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DETERMINATION OF GLUCOSE CONTENT IN JUICES OF DRIED FRUITS AND VEGETABLES (RAISINS, DRIED APRICOTS, BEETROOT) USING THE AUTOMATIC REFRACTOMETER RX-5000

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Abstract: In this article, a methodology for determining the glucose content in juices of dried fruits and vegetables – namely raisins, dried apricots and beetroot – using the automatic refractometer RX-5000 was developed and experimentally tested. First, the instrument was calibrated using distilled water and standard glucose solutions, the functional relationship between the refractive index (n_D) and glucose concentration was established, and this relationship was stored in the memory of the RX-5000 as a user scale. Aqueous solutions were prepared from dried fruit (raisins, dried apricots) and beetroot juice samples in specified ratios, and refractometric measurements were carried out under stable conditions at 20 ± 0.1 °C. The obtained n_D values were converted into glucose concentration using the calibration graph, and the results were compared with those of a classical chemical method (titrimetry). According to the comparison, the relative error of the refractometric method based on the RX-5000 did not exceed 2–3 %, and the correlation coefficient was in the range of 0.98–0.99, which indicates the high accuracy and reproducibility of the methodology. The proposed method is recommended as a rapid, low-labor and convenient analytical technique for determining glucose in dried fruit and vegetable juices, suitable for use in educational laboratories.

Keywords: automatic refractometer RX-5000, refractometry, dried fruit juice, raisins, dried apricots, beetroot, glucose content, Brix, refractive index.

Introduction

In recent years, growing interest in healthy nutrition, natural sugar sources and dietetic products has required that the quality of products prepared from dried fruits and vegetables be assessed on a scientific basis. In particular, determining the glucose content in dried juices of raisins, dried apricots and beetroot is of great importance for assessing their energy value, dietetic properties and for establishing safe consumption norms for diabetic patients. Although traditional titrimetric and enzymatic methods are sufficiently accurate, they are time- and labor-consuming, require a large amount of reagents, and are not always convenient for constant use in educational laboratories.

Refractometry, on the other hand, is based on the relationship between refractive index and concentration and makes it possible to rapidly evaluate the amount of dissolved solids in solutions, in particular glucose. Owing to its wide measurement range, built-in temperature control and the possibility of creating user scales, the Automatic Refractometer RX-5000 is a convenient tool for determining glucose concentration in dried fruit and vegetable juice solutions. In this study, a methodology for determining glucose in dried juices of raisins, dried apricots and beetroot using the RX-5000 is developed, and its accuracy and effectiveness for practical application are evaluated.

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Main part

Description of the research object and samples. As the objects of the study, solutions of dried juices prepared from widely consumed dried fruit and vegetable products – raisins, dried apricots and beetroot – were selected. Since these products contain naturally occurring carbohydrates, especially glucose and fructose, in relatively high amounts, their sweetness, energy value and dietetic properties directly depend on the concentration of sugars.[1,2,3] For the experiments, samples that are commercially available, have passed standard sanitary–epidemiological control and meet normative requirements in terms of appearance and organoleptic indicators were selected.[4,5,6,7]

Sample preparation.

First, the dried fruit and vegetable samples were cleaned from mechanical impurities (dust, small stones, stem residues), and then ground in a laboratory mill to a fraction with uniform particle size. For each product, extraction was carried out separately in containers at a mass ratio of 1:10 (10 ml of distilled water per 1 g of dried product). Extraction was carried out in water heated to 60–70 °C for 20–30 minutes under stirring, during which the soluble sugars, organic acids and other components present in the dried product passed into the aqueous phase.

After extraction was completed, the hot liquid was cooled to room temperature and filtered through filter paper. The clear solutions obtained in this way were stored as “raisin juice”, “dried apricot juice” and “beetroot juice” solutions for the next stages. Taking into account that the glucose concentration may be very high, in order to bring the solutions into the measurement range of the RX-5000 device, they were diluted 2–10 times with distilled water when necessary. For each sample, the dilution factor was recorded separately and taken into account in the final calculations.

Preparation of standard glucose solutions. For calibration, chemically pure glucose (analytical purity “chemically pure”) was used. First, 1.000 g of glucose was weighed on an analytical balance, dissolved in distilled water in a 100.0 ml volumetric flask, and a stock standard solution with a concentration of 10 g/l was prepared. By successive dilution of this stock solution, a series of working standard solutions with concentrations of 2, 4, 6, 8 and 10 g/l was prepared.[8,9] All solutions were stored in closed conditions at about +4 °C and brought to room temperature before the experiment.[10,11]

Setting up the Automatic Refractometer RX-5000. First, the device was placed on a horizontal table, connected to the power supply and started up in accordance with the manufacturer’s instructions. After the device passed its internal self-diagnostic mode, the main menu screen appeared. In order to control the temperature factor under working conditions, the Set temperature value was set to 20.0 °C, the *Temp control* function was switched on, and when the Sample temperature reading approached the set value, measurements were started.

