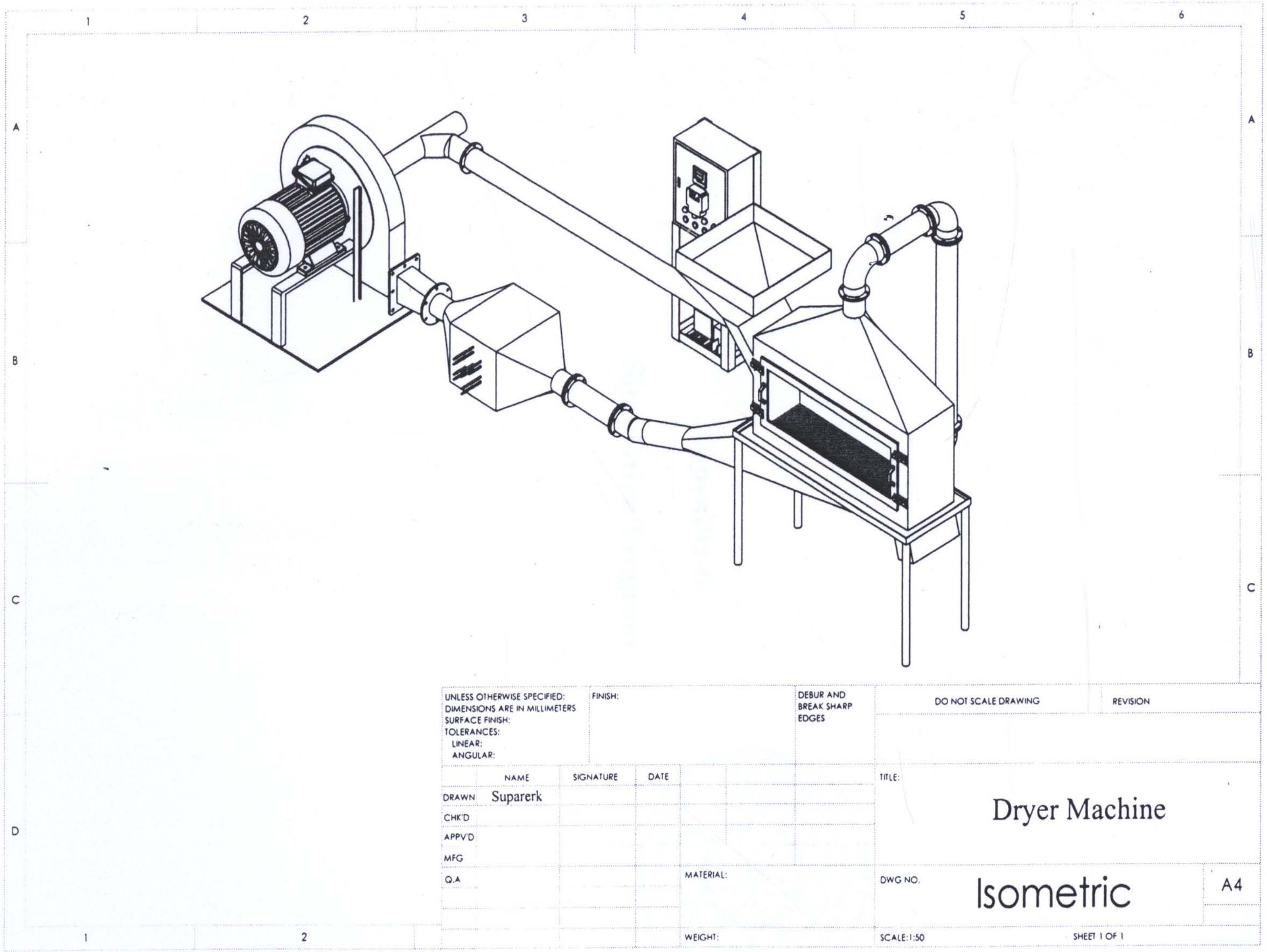

Figure A.4 Shows isometric of dryer machine

Appendix B

Simulation Program

```
function [output_Drying] = Mathmodel(input_Drying)
clc
clear all

fprintf(' ***Mathematical model of energy consumption  by New Model ***\n\n')

fprintf('Enter the weight of dry chili. (kg)\n')
HOLDUP = input(' ' )

fprintf('Enter temperature drying. 50,60,70,80,90,100.( C Degrees.)\n')
TMIX = input(' ')

fprintf('Enter hot air velocity 4, 5, 6(m/sec)\n')
v = input( ' ')
Wf1_data(100)=zeros;
error_data(100)=zeros;

format long
% number of  layer for chili
n = 3;
%Fraction of  recycle air, decimal
RC = 0.7;

%Moisture from the chili, %Wb
Min = 72.98 ;

%Moisture from the pepper. %Db
Min_d = 270.2;

% Density of dry air based heat transfer books Assoc. Sunan professor at the general
frequently Appendix Table .1  %%%

 p_(100)= zeros;
 p_(50)=1.0585;
 p_(60)=1.025;
 p_(70)=0.9965;
 p_(80)=0.968;
 p_(90)=0.942;
 p_(100)=0.916;
 pa = p_(TMIX);

 % Calculated mass flow rate negative air dry from the equation. %
 %  MIMIX = pa*A*v
 MMIX = pa*0.3*v;
```

```
%Calculated mass flow rate negative air dry each layer from the equation.
%MMIXX = MMIX/n
MMIXX = MMIX/n;

%Calculated saturated vapor pressure (PVS1) and moisture prior to drying machines
(WI).
%******Wet bulb temperature environment.*************
TWB  = 23;
T    = TWB + 273.15;
%******Dry bulb temperature environment.*************
TI   = 27;

PVS1 = exp(-7511.52/T+89.63121+0.02399897*T-0.000011654551*(T^2)-
0.000000012810336*(T^3)+2.0998405E-11*(T^4)-12.150799*log(T));

WWB  = (0.62189 * PVS1) / (101.325 - PVS1);

WI   = ((2501 - 2.411*TWB)*WWB - 1.006*(TI - TWB))/(2501+(1.775*TI) - (4.186
*TWB));


%Calculate the rate of heat loss to the drying room environment Q1 (kW). From eq.
%         Q1 = UA(T1-T2)
%         Q1 =          T1-T2
%                    -------------
%                         R
% Where         R = R1+R2+R3
%                 = (1/h1*A)+(x/k*A)+(1/h2*A)
%  Where Q1 The rate of heat loss to the environment, kW
%         A   is  Surface area of contact with the fluid material, m2
%         R   is  Resistance of heat, K/W
%         U   is  Heat transfer coefficients, W/m2.K
%             T2  is  Temperature of the external environment ,K
%             T1  is  Fluid temperature in the drying room. , K
%             k   is  Coefficient of conduction heat transfer, W/m. K
%             h   is  Coefficient of convection heat transfer, W/m2.K
%             x   is  Thickness of the material.  , m
  T1 = TMIX+273.15; % K
  T2 = TI+273.15;% K
  Q1 = ((T1-T2)/0.08356)/1000;  %kW
  %mean residence time (min)
 %Enter the rate of pepper drying machine can do that, F (kg / min)
 F_(50,4)=0.000617284;
 F_(50,5)=0.000641026;
 F_(50,6)=0.000740741;
 F_(60,4)=0.000952381;
 F_(60,5)=0.001190476;
```

```
F_(60,6)=0.001282051;
F_(70,4)=0.002380952;
F_(70,5)=0.003030303;
F_(70,6)=0.003333333;
F_(80,4)=0.003703704;
F_(80,5)=0.005555556;
F_(80,6)=0.005555556;
F_(90,4)=0.004444444;
F_(90,5)=0.006666667;
F_(90,6)=0.006451613;
F_(100,4)=0.005882353;
F_(100,5)=0.006060606;
F_(100,6)=0.0078125;
 F = F_(TMIX,v);
% Calculation time in drying.

tm = HOLDUP/F;

WF1_assume = 0.02;
Wf1 = 0.02;
Tf1 = 0 ;
sum = 0;
sum_plot = 0;
error = zeros;
fprintf('interation      Wf1            Wmix            Tf1            error\n\n')
tic
 for i = 1 : 200

                    sum  = sum +1;
    WF1_assume= Wf1 ;

            Wmix = (1-RC)*(WI)+(RC*WF1_assume);

            PV   = (1.608*101.35*Wmix)/(1+1.608*Wmix);

        Tt   = TMIX + 273.15;

        PVS  = exp(-7511.52/Tt+89.63121+0.02399897*Tt-0.000011654551*(Tt^2)-
0.000000012810336*(Tt^3)+2.0998405E-11*(Tt^4)-12.150799*log(Tt));

          % Relative humidity of air.
            RH   =(PV/PVS);
% At a constant moisture ratio.(MR)
a= (-47.095+15.209*v-1.165*v^2)+(2.077-0.0.597*v+0.039*v^2)*(TMIX)+
(-0.036+0.0095*v-0.0005*v^2)*(TMIX)^2+
(-0.0013+0.005*v+0.0000509*v^2)*(TMIX)^3+(-0.0000002959-
0.000000026*v+0.0000000156*v^2)*(TMIX)^4
```

```
b=(2.99132546701843-0.746229*v-0.11406*v^2+0.024169*v^3)+(-
0.142127+0.035141*v+0.005389813*v^2-0.001135872*v^3)*(TMIX)+(0.002174386-
0.0005326006*v-0.00008198511*v^2+0.00001717934*v^3)*(TMIX)^2+(-
0.00001052382+0.000002546052*v+0.0000003936461*v^2-
0.00000008197816*v^3)*(TMIX)^3;
k=(0.454352-0.20537*v-0.027942*v^2+0.006347248*v^3)+(-
0.032257+0.011679*v+0.001646336*v^2-
0.0003675399*v^3)*(TMIX)+(0.0006599558-0.0002093156*v-
0.00003027004*v^2+0.000006655843*v^3)*(TMIX^)2+(-
0.000003922427+0.000001167118*v+0.0000001712001*v^2-
0.00000003723841*v^3)*(TMIX)^3 ;

      for i = 1:n

                    t=(tm/10)/HOLDUP;

                    MR(i) = a*exp(-(k*t/i)/(1+b*t/i));%After drying moisture
ratio, decimal.
                    Mt(i) = (MR(i))*(Min-2.3)+2.3;%Moisture after drying each
layer (last layer to the first layer),% wb
        hpi(i)= ((-Min_d /((Mt(i)/100)-1))*HOLDUP); %Weight of pepper each
layer after drying, g.
        tmi(i)= tm/i;  %Chilli time in drying rooms each layer.

fprintf('%d          %d     %d      %d       %d\n',sum,Wf1,Wmix,Tf1,error)

      end

fprintf('mean residence time  = %6.2f Minutes.\n',tm)

        Wf1_data(sum) = Wf1;
        error_data(sum)=error;

            % Calculate the ratio of dry air mass and dry mass of pepper.
                              % From Eq.
                              %          hpi [kg]
                              % R   = ---------------
                              %         MMIXX*t  [kg/s][s]
                 R = (HOLDUP/n)/(MMIXX*tmi(n)*60);

   % Calculation of air humidity ratio for each layer, decimal

       WF1 = R*(Min-Mt(3))+Wmix;
           WF2 = R*(Mt(3)-Mt(2))+Wmix;
       WF3 = R*(Mt(2)-Mt(1))+Wmix;

       Wf1 = (WF1+WF2+WF3)/3;
```

```
        %Average outlet temperature at drying chamber, Tfl ,( C)
        Tmix = TMIX+273.15;

    % Latent heat of vaporization of water
        h_fg = 2502 ; % kJ/kg

    % Specific heat of water vapor
        Cv  = 1.88;  % kJ/kg.K

    % Specific heat  of chili
        C_pw = 252.7;  % kJ/kg.K

    %Specific heat of  dry air.
    Ca  =1.006;  % kJ/kg.K

        TF1 = (((-Q1/MMIXX)+(Ca*Tmix)+(Wmix*(h_fg+Cv*Tmix))-
(WF1*h_fg)+(R*C_pw*Tmix))/(Ca+(WF1*Cv)+(R*C_pw)))-273.15;
        TF2 = (((-Q1/MMIXX)+(Ca*Tmix)+(Wmix*(h_fg+Cv*Tmix))-
(WF2*h_fg)+(R*C_pw*Tmix))/(Ca+(WF2*Cv)+(R*C_pw)))-273.15;
        TF3 = (((-Q1/MMIXX)+(Ca*Tmix)+(Wmix*(h_fg+Cv*Tmix))-
(WF3*h_fg)+(R*C_pw*Tmix))/(Ca+(WF3*Cv)+(R*C_pw)))-273.15;

        Tfl = (TF1+TF2+TF3)/3;

    % Comparative values of random error values. WF1_assume
        error = abs(WF1_assume- Wf1);
% Calculate heat loss  at recycle air pipe.
    % The heat loss  at  recycle air pipe. Q2 (kW)
    %Pipe from the chamber and length. l = 4 m.
    %Outside diameter. d_o = 0.1016 m.
    %Inside diameter.  d_i  = 0.1004 m.
    %
    %Rate of heat transfer values.            Tfl - TI
    %              q =  ---------------------------------------- (W)
    %                     1           ln(ro/ri)          1
    %              --------------- + ------------- + ---------------
    %               hc,i*2*pi*ri*l      2*pi*k*l     hc,o*2*pi*ro*l
    % Where
    %    hc,i  is Coefficient of convection heat transfer force. hc,i = 200 W/m2.K   Heat
transfer from the reference book,  Assoć. Sunan professor at the general  often from
Table 1.2 page 16.
    %    hc,o is Coefficient of convection heat transfer.  hc,o = 25 W/m2.K   Heat
transfer from the reference book,  Assoc. Sunan professor at the general  often from
Table 1.2 page 16.
```

```
 %     k  is Coefficient of conduction heat transfer of stanless steel pipe.   k  = 14.4
W/m.K,  Heat transfer from the reference books Assoc. Sunan professor at the
General  often from Table 2.
 %
    Q2 =((Tf1 -
TI)/((1/(200*2*pi*0.0502*4))+(log(0.0508/0.0502)/(2*pi*14.4*4))+(1/(25*2*pi*0.05
08*4))))/1000;


  if RC == 0

           Tf2 = TI;
           else

           Tf2 =((-Q2/(RC*MMIX) + Ca*(Tf1+273.15) + Wf1*Cv*(Tf1+273.15))/(Ca
+ Wf1*Cv))-273.15;
  end

% Presesure drop drying system(kPa)
dp_(100,6)=zeros;
dp_(50,4) = 0.47;
dp_(60,4) = 0.46;
dp_(70,4) = 0.45;
dp_(80,4) = 0.43;
dp_(90,4) = 0.39;
dp_(100,4)= 0.38;
dp_(50,5) = 0.84;
dp_(60,5) = 0.72;
dp_(70,5) = 0.65;
dp_(80,5) = 0.63;
dp_(90,5) = 0.58;
dp_(100,5)= 0.58;
dp_(50,6) = 1.03;
dp_(60,6) = 1.01;
dp_(70,6) = 0.98;
dp_(80,6) = 0.96;
dp_(90,6) = 0.92;
dp_(100,6)= 0.91;
dp = dp_(TMIX,v);

 %Equations for the mixed air temperature and air flow to the environment before
 entering the blower.
 TX =((1.006+1.88*WI)*(1-RC)*MMIX*TI+2502*WI*(1-
 RC)*MMIX+(1.006+1.88*Wf1)*(RC*MMIX)*Tf2+2502*Wf1*RC*MMIX-
 2502*MMIX*Wmix)/((1.006+1.88*Wmix)*MMIX);

       %Calculated temperature from the blower., TB  (C)
```

```
    %Motor performance. = 85%
          TB = ((TX+273.15)+dp/((pa*0.85)*(Ca+Cv*Wmix)))-273.15;


  %*** Rate of power consumption thermal heater. QH (kWh) **********
    %QH    = Qloss + MMIX*(Ca+(Cv*WMIX))*(TMIX-TB);
    %Insulating sheet are not well thought of  losing heat. Qloss = 0 , Air density
values of  0.2934 (kg/m^3 )  To heat the Lockheed Martin Potter. 1200 K Heat transfer
from the reference books Assoc. Sunant  professor at the general  often from
Appendix.
     QH    = 0.2934*0.1243*v*(1.006+1.88*Wmix)*(TMIX-TB)*(tm/60);


   %****Calculate the power consumption of fan Ws (kWh)

     Ws    =  dp*MMIX/(pa*0.85)*(tm/60);

   %****Energy Consumption (kWh)******************

     E     =  QH+Ws;

         %  Cheak error abs[WF1_assume-WF1_mean] < 1e-6
   if error < 0.000001
      fprintf('----------------------------------------------------------------------------------
-\n')
      fprintf('Moisture after drying.    Tf1      Tf2      Tb      Qh      Ws       Energy
consumption\n')
      fprintf('      %6.2f Wb       %6.2f C %6.2f C  %6.2f C  %6.2f kWh %6.2f kWh
%6.2f kWh\n\n', Mt(1),Tf1,Tf2,TB,QH,Ws,E)


       break
   end
 end
 toc
hold on
title('Graph TRIAL ERROR (New Model 2)')
ylabel('ERROR DATA')
xlabel('Wf1 assume DATA')
plot(Wf1_data,error_data,'m')
grid on
```

