KINETICS OF INFRARED RAY DRYING OF PEELED APPLES

Bolsaia Victoria

Technical University of Moldova, Chisinau, Republic of Moldova

Bolsaia Victoria: viktoria.bolshaia@gmail.com

Abstract: The paper presents data on the study of the antioxidant treatment of cut, unpeeled apples. Were studied a number of antioxidant solutions from which were selected and proposed 3 compositions, which have a beneficial effect on the treatment process. We studied the process of drying of Idared apples with infrared rays at temperatures of 80 ... 120 ºC. It has been demonstrated that the temperature in the drying process should not exceed 90 ºC. The processing of the experimental results allowed the mathematical equation to determine the drying time.

Key words: apples, antioxidants, infrared rays, drying kinetics, chemical solutions.

Introduction

A healthy lifestyle first starts from eating. At present, Western consumer preferences are geared towards high-nutrition rich in biologically active and low-calorie substances. The main sources of high biological activity are fruit and vegetables consumed fresh. Most of them are only available during the short harvest season. One of the conservation methods, which allow the preservation of native substances and their concentration in the finished product, is preservation by dehydration. Drying helps make natural products accessible for consumption at any time of the year and under all circumstances. Removing water from fruits and vegetables ensures not only the risk of microbiological alteration, but also optimizing transportation costs, keeping dry products. Dried fruits are rich in dietary fiber that ensures normal and healthy functioning of the gastrointestinal tract. Iron, calcium, potassium, selenium, concentrated A, B and C vitamins protect the body from the harmful action of free radicals that are the source of cardiovascular, neurodegenerative, and cancerous diseases.

The production of dried fruit presents an opportunity for the processing industry in the Republic of Moldova because it has the necessary raw material, the technical-scientific basis and the possibility to compete on the market of organic products. From variety of dried fruit produced, a high demand is recorded for dried quality apples – unpeeled and without free-wooden fascicle, without significant traces of fermentative browning. They may be present on the market in the form of plates, slices, rings or cubes. The biggest problem encountered in the process of drying apples is the process of browning. The brown appearance declares the dried apples of the quality category. To prevent browning resulting from the fermentative oxidation of polyphenolic substances, it is necessary to apply thermal or chemical treatments that would combine the effective action of inhibiting browning processes with harmlessness to the human body. For these reasons, it is necessary to study the processes of oxidation of polyphenols and their inhibition by using different aqueous solutions of stabilizers and antioxidants.

Materials and methods

As a research object, were used Idared apples, approved in Moldova, rich in carbohydrates, organic acids, minerals, vitamins, pectic substances, etc., which represent high interest as a research object in the technology of drying. Preventing browning during drying and storage can be achieved by treating of cut, peeled apples, with bleaching agents and antioxidants.

In the paper, the following solutions were used for dry treatment: SO2 + NaCl; citric acid + NaCl; KCl; NaCl; SO2, citric acid + NaCl + CaCl2 + sugar with varying concentrations, duration of treatment from 4 to 40 minutes. Treated apples with solution were subjected to the infrared ray drying exposure to the MAC-210 humidity analyzer, which provides the dehydration of the sample under infrared irradiation. The analyzer is equipped with a balance which, during drying, measures and records the change of the dried sample. The maximum capacity of the balance is 210 g. The sample is weighed to an accuracy of 0.001 g. The maximum drying temperature is 160 ° C. It is possible to change the drying temperature within 60 to 160 °C with the unit step. The end of the drying process can be applied manually or automatically.

