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Software to determine the viscosity and honey's purity using a ball viscometer

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Abstract. Physics is a science that studies the laws and properties of the universe and everything in it. However, it is more interesting when it is applied to the solution of problems that influence economic and social development. In our case, applied to beekeeping to ensure the purity of honey. Some producers or intermediaries add sugar or water to honey to reduce costs and improve their income affecting the final consumer. Therefore, in this research work, an experimental methodology was proposed combined with the development of software to determine the viscosity of honey with aggregates (sugar and water) and without those, considering that the experimental methodology used here, does not alter the properties of honey. With a ball viscometer and using honey as a viscous medium, times that took metal spheres to pass through the sample tube with different densities were measured. The times were analyzed and synthesized with the application to obtain the viscosity in real-time of the different types of honey, allowing to discern which ones were pure and which had water or sugar aggregates.

1. Introduction

China is the main producer of honey, achieving almost 30% of world production [1, 2]. Followed by Turkey and other South American countries, production grows per year as well as consumption, led by The United States of America and Germany [3], where that consumption is due to their honey's characteristics of natural sweetener and its nutritional properties [4]. On the other hand, the honey quality control methods used in these countries are analytical techniques that require high-cost equipment such as chromatographs or equipment of nuclear magnetic resonance spectroscopy to make the study of the properties of honey and determinate its purity [5]. In our context, where beekeepers carry out the artisanal process and manage low production volumes these techniques are not taken account [6, 7].

That's why it was necessary to come up with an idea of developing a way to make possible an approximate honey quality control method by other means, economically viable, besides of the easily management of it. Besides, the honey tester software does a simpler procedure of analyzing the purity of a honey sample, through the calculation of the viscosity by data given from a falling ball viscometer [8–10].

2. Methodology

2.1. Poiseuille Law on viscosity

The basis of most of the viscometers that are used in practice, is the Poiseuille Equation, which gives us the flow Q (volume of fluid per time unit) that passes through a capillary of radius r and length L



between whose ends a difference of pressures Δp has been applied (see Equation (1)). That capillary of radius will be, in our study, the sample tube of the ball viscometer [11].

$$Q = \frac{v}{t} = \frac{\pi \Delta p r^4}{8 \eta L}, \quad (1)$$

where η is the fluid viscosity; then, solving Equation (1), have Equation (2).

$$\eta = \frac{\pi \Delta p r^4 t}{v 8 L} \quad (2)$$

Due to r , L and v being constants for a given tube, they can be grouped in a constant K like $\pi/8$, so the Equation (3) is obtained.

$$\eta = K \Delta p t \quad (3)$$

If the liquid flows only by the action of gravity in a vertically placed tube, the difference of pressure Δp is the one exerted by the column of liquid. That is, $\Delta p = \rho g h$, being ρ the density of the liquid and h the height of the column, Equation (4).

$$\eta = K \rho g h t \quad (4)$$

If the capillary wasn't vertical, it is necessary to take in consideration the angle it forms with the vertical. But, since h and the angle are constant values for a given tube, we can write the Equation (5).

$$\eta = K^* \rho t \quad (5)$$

The value of K^* depends, therefore, on the geometry of each specific viscometer and is usually given by the developer. It can also be determined using a liquid of known viscosity. Normally, the relative viscosities related to water are determined. For water, you will have Equation (6).

$$\eta_{water} = K^* \rho_{water} t \quad (6)$$

From Equation (6), K^* can be determined and introduced into Equation (5) to determine the unknown viscosity of the liquid under study. Since the viscosity depends on the intermolecular forces and these change with temperature, the viscosity of a liquid also varies with temperature.

2.2. Determination of the viscosity using a ball viscometer

In this order of ideas, the determination of the viscosity could be fitted, by means of a ball viscometer [12], which works by using a precision ball that slides or falls over a distance of defined measurement, along the inside of a precision glass tube (sample tube), with an inclination of 10° . The substance in question will be poured into the sample tube of the viscometer, which is inside it. The time of the fall of the sphere, will indirectly provide the viscosity of the liquid. The viscosity value is obtained by multiplying the measured time, the ball constant (which has already been calculated empirically) and the difference of specific densities between the ball used and the substance studied. A total of six balls of different diameters and specific densities, allow a measurement of the viscosity in six ranges of measurement. A glass tube with a jacket and connections for a liquid thermostat allows controlling the temperature of the substance studied (see Figure 1).

The equipment mentioned above, is a haake thermo electron ball viscometer (see Figure 1), for which, adapting the Equation 5 into the Equation 6, we have that the viscosity of the sample to be studied is given by Equation (7).

$$\eta = K^* (\rho_1 - \rho_2) t, \quad (7)$$

where ρ_1 and ρ_2 are the density of the sphere used and the sample density, respectively. And, η is given in units $[m \cdot Pa \cdot s]$.

