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Comparative Study on Thermal Conductivities of Nigerian Fruit Liquids

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ABSTRACT

Experimental studies were carried out in order to evaluate the thermal conductivity of Nigerian Fruit Liquidfrom (Cucumber, Watermelon and Tomato), under steady-state conditions. A rig was designed to carry out the experiment for measurements of the effect of temperature and Fruit medium directions on the thermal conductivity of Nigerian Fruit Liquids. Experiments were carried out within a distance of holes 20*mm* effort where thermometer probes were fixed. The heating element is a carbon-steel of 10*mm* thickness of 1000*watts*. Digital thermometer is instrumented on all Fruit medium structure directions sphere the experimentations on each tested Fruit Liquid sample. The heating element is electrically heated by varying the heat input with rheostat, at interval of 20 *volts* at 20 *minutes* heating. Experiments were run at different Fruit medium structure directions of heat flow between 15 to 180 *watts*. Results obtained were analyzed by calculating for the thermal conductivity $K\ (w/m.^{o}C)$ in the directions of the Fruit medium for each sample. A dimensionless linear regression correlation equation was done, based on the thermal conductivity, K, and temperature, T. It was observed that by linear regression, the correlation ofthermal conductivity of Nigerian Fruit Liquid varies between 0.04. to 0.5 $w/m^{o}C$, under the range of temperature T between 10 to 100^{o}C .The correlation for K with T: - $K = a + bT$. $K_{ma} = -0.4798 + 0.0409T, -0388 + 0.388T, -0.308 + 0.0316T$, *for Fruit Liquid in Radial direction* $K_{a} = -0.389 + 0.0335T, -0.212 + 0.0229T, -0.351 + 0.031T$, *for Fruit Liquid in Longitudinal direction.* $K_{me} = -0.205 + 0.0211T, -0.349 + 0.246T, -0.422 + 0.0321T$, *for Fruit Liquid in Tangential direction*

Keywords: Thermal conductivity, Nigerian Fruit Liquid, Temperature, Longitudinal, Radial and Drain directions

INTRODUCTION

Fruit Liquid is a water medium, permeable material [1]. The unique structure of Fruit Liquid causes the water apricots nature of Fruit Liquid in its mechanical and physical properties. Thermal conductivity of Fruit Liquid has been studied by many scientists. According to [2] the ability of a material to conduct heat as a result of transmitting molecular vibrations from one atom or molecule to another varies greatly depending upon the chemical nature of the material and its gross structure and feel. The thermal conductivity of Fruit Liquid varies in the three main directions of Fruit Liquid as they are usually referred to in the Fruit Liquid beverage industry – Longitudinal direction (parallel to the Fruit medium, along the length of a fruit), Radial direction, (perpendicular to the Fruit medium , along the radius of the cross section) and Tangential direction (perpendicular to the gain, tangent to each growth sphere) [3]. The Fruit medium structure of Fruit Liquid in these three directions is different. Most of the apricots properties of Fruit Liquid are due to this structure difference.The thermal conductivity of Cucumber(*in-between hard and soft Fruit Liquid*) and Watermelon (*hard Fruit Liquid*) and Tomato (*soft Fruit Liquid*) are all in their Fruit medium directions. Their thermal conductivity was determined for all three directions (radial, tangential and longitudinal) depending on a number of factors with varying degree of importance [4]. The more significant variable affecting the rate of heat flow in these Fruit Liquids are (1) Density of Fruit Liquid (2) Moisture content of Fruit Liquid (3) Direction of heat flow with respect to the Fruit medium [5]. Extractives or chemical substances in the Fruit Liquid and defects, etc.. When a temperature gradient exists in a body, experience has shown that there is an energy transfer from the high-temperature region to the low-temperature region. We say that the energy is transferred by conduction and that the heat-transfer rate per unit area is proportional to the normal temperature gradient, [5].

$$\frac{q}{A} \alpha \frac{\partial T}{\partial x} \tag{1}$$

.