Methods of research. For determination of physic-chemical properties, were used the following methods of analysis:

Table 1. *Analysis methods*

Indicator	Method of determination	Standard
Soluble dry substances	Refractometric method	GOST 28562-90
Total dry substances	Standard method	GOST 28561-90
Sugars	The Leina and Ainona method	GOST 8756.13-87
Total acidity	Titrimetric method	GOST 25555.0-82
Active acidity	Potentiometric method	GOST 25555.0-82
Sodium chloride content	The Mohr method	GOST 26186-84
Index of Browning	Spectrophotometric method	According [3]

Methods and discussions

Initial research has been geared to selecting the preventive treatment solution of apples, effective in blocking fermentative browning and harmless processes for consumer health. The condition was to replace sulfur dioxide with solutions of citric acid, NaCl, CaCl2, KCl used separately and in combination. The samples treated with solutions of sulfur dioxide and salt (0.075% and 0.2%, respectively) were used as control samples against which the selected composition and concentration of the other aqueous solutions.

Before the drying, the apples were subjected to the processing according to the technological scheme: Washing → Weighing → Removal of the seed box → Peeling → Cutting → Weighing → Treatment with antioxidants or solutions to prevent browning fermentation.

The solutions used and their concentration, as well as the results and appreciation of the appearance and taste of dried apples, are presented in Table 2.

Table 2. *Substances of preventing browning used at treated, peeled apples*

Variety	Nr. of sample	Antioxidant used	Concentration of the solution	Duration of treatment, min	Color	Taste
Idared	**1.**	SO_2+NaCl	0,075+0,2	8	light yellow	sweet
	2.	SO_2+NaCl	0,075+0,2	10	yellow	sweet
	3.	SO_2+NaCl	0,075+0,2	6	yellow	sweet

Variety	Nr. of sample	Antioxidant used	Concentration of the solution	Duration of treatment, min	Color	Taste
	4.	SO_2+NaCl	0,075+0,2	4	light yellow	sweet
	5.	Acid citric+NaCl	5+0,4	40	cream	acid taste
	6.	Acid citric+NaCl	0,7+0,3	10	cream	lightly acidic taste
	7.	Acid citric+NaCl	6,5+0,2	20	light cream	Foarte acide
	8.	Acid citric+NaCl	5+0,4	20	light brown	Acid
	9.	KCl	0,4	8	cream	sweet
	10.	Acid citric+NaCl	0,7+0,3	6	light cream	balanced
	11.	NaCl	0,4	8	light cream	balanced

The analysis of the results in Table 1 shows that, within the limits of the studied concentrations, the best sensory characteristics are obtained when treating apples with 0.9% citric acid solution and salt NaCl - 0.4%. The scientific results obtained in the laboratory were tested in the production units of the company "UNIFERAX - GRUP", Ungheni city. The inspection of the preventive treatment parameters with this solution under industrial conditions ensured excellent quality, with the production of dried apples Idared of Extra quality.

Apples Drying with infrared rays (IR). To study the drying process with IR rays, was selected the Idarea variety of apples, treated with aqueous solution of 1% citric acid, 0.4% NaCl and 0.6% CaCl2 for 6 minutes. Apples were dried with IR rays at different temperatures - 80 °C, 90 °C, 100 °C, 110 °C and 120 °C, up to 18% humidity. The high temperature of the drying process with IR rays of 90 - 120 ºC, accelerates the dehydration of the product, but causes a number of negative changes in the color of the dried apple rings. At these high drying temperatures, the apple rings are browning on the surface as a result of non-fermenting browning reactions - Maillard reactions and the process of carbohydrate caramelization. At low drying temperatures (lower than 90 °C), the drying time practically doubles.

Figure 1 shows the irradiation drying curve of peeled Idared apples, without the seed box, cut in rings to a thickness of 8 mm. Drying takes place at 80 ºC.

