Impact of Temperature on the Viscosity of Raw and Boiled Honey from Tabora, Tanzania

ABSTRACT

The study aimed at investigating and determining the viscosity of the raw honey and boiled honey from Tabora, Tanzania at constant temperature and different temperatures. The method of stokes's law has been used in the study. The physical properties especially the viscosity of raw honey and boiled honey were determined. Finally the study revealed types of honey in raw or boiled form that can be used for medical, industrial, business, and food processing.

Keywords: Viscosity, Boiled honey, Viscosity, Thermal properties

1.INTRODUCTION

1.1 Introduction and Background of the research problem

"Quality of Tanzanian honey based on physicochemical parameters namely water content, sugar content, pH, ash content, hydroxymethyl furfural (HMF) and honey color was studied using 26 honey samples collected from ten popular honey producing regions. Analyses were carried out in triplicates using standard methods" [1]. Data was analyzed using averages, correlation and ANOVA tests. Majority of the honeybees' honey samples were light colored while all stingless bees honey samples were dark colored. Dark colored honeys contained more minerals; mainly iron, copper and manganese which make them especially fit for medicinal purposes. pH values ranged from 2.61 to 4.37, stingless bees honey samples were more acidic than honeybees' honey samples. Total sugar content values (64.16-84.84 g/100g) were all above the minimum requirement of the national and international standards of not less than 60g/100g. HMF values ranged from 5.0 – 26.4 mg/kg honey, an indication of good quality, being far below the maximum limit allowed by national and international standards of 40mg/kg or 80mg/kg for honeys from the tropics.

In the study we are going to determine viscosity of boiled honey and raw honey to provide the differences between viscosities of boiled honey against viscosity of raw honey and will be stored at the same temperature and at various temperatures, the sample were collected from Tabora, Tanzania.

Viscosity is property of fluid by virtue of which a frictional force acts tangentially on the layers of the fluids in motion .Viscosity is kind of internal friction that offers resistance to the motion of one layer of fluid passed another. However, the viscosity of particular fluids can be differing due to the coefficient of viscosity of fluids. [2]

There are many types of honey but in our study, we dealt with bees' honey. Bees store honey in wax structure called honeycombs. There are two types of honey according to the preparation. There are boiled honey and raw honey. Raw honey is only strained before bottled which means it retains most of the beneficial nutrients and antioxidant that naturally contains , Boiled honey or regular honey this may undergo a variety of processing which remove nutrient like pollen and reduce its level of antioxidant. It is practically to determine the viscosity of boiled honey and raw honey by finding their coefficients of viscosity by stokes' method [3].

"In journal physics, conference series 1386, this kind of research conducted .The research explained the work an experimental methodology was proposed combined the development of software to determine the viscosity of honey aggregate (sugar and water) and without those, considering that the experimental methodology used here there does not alter the properties of honey. With ball viscometer and using honey as viscometer medium times that took metal spheres to pass through the sample tube with different densities where measured" [4].

"In journal of food engineering, this kind of research of research was conducted. This research explained that viscosity of honey was measured in two honeydew honeys (thymus, orange, helianthus, and cotton) at their initial moisture content as well as at 17%, 19%, and 21% water content at 25,30,35,40 and 45℃.It was found that viscosity varied between 0.421 and 23.405Pas.shear stress varied linearly with shear rate for all the sample indicating Newtonian behavior. Shear stress was also measured at constant shear rate as function of time. Viscosity was time independent. Arrhenius equation was used to express the variation of viscosity with temperature." [5]

"In International journal of food science, Honey brand commonly available in Indian market were characterized for their rheological and thermal properties. Viscosity of all the honey samples belonging to the differential commercial brands was found to decrease with increase in temperature (5-40℃) and their sensitivity towards temperature varied significantly. This was explained by calculating activation energy based on Arrhenius model and ranged from 54.0 to 89.0kg/mol. However shear rate was not found to alter the viscosity of honey indicating their Newtonian character. The result provides information about some key physical properties of commercial Indian honey." [6].

"In Journal of Agriculture and Social Research (JASR), this study analyzed the physical and chemical composition of seven samples which were obtained from selected market in Ibadan metropolis .The variables analyzed were PH value, % purity, and ash content, refractive index, Viscosity, color, and specific gravity. The result further revealed that the variable considered were within the standard by codex acceptability improvements in processing and packaging technique will not only enhance acceptability of those products but also brings about higher income to producers and markets"[7].