When the proportionality constant is inserted

$$q = KA\frac{\partial T}{\partial x} \tag{2}$$

where *a*re presented the heat-transfer rate of various liquid and ∂T/∂x is the temperature gradient in the direction of heat flow. The constant k is called the thermal conductivity of the liquids, and the minus sign is inserted so that the second principle of thermodynamics will be satisfied i.e. heat must flow downhill on the temperature scale, as indicated in the coordinate system of Figure.1

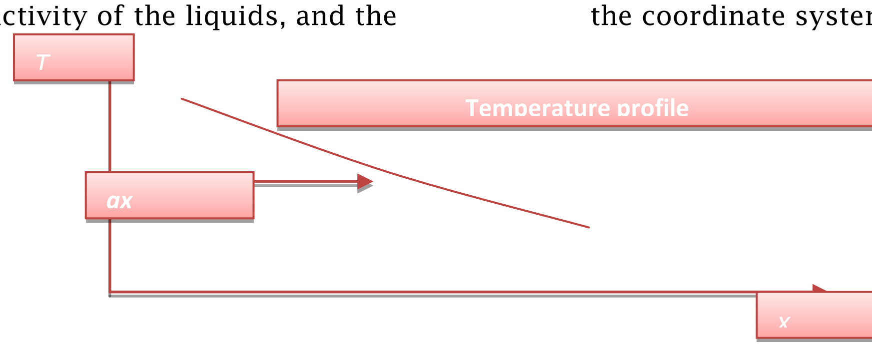

Figure. 1: Heat flow downhill on the temperature scale

Equ.1 is called Fourier's law of heat conduction after the French mathematical physicist Joseph Fourier, who made very significant contributions to the analytical treatment of conduction heat transfer. It is important to note that this Equ. 1 is the defining equation for the thermal conductivity and that k has the units of watts per meter per Celsius degree in a typical system of unit on which the heat flow is expressed in watts.We now set ourselves the problem of determining the basic equation that governs the transfer of heat in a solid, using Equ. 1as a starting point with Figure 2.

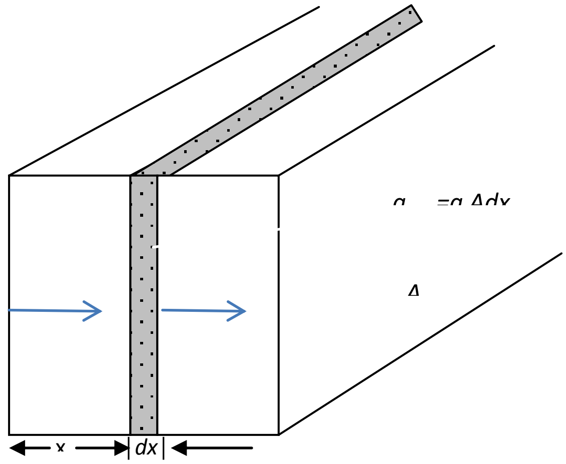

Figure. 2: Elemental Volume for one-Dimensional Heat-Conduction Analysis

Thermal conductivity has been shown by many scientists to have a very close relationship with the Fruit Liquid structure and moisture. The ability of a material to conduct heat as a result of transmitting molecular vibrations from one atom or molecule to another varies greatly depending upon the chemical nature of the material and its gross structure or texture. Thermal conductivity, k, is expressed in terms of quantity of heat, *Q* that flows across unit thickness *x*, of a material with a unit cross section, A under unit temperature difference between the two faces, T, in unit time, t:

$$k = \frac{Q * x}{A * T * t} \quad (3)$$

The heat conductivity of Fruit Liquid is dependent on a number of factors with varying degree of importance. The more significance variables affecting the rate of heat flow in Fruit Liquid are ; 1) Density of Fruit Liquid; 2) moisture content of Fruit Liquid; 3) direction of heat flow with respect to the Fruit medium ; 4) relative density; 5) extractives or chemical substances in the Fruit Liquid, and defects, etc. from numerous and varied factors affecting thermal conductivity of Fruit Liquid, Van Dusen first found that there was nearly a linear relationship between conductivity and density. So did [6].