Appendix C

Diffusion coefficients and Activate Energy

The calculation of diffusion efficient and activate energy

In this work, assumption was that water moves out in the direction of radial and chili was an isotropic solid and was in a form of short cylindrical shape. The moisture was transfer by liquid diffusion and the shrinkage was negligible during the drying. The diffusion efficient depend on the quantity of moisture and the reduce of volume was negligible, thus the equation of diffusion moisture from Fick's second law can be written by:

$$\frac{\partial M}{\partial t} = D\nabla^2 M \qquad (C.1)$$

The above equation was developed by Crank(1975) for many shape of materials such as cylindrical and spherical. Drying food products such as paddy and grain were predicted by Fick's second law, which the moisture diffusion depended on Arrhenius-type temperature for cylindrical materials. The diffusion coefficient of moisture at any temperature of drying can be determined from Eqns. (C.4) and can be written in linear equation in equation (C.5). The change of moisture ratio of chili can be showed as:

$$MR = \frac{4}{\beta^2}\exp\left(\frac{-\beta_1^2 D_{eff}}{r_c^2}t\right) \qquad (C.2)$$

$$\ln MR = \ln(\frac{4}{\beta_1^2}) - (\frac{\beta_1^2 D_{eff}}{r_c^2})t \qquad (C.3)$$

where: MR = Moisture ratio, decimal

D_{eff} = diffusion coefficient of moisture(m^2/s)

r_c = cylindrical radial of chili(0.0163 m, from experiments)

β = root zero order of Bessel function(2.4048, Heat and mass transfer, Kurt C. Rolle, 2000)

t = drying time, s

The diffusion coefficient of moisture can be determined by the slope of Eqns.C.2 which showed following equation.

$$K_0 = \frac{\beta_1^2 D_{eff}}{r_c^2} \qquad (C.4)$$

The diffusion coefficient of chili depended on the temperature of drying more than the humidity of air. So, Arrhenius(2000) developed the equation for calculate the diffusion coefficient as:

$$D_{eff} = D_0 \exp\left(\frac{E_a}{RT}\right) \tag{C.5}$$

where D_0 = initial constant of diffusion coefficient,(m^2/s)

E_a = activate energy of diffusion,(MJ .kg/mol)

R = gas constant(8.314×10^{-3} MJ.kg/mol.K)

T = relative temperature(K)

And from Eqns.C.4 can be revised that showed in this following equation.

$$\ln D_{eff} = \ln D_0 - \left(\frac{E_a}{R}\right)\left(\frac{1}{T}\right) \tag{C.6}$$

D_0 and E_a can be determined from the relation between $\ln D_0$ and $\left(\frac{1}{T}\right)$ that showed in linear equation and $\left(\frac{E_a}{R}\right)$ was the slope of graph.

Results of The diffusion coefficient and activate energy

The moisture diffusion coefficient at any temperature of chili drying were determined by the equation of Crank(1975) for shape of material as cylindrical. And the actual values were analyzed to compare values as follows.

Table C.1 The moisture diffusion coefficient at the temperature range 50 °C to 100 °C and velocity of hot air from 4 to 6 m/s.

Temperature (°C)	Effective Moisture Diffusivity , D_{eff} (m^2/s)		
	4 m/s	5 m/s	6 m/s
50	1.3118E-9	1.3330E-9	8.4181E-10
60	1.943E-9	2.4238E-9	1.1744E-9
70	4.2452E-9	4.5942E-9	5.4214E-9
80	7.3098E-9	9.3955E-9	6.3930E-9
90	1.0243E-8	1.3280E-8	7.6073E-9
100	1.3782E-8	1.5197E-8	1.074E-8

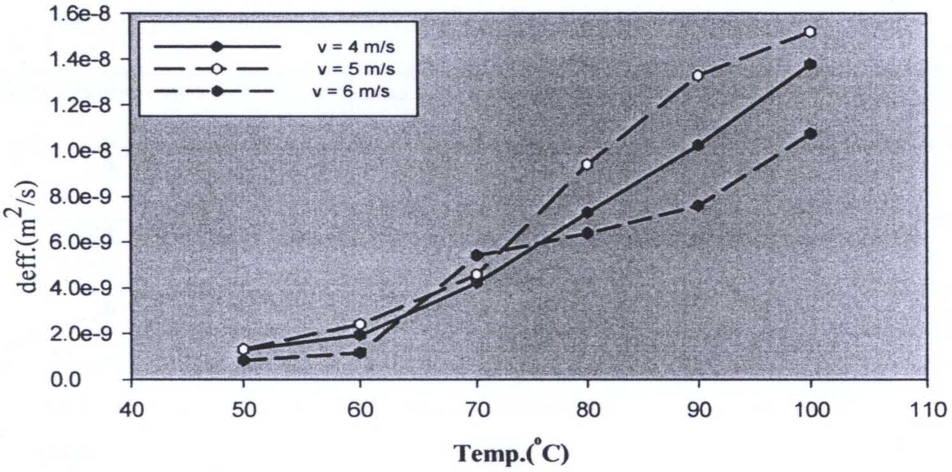

Figure C.1 The effective moisture diffusivity on drying temperature of 50, 60, 70, 80, 90 and 100°C and drying air velocity of 4, 5 and 6 m/s

Diffusion coefficient and activation energy: Chili's diffusion coefficient(Table C.1 and Figure C.1) would be changed by the temperature and drying air velocity of the drying process which stayed in a range of 1.3118E-09-1.3782E-08 m^2/s, 1.3330E-09-1.5197E-08 m^2/s and 8.4181E-010-1.0740E-08 m^2/s.

The effective moisture diffusivity of 50, 60, 70, 80, 90 and 100°C and drying air velocity of 4-6 m/s can be written as following equations:

Deff = 0.34749exp(-6237.24985/Tabs) (C.7)

Deff abs D = 0.14262exp(-5981.47279/T) (C.8)

Deff = 0.424045exp(-6439.97646/Tabs) (C.9)

Table C.2: Equations for moisture diffusion coefficients of Arrhenius(2000).

Fick's equation			R^2	**Adj. R^2**	**SSE**
v (m/s)	4	$D_{eff} = 0.14262\exp(-5981.47279 / T_{abs})$	0.9833	0.9791	0.0732
	5	$D_{eff} = 0.34749\exp(-6237.24985 / T_{abs})$	0.9733	0.9667	0.1283
	6	$D_{eff} = 0.424045\exp(-6439.97646 / T_{abs})$	0.8898	0.8623	0.6180

Table C.3: The activation energy at the temperature range 50 °C to 100 °C and velocity of hot air from 4 to 6 m/s.

Air velocity (m/s)	Activation energy, E_a(MJkg/mol)
4	49.72996484
5	51.85649527
6	53.54196435

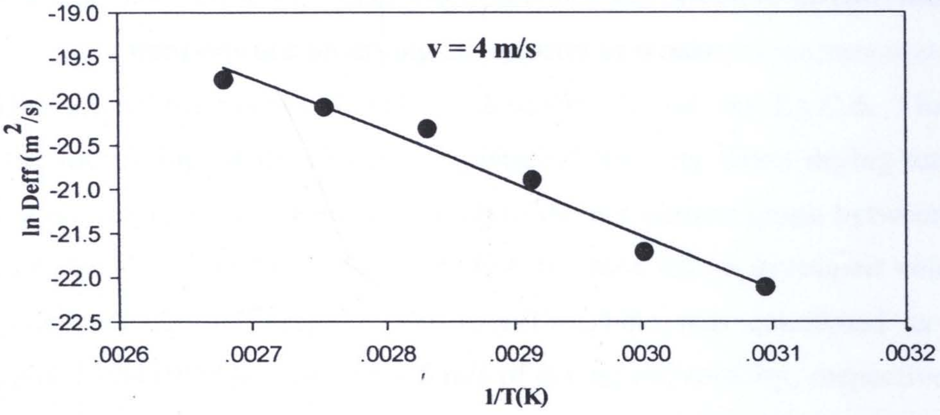

Figure C.2 The Arrhenius relationship between the effective diffusivities and temperature on drying air velocity of 4 m/s

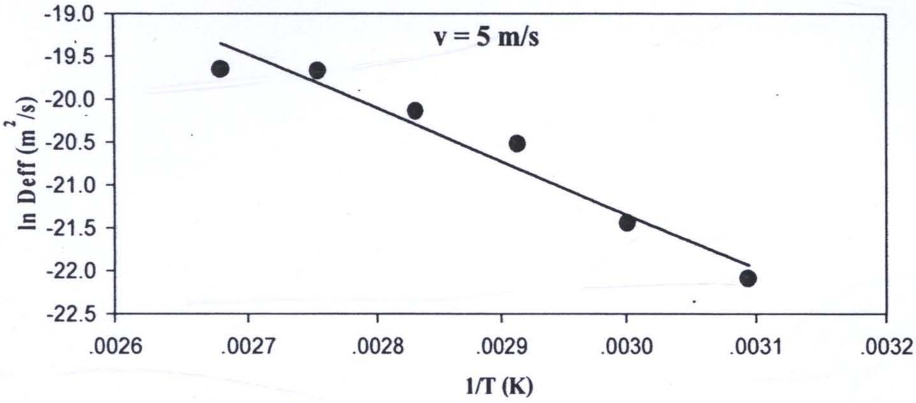

Figure C.3 The Arrhenius relationship between the effective diffusivities and temperature on drying air velocity of 5 m/s

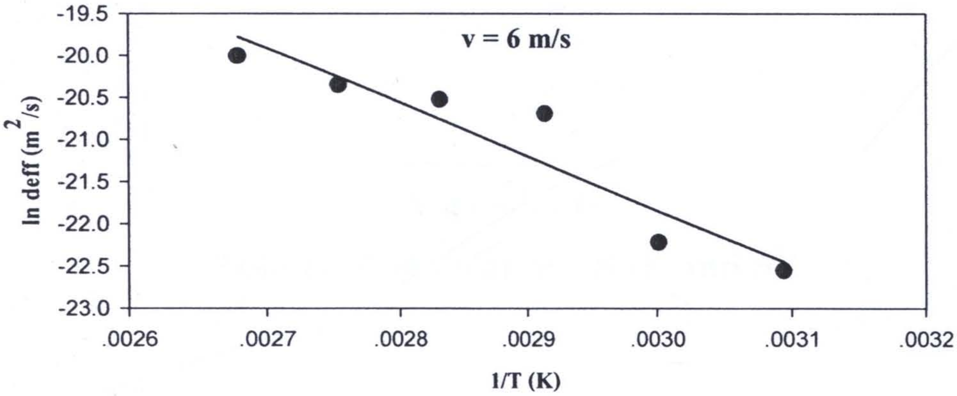

Figure C.4 The Arrhenius relationship between the effective diffusivities and temperature on drying air velocity of 6 m/s