In world, many scientists conducts this research of assessment of honey but deal on effect temperature, moisture, rheological properties and quality of honey by using various scientific method.

This study will go to reveal the difference between the boiled honey and raw honey at same temperature by stokes's law methods.

There various researches conducted in various places in world but little has been conducted for the boiled and raw honey from Tabora Tanzania. There is a research gap to for unknown samples from Tabora region in Tanzania. There different studies related with determination of viscosity of boiled honey and raw honey but of the different temperature. Its being states that the general tendency for individuals boiled honey and raw honey have different viscosities when placed in different temperature. Various researches conducted in various places in world for example in Australia [8], India [9], china [10], America[11] and some region in Tanzania but not with honey from Tabora.

Many scientific researchers have used various methods for examples, [12] uses ball viscometer method to determine the viscosity of honey that published in Industrial engineering and chemistry and [8] uses Arrhenius method to determine the viscosity of honey that published in International journal of food science and others uses palm methods, in this study use stoke's law methods.

The use of various temperature [9] to obtain the values of viscosity while the approach in this study, data will be collected by stokes' method. This study will reveal viscosity difference between boiled honey and raw honey at a constant temperature that were collected from Tabora, Tanzania.

The specifics objectivity were on the determination of the viscosity of the boiled honey, Determination of the viscosity of the raw honey. Comparison of the difference viscosity between boiled honey and raw honey at same temperature, comparison of the similarities of viscosity between boiled honey and raw honey at same temperature, and comparison the viscosity of boiled honey and raw honey at different temperatures.

Limitation

- The study has involved only honey who manufactured by insect known as sweet bees, as there many types of bees that produce honey other kind of insects or bees orchid bees, digger bees, leaf cutter bees, carpenter bees.
- The study has involved only on honey that will be taken from Tabora Tanzania, because there are many parts or regions in Tanzania that manufacturing honey.
- The study has involved same temperature and various temperature, as the temperatures variations affects the viscosity.

1.7 Significance of the work

- The study has revealed the physical properties of viscosity of honey of Tabora Tanzania
- The study has revealed the acceptability improvements in processing and packaging technique.
- The study has revealed distinction between the two kinds honey with different viscosity.
- The study has revealed how Temperature changes affect viscosity value of the raw honey and boiled honey.

2 LITERATURE REVIEW

2.1: VISCOSITY OF HONEY

Viscosity is a measure of the resistance of fluid which is being deformed by shear stress or tensile stress. For liquid, it corresponds to the informal concepts of “thickness “for example, and syrup has a higher viscosity than water [13].

Viscosity can be conceptualized as quantifying the internal frictional force that arises between adjacent layers of fluid that are in relative motion. For instance, when a viscous fluid is forced through a tube it flows more quickly near the tube’s axis than near its walls. In such cases, experiment show that some stress (such as a pressure difference between the two ends of the tube) is needed to sustain the flow through tube. This is because a force required to overcome the friction between the layers of the fluid.so for a tube with a constant rate flow, the strength of the compensating force is proportional to the fluid’s viscosity. [14]

Continuous viscosity of honey –water mixture was measured in rotating viscometer at nominal water content weight from 0% to 60% 0ver a range of temperature (30-70℃).The thermal properties of honey water mixtures that have been investigated by differential scanning calorimetry (DSC).The melt fragility during the heating process (MH) and cooling process (MC) has been calculated .The result show that viscosity and flow activation energy decrease as water content increase. This study distinguish two kinds of honey with different water content.[15].

The rheological properties of high altitudes India honey were analyzed in honeydew and nectar honey (multifocal and acacia) varieties at wide range temperature (0, 5, 10, 20, and 30).All the honey samples were significantly dominated by loss modulus (G) which displayed their viscous nature .Irrespective of geographical origin and temperature, all the honey varieties showed a Newtonian behavior .The viscosity of all honey varieties showed a strong dependence on temperature and Arrhenius model was examined this[9] .

