Teaching of Physics in Grammar Schools with Help of Food Investigation Measurements

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Abstract. Education of natural sciences is extremely important for understanding the whole world around us. In teaching of physics in the schools the experiments are of primary importance, and the pupils are definitely satisfied if the investigated materials are food samples, wellknown for them. The paper deals with 3 simple experiments of physical type. The following foodstuffs were investigated: beet sugar, apple, tomato, fruit syrups. For teaching the following experiments were prepared and carried out:

- determination of sugar content by density measurement in solutions
- examination of fruit firmness
- application of a microwave oven for determination of water content by temperature measurement

Keywords:

density, fruit firmness, microwave, physical methods, sugar concentration, water content

INTRODUCTION

Int the previous paper and lecture (Szabo, Izsak, 2016) information was given about measurements of physical type, carried out for teaching of pupils using food samples for determination of the concentration, based on boiling point, creation of galvanic battery using agricultural products, differentiation between raw and cooked eggs, without breaking the egg-shell. This work again deals with 3 measurements, using simple physical methods for investigations and connections between the measured parameters for evaluation of the results of investigations. We are sure that the experiments are of primary importance in the education, helping not only in understanding the different topics for the pupils, but the interesting demonstration creates an enjoyable atmosphere, as well. Let us mention some publications (Bozi et al, 2016)(Izsak et al, 2016), concerning the improvement of teaching of natural sciences with food experiments.

SUGAR CONCENTRATION DETERMINATION BY DENSITY MEASUREMENT

Prepare 10%, 20% and 30% solutions of beet sugar (sucrose) - or even 10 g / 100 ml, 20 g / 100 ml and 30 g / 100 ml of sugar solutions - and use an easy to implement, but sufficiently precise technique, picnometric method for measure the density of these solutions. We will see that the 10 % solution has about 1:04 g / cm^3, the 20 % one 1:08 g / cm^3, and the 30 % solution about 1.12 g / cm ^{3} density. Thus, there is a close correlation between the concentration and the density, and a simple physical measurement can be applied and monitored, without chemical analysis in the determination of the sugar concentration. Point out the following:

1. Unknown sugar concentration can be determined on the base of tabular data (eg. Chemists pocket book or internet) or calibration curve
2. The density determination method in principle is valid only for binary (two-component) system, but a wide variety of foodstuffs is known, when out of the water actually there is only one dominant component, and thus the process as a routine technique, with acceptable accuracy can be well used. E.g. sugar content degree in grape must or alcohol content of dry wine with determination of density.
3. In case of other materials than sugar the density values are different for the same concentrations, e.g. salt (NaCl) for 10% solution has approx. 1:07 g / cm^3, and for 20 % one 1.15 g / cm ^{3} measurable density.
4. Very slightly the density of the test solutions is of course influenced by temperature, as well - the tabular data generally apply to 20 ^{o}C - but the difference, measured between 15 and 20 ° C in case of 20% sugar solution is insignificant in density - 1.08233 and 1.08094 g / cm^3 - and the negligible value is within the measurement error.
5. For determination of sugar content also other physical and chemical analytical measuring methods and techniques are known, e.g. the polarimetric test which can be used for optically active substances (such is sugar). In this case the modification of the vibratioanal plane of polarized light is measured and from this is the concentration calculated. But well-known and simple procedure is also the refractometric method, when the refractive index is measured.

INVESTIGATION OF HARDNESS (FIRMNESS) OF FRUITS

Everyday experience that the quality and shelf-life of the fruits is closely related to hardness. As today practically any kind of fruits can be purchased in every season, so the measurement with the wanted fruit can be performed at any time during the school year. Of course, you should choose a determined type of fruit and testing its various versions, concerning the hardness. We used with the pupils Jonagold apple samples for the tests.

For testing the hardness we need a not too complicated measurement tool: a microphone in a wooden box made with a circular opening at the top that is coated with a light material of soft, spongy texture, to produce free vibration. The fruit to be tested is placed on this soft material. The fruit is hit easily with a stick - excitation – so a sound vibration is generated, which is recorded by the microphone. (If the microphone is connected to a computer, with a voice-evaluation program the characteristic frequency of the vibration generated sound can be determined.) Note that the registered sound vibration to be generated should be the vibration of the fruit, and not the sound audible in the air (Felföldi, 1996).

The hardness shows how much power is generated due to the size of penetration of the test object. So N/m m is the unit of measurement. Easy to see that the same is obtained if the mass and the square of the measured frequency of the sample are multiplied:

$$\frac{N}{m} = \frac{kg \cdot \frac{m}{s^2}}{m} = kg \cdot \frac{1}{s^2}.$$

So what we have to do during the measurement is the determination of the weight of the fruit and the frequency of the acoustic vibrations.

For the students it can be a useful information that instead of measuring the force and the penetration the mass and frequency can be measured, as well, that is, try to draw attention to the importance of the relationship between the physical quantities. In addition, it also does not hurt to emphasize how important is to find for investigation of foods (fruits in this case) non-destructive methods. Of course there are well-known equipments (e.g INSTRON or fructometer) for the rheological and textural measurements, but these are the devices, what probably do not have the school labs. The described measurement technique is applicable of course also in case of vegetables (e.g. tomato).

Otherwise, if the measurements are carried out with the fruit samples over several days, the pupils can compile a "series", and on this base you can determine how old (how many days) can be the sample of the given variety, and it is even possible to estimate how long it can be stored for the applied storage conditions (temperature, relative humidity of the air).

MICROWAVE OVEN FOR DETER-MINATION OF WATER CONTENT BY MEASUREMENT OF TEMPERA-TURE

In the last decades the use of microwave technique is a daily routine even in the home kitchens for increase of the temperature of different foodstuffs and meals. This is a fast, simple, economical heat-transfer technique, with minimal need of washing-up. The essence of the techniques is the following: if we switch on the apparatus it will be created a magnetic field with high energy (the frequency is appr. 2 x 10^9 Hz) of microwave range. The foodstuffs contain in general high amount of water, and the energy-transfer is realized in consequence of resonance (interaction) between the water molecules with dipoles (high permittivity) and the microwave radiation, rotating the water molecules. The rapid movement and friction of the molecules produces the heat development. Of course the applied electrical power depends on the intensity and time of the treatment.

Because the resonance (the direct energy transfer) is valid dominantly for the water content in the investigated food sample, therefore the temperature-measurement can be applied also for the estimation of the water content. Although theoretically this measurement method is applicable for water determination in any case (circumstances and samples), however in practice it can be carried out with the necessary accuracy only in that case – because of complexity of correction factors – if the conditions and the mass of the samples are the same. So e.g. in case of liquid samples with 40%, 60 % and 80 % water concentration – fruit juice and fruit syrup samples – the differentiation can be carried out easily with determination of the temperature. The following formula is used for calculation:

$$Q = c \times m \times T$$

where:
Q – input of heat energy
c – specific heat
m – mass
T – measured temperature-difference

Of course in case of real foodstuffs the sample contains many components, there are other components (e.g. sugar), as well, having much less specific heat parameters, than in case of water. These components do not get warm themselves (or only slightly) during the treatment, but from the water- which warms up continuously during the treatment – heat will be uptake. So the energy of the microwave machine is used not only for the increase of the temperature of the water inside the sample. Other energy-loss is based on the temperature-uptake of the structural materials of the oven (e.g. rotating glass-teller for sample holding) and the container of the sample. Because of these uncertainties of the characteristic parameters the precise determination of the water content is not possible, but in case of similar conditions the siginificant differences in the water content can be measured and proved.

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