METHODS

The Fruit Liquids were cut out from the source and machined to a given profile. This process was achieved with the aid of a machine cutter with an adjustable horizontal blade. After cutting, the length and width of the Fruit Liquids are 0.18m and 0.13m respectively. The Fruit Liquid was reduced to a thickness of 0.13m with the aid of a Fruit Liquid saw or smoother. The different Fruit Liquid sample or test piece selected for the tests include: *Cucumber, Watermelon and tomato*. The sample were cut into rectangular box shape. The length and width of the Fruit Liquid samples is 180mm by 130mm while the thickness is 130mm.Four tiny holes of diameter 5mm and 70mm depths were drilled in the Fruit Liquid sample. Four holes on ach sample consider sphere the Fruit medium structure direction. Two holes up and three holes down, all the holes are 50mm apart. The two lower holes sample while the two upper holes are of the same height from the bottom of the Fruit Liquid sample as well. The lower holes on the radial Fruit medium direction for each Fruit Liquid samples is label x_{L1} and x_{L2} while the upper holes are labeled x_{H1} and x_{H2}.On the other side, for longitudinal Fruit medium direction, the lower holes are labeled y_{L1} and y_{L2}, while the upper holes are labeled $y_{H1}$and y_{H2}.

The holes for tangential Fruit medium direction has Z denotations; these holes are the point from which temperature readings are taken while the x_L, x_H, y_L, y_H, z_L and z_H are the height or distance at which temperature readings are taken. x_L, y_L and z_L is 30mm from the bottom of the Fruit Liquid sample, x_H, y_H, and z_H is 50mm from the bottom of the sample; d_x, d_y, and d_z is 20mm.

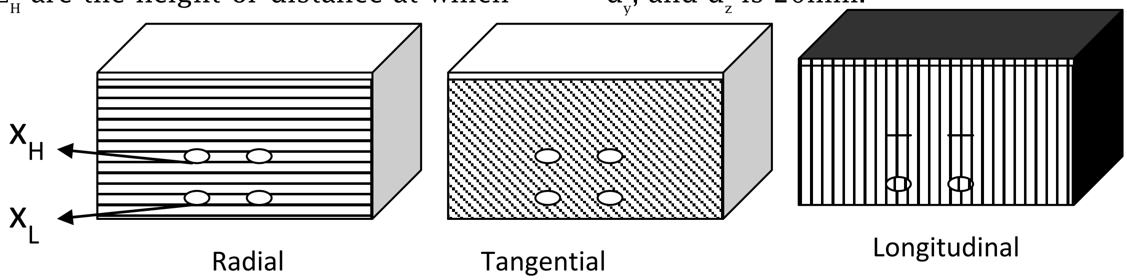

Figure 3: Fruit sample in grain structure directions

Longitudinal direction (parallel to the Fruit medium , along the length of a fruit), radial direction (perpendicular to the Fruit medium , along the radius of the round fruit on the cross section), and tangential direction (perpendicular to the Fruit medium , tangent to each growth sphere).

Figure4: set up fruit sample in laboratory

Experimental Procedure

The rig was plugged to the source of power. The lagged Fruit Liquid sample is placed on top of the rig. The thermometer probes which were connected to the digital thermometer for taking the temperature reading is inserted into each of the X_L and the corresponding X_H. The rig is then switched on and the voltage is regulated by the rheostat to 40 volts. The ammeter reading is also taken for the corresponding current before heating the atmospheric temperature was taken. The Fruit Liquid sample is allowed to heat for 20 minutes and temperature at X_L and the corresponding X_H are taken from the digital thermometer. This same test was carried on each of the four holes drilled on the sample of the Fruit Liquid in X (radial grin direction) using the same procedure.The same procedure or process was repeated when the voltage was increased to 60 volts, 80 volts, 100volts, 120 volts, 140 volts and 160 volts and their corresponding current for the same Fruit medium structure direction.This experiments was carried out on radial Fruit medium structure direction X, longitudinal Fruit medium structure direction Y and tangential Fruit medium structure direction Z.