Rheological properties of four unprocessed unifloral Australian honey (health, tea tree, yapunya, and yellow box) and an artificial honey were analyzed at 20℃ .A model previously used to describe viscosity data of various sugar and sugar mixtures was used to describe the concentration dependence of the viscosity of honey samples with varying moisture contents. The model successfully described the sugar concentration dependence of the un adulterated and medium moisture (70-85% solids) range honey samples.[16].

2.1 Theory of the research done on the problem

According George Gabriel Stokes [2] which derived an expression, now known as stokes law, state that the force acting between the liquid and falling body Interface is proportional to velocity and radius of the spherical object and viscosity of fluid. [2].

The force of viscosity on a small sphere moving through a viscous fluid is given by

$$f_d = 6\pi\mu r v$$

Where by,f_d=frictional force,μ=dynamic viscosity=radius of the spherical body,v=flow velocity. The strokes' law the following assumptions for the behavior of a particle in a fluid which are laminar flow, spherical particles, homogenous material, smooth surface, Particles do not interfere with each other [18].

Stokes 'law used to calculate the viscosity of fluid. A series of steel ball bearing of different diameter are normally used in classic experiment to improve the accuracy of the calculation.

Terminal velocity is the maximum velocity(speed) attainable by an object as it falls through a fluid. It occurs when the some of drag force (F_d) and buoyance is equal to the downward force of gravity (F_g) acting on the object. Since the net force on object is zero, the has zero acceleration. In fluid dynamic object is moving at its terminal velocity if its speed is constant due to the restraining force exerted by the fluid throuh which it is moving.

3 MATERIAL AND METHODS

3.1 Description and map of the study area

The study will have conducted in Tanzania at Muslim University of Morogoro.

Geographically the area lies north of the Magnificent Ulugulu Mountains, some 4 km from the center of Morogoro.

Founded in 2004, Muslim University of Morogoro is a private higher-education institution located in the urban setting of the small city of Morogoro (population range of 50,000-249,999 inhabitants). Officially recognized by the Tanzania Commission for Universities, Muslim University of Morogoro (MUM) is a very small (unranked enrollment range: 1,000-1,999 students) coeducational Tanzanian higher education institution formally affiliated with the Islamic religion. Muslim University of Morogoro (MUM) offers courses and programs leading to officially recognized higher education degrees in several areas of study. See the unranked degree levels and areas of study matrix below for further details. MUM also provides several academic and non-academic facilities and services to students including a library, as well as administrative services.

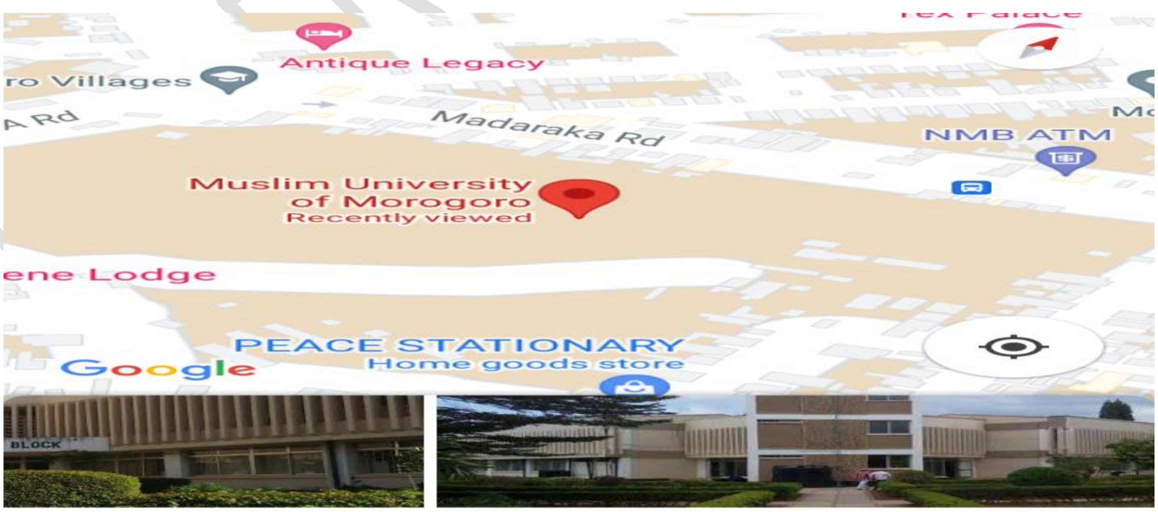


Figure 1: shows the study site location around Muslim University Of Morogoro where the practical project was conducted

Figure 2: shows the study site location around where the practical project honey was stored.