The activation energy could be described based on Eq.C.6. The Fig.C.1 showed the increasing of the effective moisture diffusivity when drying temperature and drying air velocity increased. The result of the correlation graph between (lnDeff) and (1/Tabs) as shown in Fig.C.2,C.3 and C.4, the time (h) on drying air velocity of 5 m/s obtained activation energy of diffusion(Ea). This.was calculated as 49.7299, 51.8564 and 53.5419 MJkg/mol on 4-6 m/s of drying air velocity, respectively. Thus, the air velocity affected the change of chili's activation energy. Therefore, this study can be concluded that the increase of drying air temperature and drying air velocity affected on the increase of the effective moisture diffusivity

Appendix D

Results of R^2, Adj. R^2, SSE and SE

Table D.1 shows the empirical constant, R^2 , Adj. R^2 and SSE of the six model at drying air velocity of 4 m/s

Model	**Temp. (°C)**	**Model constant**	**R^2 (Model)**	**Adj. R^2 (Model)**	**SSE (Model)**
Henderson $MR = ae^{-kt}$	50	$a = 1.185$ and $k = 0.011$	0.914	0.913	1.394
	60	$a = 1.150$ and $k = 0.023$	0.963	0.962	0.405
	70	$a = 1.151$ and $k = 0.046$	0.955	0.953	0.214
	80	$a = 1.152$ and $k = 0.065$	0.918	0.912	0.221
	90	$a = 1.146$ and $k = 0.091$	0.932	0.926	0.162
	100	$a = 1.146$ and $k = 0.130$	0.942	0.935	0.125
Logalithmic $MR = ae^{(-kt)} + n$	50	$a = 114.71, k = 0.00006$ and $n = -113.648$	0.986	0.986	0.227
	60	$a = 1.235, k = 0.0180$ and $n = -0.144$	0.952	0.952	0.512
	70	$a = 1.516, k = 0.025$ and $n = -0.428$	0.976	0.976	0.115
	80	$a = 108.246, k = 0.000$ and $n = -107.189$	0.990	0.990	0.028
	90	$a = 3.737, k = 0.015$ and $n = 2.680$	0.985	0.984	0.037
	100	$a = 1.658, k = 0.060$ and $n = -0.579$	0.975	0.973	0.054
Lewis $MR = e^{-kt}$	50	$k = 0.090$	0.867	0.866	2.158
	60	$k = 0.020$	0.938	0.937	0.670
	70	$k = 0.040$	0.926	0.924	0.352
	80	$k = 0.055$	0.882	0.878	0.319
	90	$k = 0.078$	0.902	0.898	0.234
	100	$k = 0.113$	0.916	0.911	0.180
Wang and Singh $MR = 1 + at + bt^2$	50	$a = -0.005$ and $b = -0.00001$	0.982	0.982	0.290
	60	$a = -0.016$ and $b = -0.000067$	0.970	0.970	0.323
	70	$a = -0.029$ and $b = 0.000$	0.970	0.969	0.142
	80	$a = -0.029$ and $b = 0.000$	0.989	0.987	0.031
	90	$a = -0.048$ and $b = 0.000061$	0.983	0.982	0.041
	100	$a = -0.079$ and $b = 0.001$	0.970	0.968	0.063

Table D.1 Shows the empirical constant, R^2 , Adj. R^2 and SSE of the six model at drying air velocity of 4 m/s(Cont.)

Model	Temp. (°C)	Model and constant	R^2 (Model)	Adj. R^2 (Model)	SSE (Model)
Two-term $MR = a\exp(-kt) + b\exp(-ct)$	50	$a = 29.249, k = 0.000,$ $b = -28.188$ and $c = 0.000$	0.986	0.986	0.224
	60	$a = 51.113, k = 0.011,$ $b = -50.007$ and $c = 0.011$	0.972	0.971	0.299
	70	$a = 79.19500, k = 0.093,$ $b = -75.241$ and $c = 0.094$	0.993	0.992	0.034
	80	$a = 11.245, k = -0.002,$ $b = -10.204$ and $c = -0.005$	0.991	0.990	0.026
	90	$a = 14.508, k = 0.001,$ $b = -13.454$ and $c = 0.007$	0.987	0.984	0.031
	100	$a = 21.604, k = 0.036,$ $b = -20.524$ and $c = 0.033$	0.976	0.970	0.052
Aghabashlo et al., $MR = e^{\left(-\frac{k_1 t}{1+k_2 t}\right)}$	50	$k_1 = 0.004$ and $k_2 = -0.005$	0.992	0.992	0.127
	60	$k_1 = 0.014$ and $k_2 = -0.006$	0.973	0.973	0.289
	70	$k_1 = 0.024$ and $k_2 = -0.014$	0.980	0.980	0.096
	80	$k_1 = 0.026$ and $k_2 = -0.030$	0.996	0.996	0.012
	90	$k_1 = 0.039$ and $k_2 = -0.036$	0.993	0.993	0.016
	100	$k_1 = 0.057$ and $k_2 = -0.05$	0.987	0.986	0.027

Table D.2 Shows the empirical constant, R^2 , Adj. R^2 and SSE of the six model at drying air velocity of 6 m/s

Model	Temp. (°C)	Model constant	R^2 (Model)	Adj. R^2 (Model)	SSE (Model)
Henderson $MR = ae^{-kt}$	50	$a = 1.034$ and $k = 0.009$	0.927	0.926	0.495
	60	$a = 1.077$ and $k = 0.016$	0.954	0.953	0.207
	70	$a = 1.120$ and $k = 0.053$	0.930	0.925	0.177
	80	$a = 1.098$ and $k = 0.067$	0.934	0.927	0.088
	90	$a = 1.076$ and $k = 0.081$	0.944	0.937	0.062
	100	$a = 1.057$ and $k = 0.119$	0.979	0.976	0.021
Logalithmic $MR = ae^{(-kt)} + n$	50	$a = 297.925$, $k = 0.00002$ and $n = -296.942$	0.981	0.981	0.128
	60	$a = 184.390$, $k = 0.00006$ and $n = -183.377$	0.997	0.997	0.015
	70	$a = 63.083$, $k = 0.001$ and $n = -62.049$	0.983	0.982	0.043
	80	$a = 167.059$, $k = 0.000$ and $n = -166.016$	0.990	0.989	0.014
	90	$a = 128.772$, $k = 0.000$ and $n = -127.754$	0.992	0.991	0.009
	100	$a = 1.962$, $k = 0.044$ and $n = -0.953$	0.996	0.996	0.004
Lewis $MR = e^{-kt}$	50	$k = 0.008$	0.923	0.922	0.521
	60	$k = 0.015$	0.937	0.936	0.283
	70	$k = 0.046$	0.903	0.900	0.246
	80	$k = 0.058$	0.908	0.903	0.122
	90	$k = 0.073$	0.928	0.924	0.080
	100	$k = 0.111$	0.971	0.969	0.029
Wang and Singh $MR = 1 + at + bt^2$	50	$a = -0.05$ and $b = -0.000005$	0.984	0.984	0.110
	60	$a = -0.009$ and $b = -0.000018$	0.999	0.999	0.007
	70	$a = -0.027$ and $b = 0.000$	0.982	0.981	0.046
	80	$a = -0.031$ and $b = 0.000$	0.995	0.995	0.007
	90	$a = -0.044$ and $b = 0.000$	0.994	0.994	0.006
	100	$a = -0.083$ and $b = 0.001$	0.996	0.996	0.004

Table D.2 Shows the empirical constant, R^2 , Adj. R^2 and SSE of the six model at drying air velocity of 6 m/s(Cont.)

Model	Temp. (°C)	Model and constant	R^2 (Model)	Adj. R^2 (Model)	SSE (Model)
Two-term	50	$a = 67.049, k = 0.019,$ $b = -66.146$ and $c = 0.019$	0.969	0.968	0.211
	60	$a = 145.261, k = 0.035,$ $b = -144.318$ and $c = 0.035$	0.991	0.991	0.038
$MR = a\exp(-kt)$ $+b\exp(-ct)$	70	$a = 12.386, k = 0.001,$ $b = -11.356$ and $c = -0.002$	0.983	0.981	0.043
	80	$a = 7.292, k = -0.009,$ $b = -6.282$ and $c = -0.016$	0.995	0.994	0.007
	90	$a = 5.724, k = -0.005,$ $b = 4.728$ and $c = -0.015$	0.994	0.992	0.006
	100	$a = 4.256, k = 0.033,$ $b = -3.248$ and $c = 0.016$	0.996	0.994	0.004
Aghabashlo et al.,	50	$k_1 = 0.010$ and $k_2 = 0.000$	0.981	0.981	0.129
	60	$k_1 = 0.009$ and $k_2 = -0.008$	0.998	0.998	0.008
	70	$k_1 = 0.025$ and $k_2 = -0.023$	0.988	0.988	0.031
$MR = e^{(-\frac{k_1 t}{1+k_2 t})}$	80	$k_1 = 0.031$ and $k_2 = -0.025$	0.996	0.996	0.006
	90	$k_1 = 0.042$ and $k_2 = -0.039$	0.995	0.995	0.006
	100	$k_1 = 0.079$ and $k_2 = -0.034$	0.996	0.996	0.004

Table D.3 The results of standard error of Aghabaslo model with Logarithmic model using non-linear regression analysis
MR = a*exp^(-k*t)+exp^((-b*t)/(1+d*t))+c

Velocity	Parameters	Parameters Estimate						Standard Error(SE)					
		Temparature(°C)						Temparature(°C)					
		50	60	70	80	90	100	50	60	70	80	90	100
4 m/s	a	-0.100	6.708	-10.082	0.001	0.076	-0.019	0.004	2131.767	2787.572	0.005	0.019	7.821
	k	0.038	0.000	0.000	-0.172	0.404	0.015	0.003	0.024	0.052	0.216	0.223	7.160
	b	0.005	0.014	0.025	0.024	0.045	0.063	0.000	0.000	0.001	0.001	0.002	0.010
	d	-0.006	-6.648	-0.021	-0.034	-0.040	-0.056	0.000	2131.770	0.001	0.001	0.002	0.003
	c	0.088	-0.009	10.121	0.006	0.068	0.071	0.002	0.000	2787.578	0.007	0.011	7.829
5 m/s	a	153.760	144.688	21.438	0.030	-0.003	-0.063	84204.757	84700.764	35062.872	0.039	1563.054	0.001
	k	0.000	0.000	0.000	-0.064	-0.001	0.846	0.002	0.005	0.103	0.047	510.990	0.034
	b	0.004	0.010	0.021	0.024	0.046	0.084	0.000	0.000	0.001	0.001	0.010	0.000
	d	-0.006	-0.012	-0.027	-0.046	-0.056	-0.055	0.000	0.000	0.000	0.000	0.003	0.000
	c	-153.744	-144.685	-21.424	-0.028	0.058	0.063	84204.757	84700.747	35062.875	0.041	1563.063	0.001
6 m/s	a	-67.098	-0.107	39.434	33.887	-39.631	3.640	8010.003	52.908	7756.578	36124.846	51248.973	20111.576
	k	0.000	-0.011	0.000	0.000	0.000	0.002	0.006	3.006	0.034	0.245	0.437	13.372
	b	0.001	0.007	-39.448	0.036	0.045	0.075	0.001	0.269	7756.582	0.011	0.018	1.286
	d	-0.005	-0.006	-0.032	-0.041	-0.048	-0.022	0.001	0.001	0.000	0.006	0.009	0.212
	c	67.039	0.096	0.024	33.888	39.611	-3.634	8010.005	52.907	0.002	36124.854	51248.983	20111.584

Table D.4 The results of standard error of Aghabaslo model with Lewis model using non-linear regression analysis
MR = a*exp^(-k*t)+exp^((-b*t)/(1+d*t))+c

Velocity	Parameters	Parameters Estimate						Standard Error(SE)					
		Temparature(°C)						Temparature(°C)					
		50	60	70	80	90	100	50	60	70	80	90	100
4 m/s	k	0.011	0.022	0.259	5.074	5.488	0.125	0.002	0.004	0.244	31.902	53.468	0.187
	b	7.349	7.332	-0.115	0.026	0.039	3.163	13.115	15.483	0.092	0.007	0.014	13.414
	d	2.788	2.143	-0.500	-0.030	-0.036	0.796	5.347	5.362	0.383	0.006	0.011	7.740
5 m/s	k	0.011	0.023	5.503	0.077	0.108	0.143	0.002	0.006	42.458	0.123	0.190	0.238
	b	7.903	13.536	0.020	5.937	3.102	3.146	17.797	70.468	0.004	44.740	14.040	15.408
	d	3.018	4.632	-0.025	2.143	0.882	0.737	7.374	26.372	0.004	22.917	8.519	8.877
6 m/s	k	0.008	0.015	19.054	0.077	0.091	0.124	0.000	0.001	4.15(E+06)	0.145	0.222	0.393
	b	0.372	0.269	0.024	9.67(E+05)	3.16(E+05)	11.250	0.124	0.110	0.006	7.864(E+11)	9.201(E+10)	326.508
	d	-0.008	-0.013	-0.023	4.11(E+05)	1.22(E+05)	3.282	0.073	0.067	0.006	3.334(E+11)	3.540(E+10)	128.459

Table D.5 The results of standard error of Aghabaslo model with Henderson model using non-linear regression analysis
MR = a*exp((-k*t)/(1+b*t))