RESULTS AND DISCUSSIONS

Results of Cucumber Analysis

Table 1: Cucumber in Radial Fruit medium Direction

S/N	V	I	Q	T_{L1}	T_{L2}	T_{LM}	T_{H1}	T_{H2}	T_{HM}	T_{LM}-T_{HM} (*dT*) *°C*
	Volts	*Amp*	*watts*	*°C*	*°C*	*°C*	*°C*	*°C*	*°C*	
1	40	0.4	16	37	37	37	26	26	26	11
2	60	0.5	30	40	40	40	26	26	26	14.
3	80	0.6	56	42	43	42.5	27	27	27	15.5
4	100	0.7	80	45	45	45	27	28	27.5	17.5
5	120	0.8	96	49	48	48.5	28	28	28	20.5
6	140	0.9	126	52	52	52	30	30	30	22
7	160	1.1	17.6	53	56	54.5	31	32	31.5	23

Table 2: Cucumber in Longitudinal Direction

S/N	V	I	Q	T_{L1}	T_{L2}	T_{LM}	T_{H1}	T_{H2}	T_{HM}	T_{LM}-T_{HM} (*dT*)
	Volts	*Amp*	*watts*	*°C*	*°C*	*°C*	*°C*	*°C*	*°C*	*°C*
1	40	0.4	16	39	39	39	26	27	26.5	12.5
2	60	0.5	30	40	41	40.5	27	26	26.5	14
3	80	0.6	56	44	44	44	27	28	27.5	16.5
4	100	0.7	80	48	46	47	28	28	28	19
5	120	0.8	96	49	50	49.5	28	29	28.5	21
6	140	0.9	126	52	53	52.5	31	30	30.5	22
7	160	1.1	176	57	57	57	32	32	32	25

Table 3: Cucumber in Tangential Direction

S/N	V	I	Q	T_{L1}	T_{L2}	T_{LM}	T_{H1}	T_{H2}	T_{HM}	T_{LM}-T_{HM} (*dT*) *°C*
	Volts	*Amp*	*watts*	*°C*	*°C*	*°C*	*°C*	*°C*	*°C*	
1	40	0.4	16	37	38	37.5	26	27	26.5	11
2	60	0.5	30	40	40	40	27	27	27	13
3	80	0.6	56	43	42	42.5	27	28	27.5	15
4	100	0.7	80	45	46	45.5	28	28	28	17.5
5	120	0.8	96	49	48	48.5	29	28	28.5	20
6	140	0.9	126	52	52	52	30	30	30	22
7	160	1.1	176	54	55	54.5	31	31	31	23.5

Results of Watermelon analysis

Table 4: Watermelon in Radial Direction

S/N	V *Volts*	I *Amp*	Q *Watts*	T_{L1} *°C*	T_{L2} *°C*	T_{LM} *°C*	T_{U1} *°C*	T_{U2} *°C*	T_{UM} *°C*	T_{LM}-T_{UM} *(dT)* *°C*
1	40	0.4	16	38	39	38.5	26	26	26	12.5
2	60	0.5	30	41	40	40.5	26	27	26.5	14
3	80	0.6	56	43	43	43	27	27	27	16.5
4	100	0.7	80	47	47	47	28	28	28	19
5	120	0.8	96	50	50	50	28	29	28.5	21.5
6	140	0.9	126	53	53	53	30	30	30	23
7	160	1.1	176	56	55	55.5	32	31	31.5	24