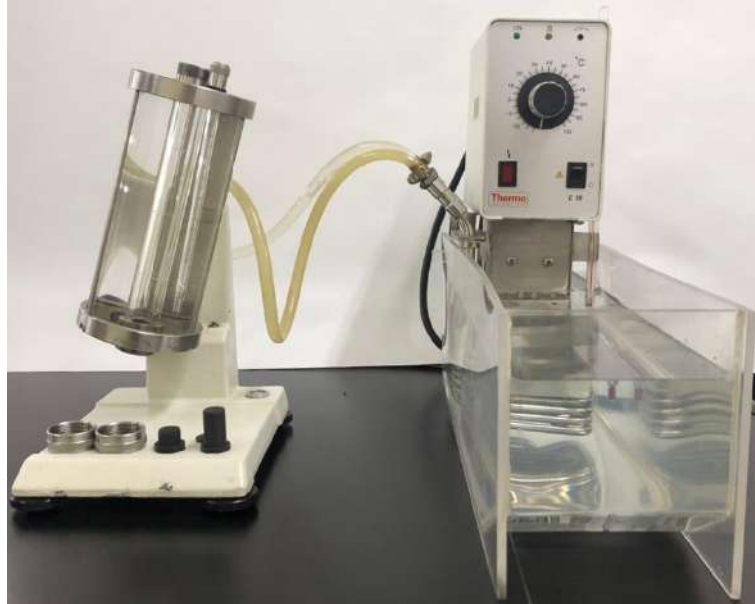


Figure 1. Haake thermo electron ball viscometer setup.

2.3. Honey tester application

The aim objective of this research work was to find a way of knowing the physicochemical magnitudes of a honey sample, allowing that, the characterization of the purity of the honey studied just by typing specific data in a software. That led us to develop a simple application that requires measurable values that can be easily obtained from the data collected through the falling ball viscometer procedure. Then, it calculates the viscosity and compares it with a range of values to determine if the sample is pure or not.

The application does this by using the Stokes Law, with an empirical constant (see Equation (8)).

$$\eta = K \cdot (\rho_s - \rho_f) \cdot t \quad (8)$$

Equation (8), η represents viscosity, K^* is the empirical constant of each sphere, which is indicated in a test certificate that goes with the viscometer, ρ_s is the density of the sphere, ρ_f is the density of the fluid in which the sphere is introduced, in this case honey, and t is the time it took the sphere to make it through the measuring distance.

3. Results and discussions

3.1. Experimental results

For the purity characterization range, it was necessary to do the respective measurements of each sample of in the ball viscometer. First of all, the sample taken from the honey that is sold in market establishments, was measured. Besides the measurement on the non adulterated honey sample, sugar and sugar with water were added, to do two more measurements, respectively.

The picking of a sphere, depends on the average time it takes for the sphere to fall through the sample tube. Before choosing one, the ball that falls the first, should be the one which the measurements will be made.

For measurements made for the results (see Table 1) the spheres 5 and 6 were used for the non adulterated commercial honey, the commercial honey with sugar, and the commercial honey with sugar and water, respectively.

Table 1. Times it took for each sphere to pass through the sample tube.

Sample	t_1 (s)	t_2 (s)	t_3 (s)	t_4 (s)	$t_{average}$ (s)
Non adulterated commercial honey	13.01	13.18	12.68	12.82	12.92
Commercial honey with sugar	16.00	15.89	15.94	15.78	15.90
Commercial honey with sugar and water	4.29	4.16	4.14	4.20	4.19

For measurements made for results in the (see Table 2), the sphere 6 was used for both pure and adulterated natural honey. The magnitudes of the spheres can be found in the (see Table 3), specifying its radius, density and the empirically calculated constant.

Table 2. Times it took for each sphere to pass through the sample tube.

Sample	t_1 (s)	t_2 (s)	t_3 (s)	t_4 (s)	$t_{average}$ (s)
Pure natural honey	5.05	5.09	5.01	5.07	5.05
Adulterated natural honey	10.10	10.20	10.18	10.22	10.17

Table 3. Table with the radius, densities and constants of the spheres used.

Sphere	Radius (cm)	Density (g/cm^3)	Constant
N. 5	0.69	8.12	7.13
N. 6	0.59	8.12	35.07

Finally, the viscosity of each sample was calculated, using the fitted Poiseuille Law with the constant of the spheres, the respective densities of the ball and the sample, and the time it took for each one to fall through the sample tube. The Table 4 shows the density and the viscosity of each honey sample.

Table 4. Results of the density of each sample and its respective viscosity.

