COMPARATIVE EVALUATION OF VACUUM AND AIR OVEN MOISTURE CONTENT DETERMINATION METHODS FOR SOME VARIETIES OF DRIED FRUITS AND VEGETABLES

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Abstract: Исследовалась кинетика высушивания в вакууме (температура 60 и 70 °C) образцов сушеных фруктов и овощей с различным исходным уровнем влажности в пределах коммерческого диапазона: яблок (4 %-28 %), вишни (18 %-32 %), моркови и тыквы (8 %-14%), томатов (17 %). В процессе высушивания вишни (60 и 70 °C), моркови и томатов (70 °C) наблюдалось непрерывное снижение массы испытуемого образца, что указывает на протекание значительных процессов деградации и искажение результатов определения содержания воды в этих продуктах. В работе представлена также кинетика высушивания исследуемых образцов при атмосферном давлении и температуре 98 °C для фруктов и 88 °C для овощей и обсуждены условия применения исследованных методов.

Key words: vacuum and air moisture determination methods; dried fruits; dried vegetables

Introduction

Drying methods are the most widely used techniques. Drying techniques with convective heating principle comprise ordinary oven drying and vacuum oven drying. It is important to be aware that drying techniques do not measure the water content as such. The result is a mass loss under the conditions applied or "moisture" is often used instead. These conditions can principally be freely chosen and the results are, consequently, variable. Drying to a constant mass is often required, but a real constancy is only achieved in rare cases. The mass loss is not only caused by water but by all the substances volatile under the drying conditions, either already contained in the original sample or produced by the heating process. The application of low pressure in vacuum ovens reduces the danger of producing volatile decomposition compounds but does not allow a distinction to be made between water and other volatile substances already present in the product. To shorten the long determination times, more intensive heating is used. The results can vary in a very broad range depending on the drying parameters applied. Mass-loss results can, however, be matched with the results of another method, particularly a reference method, by adjusting the parameters in an appropriate way. In these cases the most suitable calibration must be established for every type of product in a specific way [1].

The aim of this work was to evaluate two methods of oven moisture determination: a) under reduced pressure, and b) at atmospheric pressure, applied to traditional (apples, sour cherries, carrots) and lesser-common (sweet cherries, pumpkin and tomatoes) species of dried fruits and vegetables.

Materials and methods

The study methodology consisted of simultaneous moisture content analysis of test samples with using vacuum and air oven, evaluation of accuracy and comparison of obtained results.

In preparing the dried samples, fresh apples, cored and sliced; cherries stoned; carrots, washed, skinned, diced, and steam blanched; muscat pumpkin, peeled, de-seeded, diced, and water blanched; red tomatoes, quarters were dried in a laboratory tunnel air drier at the temperature of 60 - 65 ºC and 2,5- 3,0 m/s air velocity.

Seven samples of dried apples with various moisture in a range from 4,2% to 28,0%, six samples of dried sour cherry with moisture in a range from 18,0% to 32,0%, and one sample of dried tomatoes with moisture about 17 % were prepared. Two samples of dried carrots and in twos samples from each of the two batches (I and II) of dried pumpkins, that differed in the texture (brittle and hard or poorly elastic) were also obtained. The moisture levels met commercial moisture range for each test product. Test preparation and laboratory equipment, the procedure of analysis were in accordance with GOST 28561-90 with the following clarification: the test portion placed in a drying dish did not exceed 0.2 g at cm^2.

In preparing the tests for the analysis, dried fruits and tomatoes were cut with scissors onto 1-1.5 mm size bits; carrots and pumpkin samples from batch I, both with brittle and hard or elastic texture, were ground in the 160 W electric coffee mill, avoiding to be heated and turned into fine powder. The sieve analysis of the pumpkin I test, prepared from the sample with brittle and hard texture, showed that the oversize and undersize of 1 mm sieve was, respectively, 3% and 97%, including the 79% passage through the sieve of 0.5 mm. The test prepared from the sample with elastic texture passed through the 3 mm sieve, including the 47% passage through the 2 mm sieve.

The pumpkin samples from batch II were ground in the 90 W electric coffee mill and the corresponding tests with visually bigger particle size were obtained.

The prepared tests were packed and tightly closed.

Vacuum oven drying: A vacuum oven with automatic temperature regulation with accuracy ± 2 ºC was used. Drying parameters: the temperature 70 or 60 ºC, the pressure of 10 mm Hg. (1,33 кPa).

Air oven drying: An air oven with natural ventilation and automatic temperature regulation with accuracy ± 2 ºC was used. The drying temperature: 98 ºC or 88 ºC.