Sample collection and preparation

The samples of this study were collected at honey shop at Muslim University of Morogoro. This study used two types of sample, which are boiled honey sample, and raw honey sample. These samples both differ according to the ways local farmers harvesting and processing. The samples collected were prepared in the Laboratory to wait for further practical experiments. Both boiled honey and raw honey sample were put in small bottles of 500ml. They were then stored in cool place to make sure both sample have same or constant temperature.

3.2 Methods and material

This study uses the method of stokes' law method to determine the coefficient of viscosity of boiled honey and raw honey sample. This method helps to get data, which includes terminal velocity and radius of grass beads. It helped to draw the graph and finally we get slope that show the viscosity coefficient of the particular samples. In the world today, thereare many methods of determination viscosity including viscometer and other digital method. However this study uses the stokes' law method because it has best accuracy calculation.Number of experiment replicate, **was** conducted to the experiment order to obtain reproducible Data.

Theory.

When a spherical ball of (radius r) is dropped in viscosity field it moves in it with certain velocity v is experience's an opposing force (viscous force f_d).according to stokes law this viscous force is given by equation (1).

$6\pi\boldsymbol{\eta r}f_d = \boldsymbol{v}$ ____ **(1)**

Simultaneously it experiences an up thrust (or buoyant force)f_b and gravitational force f_g.$f_g$tries to increase the velocity of ball where as f_d decrease the velocity. After some times the ball will moves with a steady velocity. Called the terminal velocity

$$f_d = f_g - f_b$$

$6\pi\boldsymbol{\eta r v} = \frac{\mathbf{4}}{\mathbf{3}}\boldsymbol{\pi}(\boldsymbol{\rho} - \boldsymbol{\sigma})\boldsymbol{g}$

$$\eta = \frac{2}{9}\frac{(\rho - \sigma)gr^2}{v} \text{ ____ } (2)$$

ρ=density of ball bearing, $\sigma = density\ of\ liquid$, η = coefficient of viscosityin equation (2), r = radius 0f ball bearing, g = acceleration due to gravity.

APPARATUS AND MATERIALS

The apparatus used in this methods are A long cylindrical gas jar, Retort stand, Vernier caliper, Micrometer screw gauge, bearing ball , Stop watch, Thread, Meter scale, Raw and Boiled honey, Thermometer, beaker, Note book, pencil, Plastic measuring cylinder

PROCEDURE

Procedure A

1. A long cylindrical glass jar with marketing is taken
2. Fill the glass jar with the experimental liquid (raw honey and boiled honey)
3. Two points A and B are marked on the jar. The mark A is made well below the surface of liquid so that when the ball reaches B it would have acquired terminal velocity V.
4. The radius of the metal spherical ball is determined using screw gauge
5. The spherical ball is dropped gently into the liquid
6. Start the stop clock when the ball crosses the point A. Stop the clock when the ball reaches B
7. Note the distance between A and B and use it to calculate terminal velocity.
8. Now repeat the experiment for different distances between A and Make sure that the point A is below the terminal stage.

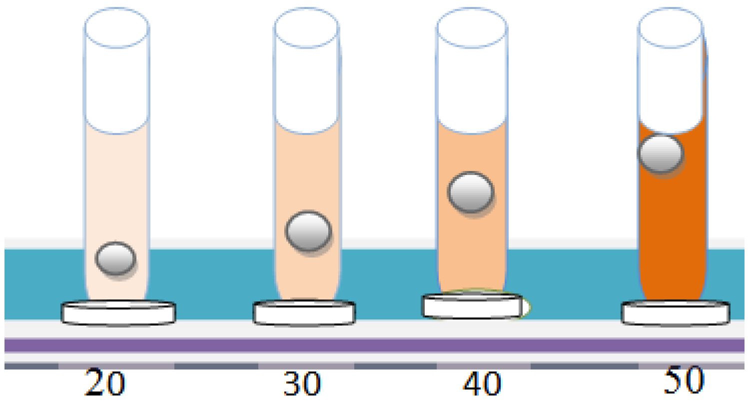


Figure 3: shows the how the practical part was conducted

Procedure B

1.A long cylindrical glass jar with marking is taken

2.Fill the glass jar with the experimental liquid (which raw honey and boiled honey)

3.Two points A and B are marked on the jar. The distances mark A and B should be constant.