Table 5: Watermelon in Longitudinal Direction

S/N	V *Volts*	I *Amp*	Q *watts*	T_{L1} *°C*	T_{L2} *°C*	T_{LM} *°C*	T_{U1} *°C*	T_{U2} *°C*	T_{UM} *°C*	T_{LM}-T_{UM} *(dT)* *°C*
1	40	0.4	16	40	40	40	27	27	27	13
2	60	0.5	30	42	42	42	27	27	27	15
3	80	0.6	56	45	44	44.5	27	28	27.5	17
4	100	0.7	80	48	46	47	28	28	28	19
5	120	0.8	96	51	51	29	29	29	29	22
6	140	0.9	126	55	55	55	30	30	30	25
7	160	1.1	176	57	58	57.5	31	30	30.5	27

Table 6 : Watermelon in Tangential Direction

S/N	V *Volts*	I *Amp*	Q *watts*	T_{L1} *°C*	T_{L2} *°C*	T_{LM} *°C*	T_{U1} *°C*	T_{U2} *°C*	T_{UM} *°C*	T_{LM}-T_{UM} *(dT)* *°C*
1	40	0.4	16	38	38	38	26	26	26	12
2	60	0.5	30	41	40	40.5	27	27	27	13.5
3	80	0.6	56	43	43	43	27	27	27	16
4	100	0.7	80	48	47	47.5	28	28	28	19.5
5	120	0.8	96	51	52	51.5	30	29	29.5	22
6	140	0.9	126	55	55	55	31	31	31	24
7	160	1.1	176	57	57	57	32	32	32	25

Result of Tomato Analysis

Table 7: Tomato in Radial Fruit medium Direction

S/N	V *Volts*	I *Amp*	Q *watts*	T_{L1} *°C*	T_{L2} *°C*	T_{LM} *°C*	T_{U1} *°C*	T_{U2} *°C*	T_{UM} *°C*	T_{LM}-T_{UM} *(dT)* *°C*
1	40	0.4	16	41	41	41	27	26	26.5	14.5
2	60	0.5	30	45	44	44.5	27	28	27.5	17
3	80	0.6	56	47	47	47	28	28	28	19
4	100	0.7	80	50	50	50	29	29	29	21
5	120	0.8	96	53	53	53	30	29	29.5	23.5
6	140	0.9	126	56	55	55.5	31	30	30.5	25
7	160	1.1	176	59	59	59	33	31	32	27

Table 8:Tomato in Longitudinal Direction

S/N	V *Volts*	I *Amp*	Q *watts*	T_{L1} *°C*	T_{L2} *°C*	T_{LM} *°C*	T_{U1} *°C*	T_{U2} *°C*	T_{UM} *°C*	T_{LM}-T_{UM} *(dT)* *°C*
1	40	0.4	16	42	42	42	27	27	27	15
2	60	0.5	30	46	46	46	28	28	28	18
3	80	0.6	56	50	51	50.5	29	30	29.5	21
4	100	0.7	80	56	56	56	32	32	32	24
5	120	0.8	96	61	61	61	34	34	34	27
6	140	0.9	126	65	66	65.5	36	36	36	29.5
7	160	1.1	176	69	70	69.5	38	37	37.5	32

Table 9: Tomato in Tangential Direction

S/N	V *Volts*	I *Amp*	Q *watts*	T_{L1} *°C*	T_{L2} *°C*	T_{LM} *°C*	T_{U1} *°C*	T_{U2} *°C*	T_{UM} *°C*	T_{LM}-T_{UM} *(dT)* *°C*
1	40	0.4	16	41	41	41	26	26	26	14
2	60	0.5	30	44	43	43.5	27	27	27	16.5
3	80	0.6	56	46	46	46	28	28	28	18
4	100	0.7	80	49	48	48.5	29	28	28.5	20
5	120	0.8	96	52	52	52	29	29	29	23
6	140	0.9	126	55	55	55	30	30	30	25
7	160	1.1	176	59	59	59	32	31	31.5	27.5

