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Determination of Thermal Properties of Coriander Seeds Anditsvolatile Oil (Coriandrumsativum)

Vijay Singh Sharanagat

Abstract:-

The effect of temperature and moisture content on the thermal properties such as thermal conductivity, specific heat andbulk thermal diffusivity was evaluated. The thermal conductivity was measured by the transient technique using a line heat source. The maximum slope method was used to analyse the line source heating data for thermal conductivity determination. The specific heat capacity was measured by different scanning calorimetry and ranged from 730 to 4014 J/kg k at 3 to 15% mc (w.b.). The thermal conductivity of coriander seeds ranged from 0.0406 to 0.0989 W /m k and increased with moisture content in the range of 8 to 16 % mc (w.b.). Thethermal diffusivity ranged from9.67823E-08to 1.68255E-07 m2/s at 8% mc (w.b.).such Thermal properties are useful in designing and fabrication of ambient and cryogenic grinding system for spices and other similar commodities.

Introduction:

Corianders seeds are dried when they are ripe .They have an aromatic odor and agreeable spicy test. The seed consist of moisture 11.2percent, protein 14.1percent, fat 16.1percent, minerals 4.4percent, fiber 32.6percent and carbohydrates 21.6percent per 100 grams. Their mineral and vitamin content are calcium, Iron, phosphorous, carotene, thiamine, riboflavin, niacin. Coriander juice is highly beneficial in deficiencies of Vitamin A, B1, B2, C and iron.

Thermal conductivity, thermal diffusivity andspecific heat capacity are three important engineeringproperties of a material related to heat transfercharacteristics. These parameters are essential in studying heating, drying and cooling processes for coriander seeds,Measurement of the thermal conductivity of agricultural products of various types such as granular materials byK. K. DUA and T.P. OJHA(1969), Physical properties of coriander reported by YalcinCoskuner and ErsanKarababa (2006).

Specific heatmeasurement method, differential scanning calorimetry (DSC) has been the most accurate and rapid method. Develop relationship between specific heat,temperature and moisture content ofborage seeds and described DSC by Yang et al. (2002), Most of the methods have been employed by researcher in determining the specific heat of food, seeds and agricultural materials by Mohsenin N N[5]. Thermal properties of cumin seed are determined by K.K. Singh and T.K. Goswami (2000).The objective of this study is to determine the thermalconductivity, specific heat capacity and thermal diffusivity of coriander seeds as a function of seed moisture content and temperature.

1. Materials and methods

1.1 Sample preparation

Coriander seeds for analysis were obtained from a CIPHET. The seeds were conditioned to five different moisture contents ranging from 3 to15 w.b.For lower moisture content of the sample, the predetermined quantity of coriander seed was dried down to the desired moisture content. The calculated amount of distilledwater was added to achieve higher moisture content. The samples were dried in vacuum drying oven at 72^{o}C (recording mc at every 15 min interval) to achieve below 11.2 percent mc. Samples were stored in sealed, moisture free and water proof flexible polythene bags. The samples were kept at five oC in arefrigerator for one week to allow the moistureto uniformly distribute into the Coriander seeds. The moisture contents of the samples were determined using the **HB43-S Halogen** Moisture Analyser.

1.2 Thermal conductivity measurement

Thermal conductivity, *k*, is the property of a material's ability to conduct heat. Thermal conductivity is measured in watts per meter kelvin (W/(m·K)) or $W{\cdot}m^{-1}{\cdot}K^{-1}$.Thermal conductivity is primarily dependent on composition, but also on any factor that affects the heat flow paths such as porosity and shape, size and arrangement of void spaces, homogeneity, fibers and their orientation (Sweat 1986). The line source method is the most widely used transient-state method.The thermal conductivity was measured by using Quick Thermal Conductivity MeterKemtherm QTM-D3, (Kyoto Electronics, Manufacturing (KEM) Co.Ltd,Tokyo, Japan). In this uses a thermal conductivity probe as a heating source, and estimates the thermal conductivity based on the relationship between the sample core temperature and the heating time. In principle, the heat is generated in a hot wire at a rate q in W:

$$Q = I^2R \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where I is the electric current in A and R is the electric resistance in ohm/m.
To make a measurement, the probe was put on the material of interest. From thermal equilibrium, the probe heater was energized and heated the medium with constant power. The temperature rise at the heat source was monitored. Following a brief transient period, the plot of the temperature versus the natural logarithm of time became linear. The slope was equal to Q/(4πk). The thermal conductivity could be calculated from the relation:

$$k = Q(ln\frac{t_2-t_0}{t_1-t_0})/4\pi(T_2 - T_1)……………..(2)$$

Where k = thermal conductivity of sample [W/m°C]
Q = power dissipation by heater wire [W/m]
t_1 = time since probe heater was energized [s]
t_2 = time since probe heater was energized [s]
t_0 = time correction factor [s]
T_1 = temperature of probe thermocouple at time t1 [°C]
T_2 = temperature of probe thermocouple at time t2 [°C]

The time correction factor t_0 compensates for the finite size of the probe and for differences in properties between sample and probe material. Its value is calculated from the data. Equation (2) shows a linear relationship between (T2 – T1) and ln(t) with the slope $s = Q/4\pi k$. The slope S can be obtained from the experimental data of (T2-T1) versus ln(t) by linear regression, and the thermal conductivity can then be calculated from the linear slope S:

$$k = \frac{Q}{4\pi S}……………..(3)$$

1.3 Measurement of specific heat capacity

Specific heat, Cp is the amount of heat needed to raise the temperature of unit mass by unit degree at a given temperature. The SI units for Cp are therefore (kJ /(kg K)). Specific heat of solids and liquids depends upon temperature but is generally not sensitive to pressure. It is common to use the constant pressure specific heat, Cp, which thermodynamically represents the change in enthalpy H (kJ Kg–1) for a given change in temperature T when it occurs at constant pressure P:

$$Cp = (\delta H/\delta T)_P \quad ………………… (4)$$

Only with gasses is it necessary to distinguish between Cp and Cv, the specific heat at a constant volume. Assuming there is no phase change, the amount of heat Q that must be added to a unit mass M (kg of mass or specific weight kg/m3) to raise the temperature from T2 to T1 can be calculated using the following equation:

$$Q = MCp (T2-T1) ………………(5)$$

Differential scanning calorimetry or **DSC** is a thermo-analyticaltechnique in which the difference in the amount of heat required to increase the temperature of a sample and reference is measured as a function of temperature. Both the sample and reference are maintained at nearly the same temperature throughout the experiment. Generally, the temperature program for a DSC analysis is designed such that the sample holder temperature increases linearly as a function of time.

Differential scanning calorimeter technique was used to determine the specific heat capacity of coriander powder attemperatures ranging from -90 to 90^{0}C by thermal analyser (DSC 204 Phoenix, Thermische Analyse, NETZSCH, Germany).DSC experimentalprocedure for cumin seed described by K.K. Singh and T.K. Goswami (2000).DSC thermogramdescribes the heat flow rate as a function of temperature, from which the specific heat of the sample is determined .In brief,Specific heat capacity (Cp) is a material property describing the energy required to induce a certain change in the temperature of a unit mass of the material. To measure this quantity, a differential scanning calorimeter (DSC) may be used. The DSC measures specific heat capacity by heating a sample and measuring the temperature difference between the sample and a reference. In test Reference and sample crucibles are placed on a sample carrier within a furnace of cylindrical geometry which generates heat radially toward the center. Temperature is detected by thermocouples in contact with each crucible. One thermo-element is shared between the crucibles allowing the temperature difference to be measured as a voltage. Three measurements are necessary for calculating specific heat. First a “Baseline” is recorded. This is the response with both crucibles empty, yielding a signal bias inherent in the system. Next is a reference test, in which a sample with a well-defined specific heat is tested for comparison to an experimental sample. Finally, an experimental sample is tested. The “Baseline” allows removal of system bias from the data, while the reference test allows calculation of the specific heat of the experimental sample as a ratio of the reference material specific heat.