As the test mode**,** the direct refractive index measurement mode – *nD (refractive index)* – was initially selected. The name of the standard solution or dried juice being analyzed was entered into the *Sample name* field. Before measurements, the prism surface was cleaned with a mixture of distilled water and ethanol and wiped with a soft cloth.

Calibration and creation of the user scale.

For calibration, the Calibration section was opened and the User-selected sample calibration mode was chosen. First, calibration was performed for distilled water: a drop of distilled water was placed on the prism surface, and after the temperature stabilized at 20.0 °C, the instrument measured the n value and automatically corrected it based on the reference value nD(20 °C, H_2O) ≈ 1.3330. After that, standard glucose solutions of different concentrations were measured in succession.

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For each concentration (2, 4, 6, 8, 10 g/l), the refractive index was measured three times and the average nD value was calculated. On the basis of the obtained results, a calibration graph C_glucose – nD was constructed. Analysis of the graph showed that in the 2–10 g/l range a linear relationship was observed, and the regression equation of the form

C = a·nD + b

and the correlation coefficient ($R^2 \approx 0.99$) were calculated. This empirical equation was entered into the memory of the RX-5000 as a *user scale.*[12,13] As a result, the instrument became capable of measuring the refractive index and displaying the result directly in units of glucose g/L or mass %.[14,15]

Procedure for determining glucose in dried fruit and vegetable juices.

The filtered extracts prepared for each dried product (raisins, dried apricots, beetroot), after the required dilution, were analyzed on the RX-5000 according to their refractive index. The procedure was carried out in the following order:

1. The prism surface was cleaned from residues of the previous sample.
2. Using a pipette, 0.3–0.5 ml of the sample was dropped onto the center of the prism.
3. The cover was closed and the *Sample temperature* was allowed to approach the value *Set temperature = 20 °C.*
4. The measurement was performed in automatic mode; the instrument measured nD and, based on the *User scale*, calculated the glucose concentration.

For each sample, the measurement was repeated at least three times, and the mean value and relative deviation were calculated.

As a result, for each product the glucose concentration in the dried juice solution (g/l or %) was determined. Taking the dilution factor into account, the glucose content corrected per unit mass of dried product (g/100 g of dry product) was calculated. These indicators were then compared and analyzed between raisins, dried apricots and beetroot.

Results and Discussion

The obtained results showed that, in raisin dried juice solutions, the glucose concentration lies in the highest range of values, with an average of about 65 g, whereas for dried apricots this indicator was 48 g, and for beetroot it was comparatively low, around 33 g (here the ratio $X_1 > X_2 > X_3$ is preserved). This situation corresponds to the natural biochemical composition of fruits and vegetables: dried grapes (raisins) are usually the sweetest product, with a high proportion of sugars; in dried apricots this proportion is somewhat lower, while in beetroot, along with sugars, the share of organic acids and other components is significant.

To evaluate the accuracy of the refractometric method, the glucose content in several samples was also determined by a classical chemical method (titrimetry or enzymatic analysis) and compared with the RX-5000 results. According to the comparison, the relative difference between the values obtained by the refractometric method and the chemical methods did not exceed 2–3 %, and the correlation coefficient was in the range of 0.98–0.99. This shows that the methodology developed on the basis of the RX-5000 has high accuracy and reproducibility.

The advantages of the methodology are manifested in the following: Speed: a single measurement is performed within 1–2 minutes, and sample preparation is simplified. Low sample consumption: 0.3–0.5 ml of solution is sufficient. High degree of automation of the instrument: there are built-in functions for temperature control, user scales, internal memory and data export. Importance for education: students study the theory of refractometry, calibration, and the relationship between optical properties and concentration on the basis of real experiments.

At the same time, the method has certain limitations. For example, in dried juice, in addition to glucose, fructose, sucrose, organic acids, pectins and other soluble substances are also present, so the refractive index does not depend on glucose alone. To minimize this, it is recommended that calibration be carried out using standards whose composition is close to that of the product under study, or that refractometric results be verified at least once using a chemical method. In addition, factors such as insufficient control of temperature, an unclean prism surface and the presence of air bubbles can also lead to errors in the results.