Velocity	Parameters	Parameters Estimate						Standard Error(SE)					
		Temparature(°C)						Temparature(°C)					
		50	60	70	80	90	100	50	60	70	80	90	100
4 m/s	a	1.038	1.076	1.062	1.022	1.030	1.040	0.005	0.016	0.018	0.010	0.015	0.025
	k	0.005	0.016	0.028	0.027	0.043	0.065	0.000	0.001	0.002	0.001	0.002	0.006
	b	-0.005	-0.005	-0.012	-0.029	-0.035	-0.045	0.000	0.000	0.001	0.001	0.002	0.004
5 m/s	a	1.033	1.031	1.028	1.016	1.027	1.036	0.004	0.008	0.009	0.011	1.036	0.017
	k	0.005	0.011	0.022	0.026	0.041	0.083	0.000	0.000	0.001	0.001	0.083	0.005
	b	-0.005	-0.009	-0.024	-0.042	-0.054	-0.044	0.000	0.000	0.001	0.001	-0.044	0.003
6 m/s	a	0.926	0.986	1.019	1.007	0.990	1.003	0.003	0.003	0.016	0.010	0.012	0.013
	k	0.004	0.008	0.026	0.032	0.040	0.079	0.000	0.000	0.002	0.002	0.002	0.005
	b	-0.005	-0.008	-0.022	-0.035	-0.039	-0.034	0.000	0.000	0.001	0.001	0.002	0.004

Table D.6 The results of standard error of Aghabaslo model with Wang and Singh model using non-linear regression analysis
MR = 1+a*t+b*t**2+exp((-c*t)/(1+d*t))

Velocity	Parameters	Parameters Estimate						Standard Error(SE)					
		Temparature(°C)						Temparature(°C)					
		50	60	70	80	90	100	50	60	70	80	90	100
4 m/s	a	-0.006	-0.020	-0.038	-0.037	-0.063	-0.110	0.001	0.001	0.009	0.034	0.057	0.093
	b	(-1.86(E-6))	9.69(E-05)	0.000	(-7.91(E-5))	0.001	0.003	0.000	0.000	0.000	0.001	0.002	0.004
	c	5.70(E+06)	1.11(E+07)	7.31(E+06)	1.95(E+06)	2.28(E+06)	4.54(E+06)	3.14(E+12)	1.12(E+13)	1.01(E+13)	1.87(E+12)	3.32(E+12)	1.33(E+13)
	d	2.06(E+06)	4.62(E+12)	3.35(E+06)	6.72(E+06)	9.22(E+06)	2.32(E+06)	1.14(E+12)	5.18(E+12)	4.62(E+12)	6.44(E+11)	1.34(E+12)	6.83(E+12)
5 m/s	a	-0.005	-0.015	-0.033	-0.030	-0.082	-0.121	0.001	0.003	0.017	0.063	0.089	0.120
	b	(-1.26(E-5))	2.84(E-05)	5.24(E-05)	0.000	0.001	0.003	0.000	0.000	0.000	0.002	0.004	0.006
	c	0.157	8.349E+06)	3.81(E+06)	8.85(E+05)	2.47(E+06)	1.63(E+06)	0.041	9.24(E+12)	5.04(E+12)	6.25(E+11)	4.33(E+12)	1.96(E+12)
	d	-0.007	3.05(E+06)	1.49(E+06)	2.6(E+05)	1.20(E+06)	7.56(E+05)	0.025	3.37(E+12)	1.97(E+12)	1.84(E+11)	2.11(E+12)	9.11(E+11)
6 m/s	a	-0.007	-0.011	-0.030	-0.031	-0.064	-0.108	0.001	0.003	0.011	0.021	0.045	0.071
	b	7.15(E-06)	1.34(E-05)	(-2.42(E-5)	0.000	0.001	0.004	0.000	0.000	0.000	0.001	0.004	0.007
	c	0.094	0.153	0.528	13.357	0.640	0.696	0.028	0.060	0.411	1.970(E+21)	0.790	1.018
	d	-0.008	-0.013	-0.034	-0.031	-0.063	-0.078	0.019	0.040	0.261	1.453(E+20)	0.539	0.715

Table D.7 The results of standard error of Aghabaslo model with Two-Term model using non-linear regression analysis

$MR = a*exp((-k*t)/(1+c*t))+b*exp((-m*t)/(1+n*t))$

Velocity	Parameters	Parameters Estimate						Standard Error(SE)					
		Temparature(°C)						Temparature(°C)					
		50	60	70	80	90	100	50	60	70	80	90	100
4 m/s	a	8.558	9.489	3.428	1.018	1.072	0.990	1240.268	5462.625	1.457	0.046	1.118	1.512
	k	-0.012	-5.30E-02	0.11	0.028	0.071	0.064	0.129	1.643	0.030	0.001	0.062	0.027
	c	0.001	0.016	0.008	-0.029	-0.020	-0.056	0.039	0.408	0.005	0.002	0.033	0.018
	b	-7.57	-8.527	-2.411	0.006	0.052	0.050	1240.267	5462.623	1.451	0.041	1.137	1.521
	m	-0.014	-0.058	0.139	0.031	0.017	-0.020	0.145	1.806	0.021	0.260	0.298	3.237
	n	0.001	0.017	-0.021	-0.143	-0.045	-0.005	0.041	0.428	0.010	0.089	0.139	4.290
5 m/s	a	8.16	2.962	1.055	0.921	1.001	0.739	1218.772	0.656	0.720	0.004	1.252	2.045
	k	-0.012	3.80E-02	2.20E-02	0.024	0.039	0.084	0.140	0.005	0.014	0.000	0.017	0.030
	c	1.00E-03	-0.002	-0.024	-0.047	-0.056	-0.006	0.042	0.001	0.003	0.000	0.014	0.027
	b	-7.171	-1.944	-0.031	0.080	0.024	0.285	1218.771	0.653	0.723	0.003	1.262	2.049
	m	-0.013	0.049	0.071	0.000	-0.016	0.042	0.157	0.004	0.578	0.001	3.802	0.400
	n	0.001	-0.012	-0.028	-0.210	0.000	-0.041	0.044	0.002	0.256	0.067	3.884	0.132
6 m/s	a	4.121	41.645	0.824	1.000	0.983	0.978	2.832	161725.866	0.009	0.014	0.014	0.975
	k	0.012	0.007	0.024	0.029	0.037	0.081	0.001	0.057	0.001	0.006	0.004	0.053
	c	-4.00E-03	-0.001	-0.033	-0.040	-0.043	-0.032	0.000	0.108	0.001	0.025	0.007	0.054
	b	-3.153	-40.659	0.17	2.928 E-8	1.229 E-11	0.025	2.83	161725.867	0.007	0.000	0.000	0.982
	m	0.013	0.007	0.000	-2.546	-1.704	0.026	0.001	0.058	0.000	46.218	152.547	0.671
	n	-0.005	-0.011	-0.116	0.117	0.014	-0.077	0.001	0.108	0.010	1.556	3.465	0.403

Table D.8 The results of R-square, Adjust R-square and SSE of from corelation polynomial equation analysis(Aghabaslo et al., with Henderson's model)

No	Corelation equation	R^2			adj.R^2			SSE		
		velocity m/s			velocity m/s			velocity m/s		
		4	5	6	4	5	6	4	5	6
1	a=a1+b1*T+C1*T^2	0.209	0.612	0.809	0.000	0.354	0.683	0.0016	9.36E-05	0.001
2	a=a1+b1*T+C1*T^2+d1*T^3	0.857	0.803	0.979	0.624	0.507	0.946	0.0003	4.76E-06	0.0001
3	a=a1+b1*T+C1*T^2+d1*T^3+e*T^4	0.946	0.845	0.997	0.740	0.775	0.985	0.00E+00	0.00E+00	0.00E+00
4	k=a1+b1*T+C1*T^2	0.954	0.954	0.959	0.923	0.924	0.931	0.0001	0.0002	5.11E-05
5	k=a1+b1*T+C1*T^2+d1*T^3	0.987	0.992	0.979	0.968	0.979	0.948	2.89E-05	3.20E-05	2.54E-05
6	k=a1+b1*T+C1*T^2+d1*T^3+e*T^4	0.987	0.999	0.987	0.935	0.995	0.935	0.00E+00	0.00E+00	0.00E+00
7	b=a1+b1*T+C1*T^2	0.963	0.893	0.945	0.938	0.829	0.908	5.32E-05	2.07E-04	6.51E-05
8	b=a1+b1*T+C1*T^2+d1*T^3	0.986	0.999	0.991	0.966	0.997	0.978	1,94E-05	2.43E-06	1.06E-05
9	b=a1+b1*T+C1*T^2+d1*T^3+e*T^4	0.990	1.000	1.000	0.959	1.000	1.000	0.00E+00	0.00E+00	0.00E+00

Appendix E

Results of moisture ratio with bed thickness

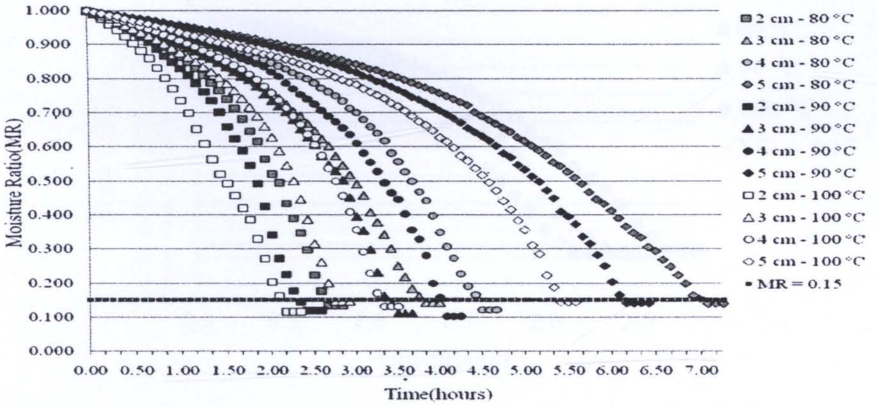

Figure E.1 The change of moisture ratio with drying time on hot air velocity of 4 m/s at bed thickness of 2, 3,4 and 5 cm

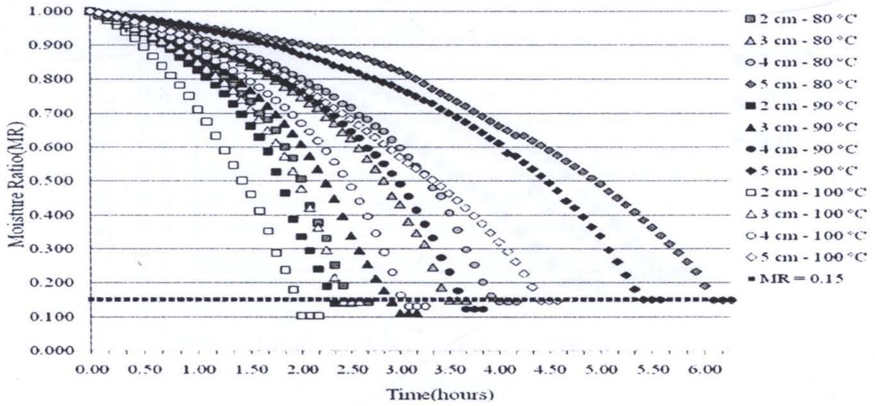

Figure E.2 The change of moisture ratio with drying time on hot air velocity of 5 m/s at bed thickness of 2, 3,4 and 5 cm

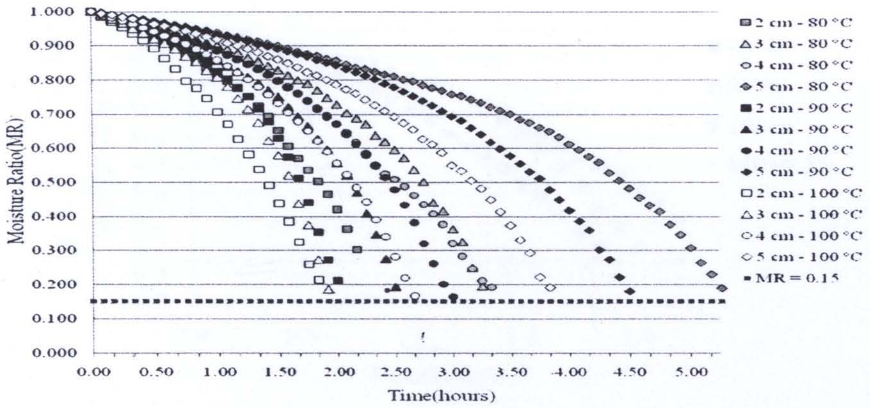

Figure E.3 The change of moisture ratio with drying time on hot air velocity of 6 m/s at bed thickness of 2, 3,4 and 5 cm

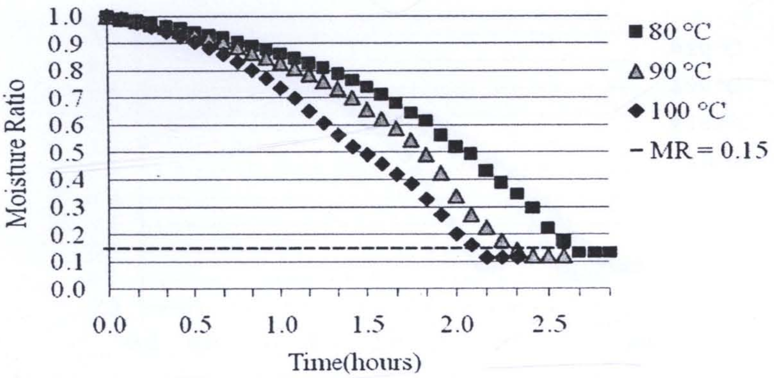

Figure E.4 The change of moisture ratio with drying time on hot air velocity of 4 m/s at bed thickness of 2 cm

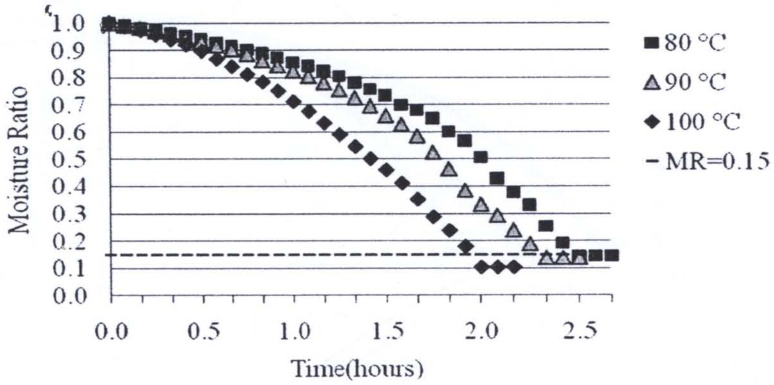

Figure E.5 The change of moisture ratio with drying time on hot air velocity of 5 m/s at bed thickness of 2 cm