4.Use the only one ball bearing to find the time taken to completely mark A to B with different values of temperature starting with 30,40,50,60 and 70℃

5.Record the table that contains the temperature θ *and time* t

4.0 RESULTS AND DISCUSSIONS

4.1 RESULTS

After practices the laboratory experiment we obtains the various result in both at constant temperatures and different temperatures The procedure was repeated ten times.

Table 1 : The result from procedure (a) of raw honey at constant temperatures(20℃)

Ball bearing	Mass(gram)	Radius(m)	Distance covered from mark A to B	Time taken from mark A to B	Terminal velocity (v)
A	45	$5.05\ 10^{-3}$	0.2	7.31	0.027
B	56	5.55×10^{-3}	0.2	6.28	0.032
C	69	6.4×10^{-3}	0.2	5.60	0.036
D	81	7.1×10^{-3}	0.2	4.90	0.042

Table 2 : The result from procedure (a) of boiled honey at constant temperature(20℃)

Ball b earing	Mass(gram)	Radius(m)	Distance covered from mark A to B	Time taken from mark A to B	Terminal velocity (v)
A	45	5.05×10^{-3}	0.2	6.18	0.032
B	56	5.55×10^{-3}	0.2	5.44	0.037
C	69	6.4×10^{-3}	0.2	5.00	0.040
D	81	7.1×10^{-3}	0.2	4.69	0.043

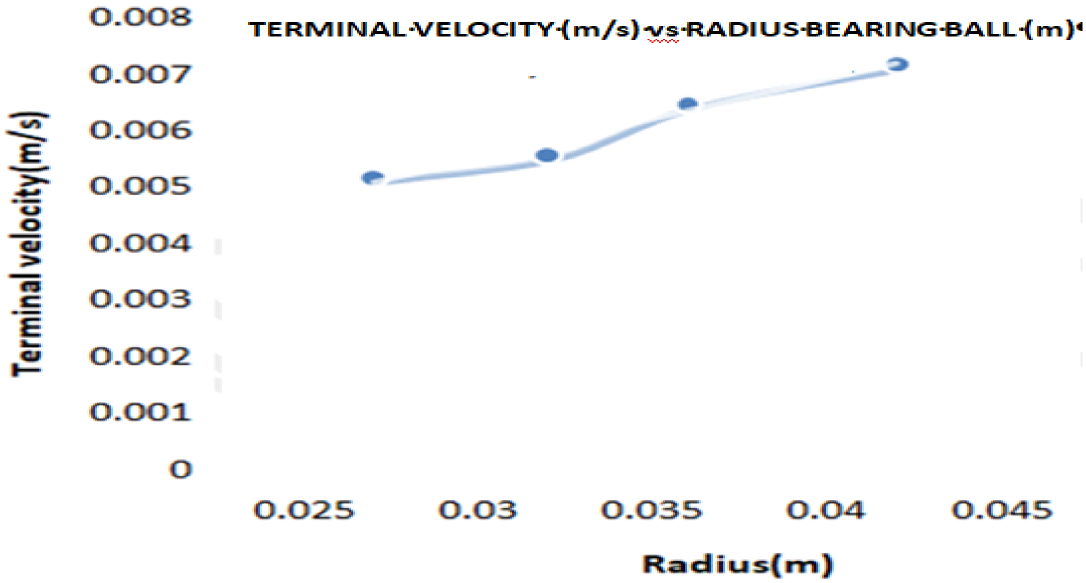
Table 3 : The result from procedures (b) of raw honey at various or different temperatures

We use only ball bearing A has mass of 45 g covered distances is 30 cm.