We investigated two methods of moisture: 1) drying for a specified time at a specified temperature, and 2) drying to a constant mass.

With method 2), drying tests were kept in the heated oven for a time equal to approximately 70 % of the total drying time, established a priori, and then weighed. The drying was continued until two consecutive weighings do not differed by more than 0.40 mg per g of test taken, the second weighing following an additional drying time (about 10 % of the total drying time).

Mathematical treatment: The mathematical treatment of the experimental results was carried out according to [2] and included: a) calculating the average values of parallel measurements, precision estimations, and confidence intervals, using t-test; b) checking by the Fisher – test the hypothesis of the mean values equality c) regression analysis and checking linear hypothesis using F- test, d) correlation analysis and calculated regression line by using the method of least squares.

Results and discussion

Moisture variations in the samples, depending on vacuum and air oven drying time, were presented and analyzed in a graphic form.

The test samples of apples lost the bulk of the moisture during the first 2-hours and reached constant mass for 6-12 hours of vacuum drying at 70 °C. The mean value of moisture reduction for the drying period from 6 h until reaching a constant mass was ranged from 0 to 0.34 abs.%, average 0.20 ± 0.10 abs.%.

None of test sample of sour cherries attained a constant mass during the vacuum drying for 83 hours at 60 °C and for 30 hours at 70 °C.

The samples of dried carrots, regardless of their initial moisture content, reached a constant mass after 48 hours of vacuum drying at 60 °C; at the same time, the mass decreasing in both of the samples took place at 70 °C throughout the 48 hours measurement period. 8.3 and 14.6 hours of vacuum drying at 70 °C resulted in the moisture values equal to those obtained at 60 °C when constant mass was attained, respectively for the brittle (hard) and elastic samples.

Vacuum drying kinetics, obtained for dried pumpkin at 70 °C, showed that all the studied samples reached a constant mass during the test. Both brittle samples with a moisture of about 8 %, from the batch (I) and (II), differed in bits' size, and the sample with elastic texture and moisture content of about 14% from the batch (I) were completely dried for 18 hours. At the same time it took 23 hours to achieve a constant mass in the second elastic sample (batch II). Such increasing in the drying time may be the result of the larger sample particles, obtained with low-powered mill, in combination with the higher sample moisture (about 16 %).

Constant mass of dried tomatoes was not reached after 24 hours of vacuum drying at 70 °C; continuous rising of moisture during all measurement time was observed by the relevant graphic.

The results were evaluated with the following: 1) an application of drying to a constant mass indicates no significant sample degradation, and means that the applied drying conditions allows you to get the result what meet the water content, and 2) a continuous decreasing test sample mass during drying indicates significant degradation and the possible distortion measurement results.

In the entire investigated moisture range (4%...28%), the results obtained for apple drying confirm the admissibility of the following vacuum drying parameters: 6 h, 70 °C. These parameters correspond to the official laboratory method used in [3].

Cherries and tomatoes lose mass continuously, even in mild drying conditions which were used in the experiments; it indicates a significant degradation of these materials. The reduction in mass, observed during the cherry samples drying, may result from the anthocyanin destruction [4]. Tomatoes are extremely sensitive to drying temperature, and degradation reaction proceeds via browning. At temperatures of 50-60 °C browning reactions occur uniformly throughout the process of tomatoes drying [5] and, therefore, a resulting loss in the sample mass can take place even when the temperature of moisture determination will be reduce below 70 °C. Because drying to constant mass was unacceptable for dried cherries and tomatoes, it seems reasonable to determine the moisture by drying for specified time.

As follows from the results, the method of vacuum drying to constant mass at 70 °C is suitable for dried pumpkin analysis, but not dried carrots. The processes occurring during carrot drying and affecting the change in material mass are reflected in the scientific literature [6]. There are fat, carotene, tocopherol oxidation, native volatile loss, and deamination of amino acids. Good results were obtained for dried carrots at

60 ° C. At this temperature, a constant mass was reached for the same time, regardless of the initial moisture content of the samples. Thung S. [7] concluded that the temperature below 70 °C in determining the moisture content in the dehydrated vegetables by vacuum drying should be used to avoid the effects of thermal decomposition. 60 °C compared to 70 °C may be advantageous also for the pumpkins, because of a possible drying time leveling for the samples with different initial moisture content; so the method of specified time can be used.