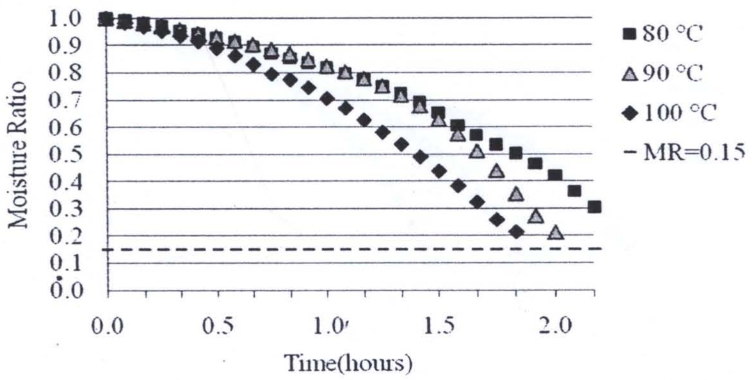

Figure E.6 The change of moisture ratio with drying time on hot air velocity of 6 m/s at bed thickness of 2 cm

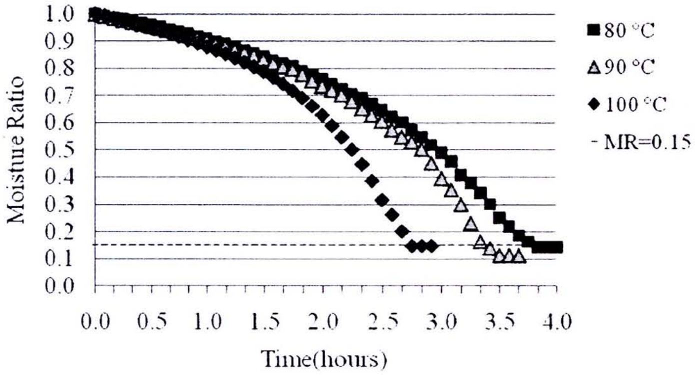

Figure E.7 The change of moisture ratio with drying time on hot air velocity of 4 m/s at bed thickness of 3 cm

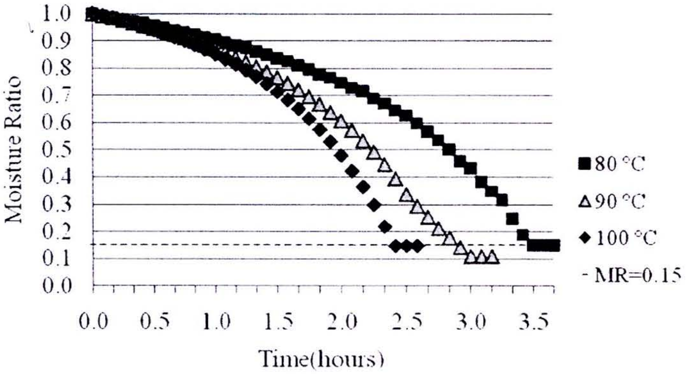

Figure E.8 The change of moisture ratio with drying time on hot air velocity of 5 m/s at bed thickness of 3 cm

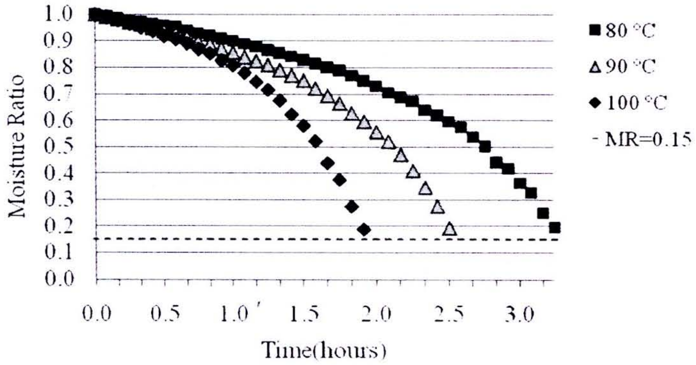

Figure E.9 The changed of moisture ratio with drying time on hot air velocity of 6 m/s at bed thickness of 3 cm

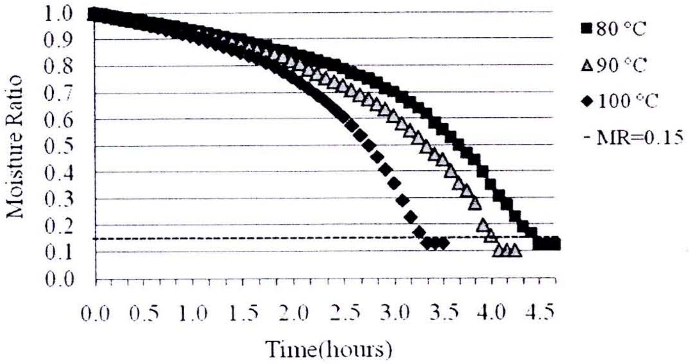

Figure E.10 The change of moisture ratio with drying time on hot air velocity of 4 m/s at bed thickness of 4 cm

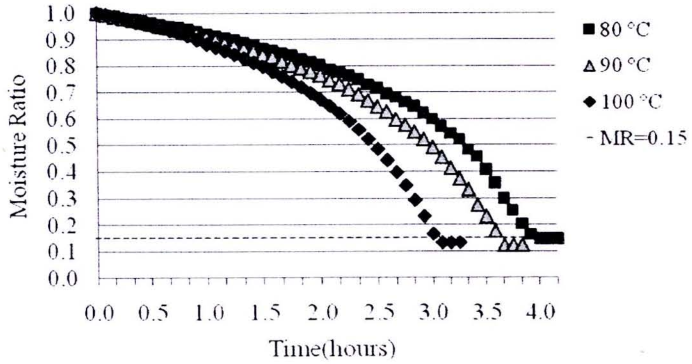

Figure E.11 The change of moisture ratio with drying time on hot air velocity of 5 m/s at bed thickness of 4 cm

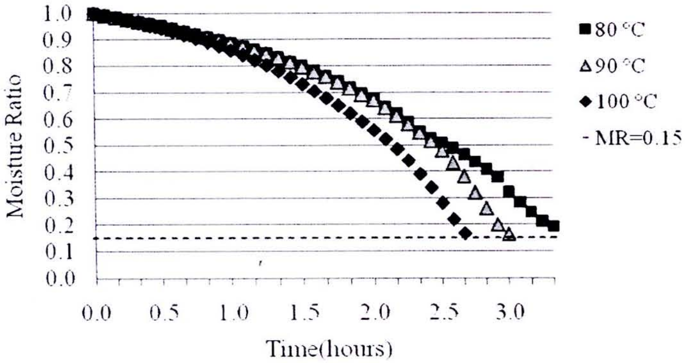

Figure E.12 The change of moisture ratio with drying time on hot air velocity of 6 m/s at bed thickness of 4 cm

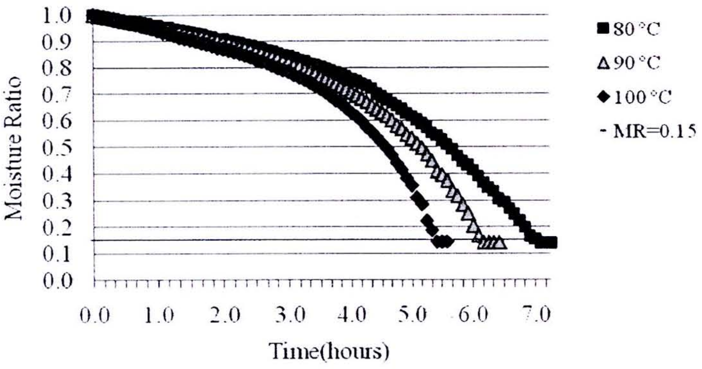

Figure E.13 The change of moisture ratio with drying time on hot air velocity of 4 m/s at bed thickness of 5 cm

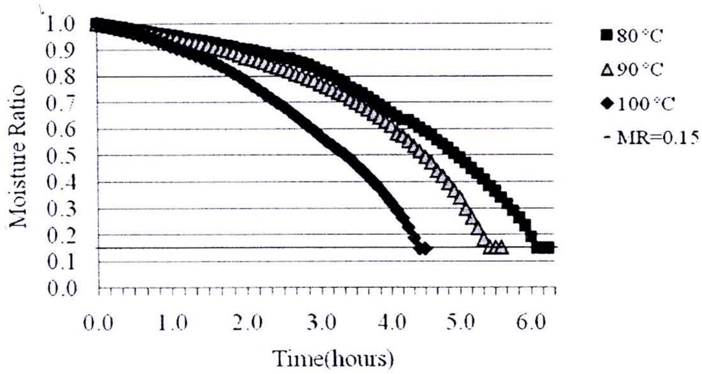

Figure E.14 The change of moisture ratio with drying time on hot air velocity of 5m/s at bed thickness of 5 cm

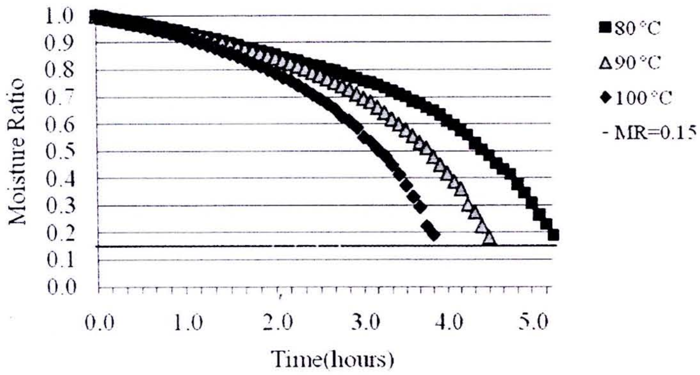

Figure E.15 The change of moisture ratio with drying time on hot air velocity of 6 m/s at bed thickness of 5 cm

APPENDIX F

Design Procedure

Design Procedure

From the data could be design continuous chili dryer using fluidized bed technique as following:

1. The quantity of water was evaporated from chili could be define as follow(M_w):

$$W_f = W_i \frac{(100 - M_i)}{(100 - M_f)} \qquad (1)$$

Where:

W_f = Final weight of chili, kg

M_i = Initial moisture content by decimal = 0.73 or 72.98% on wet basis,

W_i = Initial weight = 1 kg

M_f = Final moisture content(moisture content standard of dried chili, Thailand) = 13%

Substitute W_i = 1 kg, M_i = 72.98 % and M_f = 13%, into Equation(1)

$$W_f = (1\text{kg})\frac{(100 - 72.98)}{(100 - 13)} = 0.31 \text{ kg}$$

The quantity of water evaporation from chili 1 kg shown that

$$M_w = W_i - W_f \qquad (2)$$

substitute W_i = 1 kg and W_f = 0.31 kg into Equation(2)

$$M_w = 1.0 - 0.31 = 0.69 \text{ kg}$$

Also, quantity of water was evaporated from chili(1 kg) equal 0.69 kg.

If W_i = 10 kg quantity of water was evaporated from chili = 6.9 kg

(2) Calculate the rate of water evaporation from above water evaporation can be show as following($\dot{M}_w$):

2.1 Experiment chili(1 kg) drying at drying temperature of 80, 90 and 100 °C in Oven dryer (3 sample for each drying temperature)

2.2 Determine average drying time from all experiment which the final moisture content nearly 13% on wet basis

2.3 Investigate the chili's physical characteristics would turn into red, flat and shiny, crispy and no burning smell.

2.4 The results from experiments found that average drying time equal 2 hours 30 minute or 150 minute at drying time of 90°C.

$$\because \quad \dot{M}_w = \frac{W_i(kg)}{time(s)} \qquad (3)$$

$$\therefore \quad \dot{M}_w = \frac{0.69(kg)}{9000(s)} = 7.67 \times 10^{-5} \text{ kg-water/s}$$

If initial weight $W_i = 10$ kg rate of water evaporation($\dot{M}_w$) = 7.67×10^{-4} kg-water/s

(3) Calculation the rate of hot air for drying could express as following:

$$\dot{M}_a = \frac{\dot{M}_w}{M_o - M_i} \qquad (4)$$

Where :

$\dot{M}_a$ = rate of hot air for drying(kg-air/s)

$\dot{M}_w$ = rate of water evaporation(kg-water/s)

M_i = moisture ratio of air before drying(kg-water/kg-dry air)

M_o = moisture ratio of air after drying(kg-water/kg-dry air)

Assume:

- dry bulb temperature of 30°C and 90°C
- Relative humidity of 70% and 10% RH

From psychometric chart(Soponronnarit, 1997, P29)

From psychometric chart(Soponronnarit, 1997, P29)

At dry bulb temperature of 30°C and 70%RH-- the moisture ratio of air before drying(M_i) equal 0.02 and at 90°C and 10%RH, $M_o = 0.048$

Substitute ($\dot{M}_w$) = 7.67×10^{-4} kg-water/s, $M_i = 0.02$ (kg-water)/kg-dry air and $M_o = 0.048$ (kg-water)/kg-dry air into Equation(4)

$$\dot{M}_a = \frac{7.67 \times 10^{-5}}{0.048 - 0.02} \text{(kg-water/s)/(((kg-water)/kg-dry air))}$$

∴ Rate of hot air for drying, $\dot{M}_a$ = 2.739×10^{-3} kg-dry air/s

If initial weight $W_i = 10$ kg rate of hot air for drying, $\dot{M}_a = 2.739 \times 10^{-2}$ kg-dry air/s

(4) Calculation drying air flow rate of hot air can be express as equation(5):

$$\dot{Q}_{air} = \frac{\dot{M}_a}{\rho_{air}} \tag{5}$$

$\dot{Q}_{air}$ = drying air flow rate of hot air, m^3/s

ρ_{air} = density of hot air, kg/m^3 : = 0.9627 kg/m^3 ,$C_{p(air)}$= 1.0103 kJ/kg.K(90 °C, Fundamentals of Heat and Mass Transfer, Frank et.al., 1996, P839)

$$\dot{Q}_{air} = \frac{2.739 \times 10^{-3}}{0.9627} \text{ (kg-dry air/s)/(kg/m}^3\text{)}$$

∴ $\dot{Q}_{air} = 2.845 \times 10^{-3}$ m^3/s or 0.002845 m^3/s($W_i = 1$ kg)

If initial weight $W_i = 10$ kg ,drying air flow rate,

$\dot{Q}_{air} = 10 \times 2.845 \times 10^{-3} = 2.845 \times 10^{-2}$ m^3/s or 0.02845 m^3/s

Then, select blower within condition of $\dot{Q}_{air} \geq 0.02845$ m^3/s for chili drying 10 kg

The blower was selected was TB30 series $\dot{Q}_{max} = 2500$ m^3/s or = 0.69 m^3/s.

