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RESEARCH REGARDING ENERGY OPTIMIZATION IN THE DEHYDRATION PROCESS OF TOMATOES

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Abstract: *The paper presents a research methodology and the results obtained in tomato dehydration with laboratory technical equipment. Tomatoes with the diameter of 30, 60 and 80 mm, cut in halves, quarters and slices with a 5 mm and 10 mm thickness were used. The temperatures used for dehydration were 30, 40, 50 and 60 ^{0}C. The quality restrictions imposed to the dehydration process refer to maintaining the nutritional components apreciated by the content of vitamin C, keeping the color as close as possible to the color of fresh products and the requirements regarding slice dimension imposed by the destination of the dehydrated products. As energy optimization criteria, the total time of dehydration process and the actual energy consumption for comparative situations are considered.*

Key words: *dehydration, energy optimization, tomatoes.*

1. Introduction

Tomatoes, (Figure 1) are considered extremely valuable vegetables in terms of food.

Fig. 1. *Tomatoes* [7]

They are consumed in all regions of the world either fresh, processed or preserved. Tomato fruits contain vitamins (A, B1, B2, C, PP), carbohydrates, proteins, organic acids and mineral salts (Ca, Fe, P, K) and they have an important catalytic role in the human body metabolism [2].

The Marketing standard of the *EU* divides tomatoes into four main types, depending on color, shape, mass and dimensions [1]:

- round tomatoes: these are used more often, are round, soft, generally they have a red color, fit to be consumed fresh;
- ribbed tomatoes: these are bigger than round tomatoes and because of their shape they are also called grooved tomatoes;
- cherry tomatoes, cocktail tomatoes: the name indicates the similarities of tomatoes at shape and dimensions with cherries. Similarly, there are small tomatoes in plum or grape shape;
- oblong tomatoes, elongated tomatoes, plum tomatoes: this is a variety with

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consistent pulp, with few seeds, used both for fresh consumption and processing.

In Table 1 the chemical composition of tomatoes is presented - medium values for 100 g fresh product [4].

Chemical composition of tomatoes Table 1

Substance	Value	UM
Total sugar	4.32	[g]
Glucose	2.02	[g]
Fructose	2.30	[g]
Water	94.20	[mg]
Carotene	0,82	[mg]
Vitamin B1	0.057	[mg]
Vitamin B2	0.035	[mg]
Vitamin B6	0.10	[mg]
Vitamin C	24.20	[mg]
Vitamin K	0.65	[mg]
Biotin	4.00	[mg]
Nicotinic amide acid	0.53	[mg]
Iron	0.95	[mg]
Magnesium	20.00	[mg]
Sodium	6.30	[mg]
Potassium	279.00	[mg]
Phosphor	26.00	[mg]
Fluorine	60.00	[mg]
Leucine	0.039	[g]
Isoleucine	0.02	[g]
Valine	0.026	[g]
Methionine	0.006	[g]
Phenylalanine	0.027	[g]
Tyrosine	0.014	[g]
Threonine	0.031	[g]
Tryptophan	0.008	[g]
Lysine	0.040	[g]
Histidine	0.014	[g]
Arginine	0.028	[g]

The physical properties that influence the dehydration process of tomatoes are represented by: *shape* (round or elongated), *dimension* (appreciated by diameter of 30…80 mm or mass of 20…280 g), *specific mass*, *volumetric mass* (600…1000 kg/m^3), *specific heat* (0.95 kcal/kg^{0}K), *thermal conductivity* (tomatoes have poor thermal conductivity), *slicing mode* (*halves, quarters and slices*) etc. [2].

The color, flavour and *taste* have a great importance in establishing the commercial value of tomatoes. Taste is determined by the content of sugar, organic acids, polyphenols etc. Flavour is the result of sensations produced on olfactory organs by some volatile substances that develop in different phases of the products' growth and maturation. At full maturity the flavours are variety specific.