Linear Regression Correlation of K and T

From the Fourier equation of thermal conductivity

$$K = \frac{Q}{A} \times \frac{dx}{dT}$$

$K = n + mT$, $K = a + bT$

$y = a + bx$

where $m = b$

$n = a$

apply liner regression equation

$$y = bx + a$$

where :

$$b = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2}$$

$$a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$$

$$r = \frac{n\Sigma xy - \Sigma x\Sigma y}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

Comparisons on Thermal Conductivities of Nigerian Fruit Liquids

Investigation under Radial Test

Table 10 of graph Figure5 depicts that the range of *K* of Cucumber is 0.048 to 0.51 *w/m°C*, Watermelon 0.0479 to 0.506 *w/m°C* and Tomato 0.0476 to 0.502 *w/m°C*. It is therefore deduced that Cucumber has highest thermal conductivity followed by Watermelon, then Tomato under radial test.

Table: 10: Table of K of the Fruit LiquidSamples in Radial Direction

S/NO	ΔT (°C)	Watermelon-K (w/m, °C)	Cucumber-K (w/m, °C)	Tomato-K (w/m, °C)
1	12	0.0478	0.0489	0.0476
2	14	0.0893	0.0891	0.088
3	16	0.166	0.165	0.163
4	18	0.235	0.234	0.232
5	20	0.279	0.278	0.276
6	22	0.368	0.364	0.361
7	24	0.51	0.506	0.502

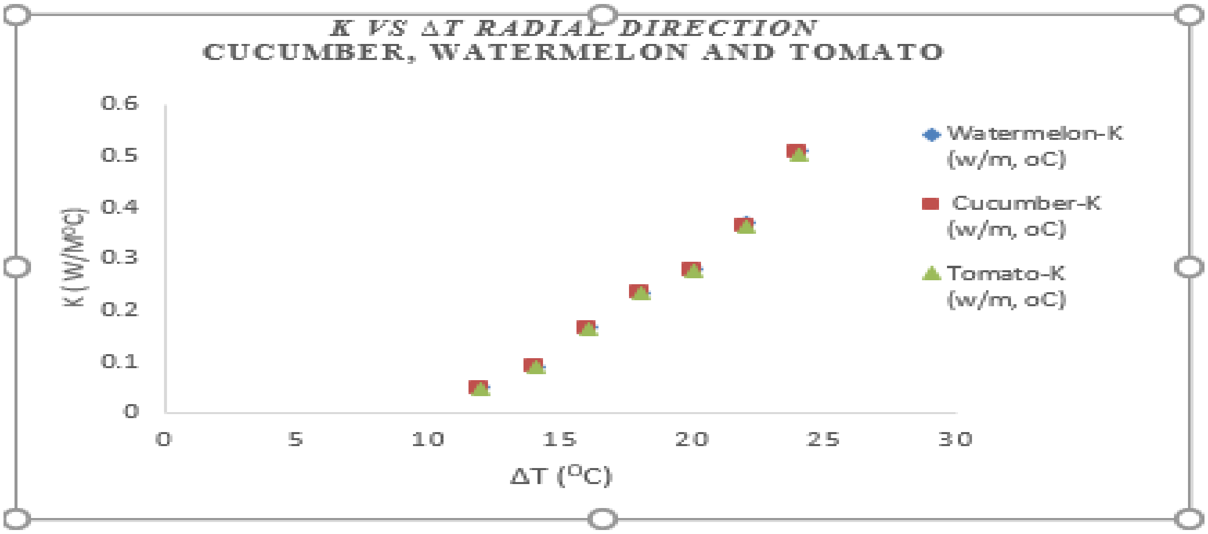

Figure5: K vs ΔT radial direction for the three samples

Investigation Under Longitudinal Test

Table 11 of graph Figure6 shows that the range of *K* of Cucumber is 0.047 to 0.51 *w/m°C*, Watermelon is 0.046 to 0.50 *w/m°C* while Tomato is 0.47 to 0.493 *w/m°C*. This shows that Cucumber has the highest *K* value followed by Watermelon and Tomato under longitudinal test.