Sample	ρ_s (g/cm^3)	η ($m \cdot Pa \cdot s$)
Non adulterated commercial honey	1.55	2980.19
Commercial honey with sugar	1.58	3648.66
Commercial honey with sugar and water	1.52	197.01
Pure natural honey	1.41	1206.88
Adulterated natural honey	1.41	2394.76

And with this data, we calculated the standard deviation in the measurement of the natural honey. As this was going to be the standard for pure honey, that is going to be used later in the software and was $21.71 (m \cdot Pa \cdot s)$. In this order of ideas, the results show the relation of the viscosity with the purity of a sample, making visible the possible appropriate judgment for the choosing of a real pure honey, where the pure honey indicates a more viscous term. It's important to take into account that the presence of the thermostat in the falling ball viscometer setup is necessary, to maintain the temperature of the sample at the same value, doing this, that the viscosity of the sample does not change. To clarify, the results of the pure honey allows us to do a respective viscosity range for the actual purity, to differentiate the pure characterization, from an approximate sample fitted to resemble the viscosity of a pure sample. This avoids the scam by the producers of adulterated honey, supposedly pure.

3.2. Results of the script and the application

The software that we developed was written in python using the tkinter package for the graphical user interface, the main aim was to create a software easy to handle, intuitive to the user, that only requires 3 data inputs and a setting between 6 different measurement constants one per sphere. This application is calibrated around the use of a falling ball viscometer. After the data is entered, the user only needs to press a button and the software will evaluate the purity of a sample of honey using the computer calculations.

The script for the application is composed of two parts as shown in Figure 2:

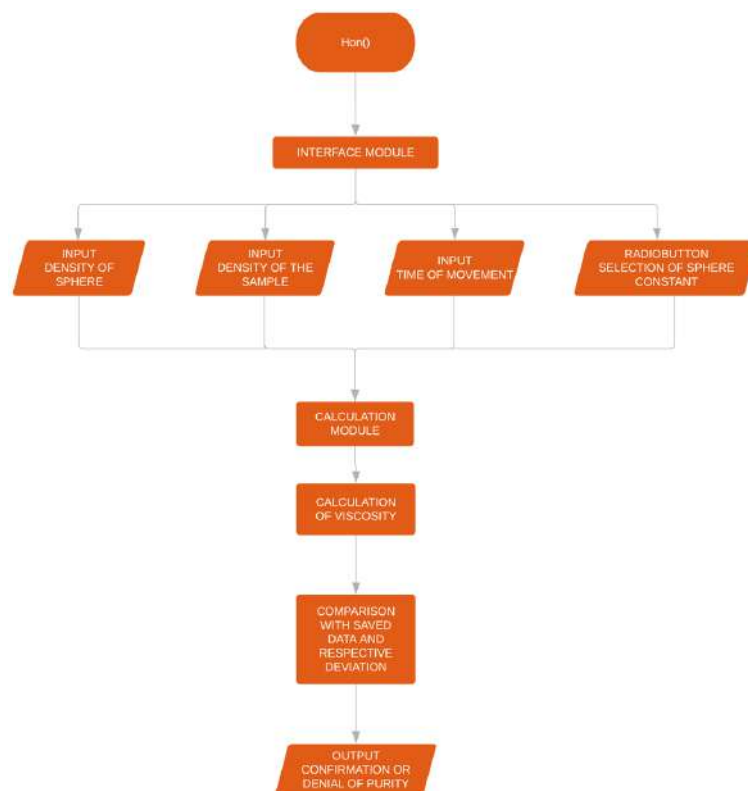


Figure 2. Python script flowchart.

- The interface: This is the first part of the script, and the one that it is in charge of making the window which the user can interact with. This is made with the package tkinter of python, a package that allowed us to create a window in which are place input boxes, labels and buttons that tell the user what to do, and that at the end shows the results of the calculating process.

- The commands: the second part of the script is the methods, that are essentially the core of the program. This is where the commands for the buttons of the interface are located. These are made with methods, that take the information put in the interface and make calculation with them, giving the result that the user requires. Also, in this part are located the commands for the help menu which the user can access from the interface.

In the following link, you can get a look at the script and the ".exe" file to run on windows systems 32 and 64 bits <https://github.com/dantrica/Viscometer.git>.

4. Conclusions

This research work allows us to understand one of the topics of hydrodynamics regarding viscosity, in our case honey, a product made by beekeepers in our region, Santander. The development of this, led us to be able to relate the purity of the product with its viscosity, to later compare it with the purity range of pure honey, granting this, the presence of adulterations or aggregates in the product (sugar and water).

Development of tools that allows the beekeeper community of Santander, to give guarantees of their product, according to the physicochemical results of their product and also the pertinence in the production and marketing of honey, through the development of an application for viscosity measurements, in order to give more publicity in regard to product quality.

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