Conservation by drying of tomatoes presents multiples advantages, both for farmers and processors from the food industry. In case of farmers, the valorification at a good price of a product existent on the market in the maximum maturity period is assured, and for the processors, the volume occupied by the dehydrated products is 5...10 times smaller than the fresh products. Also, the acquisition prices of dehydrated products during summer will be more convenient for the processors of different recipes than using fresh products during winter or spring.

2. Material and Methods

Dehydration is defined as the process triggered artificially based on thermal transfer, controlled and managed by man, through which the "vaporization" of water from the material to be dried is realized, which allows moisture removal from the material presented in form of: paste, granules, sheets, cubes, nuts etc. or even in their natural shape [5].

The experimental research was carried out according to a methodology that involved two stages: preliminary actions and the actual experimental research.

2.1. The preliminary actions before experimental research

Preliminary activities before experimental research are presented in Figure 2.

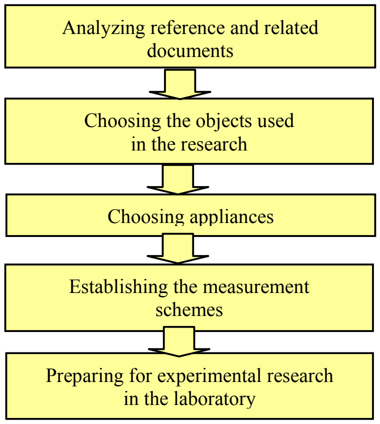

Fig. 2. *The working methodic regarding preliminary actions before experimental research*

2.2. Experimental research objects

Experimental research objects are represented by tomatoes to be dried and by the mini-laboratory dryer Precisa AC60 used on which the temperature can be set between 5…250 ^{0}C. The equipment can be used for determination of moisture and dried substance content of products (at 105 ^{0}C), as a sterilizer (at temperatures greater than 100 ^{0}C), or as a dryer at low temperatures (Fig. 3).

Fig. 3. *Mini-dryer Precisa AC60* [6]

2.3. Experimental research device

For the experimental research many devices and instruments such as the following were used:

- device for measuring the electrical energy consumption Qualistar View;
- thermo-hydro-anemometer KIMO type VT300;
- infrared thermometer Fluke 568;
- analytical balance Sartorius;
- desiccator, tubes, chemical reagents etc.

2.4. Conducting research

The experimental research performed in the RP7 laboratory of the Food and Tourism Faculty within the *Transilvania* University of Braşov have been conducted in the period January-July 2012 according to the research methodology presented in Figure 4 and its objective was the energy optimization of the drying process by determining the drying time and humidity evolution of tomatoes at different temperatures (30 ^{0}C, 40 ^{0}C, 50 ^{0}C, 60 ^{0}C) and in different slicing forms (halves, quarters, 5 mm slices, 10 mm slices).

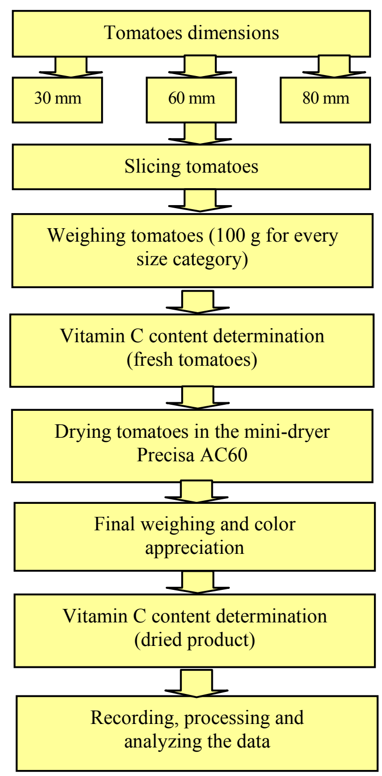

Fig. 4. *Experimental research methodology*

The vitamin C content was determined by Iodometric method, both for fresh and dried products [3]. The method is based on the oxidation of ascorbic acid with excess iodine. The iodine obtained *in situ* in the reaction between iodated and potassium iodide can be used as oxidant. Chemically, vitamin C is γ lactone of a hexon acid. It is also named ascorbic acid.