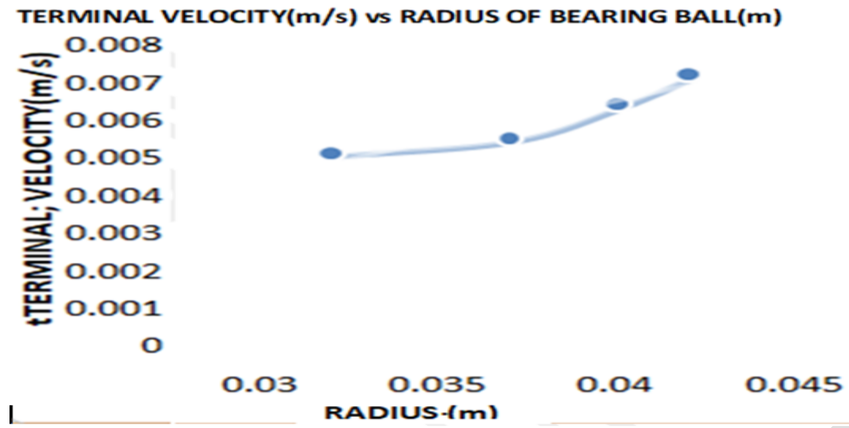
Temperature(℃)	Time taken (s)	Distance (m)
30	5.6	0.3
40	4.6	0.3
50	3.6	0.3
60	2.44	0.3
70	1.56	0.3

Table 4 : The result from procedures (b) of boiled honey at various temperatures or different temperatures.

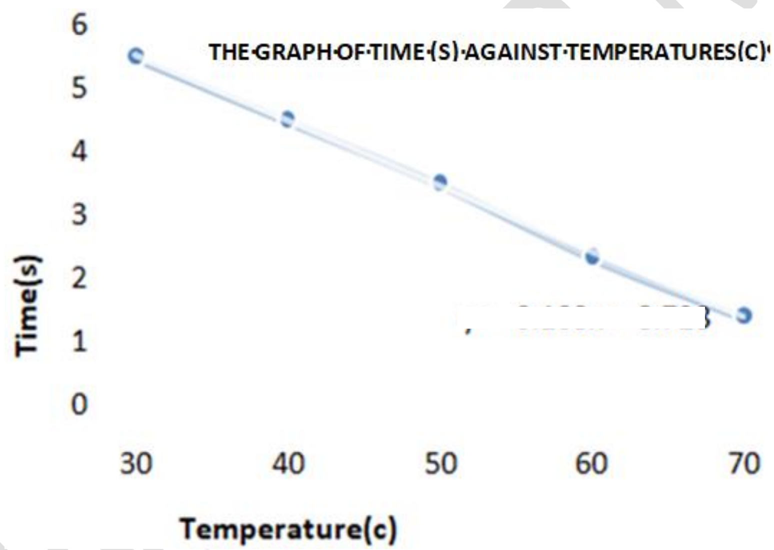
Temperature(℃)	Time taken(s)	Distance (m)
30	5.0	0.3
40	4.2	0.3
50	3.3	0.3
60	2.1	0.3
70	1.23	0.3