Also, this study use blower TB30, Vent type, for drying chili 10 kg that air flow rate

$$\dot{Q}_{air} \geq 0.02845\,m^3/s$$

(5) Determine physical properties of chili:

Specific heat of chili can be calculate from empirical equation(Siebel's 1982)

$$Cp = 0.837 + 3.348M_i \qquad (8)$$

Substitute $M_i = 0.73$ into Equation(1) that can be show following;

$$Cp = 0.837 + 3.348(0.73)$$

Also, specific heat of chili(Jinda type), $Cp = 3.28$ kJ/kg.K

(6) Density of chili

6.1 Determine weight of the chili container as shown in Figure F.1

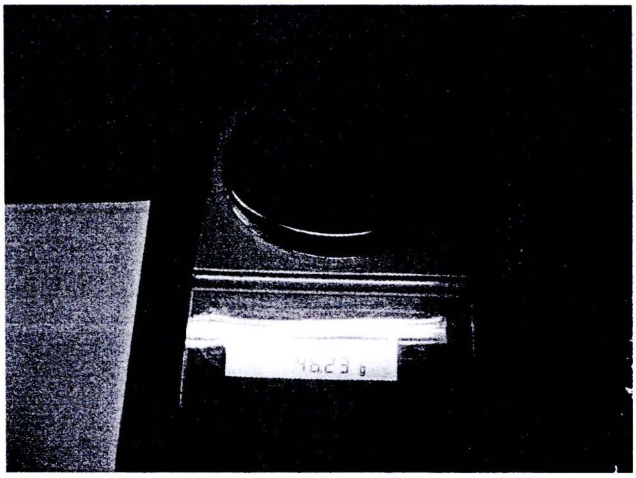

Figure F.1 Chili container

6.2 Determine weight of the chili as shown in Figure F.2

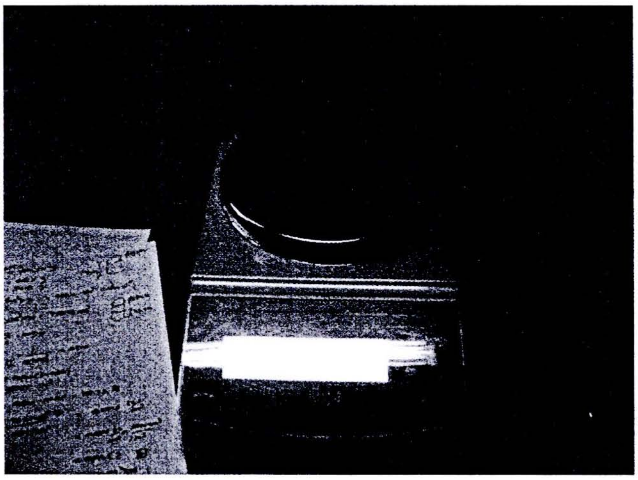

Figure F.2 Shows the chili weighing

6.2 Fill the water into chili container as fully fit.

6.3 Weighing chili and water as shown in Figure F.3

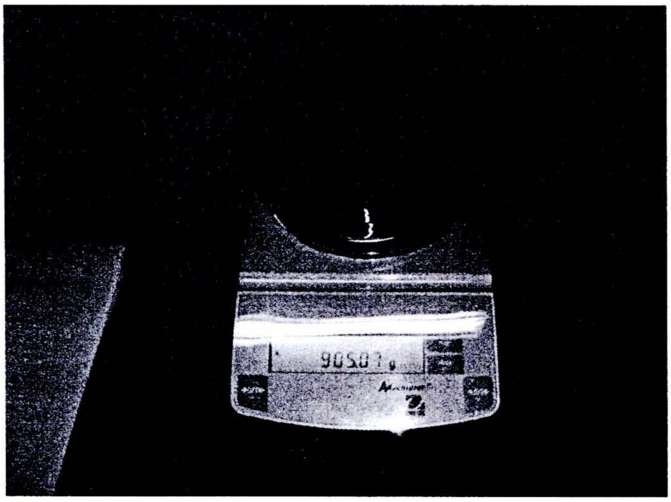

Figure F.3 Shows the chili and water weighing

(7) Void fraction can be determine as Equation(9):

Find by replacing the liquid in cylindrical containers-- radius of 6.5 cm. height of 7 cm.

$$\varepsilon = \frac{V_{water}}{V_{Total}} \tag{9}$$

Where: ε = void fraction of chili(dimensionless)

V_{water} = average volume of water used to fill in the container(477.83 cm^3)

V_{total} = total container volume, 929.12 cm^3

Substitute V_{water} and V_{total} into Equation(9)

$$\varepsilon = \frac{477.83}{929.12} = 0.514$$

Also, void fraction; $\varepsilon = 0.514$

(8) Spherically of chili particle;

$$\phi = \frac{1}{14(\varepsilon^3)} \tag{10}$$

$$\therefore \phi = \frac{1}{14(0.514^3)} = 0.526$$

Also, spherically of chili particle, $\phi = 0.526$

(9) Density of fresh chili can be determined as following:

$$\rho_p = \frac{W_p}{V_{ap}} \tag{11}$$

$$V_{ap} = V_{total} \times (1 - \varepsilon) \tag{12}$$

Substitute, $V_{total} = 929.12\ cm^3$ and $\varepsilon = 0.514$ into Equation(12) and found that

$V_{ap} = 929.12 \times (1-0.514) = 451.55\ cm^3$

Replace $W_p = 381.37$ g and $V_{ap} = 451.55\ cm^3$ into Equation(11) found that

$$\rho_p = \frac{381.37}{451.55} = 0.844 \text{ g/cm}^3 = 844 \text{ kg/m}^3$$

$\therefore$ density of fresh chili, $\rho_p = 844$ kg/m^3

Where

ρ_p = density of fresh chili, kg/m^3

V_{ap} = average volume of fresh chili, cm^3(451.55 cm^3)

W_p = average weight of fresh chili, g(381.37 g.)

(10) Minimum velocity and terminal velocity in fluidization of chili

(10.1) Minimum fluidization velocity (U_{mf})

From Equation of Kunii and Livenspiel[1991]:

In this study the author assume : temperature of hot air of 1200 K because high temperature or temperature increase as well as the viscosity of hot air increase(Kitti,2004):

- Viscosity of hot air, $\mu = 473.00 \times 10^{-7}$ N.s/m^2
- Gas density, $\rho_g = 0.2902$ kg/m^3

$$U_{mf} = \frac{\varepsilon^3_{mf}}{180(1-\varepsilon_{mf})} \frac{(\rho_p - \rho_g)(\phi d_p)^2 g}{\mu} \qquad (13)$$

$$U_{mf} = \frac{(0.514)^3}{180(1-0.514)} \frac{(844-0.2902)(0.526 \text{x} 9 \text{x} 10^{-3})^2(9.81)}{473.00 \text{x} 10^{-7}}$$

$\therefore U_{mf} = 6.09$ m/s

Also, minimum velocity for Fluidization of chili = 6.09 m/s

ϕ = sphericity of particle

ε_{mf} = bed voiding at minimum fluidization

ρ_g = gas density, kg/m^3

ρ_p = dry particle density, kg/m^3

μ = viscosity of hot air, kg(m.s)$^{-1}$

(10.2) Terminal velocity (U_t)

$$U_t = 8.4U_{mf} \quad (14)$$

$$U_t = 8.4x6.09$$

$$\therefore U_t = 51.16 \text{ m/s}$$

Also, terminal velocity for Fluidization of chili = 51.16 m/s

(11) Calculation rate of heat transfer for fluidization drying process from following:

$$\dot{Q}_{min} = \rho_g U_{mf} A C_a (T_i - T_o) \quad (15)$$

Substitute ρ_g = 0.2902 kg/m^3, U_{mf} = 6.09 m/s, A = 0.3 m^2, C_a = 1.175 and $(T_i - T_o)$ = 10 K(Assumed that the heat loss in the system) into Equation(15) as shown following:

$$\dot{Q}_{min} = 0.2902(kg/m^3)x6.09(m/s)x0.3(m^2)x1.175(kJ/kg.K)x10(K)$$

$$\therefore \dot{Q}_{min} = 6.23 \text{ kJ/s or } 6.23 \text{ kW}$$

$$\dot{Q}_{max} = \rho_g U_t A C_a (T_i - T_o) \quad (16)$$

And substitute ρ_g = 0.2902 kg/m^3, U_{mf} = 51.16 m/s, A = 0.3 m^2, C_a = 1.175 and $(T_i - T_o)$ = 10 K(Assumed that the heat loss in the system) into Equation(16) as shown following:

$$\dot{Q}_{max} = 0.2902(kg/m^3)x51.16(m/s)x0.3(m^2)x1.175(kJ/kg.K)x10(K)$$

$\therefore \dot{Q}_{min} = 52.33$ kJ/s or 52.33 kW

Where $\dot{Q}_{min}$ = minimum of heat transfer rate, kJ/s

$\dot{Q}_{max}$ = minimum of heat transfer rate, kJ/s

ρ_g = density of hot air, kg/m^3

U_{mf} = minimum velocity for fluidization, m/s

U_t = terminal velocity for fluidization, m/s

A = bed drying area, m^2

C_a = specific heat of air, kJ/kg.K

T_i = drying temperature, °C

T_o = outlet temperature from the chamber, °C

Also, the dryer machine in this experiment was designed under condition of rate of heat transfer with $6.23 \leq \dot{Q} \leq 52.33\text{kW}$ and rate of air flow in drying system as $\dot{Q}_{air} \geq 0.02845\,\text{m}^3/\text{s}$

Appendix G

Figures of dried chili and results of energy consumption from experiments and simulation

The physical characteristics of the chili when dried in the temperature conditions and velocity of hot air as 4 m/s(Fig G.1-G.6)and 6 m/s(Fig. G.7-G.12) The results of the dried chili that looks different as the following presentation.