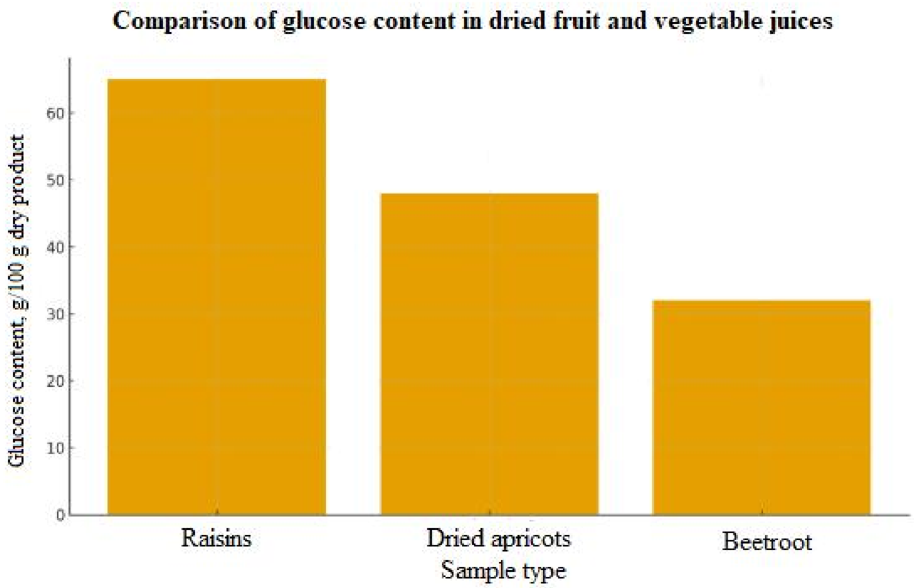

Figure 1. Diagram of glucose concentrations in 100 g/ml of dried fruit and vegetable juices.

The analysis of the results shows that the glucose content in dried fruit and vegetable juices varies significantly depending on the type of product (Figure 1). The dried raisin juice exhibited the highest glucose concentration, at approximately 65 g per 100 g of dry product. This result is explained by the natural sweetness of grapes and the concentration of dissolved substances due to water evaporation during the drying process. For dried apricots, the average glucose content was around 48 g per 100 g, which indicates that, although its sweetness is lower than that of raisins, its energy value remains sufficiently high. The dried beetroot juice showed the lowest glucose content, at about 32 g per 100 g, which is associated with the relatively high

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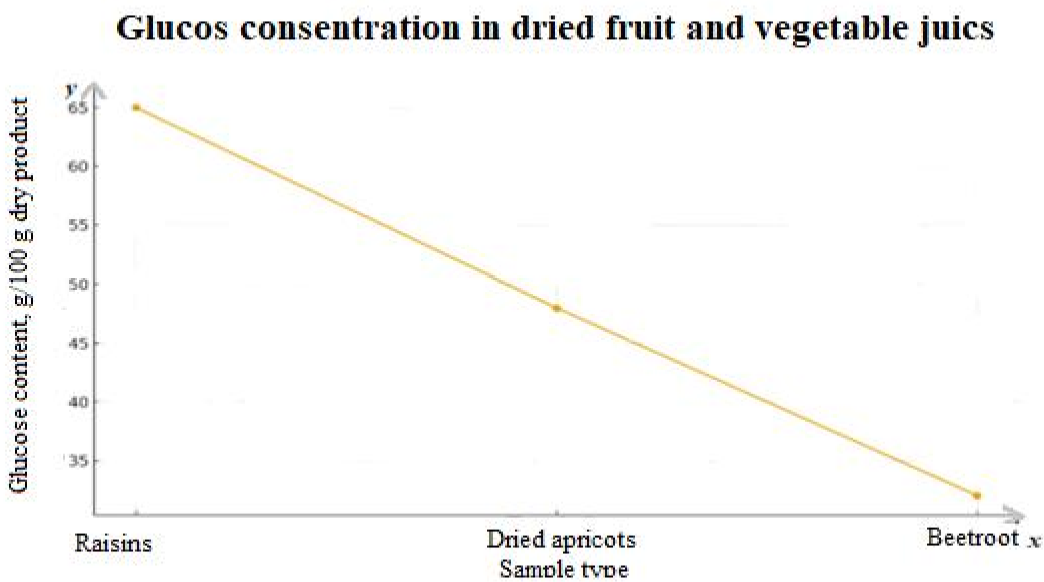

Figure 2. Graph showing the increase in glucose concentration in 100 g/ml of dried fruit and vegetable juices.

Conclusion

As a result of the studies carried out, a practically convenient, rapid and sufficiently accurate methodology was developed for determining the glucose content in dried juices of fruits and vegetables – raisins, dried apricots and beetroot – using the Automatic Refractometer RX-5000. By constructing a calibration graph based on standard glucose solutions and entering a user scale into the memory of the RX-5000, a linear relationship between the refractive index and glucose concentration ($R^2 \approx 0.98–0.99$) was demonstrated, and the instrument was enabled to display the result directly in units of g/l or mass %.

The analysis of dried fruit and vegetable extracts showed that, in terms of glucose content, raisin juice exhibits the highest values, dried apricot juice intermediate values, and beetroot juice comparatively low values, which is consistent with their natural biochemical composition. When the results of the refractometric method were compared with those of classical chemical methods, the relative difference did not exceed 2–3 %, confirming that the methodology has high accuracy and reproducibility. The main advantages of the method are the speed of analysis, low sample consumption, automatic temperature control, the possibility of creating user scales, and storing data in digital form.

At the same time, it should be taken into account, as a natural limitation of the method, that the refractive index depends not only on glucose, but also on fructose, sucrose, organic acids and other soluble substances. In the future, the development of complex calibration models tailored to product composition, the integration of refractometry with other instrumental methods, and the creation of a set of specialized laboratory exercises based on the RX-5000 for educational laboratories will make it possible to further deepen research in this field.

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