Table 11 : K for the Fruit Liquid Samples in Longitudinal Direction

S/NO	ΔT (°C))	K - (w/m, °C) - Cucumber	K - (w/m, °C) - WATERMELON	K - (w/m, °C) - TOMATOE
1	14	0.047	0.046	0.0474
2	16.5	0.0891	0.089	0.088
3	19	0.165	0.165	0.164
4	21	0.234	0.233	0.230
5	23.5	0.278	0.276	0.2736
6	26	0.363	0.361	0.356
7	28	0.51	0.50	0.493

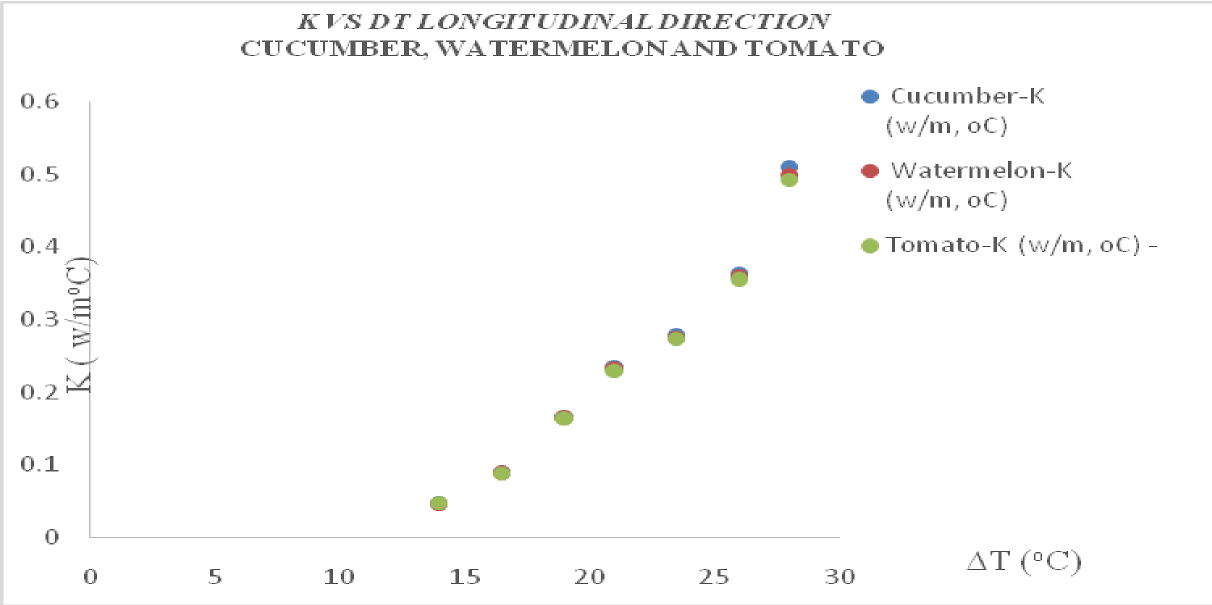

Figure6: K vs dT longitudinal direction for the three samples

Investigation Under Tangential Test

Table 12 of graph Figure 6 shows that the range of *K* of Cucumber is 0.048 to 0.51 *w/m°C*, Watermelon is 0.0476 to 0.496 *w/m°C* while Tomato is 0.0479 to 0.505 *w/m°C*. This means that Cucumber also has the highest *K* values followed by tomato then Watermelon under tangential test.