Sample crushed and a portion of the powder obtained was filled in the aluminium crucible (6 mm diameter and 1.5 mm deep) which was covered with an aluminium lid. The sample was brought to the initial temperature of -150 oC by cooling with liquid nitrogen. It was allowed to equilibrate isothermally and then scanneddynamically at the rate of 10^{0}C min^{-1} over theselected temperature range of-150 to200^{o}C. Finally,the weighed five milligram sample ofcoriander was taken to run the experiment for specific heat.The DSC provided thermogram, in which ordinate shows the heat flow rate mW/mg as a function of time and temperature. The thermogram is used to evaluate the specific heat of the sample. The thermogram obtained is shown in Fig. 2.With the help of this thermogram using the Proteus Analysis software the desired results such as specific heat, latent heat, solidification point, melting point, and glass transition temperature were evaluated. All experiments were performed in triplicate and the mean values were reported.

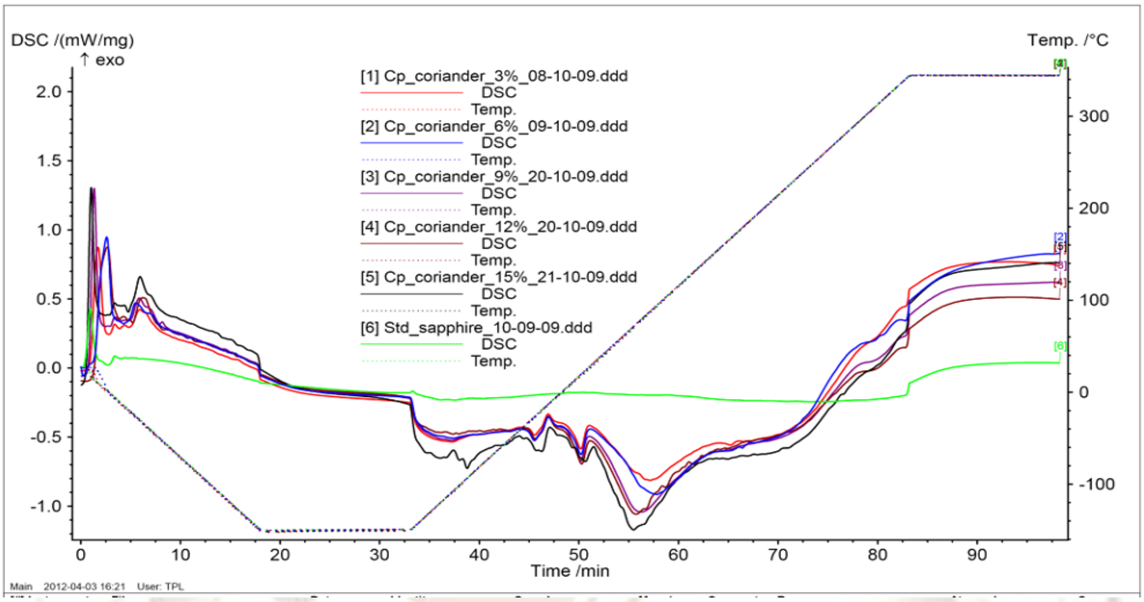


Fig.2 ThermogramFor Different Moisture Content

1.4 Thermal diffusivity

Thermal diffusivity determines the speed of heat of three-dimensional propagation or diffusion through the material. It is represented by the rate at which temperature changes in a certain volume of food material, while transient heat is conducted through it in a certain direction in or out of the material (depending if the operation involves heating or cooling).Thermal conductivity, thermal diffusivity and specific heat capacity each can be measured by well-established methods, but measuring any two of them would lead to the third through the relationship

$$\propto = \frac{k}{\rho c_p} \text{.................}(6)$$

Where α is the thermal diffusivity, k is the thermal conductivity, ρ is the bulk density and Cp is the specific heat. Eq. (6) shows that αis directly proportional to the thermal conductivity at a given density and specific heat. Physically, it relates the ability of the material to conduct heat to its ability to store heat.

