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Evaluation of organoleptic and texture properties of dried apples by hybrid electronic tongue

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ABSTRACT

The aim of this paper is to use hybrid electronic tongue in the qualitative and quantitative analysis of extracts obtained from raw and dried apples prepared by different food processing techniques (drying techniques). The system is based on potentiometric and voltammetric sensors, moreover data recorded by spectrophotometry, amperometry and conductometry techniques were applied to enhance the classification ability of the device. The combination of the data from various measurement techniques (hybrid electronic tongue) leads to improved differentiation of the dried apple extracts samples comparing to separate techniques. Appropriate chemometric techniques were used to the recognition and classification of samples, whereas the efficiency of the qualitative and quantitative analysis was evaluated on the basis of Root Mean Squared Error (RMSE), determination coefficient (R^2), slope (a), and intercept (b) parameters.

1. Introduction

In the era of expanding the production of ready meals and products for direct consumption the drying of fruits and vegetables is important. Although drying is one of the oldest methods of food preservation, the process is widely used and it is oriented on continuous development [1–4]. Fruits and vegetables contain a large quantity of initial moisture content and are therefore highly susceptible to rapid quality degradation, even to the extent of spoilage, if not kept in thermally controlled storage facilities. Moreover seasonality of plant materials often leads to a surplus of fruit and vegetable, and drying makes it possible to easily and quickly convert these perishable products into more stabilized ones that can be kept under a minimal controlled environment for an extended period of time [5]. On the other hand, drying changes the physical and biochemical form of the fruit leading to shrinkage and change of color, texture, taste, and so on [6,7]. These properties are important in selecting a product by the consumer.

Color is an important indicator of food quality. The color of the dried product has a strong influence on the acceptability of the product by the consumer, because the first assessment of the food is made mainly based on visual impression [8–10]. The methods of drying and process parameters have a significant effect on it [8]. During the drying of plant products color changes occur as a result of the browning reaction, both enzymatic and non-enzymatic [11,12].

Unfortunately, convective drying causes adverse change of color. With the increase of temperature of drying air and drying time, the color becomes darker [9,13]. Similarly, infrared drying often causes darkening of the tissue as a result of the browning reaction [14]. However, using the microwave power for drying gives the product with much better color than convective drying. Microwaves cause small color changes [15,16]. Moreover, drying effect on tissue texture changes such as firmness and hardness of the material [17]. Loss of the fragility of foods is associated with increased water content, which is a plasticizer [18]. With the increase of water activity decreases mechanical strength of the product. Texture also significantly affects the acceptability of the product by the consumer [11].

Both the color and texture of dried tissue (which are measured with physical methods), affect the sensory evaluation made by consumers. However, the correlation is not straightforward and obvious, therefore taste and quality must be judged with human panels, which is a time-consuming, subjective, and costly method. That is the main reason for conducting research focused on estimation of organoleptic properties of food with objective methods. One of the most promising tools used in this area are sensor arrays coupled with pattern recognition blocks, i.e. electronic tongues [19].

An electronic tongue was developed as a device inspired by the natural sense of taste [20]. Of course, nowadays systems performance is a very far analogy of natural counterparts, despite of that the electronic tongues can be applied successfully in specific applications. The use of such systems enables to perform

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the recognition and classification of sample images [19,21,22]. The number of papers describing the application of electronic tongue for the measurement of environmental samples [23], biotechnological samples [24], food [25], body fluids [26] and pharmaceuticals [27] is steadily growing.

Commonly, potentiometric and voltammetric sensors are applied to build the sensor array of an electronic tongue, but also optical, amperometric, and conductometric sensors are involved as well [21]. Pattern recognition system enabling appropriate analysis of sensor array responses comprises various chemometric methods including neural networks. In last years, so-called hybrid electronic tongues have become more popular. They are based on various sensing schemes, which allows for obtaining more information about the samples than separately used techniques, which, in turn, enables more accurate characteristics and clearer distinction between them [28].

The literature reports the application of electronic tongues for the analysis of many foodstuffs: non-alcoholic beverages [29], water [30], juices [31], etc. With the use of electronic tongue and sensory evaluation apple juice samples and modified juices were studied for apple taste, sweet taste and sour taste estimation [32]. Potentiometric electronic tongue was applied to distinguish different fruit juices [33]. Following example is an electronic tongue based on potentiometric sensors, HPLC and FTIR spectroscopy, which was used to the qualitative and quantitative analysis of apple varieties [34].

In this work we propose a hybrid electronic tongue based on potentiometry, voltammetry, amperometry, conductometry and spectroscopy for the evaluation of organoleptic properties of dried apples. Moreover, the correlation of sensor array responses with taste, color and texture properties is studied, which could be useful for future quality control, estimation of nutritional value, and organoleptic evaluation purposes.