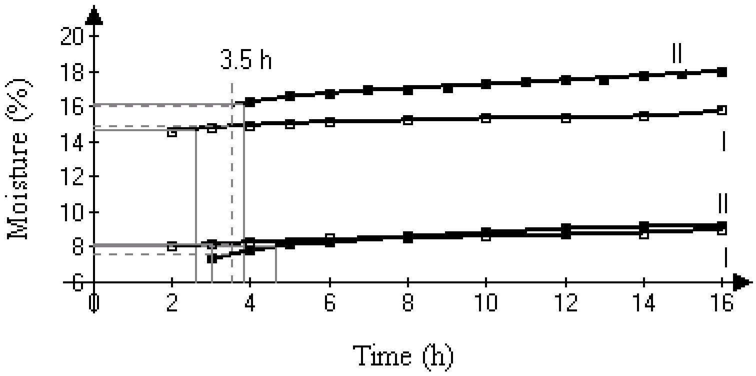

Fig. 1. Moisture measured for dried pumpkin samples from batch I and II vs. there air drying time at 88 °C

The measured moisture values for dried pumpkin samples vs. there air drying time at 88 °C are shown in Figure 1. The samples tested within 16 hours of drying have not reached a constant mass, regardless of their initial moisture content. These samples were used for the moisture content parallel determinations by vacuum method using the parameters: 70 °C, 6 h. Moisture values obtained in a vacuum oven, are plotted as horizontal lines. The drying time in an air oven, at which moisture measured by the two methods are the same, are determined by the intersection point of the horizontal and the corresponding curve. The time range is from 2,6 to 4,6 hours, the average – 3,5 h. Moisture values referring to 3,5 hours of air drying were determined for each of the tested samples and significant differences (at the confidence level P=0.95) between the values obtained by the two methods were found. The differences range from minus 0,425 abs. % to 0,14 abs. %.

The mass of tomato samples decreases continuously during 16 hours of air drying at 88 °C. 2,5 hours of the air drying (W=17,37±0,34 %; s=0,2276; n=3) corresponds to 24 h of vacuum drying at 70 °C (W=17,405±0,394 %; s=0,2350; n=4). Unfortunately, the moisture value referring to 6 h vacuum drying (W=15,16±0,34 %; s=0,2159; n=4) is out of the range of air drying results.

A comparison of the moisture content measurement results in dried cherries, obtained by air oven drying method (98 °C, 3 h) and vacuum oven drying method 70 °C, 6 h), was studied. Non-linear regression relationships between the values of moisture determined by the two methods were presented in graphical form. Using the method of least squares closest correlations of the following types were established for dried sour cherries (1) and dried sweet cherries varieties Rossoşanscaia zolotaia (2) and Tehlovan (3):

$$W_v = (5.26784 \times 10^{-4}) \times W_{\grave{a}}^3 - 0.019562 \times W_a^2 + 1.19910 \times W_a - 0.0021339 \quad (1)$$

R^2 =0.99999, S= 0.0296421;

$$W_v = -(4.03946 \times 10^{-4}) \times W_a^3 + 0.022432 \times W_a^2 + 0.729918 \times W_a - 0.00168 \quad (2)$$

R^2 =0.9998, S = 0.176087;

$$W_v = (6.79154 \times 10^{-4}) \times W_{\grave{a}}^3 - 0.032741 \times W_a^2 + 1.30891 \times W_a + 0.00199081 \quad (3)$$

R^2=0.9993, S = 0.2585;

Evidently, the obtained correlations or graphs should be used to better match methods. It should be noted that the investigated varieties of cherries have a significantly different quality: Rossoşanscaia zolotaia belongs to the light-colored fruits (yellow), with a gentle pulp, Tehlovan - to a group of dark-red fruit with firm, crisp pulp [8]. Additional studies may be needed to confirm that the established differences in the moisture determination are not random.

Conclusions

Different kinds of dried fruits and vegetables require an individual approach to choose the behavior for moisture content determining, with using both vacuum and atmospheric oven.

Method of drying to constant mass under reduced pressure can be applied to dried apples (70 °C), carrots (60 °C), pumpkins (70 °C). It is not suitable for the dried sour cherries and tomatoes analysis at temperatures both 60 °C and 70 °C, due to significant degradation of there chemical composition under the influence of prolonged exposure to temperature. Method of drying to constant mass at temperature of 88 °C and atmospheric pressure also can not be used for dried pumpkin and tomatoes analysis.

3,5 and 2,5 hours, respectively, were found as specified drying time.

Some differences in the results of moisture measurement in cherries, using vacuum

(70 °C, 6 h) and air (98 °C, 3 h) drying methods, were noticed, and the empirical relationships between the moisture values obtained by the two methods were established.

Nomenclature

W umiditate, %

n number of parallel measurements

s standard deviation estimation

R^2 coefficient of determination

Symbols used as subscripts: v-vacuum; a – aer.

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