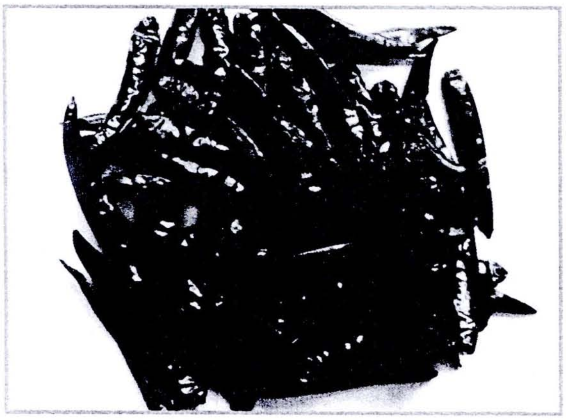

Figure G.1 Physical characteristics of chili after drying at 50 °C

Figure G.2 Physical characteristics of chili after drying at 60 °C

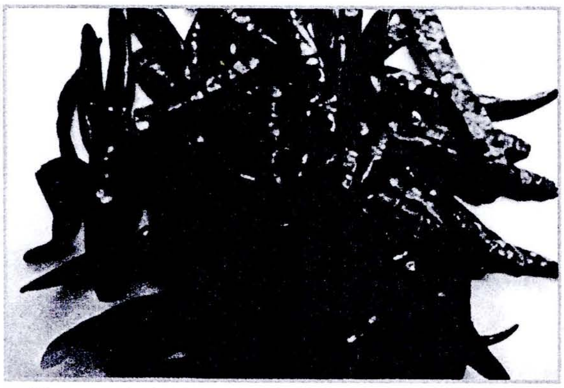

Figure G.3 Physical characteristics of chili after drying at 70 °C

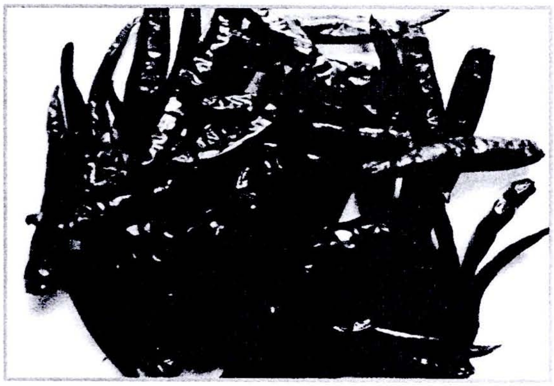

Figure G.4 Physical characteristics of chili after drying at 80 °C

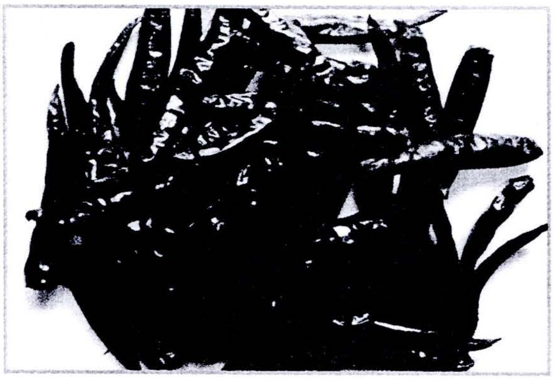

Figure G.5 Physical characteristics of chili after drying at 90 °C

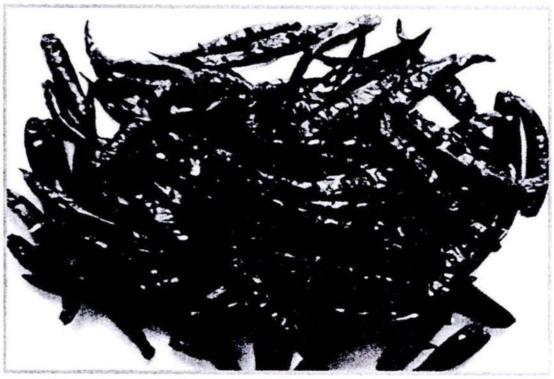

Figure G.6 Physical characteristics of chili after drying at 100 °C

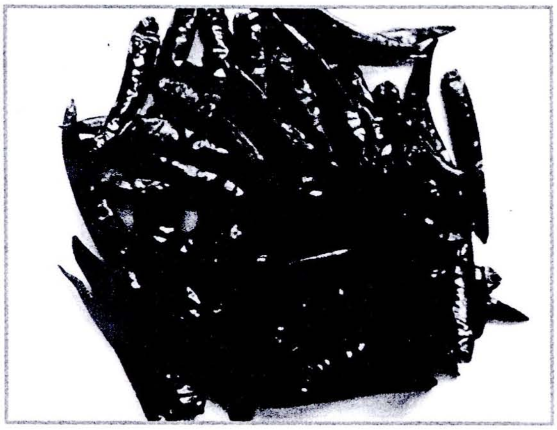

Figure G.7 Physical characteristics of chili after drying at 50 °C

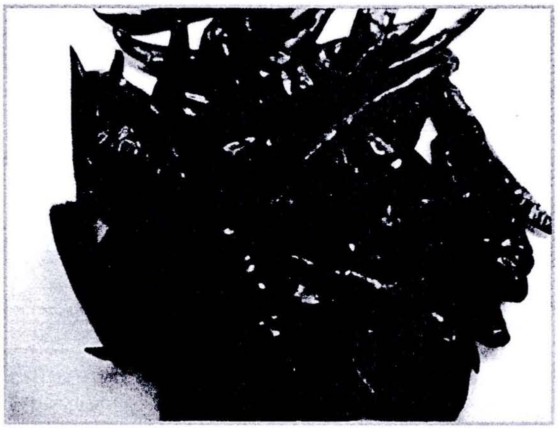

Figure G.8 Physical characteristics of chili after drying at 60 °C

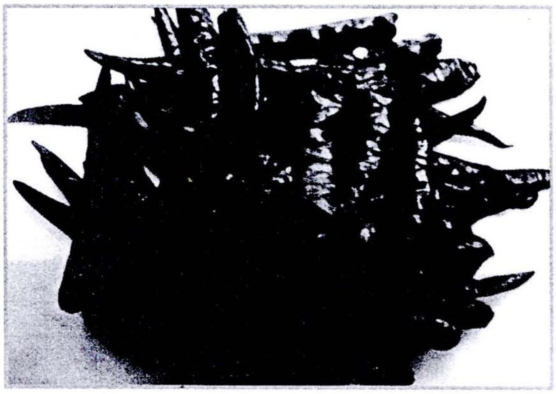

Figure G.9 Physical characteristics of chili after drying at 70 °C

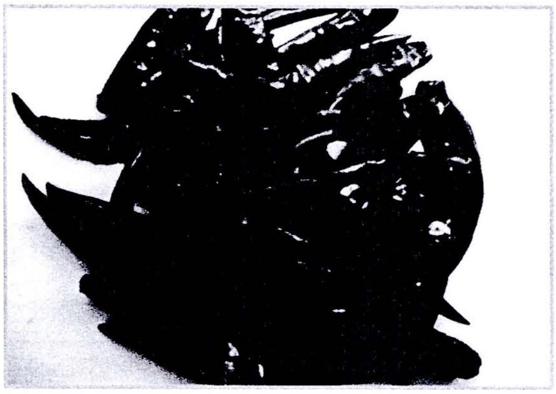

Figure G.10 Physical characteristics of chili after drying at 80 °C

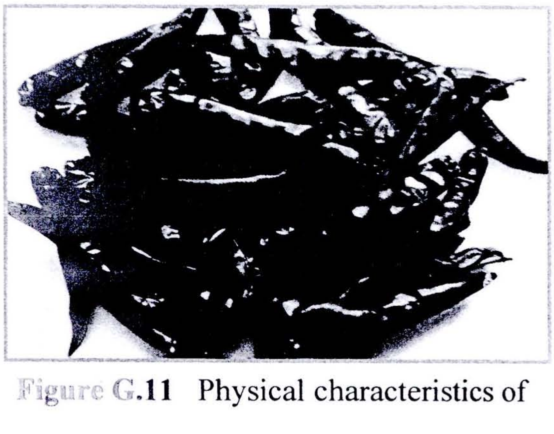

Figure G.11 Physical characteristics of chili after drying at 90 °C

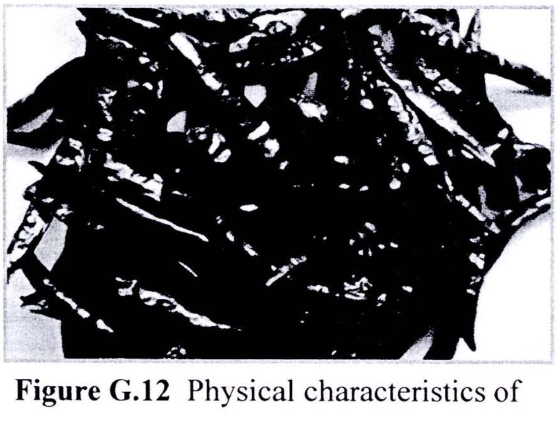

Figure G.12 Physical characteristics of chili after drying at 100 °C

Table G.1 Results of energy consumption from experiments and simulation

velocity	Temperature	Drying Time	Moisture content(wb)		Tf1(°C)		Tf2(°C)		Tb(°C)		Qh(KWh)		Ws(kWh)		Total energy(kWh)	
(m/s)	(°C)	(hours)	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation
4	50	27.00	8.19	13.64	45.34	47.75	42.14	47.12	41.65	41.60	97.20	30.42	15.64	15.89	112.84	46.31
	60	17.50	9.96	13.67	54.00	55.52	54.31	54.62	42.14	46.88	73.50	22.48	10.53	7.34	84.03	29.83
	70	8.00	10.47	13.62	62.00	62.15	62.43	61.02	45.20	51.42	33.60	17.67	4.72	3.97	38.32	21.64
	80	4.50	8.90	13.64	72.00	67.74	70.70	66.40	47.43	55.26	18.90	15.00	2.74	2.41	21.64	17.40
	90	3.75	7.14	13.36	80.34	72.52	78.50	71.00	53.17	58.55	18.00	13.53	2.24	1.54	20.24	15.07
	100	3.00	7.45	13.56	88.85	76.72	85.19	75.03	60.37	61.52	20.25	12.58	2.22	1.17	22.47	13.75
5	50	26.00	7.79	13.63	46.70	48.14	47.61	47.62	42.67	42.35	93.60	32.99	22.92	33.90	116.52	66.88
	60	14.00	9.24	13.68	56.00	56.20	55.53	55.46	46.60	47.75	50.40	24.37	12.66	13.25	63.06	37.62
	70	6.00	6.53	13.60	65.00	62.26	64.14	61.35	50.61	51.87	19.80	16.88	4.93	5.58	24.73	22.46
	80	3.75	8.17	13.56	73.00	67.36	71.30	66.30	53.14	55.42	18.00	14.00	3.41	3.29	21.41	17.29
	90	3.00	7.54	13.22	80.56	72.68	78.30	71.46	54.38	59.10	14.40	13.14	2.57	2.25	16.97	15.38
	100	2.75	7.14	13.53	89.03	79.49	88.08	78.05	62.29	63.84	16.50	13.33	2.48	1.95	18.98	15.28

Table G.1 Results from experiments and simulation(Cont.)

velocity (m/s)	Temperature (°C)	Drying Time (hours)	Moisture content(wb)		Tf1(°C)		Tf2(°C)		Tb(°C)		Qh(KWh)		Ws(kWh)		Total energy(kWh)	
			Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation
6	50	22.50	14.72	13.64	47.10	48.44	46.75	48.00	40.60	42.78	40.50	37.05	23.69	47.88	64.19	84.93
	60	13.00	13.37	13.63	57.00	56.80	55.79	56.17	44.42	48.56	46.80	26.98	14.00	22.18	60.80	49.16
	70	5.00	11.82	13.66	67.00	63.93	63.22	63.13	49.86	53.48	21.00	19.81	5.30	10.91	26.30	30.71
	80	3.25	16.63	13.61	74.00	70.58	71.20	69.62	54.06	58.10	15.60	17.00	3.69	6.89	19.29	23.89
	90	2.75	16.78	13.37	80.10	77.35	79.90	76.21	56.03	62.77	18.15	16.10	3.06	4.96	21.21	21.06
	100	2.25	12.19	13.60	89.60	84.87	88.48	83.54	65.39	68.01	16.20	16.26	2.47	4.25	18.67	20.51

Appendix H

Research Publication

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Drying Characteristics of Chili Using Continuous Fluidized-Bed Dryer

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Abstract: Problem statement: The objective of this study was to obtain the dying characteristics of the Jinda chili, a commonly grown variety in the Northeatern of Thailand, using the continuous fluidizedbed dryer in reducing moisture content of dried chili up to 13% wet basis as comparable to the dried chili in the market and to investigate the effect of drying temperature and drying air velocity. **Approach:** Drying characteristics was to study under varying conditions of drying temperature (50, 60, 70, 80, 90 and 100°C) and drying air velocity (4, 5 and 6 m sec^{-1}). **Results:** The drying time decreased within the increasing of drying temperature and drying air velocity. Drying air velocity affected the drift and continuously moves of chili particle outward from dryer chamber under continuous fluidized-bed technique. The decreasing of moisture content effected with increasing of a compound capsaicin of dried chili compare to fresh chili. The diffusion coefficient of moisture content increased with increasing all drying temperature and drying air velocity. **Conclusion:** Drying temperature was the significant factor of the chili moisture content reduction. Drying air velocity affected the move of chili outward from chamber under the continuous fluidized bed drying process.

Key words: Jinda chili, fluidized-bed, Capsicum

INTRODUCTION

Chilli is known by different names in different parts of the world. The genus Capsicum which is commonly known as "red Chile", "chili pepper", "hot red pepper", "tobasco", "paprika", and "cayenne", (De, 2003). Chili peppers (*Capsicum* spp.) are appreciated for their pungency, taste and aroma as food additive, pigment and for their physiological and pharmaceutical uses (Cisneros-Pineda *et al.*, 2007). Hot chili pepper is a common spice in Thai cuisine and it is widely consumed as a food additive throughout the world, particularly in South East Asia and Latin-American countries (Laohavechvanich *et al.*, 2006). As, ripe chilies usually have initial moisture content as high as 300-400% (db), this has to be reduced to 8-11% (db) for the safe storage (Satyanarayana and Vengaiah, 2010). Traditionally, fresh chilies are preserved by drying immediately after harvest under the sun without any special treatment (Kaleemullah and Kailappan, 2005). Haddad (2009) studied the mathematical method for defining the dimensions of drying machine to obtain optimum productivity with lowest power energy consumption and basic theoretical backgrounds of the engineering design procedure of a drying plant. Shafri and Ezzat (2009) studied on quantitative performance of spectral indices in large scale plant health analysis. Accordingly, procurement of machineries and drying apparatus are burdens to some operators (Tasirin *et al.*, 2006).

Chili is one of economic plants and involve with Thai society, especially with its daily cooking. A very unique characteristic of chili is the spiciness which comes from the chemical substance called Capsaicin. Chili can be grown all year round. However, the good periods of growing chili in the Northeastern of Thailand are in rainy season and winter. During those periods there will be a problem of overflow with chili in the market. Dried chili was introduced to be controlled the quantity and the stability of price of during that period. Preservation of chili for other period is also the other way to keep the price. The conventional method to preserve the chili is to dried up under the sun by spreading the chili in the large open area. The duration needed depends on the quality of sunlight, temperature and air humidity. One of the problems by this technique

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is that the level of moisture content of dried chili was not the same and other problems are caused by weather, fungus, which decrease the length of time that can be kept. Moreover, there might also be a contamination in the chili. The main advantage of fluidized-bed dryer is the high transfer rate for heat and mass between gas and solid that ensure a rapid and uniform drying. Apart from this, heat transfer rate between the fluidized layer and immersed object is high. Therefore, only a small area is needed for heat transfer (Tasirin *et al.*, 2006). And technological innovation was adapted to protect crop might bring about significant benefits to farmers (Luce *et al.*, 2006).

Also, this study focused on drying characteristic, the drying effective diffusivities and activation energy on drying process of capsicum using continuous fluidized-bed dryer in order to investigate physical characteristic of chili after drying, to consider the effect of drying temperature and drying air velocity, to suggest drying method using suitable condition which was concerned with the quality of a product.

MATERIALS AND METHODS

Sample preparation: Since there are many kinds of chili, the researcher decided to use Jinda chili; a kind of chili which is largely sold in the Northeastern market of Thailand in both fresh and dried type. The clean chili would be processed in the Central Laboratory (Thailand) Ltd., Khon Kaen Branch, in order to specify the initial moisture content 72.98% on wet basis (Stephen and Emmanuel, 2009) and contained 0.07 of capsaicin quantity substance (g 100 g^{-1}) by HPLC based on AOAC (1995) 995.03 in house method, before the continuous fluidized bed drying was used in the experiment, where the chili's weighted 1000 g would be started.