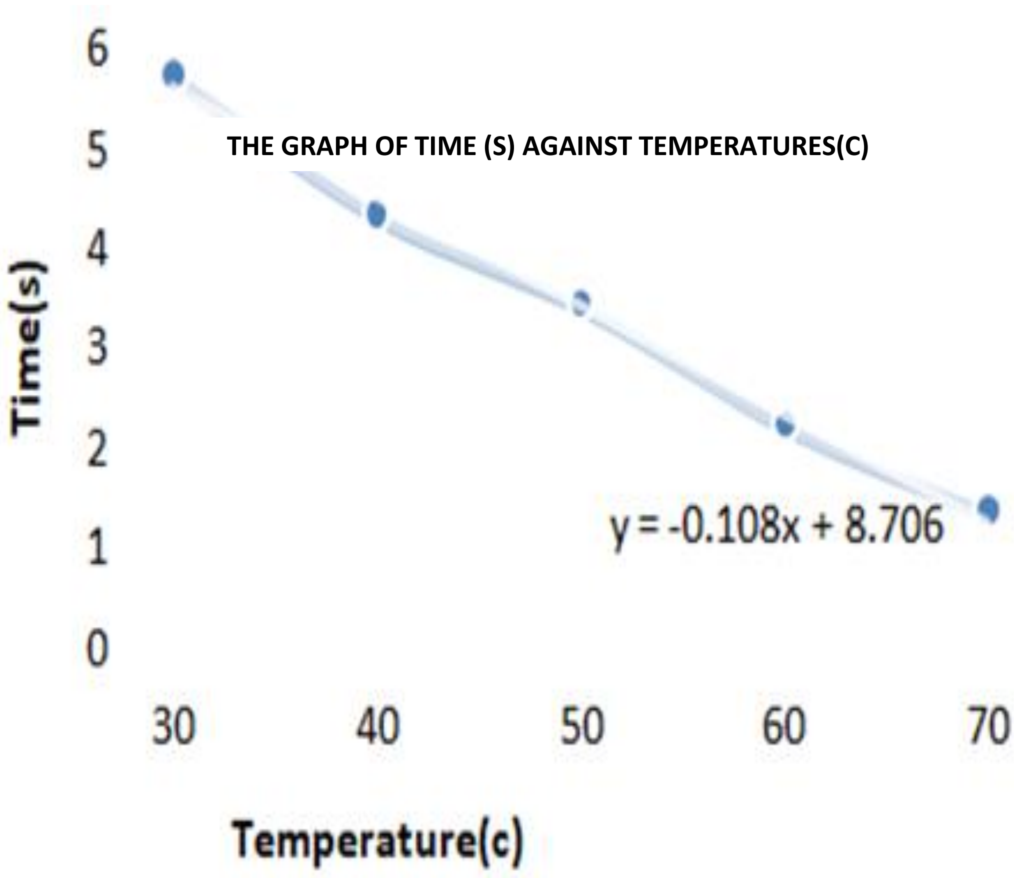
Graph. 1 : The Graph of Terminal Velocity against Radius of Bearing Ball of Raw Honey at Constant Temperature (20℃)



Graph.2 The graph of terminal velocity against radius of bearing ball of boiled honey at constant temperature (20℃)



Graph . 3 : The graph of times (s) against the temperature (℃) of raw honey



Graph. 4 : The graph of times (s) against the temperature (℃) of boiled honey

4.2. Calculation of Result from the Graphs;

1. graph from raw honey at constant temperatures

The coefficient of viscosity of raw honey = $\frac{2}{9}\frac{(\rho-\sigma)gr^2}{v}$

But radius(m) =0.0051s/m. $\rho = 2800$kg/m^3,$\sigma = 1490kg/m^3, g = 9.8m/s$.v=0.027

The coefficient of viscosity $\boldsymbol{\eta}$ = 2.75Nsm^{-2}

2. graph from boiled honey at constant temperatures

The coefficient of viscosity of raw honey = $\frac{2}{9}\frac{(\rho-\sigma)gr^2}{v}$

But radius (m) =0.0051s/m. $\rho = 2800$kg/m^3,$\sigma = 1490kg/m^3, g = 9.8m/s$.v=0.032

The coefficient of viscosity $\boldsymbol{\eta}$ = 2.32Nsm^{-2}

3. The comparisons of viscosity coefficient of raw honey and boiled honey at constant temperatures.

Therefore, the value of coefficient of raw honey is greater than boiled honey according to our result above;

The difference coefficient between the raw honey and boiled honey is 2.75-2.31=0.43Nsm^3

4.The comparisons of viscosity coefficient of raw honey and boiled honey at different temperatures by using their slopes.

From the graph of time against temperature of both raw honey and boiled honey we obtain the following data;

The slope of times against temperature of raw honey is- 0.1036$s/℃$

The slope of times against temperature of boiled honey is- 0.1084$s/℃$

Therefore, the slope of raw honey is greater than boiled honey by 0.0048$s/℃$.

4.3 DISCUSSION AND CONCLUSION

According to the stoke law method, the value of coefficient of viscosity show that the viscosity of liquid or sample is large or low, because the viscosity of liquid depend on the nature of liquid.

According to results obtained from experiment of this study through tables, graphs and calculation, the value of coefficient of viscosity of raw honey at constant temperature is 2.75 Nsm^{-2} and the value of coefficient of viscosity of boiled honey is 2.32Nsm^{-2} at constant temperature of 20℃ ,this result reveals that the raw honey is more important than boiled honey because the viscosity of raw honey is greater than boiled honey .the boiled honey has low value due to various factor such as amount of moisture content, and rheological properties. Rheology is the study of these properties, which are important in many industries and fields, including food science, manufacturing, and physiology. Rheological properties are the material properties that describe how a material deforms or flows when a force or stress is applied. Some common rheological properties include: Viscosity: The opposition to flow in a material. For example, honey is more viscous than water and flows more slowly. Thixotropy: A property of some materials that change viscosity in response to stress. For example, a material may become less viscous when agitated, but more viscous when left at rest.