Bulk density is a property of powders, granules and other "divided" solids, especially used in reference to mineral components (soil, gravel), chemical substances, (pharmaceutical) ingredients, foodstuff or any other masses of corpuscular or particulate matter. It is defined as the mass of many particles of the material divided by the total volume they occupy(11, 12). The total volume includes particle volume, inter-particle void volume and internal pore volume.The average bulk density of coriander was determined by using a container of known volume. The container was weighed. Then container was filled with coriander seeds and weights it and subtracted weight of container from total weight.

$$Bulkdensity(Kg/m3) = \frac{Weightofknownvolumeof Grains}{Volumeof Grains}$$

Glass transition temperature:

The glass transition temperature (Tg) of a non-crystalline material is the critical temperature at which the material changes its behaviour from being 'glassy' to being 'rubbery'. 'Glassy' in this context means hard and brittle (and therefore relatively easy to break), while 'rubbery' means elastic and flexible.

2.5 Results and discussion

1.5 .1 Thermal conductivity

Figure 3 shows triplicate thermal conductivity data of coriander seeds as a function of moisture content(w.b.)8 to 16 and 10 to30^{0}C initial temperatures. The average thermal conductivity of coriander seeds varied from 0.0406 to 0.0989 W/m K, depending upon sample temperature and moisture content. It was observed that the thermal conductivity increased with increasing temperature and moisture content of the seed material and results are shown in Eq. (7). The increase is because of the Increase in mc increases the bulk thermal conductivity as moisture has higher thermal conductivity than that of air.