Table of 12: K for the Fruit Liquid Sample in Tangential Direction

S/NO	T (°C)	Watermelon-K (w/m, °C)	Cucumber-K (w/m, °C)	Tomato-K (w/m, °C)
1	13	0.048	0.049	0.0476
2	15	0.0892	0.0891	0.088
3	17	0.166	0.165	0.164
4	19.5	0.235	0.234	0.23
5	21	0.28	0.276	0.274
6	23	0.365	0.361	0.355
7	25	0.51	0.505	0.498

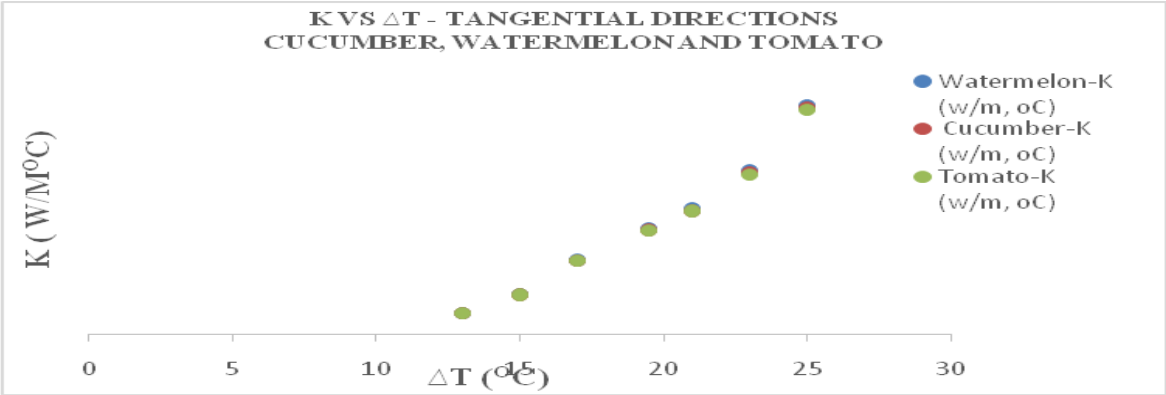

Figure6: K vs dT Tangential direction for the three samples

CONCLUSION

After experimental investigation on the three Fruit Liquid samples oncosphere their thermal conductivitiesthe following conclusions were deduced:Thermal conductivity of cucumber is highest in radial test with range of *K* - 0.048 to 0.51 *w/m^{o}C*, Watermelon 0.0479 to 0.506 *w/m^{o}C* and tomato 0.0476 to 0.502 *w/m^{o}C*.. The thermal conductivity of Cucumber is highest in longitudinal test with range of K - 0.047 to 0.51 *w/m^{o}C*, Watermelon is 0.046 to 0.50 *w/m^{o}C* while tomato is 0.47 to 0.493 *w/m^{o}C*.The thermal conductivity of Cucumber is also highest in tangential test with range of K - 0.048 to 0.51 *w/m^{o}C*, Watermelon is 0.0476 to 0.496 *w/m^{o}C* while tomato is 0.0479 to 0.505 *w/m^{o}C*. From the results obtained, it is shown that thermal conductivity of Fruit Liquid is a structure dependent property, which depend on the Fruit medium directions of Fruit Liquid in radial, longitudinal and tangential.

REFERENCES

1. Gronli, W.C (2013). Factors Affecting Thermal Conductivity of Fruit Liquid" Beabon publishing company Inc. U.S.A pp 41,63.
2. Haygreen, C.L and Browyer, E.D. (2010). Fruit Liquids Anatomical Structure" 2nd Edition, Ruston Publishing company Inc. U.S.A pp 254.
3. Kollman, W.A, and Cote, B (2009). Fruit Liquid and Its composite Materials", Spsphere – Veilag, New York, pp 52, 57.
4. Kollman, W.A and Malquist, B (2019). Theoretical Modeling of Thermal conductivity of Fruit Liquid" Encyclopedia of Fruit Liquid Materials, pp 661, 3rd Edition, New York Willey and Sons.
5. Moore, C,J (2000). Heat Transfer Across Surface in Contact" Studies of Transient in One-Dimensional Composite System, Southern Methodist Univ. Thermal /Fluid Sci. Ctri. Res. 67-1 Dallas, Tex, pp 231.
6. Rohsenow, W.M and J.P Hartnet (2008). Eds Handbook of Heat Transfer and Thermal conductivity, 20, New York; McGraw-Hill, pp 121.