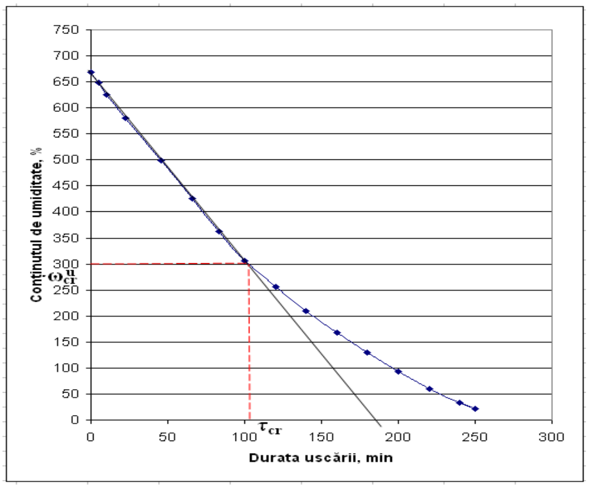

Fig. 1. *IR irradiation curve of Idared apples at t = 80 °C*

Analyzing the graph of the drying curve (Figure 1), it found that the critical humidity is reached a moisture content of 300% and the drying time 108 min. The drying rate in the second period is 140 minutes. The variation of the drying rate (with IR rays) of apple rings at 80 °C is shown in Figure 2.

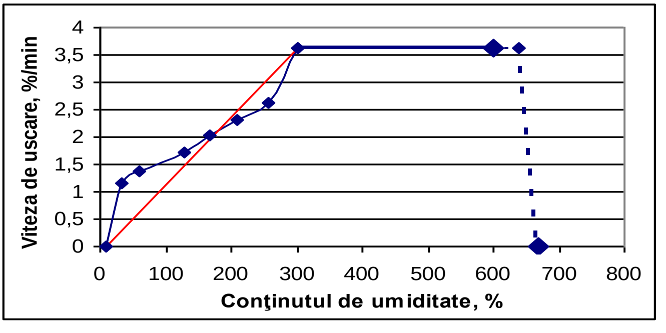

Fig. 2. *Speed Curve of drying irradiation of Idared apples at t = 80 °C*

The maximum drying speed, which is maintained during the first drying period, is 3.62% /min. For determining the drying time for the entire period, differentiating the drying curve in a second period and the ratio to the drying rate N in the first period. The data obtained are recorded in Table 2 below.

Table 3. *Experimental calculations for the drying apples with of IR-ray during II period*

Nr. Points of II period	**ω^u, %**	**τ, min**	**$\omega_{cr} - \omega_2$**	**$\tau_2 - \tau_{cr}$**	$\frac{\tau_2 - \tau_{cr}}{\omega_{cr} - \omega_2}$	**M^1**
a	300,00	103				
1	255,6	120	44,4	17	$382{,}9 \cdot 10^{-3}$	$9{,}00 \cdot 10^{-3}$
2	209,8	140	90,2	37	$410{,}2 \cdot 10^{-3}$	$10{,}00 \cdot 10^{-3}$

Nr. Points of II period	ω^u, %	τ, min	$\omega_{cr}-\omega_2$	$\tau_2-\tau_{cr}$	$\frac{\tau_2-\tau_{cr}}{\omega_{cr}-\omega_2}$	M^1
3	167,7	160	132,3	57	$430{,}8\cdot10^{-3}$	$11{,}22\cdot10^{-3}$
4	129,3	180	170,7	77	$451{,}1\cdot10^{-3}$	$12{,}81\cdot10^{-3}$
5	60,4	220	239,6	117	$488{,}3\cdot10^{-3}$	$18{,}96\cdot10^{-3}$
6	33,0	240	267,0	137	$513{,}1\cdot10^{-3}$	$27{,}67\cdot10^{-3}$

M – is calculated only for the second period based on the formula below

$$M^1=\frac{2{,}3}{\omega_{cr}-\omega_2}\lg\frac{\omega_{cr}-\omega_e}{\omega_2-\omega_e} \quad (1)$$

Using the values of the M1 expression in Table 3 we can determine the coefficients A and β, constructing the graph of dependence:

$$\frac{\tau_2-\tau_{cr}}{\omega_{cr}-\omega_2}=f(M) \quad (2)$$

For this purpose, in the figure nb. 3, the points of relation of formula 2 are recorded. Through these points draw a straight line, which intersects the ordinate from point A, which corresponds to the critical humidity of the product in the drying process. From point A it goes horizontally to the C-coordinate intersection. The ABC triangle is obtained.