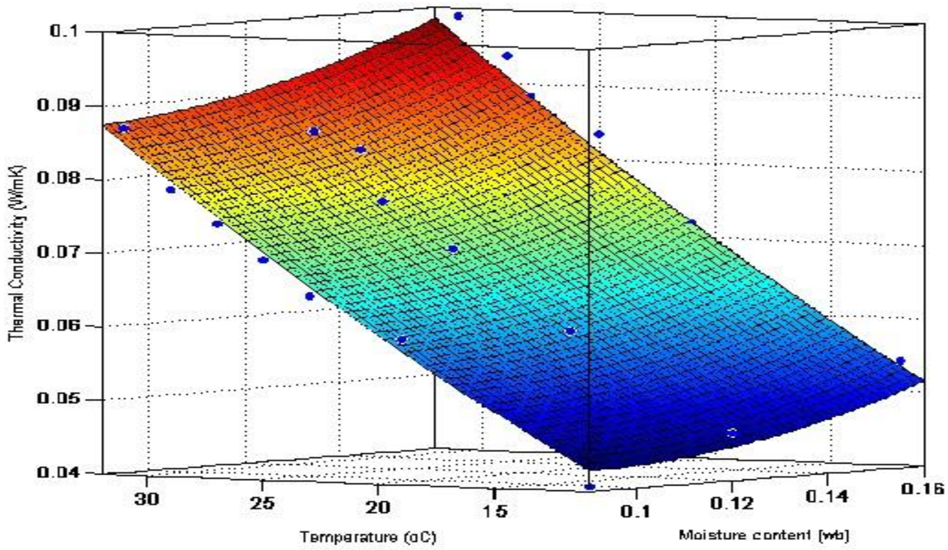


Fig. (3)Variation in thermalconductivity with moisture content and temperature

$$K = -0.008149 + 0.3714 * M + 0.002156 * T - 0.3393 * M^2 - 0.007604 * M * T + 1.837e - 005 * T^2 \; (R^2=0.9581)$$

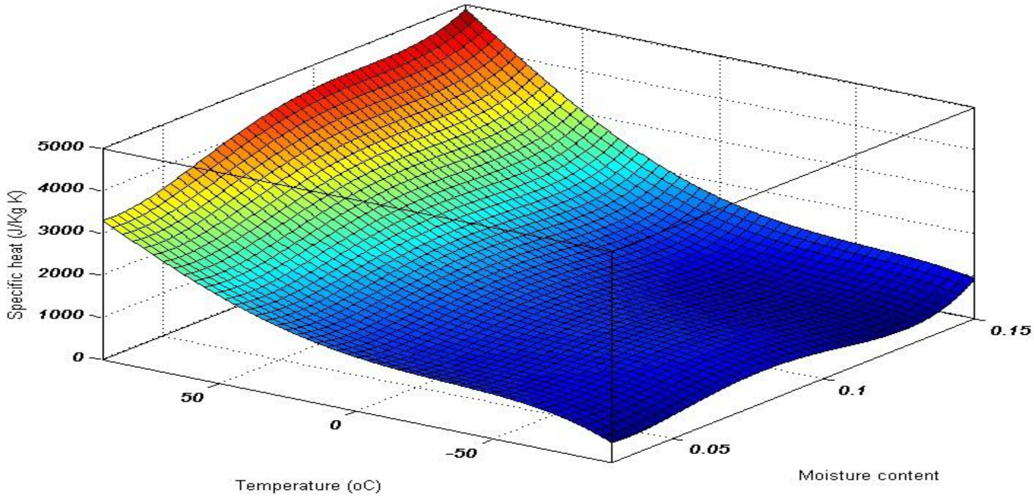
……………………………..Eq.(7)

2.5.2 Specific heat capacity

Fig. 4 Illustrates a typical DSC thermogram of specific heat of coriander seed at different moisture content of 3 to 15 % wet basis. The thermal analysis processor evaluated the specific heat over the rangeof -90 to 90 °C. The data of the five samples at 3 to 15% MC wet bases are analysis. Replication was good as demonstrated by the high values of the R^2.

Sample	MC%(w.b.)	Temp.	Fitted Equation	R^2
1	3	-90 – 90	C_p = 9E-05T^2 + 0.0126T+1.2921	0.9611
2	6	-90 – 90	C_p = 1E-04T^2 + 0.0137T+1.3439	0.9505
3	9	-90 – 90	C_p = 0.0001T^2 + 0.0179T+1.4435	0.9596
4	12	-90 – 90	C_p = 0.0002T^2 + 0.0195T+1.1219	0.9656
5	15	-90 – 90	C_p = 0.0001T^2 + 0.0197T+1.7182	0.9531

As the temperature was raised from -90 to 90^0C, specific heat was found to increase from 730 to 4014Jkg-1 K-1 as shown in Fig. (4), with increasing mc from 3 to 12% (w.b).Eq. (8) shows the relationship of specific heat with increasing mcand temperature among the moisture content, temperature and specific heatThe specific heat increased with moisture content but not linearly as reported by other research workers (Kazarian& Hall, 1965; Dutta et al., 1988; Murata et al., 1987; Mohsenin, 1980; and Hsu et al., 1991)



Fig(4)Variation in specific heat with varying temperature and moisture content

$$Cp = 3430 - 1.409e^{5}M + 9.843T + 3.011e^{6}M^{2} - 151MT + 0.07873T^{2} - 2.57e^{7}M^{3} + 3422M^{2}T + 1.953\,MT^{2} + 0.0009345T^{3} + 7.57e^{7}M^{4} - 1.399e^{4}M^{3}T - 7.213M^{2}T^{2} - 0.002914MT^{3} - 7.002e^{-6}T^{4}$$

(R^2=0.9645)………………………………..(8)

2.5.3 Thermal diffusivity

Thermal diffusivity was calculated according to Eq. (6). Variation in Bulk density of coriander seed with moisture content are shown in Equation (9).The average bulk density of coriander seeds in kg/ $m^3$was vary from 260 to 245.5 in 8 to 15 % MC (w.b). As we increases the moisture content of seeds bulk density decreases.