Experiments set-up: Figure 1 showed a schematic diagram of a dryer, a continuous chili artificial dryer which consisted of its essential devices, heaters, drying chamber, instruments for measurement, centrifugal blower-3 horsepower motor driven and 1450 rpm of revolution. The air flow rate was adjusted by the blower speed control which was reused again by the use of air circulation, delivering to the drying process. The heating system consisted of 8 electric sets with 1.5 kW heater placed inside the duct. The temperature in drying chamber was adjusted by the heater power control. The drying chamber was conducted from stainless steel sheets as rectangular tunnel with 1000 cm long, 30 cm wide and 50 cm high. It was brought into this study that relied on the continuous fluidized bed dryer.

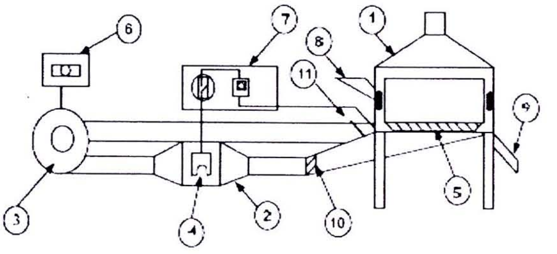

Fig. 1: Schematic of the dryer (1) Drying chamber; (2) Heater casing; (3) Blower; (4) Heater; (5) Trays; (6) Blower speed control; (7) Heater power control; (8) Inlet gate of products; (9) Outlet gate of products; (10) Air distributor plate; (11) Thermocouple sensor

In the measurement of temperature, K type thermocouples were used with manually controlled temperature (Shinko, MCD-130-R/E, Japan), with accuracy of ±1°C. The temperature recorded with a manually controlled 32-channel automatic digital thermometer (Hioki, 8422-51, Japan). The drying air velocity passing through the system was measured by a 0.8-12.0 m sec^{-1} range anemometer mini vane (Digicon, DA-45, Japan) with accuracy of 0.01 m Sec^{-1} and uncertainly of ±(2%+0.2 m sec^{-1}). A thermohygrometer (Digicon, T-126TH-S, Japan) with accuracy of 0-100%RH and uncertainly of ±2.5% RH (30-90RH). Moisture loss was recorded at intervals of 5 min during drying for determination of drying curves by a digital balance (Ohaus, Adventurer-ARC210 and USA) in the measurement range of 0-2100 g and readability of 0.01 g.

Drying experiment was carried out at drying air temperature of 50, 60, 70, 80, 90 and 100°C and drying air velocity was at 4, 5 and 6 m sec^{-1}. Drying Nomenclature t drying time (min) D_{eff} coefficient of moisture diffusion (m^2 sec^{-1}) RC radius of a cylindrical object (m) Rg fixed rate of gas MJ. kg mol. K^{-1}) β Bessel function's root at zero T relative temperature (K). D_o initial constant number of moisture diffusion, (m^2 sec^{-1}) Ea activation of moisture diffusion (MJkg mol^{-1}) was continued until chili were drifted or continuously moved from drying chamber. During the experiment ambient temperature, relative humidity, inlet or outlet temperatures of drying air in drying chamber were recorded.

Coefficient of moisture diffusion and activation energy: The solute or heat transport in a flat duct was defined by Johnson *et al.* (2008). Materials, paddy, seed of herbs were completely predicted by diffusion number in Fick's second law. Also it was used in alculating chili moisture coefficient at every emperature level in drying process according to the quation mentioned below:

$$MR = \frac{4}{\beta_1^2}\exp\left(\frac{-\beta_1^2 D_{eff}}{r_c^2}t\right) \quad (1)$$

Coefficient of chili's moisture diffusion was hanged by the temperature more than the moisture, so t was developed the equation to solve the coefficient umber of chili's moisture diffusion which was a type f Arrhenius's relation:

$$_{eff} = D_0\exp(E_a/R_gT_{abs}) \quad (2)$$

$$nD_{eff} = \ln D_0-(E_a/R_g)(1/T_{abs}) \quad (3)$$

It could obtain initial number of D_0 and E_a from the esult correlation between $\ln D_0$ and (1 T_{abs}) which was he equation of a straight line (Eq. 3), (E_a/R_g) was the lope number of a graph.

RESULTS

rying characteristics: The result of drying of apsicum based on continuous fluidized-bed dryer evealed that the drying time decreased from 27 h 50°C and 4 m sec^{-1}) to 2 h 25 min (100°C and 6 m sec^{-1}) when drying air temperature increased from 50, 0, 70, 80, 90 to 100°C and drying air velocity ncreased from 4-6 m sec^{-1}, respectively (Table 1). The hange of moisture content of chili on wet basis from he experiment using the dryer machine (Fig. 1) showed hat on drying air velocity of 4 m sec^{-1}, 5 m sec^{-1} and 6 n sec^{-1}, the chili's initial weight was 1000 g and final weight was 292.25 g. Moreover, it contained the moisture content of 7.54% (wb) from experiment and .08% (wb) from central laboratory.

After the experiment(1 month ago), 6 samples of lried chili on drying air velocity of 5 m sec^{-1} were letermined the final moisture content (g 100 g^{-1}) on wet basis (Stephen and Emmanuel, 2009) and the compound capsaicin by HPLC based on AOAC (1995) 995.03 in house method. The capsaicin quantity of dried chili on drying air velocity of 5 m sec^{-1} and lrying temperature of 50, 60, 70, 80, 90 and 100°C were 0.25, 0.24, 0.23, 0.19, 0.23 and 0.19 g 100 g^{-1}, respectively. The capsaicin quantity of fresh chili on initial moisture content of 72.98% (wb) were 0.07 g 100 g^{-1}. The result was certificated by Central Laboratory (Thailand) Ltd., Khon Kaen Branch: Nai Muang, Khon Kaen Thailand.

Diffusion coefficient and activation energy: Chili's diffusion coefficient would be changed by the temperature and drying air velocity of the drying process which stayed in a range of 1.3118E-09-1.3782E-08 m^2 sec^{-1}, 1.3330E-09-1.5197E-08 m^2 sec^{-1} and 8.4181E-010-1.0740E-08 m^2 sec^{-1}. The effective moisture diffusivity of 50, 60, 70, 80, 90 and 100°C and drying air velocity of 4-6 m sec^{-1} can be written as following equations:

$$D_{eff} = 0.34749\exp(-6237.24985/T_{abs}) \quad (4)$$

$$D_{eff}\,abs\,D = 0.14262\exp(-5981.47279/T) \quad (5)$$

$$D_{eff} = 0.424045\exp(-6439.97646/T_{abs}) \quad (6)$$

DISCUSSION

The result shown in Table 1 found that moisture content of dried chili (central laboratory) was higher as it was compared to the experimental result.

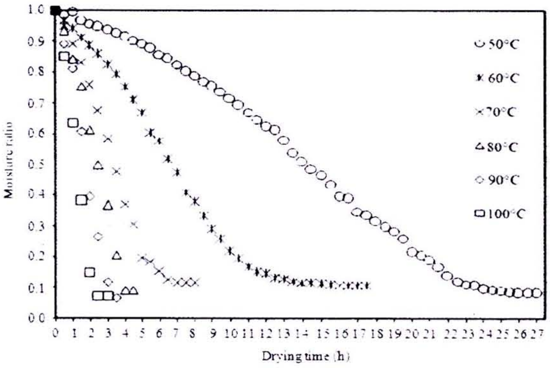

Fig. 2: Change of Moisture Ratio (MR) with drying time (h) on drying air velocity of 4 m sec^{-1}

Table 1: The results from the experiment and central laboratory (Thailand) Ltd., Khon Kaen branch

Drying temperature (°C)	Moisture content (% wb)			Moisture content	Compound capsaicin	Drying time (h)		
	4 m sec^{-1}	5 m sec^{-1}	6 m sec^{-1}			4 m sec^{-1}	5 m sec^{-1}	6 m sec^{-1}
50	8.19	7.79	14.72	9.40*	0.25**	27.00	26.00	22.50
60	9.96	• 9.24	13.37	10.67*	0.24**	17.50	14.00	13.00
70	10.47	6.53	11.82	6.71*	0.25**	8.00	5.00	5.00
80	8.90	8.17	16.63	9.12*	0.19**	4.50	3.75	3.25
90	7.14	7.54	16.78	8.08*	0.23**	3.75	3.00	2.75
100	7.45	7.14	12.19	7.88*	0.19**	3.00	2.75	2.25

*: Stephen and Emmanuel (2009); **: Testing by HPLC based on AOAC (1995) 995.03 in house method

Consequently, the decrease of moisture content affected the increase of 'capsaicin quantity of dried chili compared to fresh chili. The experimental result showed drying time decreased with the increasing of drying temperature and drying air velocity shown in Fig. 2-4. It also found that the suitable condition for drying process was 90°C of drying chamber's temperature and the drying air velocity at 5 m sec^{-1}.

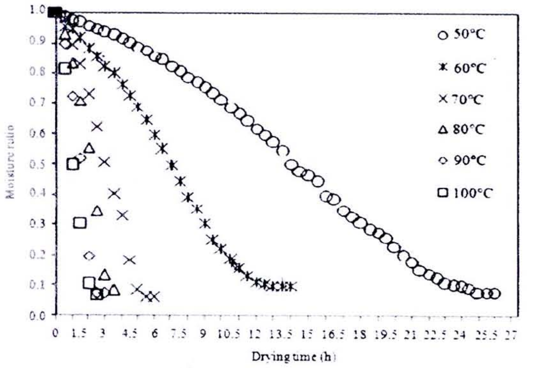

Fig. 3: Change of Moisture Ratio (MR) with drying time (h) on drying air velocity of 5 m sec^{-1}

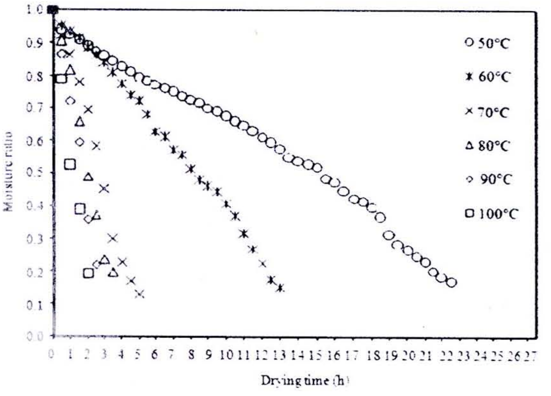

Fig. 4: Change of Moisture Ratio (MR) with drying time (h) on drying air velocity of 6 m sec^{-1}

Fig. 5: Photograph of dried chili on the temperature of 90 °C and drying air velocity of 5 m sec^{-1}

In addition, with the duration of 3 h, the chili's physical characteristics would turn into red, flat and shiny, crispy and no burning smell-showed in Fig. 5. It was found that the drying temperature affected the decrease of chili's weight and moisture content. The drying air velocity affected on the fluidized bed particles movement and the chili's continuous migration outwards the drying chamber.

The activation energy could be described based on Eq. 3. The Fig. 6 showed the increasing of the effective moisture diffusivity when drying temperature and drying air velocity increased. The result of the correlation graph between ($\ln D_{eff}$) and ($1/T_{abs}$) as shown in Fig. 7-9, the time (h) on drying air velocity of 5 m sec^{-1} obtained activation energy of diffusion Ea.

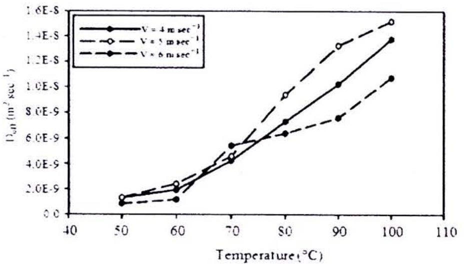

Fig. 6: The effective moisture diffusivity on drying temperature of 50, 60, 70, 80, 90 and 100°C and drying air velocity of 4, 5 and 6 m sec^{-1}

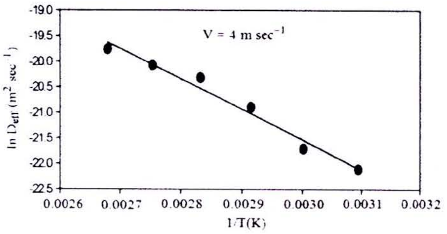

Fig. 7: The Arrhenius relationship between the effective diffusivities and temperature on drying air velocity of 4 m sec^{-1}

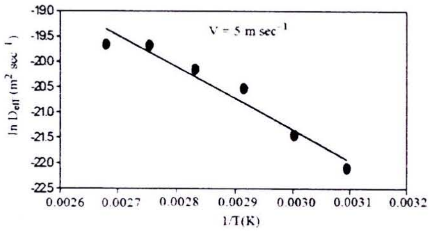

Fig. 8: The Arrhenius relationship between the effective diffusivities and temperature on drying air velocity of 5 m sec^{-1}

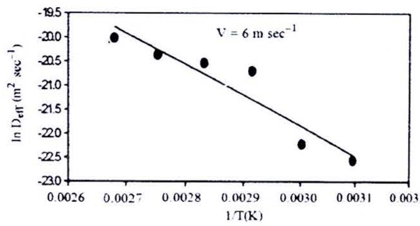

Fig. 9: The Arrhenius relationship between the effective diffusivities and temperature on drying air velocity of 6 m sec^{-1}

This was calculated as 49.7299, 51.8564 and 53.5419 MJkg mol^{-1} on 4-6 m sec^{-1} of drying air velocity, respectively. Thus, the air velocity affected the change of chili's activation energy.

CONCLUSION

Drying temperature was the significant factor of the chili moisture content reduction and the increase of capsaicin quantity substance of dried chili compared to fresh chili. The drying air velocity affected the move of chili particles. Drying was continued until chili were drifted or continuously moved from drying chamber under continuous fluidized-bed drying process. The suitable condition result of this study was drying temperature of 90°C, drying air velocity of 5 m sec^{-1} and drying time of 3 h because of the best physical characteristic of dried chili, high compound capsaicin and the shorten drying time. Consequently, the increase of drying air temperature and drying air velocity affected on the increase of the effective moisture diffusivity.

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