2. Experimental

2.1. Preparation of dried apples

The experimental material comprised apples (var. Idared). It originated from the Department of Fruit Culture Experimental Fields of SGGW (Warsaw University of Life Sciences) and was obtained in December. Apples were peeled and cut into slices 0.005 ± 0.001 m thick and diameter of 0.03 m. The cut material was immersed in the 0.1% citric acid solution to prevent enzymatic browning reactions and it was blotted with filter paper.

Convective drying was performed in a prototype dryer. Samples were placed on a perforated tray positioned co-current to air flow. Air velocity was 2 m/s and temperature was 70 °C. The dryer was loaded with 1.92 kg/m^2 of apple tissue. The drying process was carried on until constant mass was achieved.

Microwave-convective drying was performer in a laboratory dryer fabricated by Promise Tech Inc. (Wroclaw, Poland) with microwave incident power of 300 W. Samples were placed on a rotating tray on shelves positioned perpendicular to air flow. Air velocity was 3.5 m/s and temperature 40 °C. The dryer was loaded with 2.4 kg/m^2 of apple tissue. Drying was run until about 10% water in the dried material was reached.

Infrared drying was performed in a dryer equipped with infrared electric bulbs. The infrared emitters were located 0.2 m from the dried product. The total power of emitters was 7.875 kW/m^2. Samples were placed on a perforated tray positioned co-current to air flow. The flow of ambient air over the heated surface was set at 1.2 m/s. The dryer was loaded with 1.26 kg/m^2 of apple slices. Drying was run until constant mass was reached.

2.2. Color measurements and texture analysis

Quantitative evaluation of the color changes in dried apples was done by a portable tri-stimulus colorimeter (Minolta Chroma CR-300, Osaka, Japan) for direct measurement of the color parameters of the raw and dried samples. The color values were expressed as L^* (whiteness or brightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness) parameters. The diameter of the measuring area was 8 mm. Measurements were taken at fifteen random points for each sample. The total color difference ΔE was calculated using following equation:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \qquad (1)$$

where ΔL, Δa, Δb represent the deviations of the individual values from the respective values from a fresh raw apple [8].

The study of mechanical properties was carried out using TA-TX2 texture analyzer (Stable Micro Systems Ltd., Surrey, UK) with a 25 kg load cell. Experiment was run with a cutting blade with a length of 62 mm, a width of 24 mm and a thickness of 0.5 mm. Test was performed to completely cut slice of dried apples with the head velocity of 1.0 mm/s and with a force of 15 N. For the examination, randomly selected 10 slices of fresh or dried material were used. Work of cutting was calculated as the area under the curve illustrating the change of force (N) as a function of head shifts (mm) to achieve maximum strength.

2.3. Organoleptic assessment

Sensory evaluation was conducted after 24 h from the drying process. The assessment was performed on a scale from one to five by 6-person panel of experts. Dried samples were provided in random order in transparent containers to the evaluators. To assess the smell, approximately 50 g of dried material in the bag opened just before the evaluation was given to the panelists. For quantitative expression of the quality and sensory intensity of dried material, the following factors were used: color, smell, taste, hardness and overall quality of the dried material. The evaluation was performed twice in three months apart.

2.4. Preparation of dried apple extracts

Each dried sample was minced using flay. Apple powder was mixed with distilled water in the same amount which was removed during the drying process. After 15 min samples were centrifuged at 11,000 rpm for 10 min. Then they were decanted from above the surface and then passed through a filter paper in order to achieve homogeneous solutions of dried apple extracts.

2.5. Preparation of potentiometric sensors

All inorganic salts used, 1-morpholinoethanesulfonic acid (MES), sulfuric acid and sodium hydroxide were of analytical grade and were obtained from Fluka. The working solutions of salts (0.1 M) were prepared in redistilled water. The polymeric membrane components: high-molecular weight poly(vinyl chloride) (PVC); plasticizers: bis(2-ethylhexyl) sebacate (DOS), *o*-nitrophenyl octyl ether (*o*-NPOE); lipophilic salts: potassium tetrakis[3,5-bis(trifluoromethyl)phenyl]-borate (KTFPB), potassium tetrakis(4-chlorophenyl)borate (KTPClPB), tridodecylmethylammonium chloride (TDMAC); ionophores: ETH 129 (calcium ionophore II), calix[6]arene-hexaacetic acid hexaethylester 4-tert-butylcalix [4] arene–tetraacetic acid tetraethyl ester (sodium ionophore X), valinomycin (potassium ionophore I), were purchased from Fluka. The membrane components (100 mg in total – appropriate ionophore, 20–50 mol% versus ionophore lipophilic