$\rho = 264.48 - 0.6039M$(R^2=0.9741)……………(9)

The relationship between temperature and thermal diffusivity at different moisture contents is shown in Fig.5. It can be observed that the thermal diffusivity increased with increase in temperature at all the moisturecontents and followed a second order polynomial relationship. The thermal diffusivity varied from $9.67823E^{-08}$to$1.68255E^{-07}$ m^2/s with increase in temperature from 10°C to30 0C for the moisture content of 8% (w.b).The variation of thermal diffusivity with moisture content and temperature exhibited a second order polynomial relationship.The increase in thermal diffusivity at the different moisturecontent may be due to fact that thevalue of bulk density decreased at these moisture content(13).

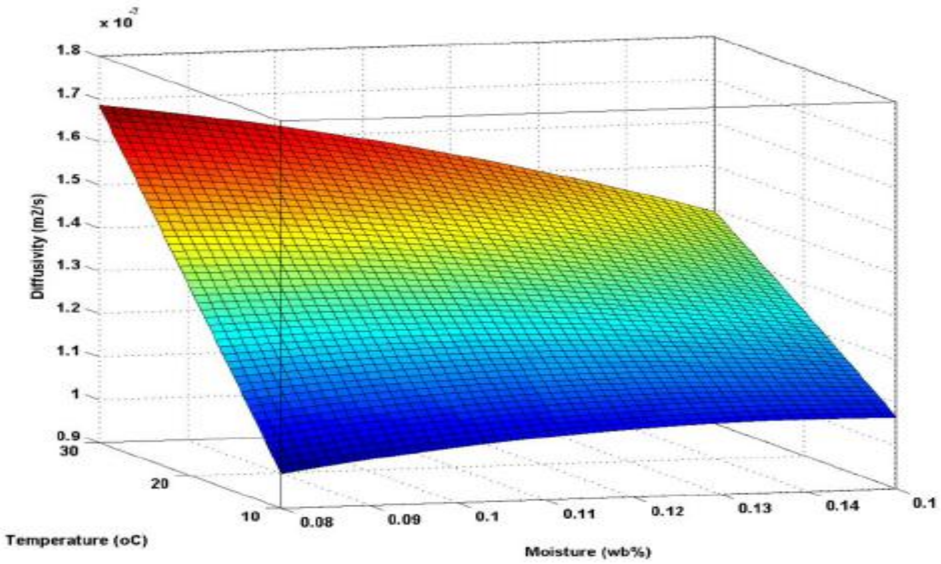


FIG.(5) VARIATION IN THERMAL DIFFUSIVITY WITH MOISTURE CONTENT AND TEMPERATURE

$$\alpha = 2.425e^{-009} + 9.305e^{-007}M + 5.81e^{-009}T - 2.34e^{-006}M^2 - 2.696e^{-008}MT - 3.358e^{-012}T^2$$

(R^2=0.9996) …………(10)

2.5.4 Glass transition temperature

DSC defines the glass transition as a change in the heat capacity as the polymer matrix goes from the glass state to the rubber state. This is a second order endothermic transition (requires heat to go through the transition) so in the DSC the transition appears as a step transition(Fig.5) and not a peak such as might be seen(Fig.6) with a melting transition and it is always lower then melting temperature.From the DSC thermogram analysis of coriander oil (Fig.5) the glass transition temperature was found to be onset -32.3 °C, mid -30.6 °C and end point -29.5 oC. Fig.5 shows thermogram with different stages of coriander oil in a temperature range -50 to 80 oC .fig.5 shows temperature of crystallization and melting process are in rang , these process are not a one temperature process.