Vitamin C content (mg/100 g product) can be calculated with the formula:

$$0.352(V_p \cdot V_m)\cdot 100 \cdot \frac{d}{m}, \quad (1)$$

where: V_p is the volume of KIO_3 solution used in the sample titration, in mL; V_m - blank volume = 0.3 mL; d - dilution volume = 25 mL; m - probe mass = 0.5 g.

3. Results and Discussions

3.1. Vitamin C content

In the case of ***fresh tomatoes***, V_p = 1 mL, and the vitamin C content is:

$$0.352\cdot(1\cdot 0.3)\cdot 100\cdot\frac{25}{0.5}= \\ =528\ [\text{mg/100 g product}]. \quad (2)$$

In the case of ***dried tomatoes at 30 ^{0}C***, V_p = 3 mL, and the vitamin C content is:

$$0.352\cdot(3\cdot 0.3)\cdot 100\cdot\frac{25}{0.5}= \\ =1584\ [\text{mg/100 g product}]. \quad (3)$$

Similarly the vitamin C content for the temperature of 40 ^{0}C, 50 ^{0}C and 60 ^{0}C was determined. By increasing the drying temperature, the vitamin C content decreases. This means that when the drying temperature is established, it must be taken into account what will represent an energy optimization factor of the drying process.

Following the above presented data, it was found that the vitamin C content variation is inversely proportional with the moisture content reduction, so, the lower the water content, the higher the vitamin C in the dried product, even if globally there is a loss of vitamin C content.

3.2. Electrical energy consumption

During the experimental research in the laboratory, the installed power of the oven for all the temperatures (30 ^{0}C, 40 ^{0}C, 50 ^{0}C and 60 ^{0}C) was followed, both at full load and idle, as presented in Figure 5.

For the electrical energy consumption calculation for each sample, the value of total consumed power is multiplied by the total drying time obtained for each size category and slicing mode, like in the formula:

$$E = P \cdot t\ [\text{J}]. \quad (4)$$

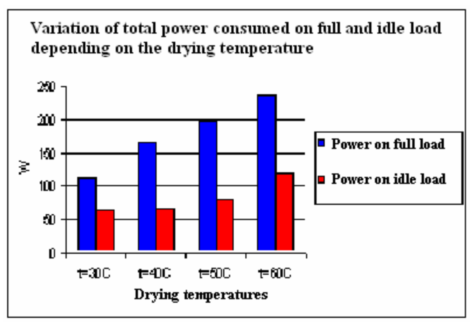

Fig. 5. *Variation of total consumed power and idle depending on drying temperature*

From the chart presented in Figure 5 it can be observed that the value of total consumed power is higher as the drying temperature increases, both in idle and full load.

3.3. Energy optimization of the drying process

The data measured and recorded during the experimental research were processed and are presented as charts.

In the experimental research the necessary time to bring the product at final humidity, assuring the quality parameters imposed to the final product was considered the energy optimization criteria. Even if the component of energy consumption for moisture evacuation doesn't depend on the drying time, the smaller the amount of processing time, the lower the component of energy consumption in the idle mode of the drying chamber.

Energy optimization of the drying process by reducing time can be done by:

- *slicing into minimum dimensions accepted by the quality imposed to the final product;*
- *using the highest temperature of the drying agent which does not affect the quality of the final product;*
- *choosing the minimum dimensions of the products to be dried, according to the qualitative indices imposed to final products.*

3.3.1. Energy optimization by choosing the slices' dimensions, in case of tomatoes with a 30 mm diameter

In Figure 6 the influence of the slicing mode on drying time is presented, in the case of tomatoes with a 30 mm diameter, dried at 30 ^{0}C, and in Figure 7 the drying curves and the regression equations for each slicing mode are presented.