Also, according to the stokes law equation, time is directly proportional to the coefficient of viscosity. Therefore the slope from both graphs of time against temperature show negative sign, that implies when temperature increase the value of the coefficient of viscosity decrease. However, according this study, the slope of times against temperatures of raw honey is greater than the slope of graph of time against the temperatures of boiled honey. This study show that the value of coefficient of viscosity of raw honey decrease slowly compared to the value of coefficient of viscosity of boiled honey due to the effect of the temperature. Therefore, the raw honey is affected by temperature at low rate compare to the boiled honey.

Therefore, According to the data above the tables, graphs and calculation, the viscosity of raw honey from Tabora Tanzania is 2.75Nsm^{-2}, the boiled honey is 2.32Nsm^{-2}at constant temperatures and when temperatures increase the viscosity of both raw honey and boiled honey decrease but boiled honey affected more than raw honey due to bond formation.

Based on the physicochemical parameters studied, Tanzanian honeys from honeybees were found to be of high quality meeting recommend national and international standards [1]. However, all stingless bees' honey samples deviated from these standards on moisture content and two samples on ash content. With few exceptions, colour and moisture content are two most important physicochemical parameters that may give a fair clue on the quality of the honey. The two parameters are also easy to measure. The results of this study indicate that Tanzanian honey samples compare well with samples in many parts of the world but also fall within the limit of international standards. Nevertheless, more studies are needed to evaluate the quality of Tanzanian honeys based on medicinal, nutritional, antioxidant and viscosity properties. Honey offers nutritional and therapeutic benefits to people, hence understanding its quality and consumer preferences is essential for its consumption. In this study, the physicochemical properties, mineral content, and consumer preferences of honey samples from various Tanzanian geographical zones and botanical origins were investigated [19]. Thirty-two honey samples from *acacia* species and *miombo* woodland origins were purchased from beekeepers in five zones of Tanzania, and analyzed for those parameters using standard methods. The lake zone *acacia* samples had significantly ($p < 0.05$) higher moisture while the northern zone *miombo* samples had higher acidity than other samples. The lake zone *miombo* sample had a higher viscosity than other samples. Potassium was the most abundant mineral (380.2 ± 89.30–3488.1 ± 87.17 mg/kg) in honey and all minerals differed significantly ($p < 0.05$) between botanical origins and geographical zones with *miombo* samples in all zones having higher values than their *acacia* counterparts. Furthermore, the eastern zone *miombo* and lake zone *acacia* honey were the most acceptable samples by consumers. Therefore, the Tanzanian honey quality and consumer preferences vary significantly with botanical and geographical origins. Nevertheless, despite the variations, quality values were within the national and internal standard bounds, hence the consumption of these honey is encouraged based on their known benefits. Honey viscosity decreases exponentially as temperature increases

In discussing honey [20];Honey viscosity decreases as moisture content increases. For example, the activation energy of honey decreases linearly as moisture content increases.The viscosity and flow activation energy of honey-water mixtures decrease as water content increases.Shear stress varies linearly with shear rate for honey, indicating Newtonian behavior.

Viscosity is a significant physical and sensory characteristic of honey that affects its quality and how honey-processing equipment is designed.Viscosity of honey was measured in two honeydew honeys (pine and fir) and four unifloral nectar honeys (thymus, orange, helianthus.The electrical conductivity increased linearly both with temperature and upon dilution. The refractive index decreased linearly with continuous viscosity of honey–water mixture was measured in a rotating viscometer at nominal water content weight from 0% to 60%.

RECOMMENDATION;

The study of determination of viscosity of raw honey and boiled honey from Tabora Tanzania was very important because many people use honey for food and medical purpose. Knowing the rheological properties such as viscosity helps on the uses of the products . The study dealt with the method of stokes law and recommends other methods such viscometer, AAS,XRF, PIXE for this exercise. Also, more data are needed for all types of honey found in Tanzania, East Africa and Africa so as to internationalize the results.

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Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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