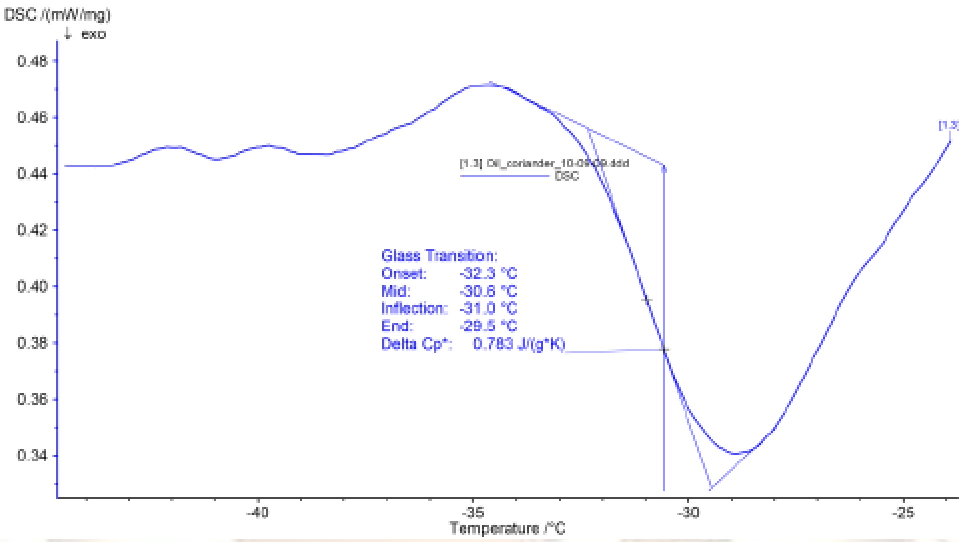


FIG.(5) GLASS TRANSATION TEMPERATURE OF CORIANDER OIL

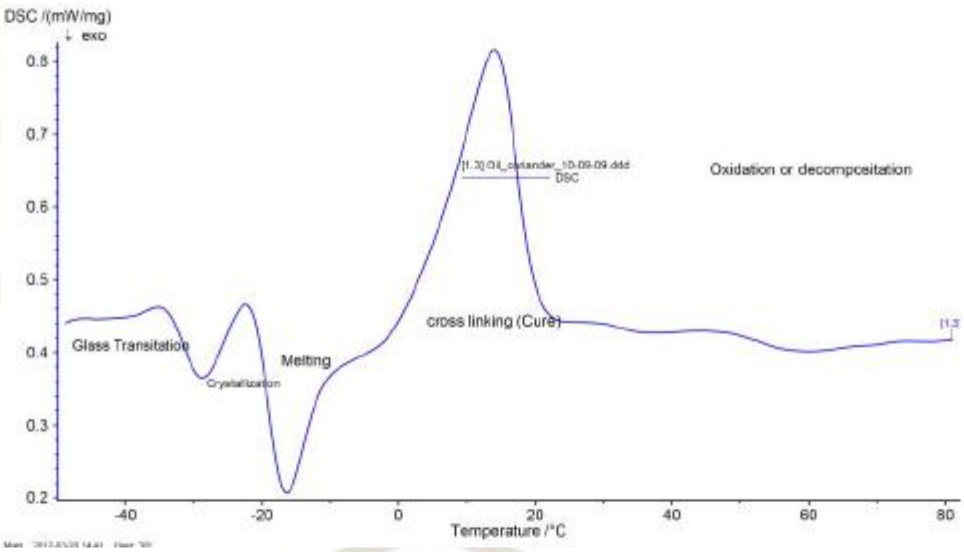


Fig.(6)DIFFERENT STAGES OF CORIANDER OIL

Conclusions

1. The specific heat increased from 730 to 4014.6 J/(kg K) with increase in temperature from -90 °C to 90°C and moisture content from 3% to 15% wet basis. Its variation with temperature and moisture content is best represented by fourth order polynomials.
2. Thermal conductivity increased from 0.0406 to 0.0989 W/m K with increase in temperature from 10°C to 30°C and moisture content from 8 % to 15 wet basis. Its variation with temperature and moisture content is best represented by second order polynomials.
3. Thermal diffusivity increased from $9.67823E^{-08}$to$1.68255E^{-07}$ m^2/s with increase in temperature from 10 to 30 °C at moisture content of 8% wet basis. And it also followed second order polynomial relationship.

4. Glass transition temp of coriander oil was found to be onset -32.3 ^oC, mid -30.6 ^oC and end point -29.5 ^oC.

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