In the ABC triangle, the angle α can be expressed by the following relationship:

$$tg\alpha=\frac{BC}{AB}=a \quad (3)$$

According to experimental data for different products, the M dependency graph $\frac{\tau_2-\tau_{cr}}{\omega_{cr}-\omega_2}$ has a straight line that intersects Oy. Moving the points above the line indicates that the value of the m coefficient was chosen too low. Conversely, the points below the line show that the m value was chosen too high. From Figure 3 we can select the value of b = 320 · 10-3, but *a* is considered:

$$a=\frac{(521-320)\cdot10^{-3}}{25\cdot10^{-3}}=8{,}04 \quad (4)$$

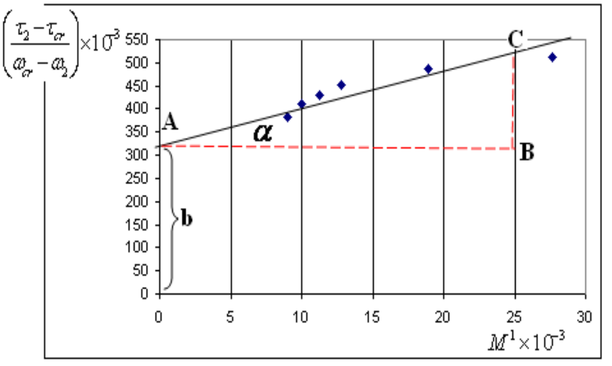

Fig. 3. *The dependency graph* M^1 *of* $\frac{\tau_2-\tau_{cr}}{\omega_{cr}-\omega_2}$

So a = 32.5 and b = 265 $\cdot10^{-3}$. The coefficients in the formula for determining the drying time are correspondingly equal to:

$$A = a\cdot N = 8{,}04\cdot 3{,}62 = 29{,}1 \qquad \beta = b\cdot N = 320\cdot 3{,}62\cdot 10^{-3} = 1{,}158$$

Determine the drying time of the product at each point of the second drying period in which the differentiation was carried out. For the exponent m = 1 the duration in each point is determined by the formula 5:

$$\tau = \frac{1}{N}\cdot\left[(\omega_1-\omega_{cr})+2{,}3A\cdot\lg\frac{\omega_{cr}-\omega_e}{\omega_2-\omega_e}+\beta(\omega_{cr}-\omega_2)\right] \qquad (5)$$

Conclusions

1. The production of dried apples should be directed to quality products, harmless to the human organism with the possibility of launching into organic production.

2. Following the study of the antioxidant treatment process 3 compositions were selected which ensure high quality of dried apples: 1% a. Citric + 0.4% NaCl + 0.5% CaCl2; 1% citric acid + 0.4% NaCl + 0.5% CaCl2 + 12% sugar; 0.7% a. Citric + 0.3% a. ascorbic + 0.4% NaCl + 0.5% CaCl 2.

3. The study of the kinetics of infrared drying allowed the elaboration of the drying regime and the obtaining of the mathematical equation for determining the drying time of the peeled apples, cut and without the seed box

Bibliography:

1. Филоненко Г. К., Гришин М. А., «Сушка пищевых растительных материалов», изд. Пищевая Промышленность, Москва, 1971.

2. Бантыш Л.А., Карабуля Б.В., О применение генераторов ИК-излучения при сублимационной сушке фруктово-ягодного сырья. Тезисы докладов теории, техники, технологии и экономике сублимационной сушки пищевых продуктов .М.1973г.

3. Карабуля Б.В., Либерман Л.Ш., Сушка вспененных фруктовых пюре. Консервная и овощесушильная пром-сть, 1983, № 2, с.37 – 38.