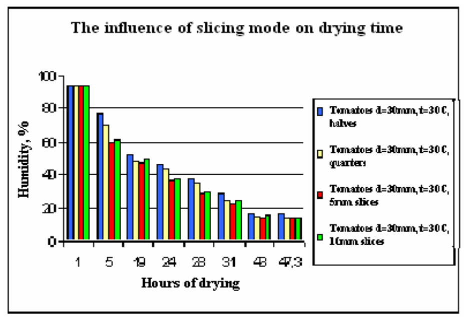

Fig. 6. *The influence of the slicing mode on drying time in the case of tomatoes with a 30 mm diameter*

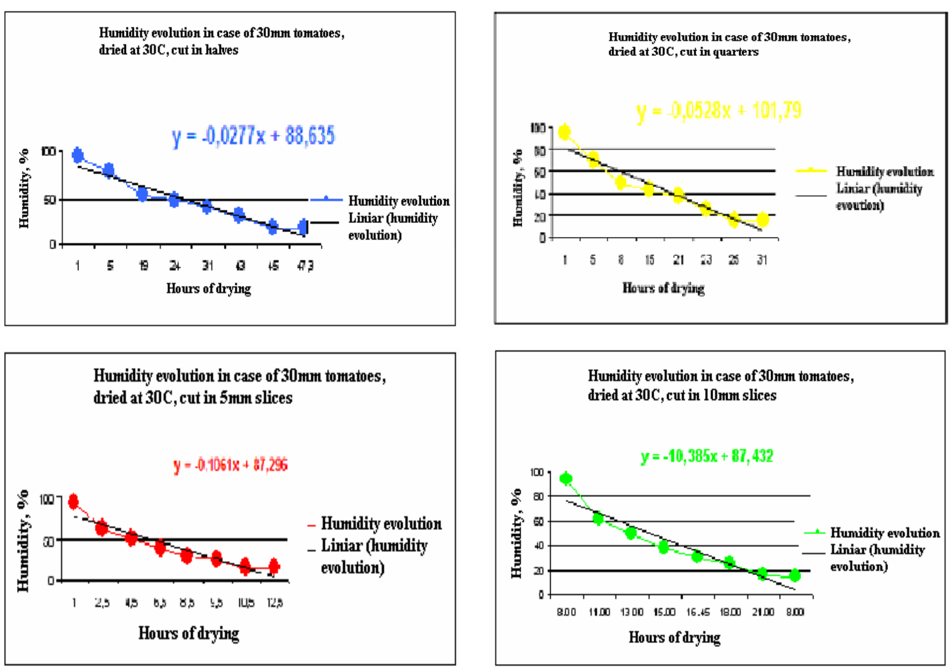

Fig. 7. *Drying curves and regression equations for each slicing system*

As can be seen in Figure 6, the best humidity evolution is in the case of tomatoes with a 5 mm thickness, concerning the final humidity and the total drying time.

Because the slicing system for 5 mm thick slices is the most efficient, regarding drying time and energy consumption, the following interpretations refer to the 5 mm thickness, in order to optimize the energy consumption by establishing the optimal drying temperature related to the minimum time necessary to attain the humidity limit for the product's suitability to be conserved.

3.3.2. Energy optimization by choosing the temperature of the drying agent

In Figure 8 we present the influence of the drying agent temperature on the drying time in the case of tomatoes with a 30 mm diameter (30 ^{0}C, 40 ^{0}C, 50 ^{0}C and 60 ^{0}C) and also the mass regression equations for each sample that was cut in halves, quarters and slices with a 5 mm and 10 mm thickness.

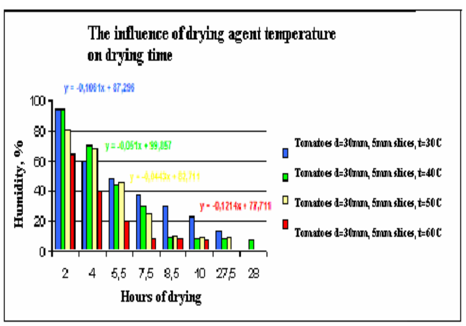

Fig. 8. *The influence of the drying agent temperature on drying time in the case of tomatoes with a 30 mm diameter*

It is considered that mass decrease is the result of the elimination of a part of the humidity content.

As it is presented in Figure 8 the shortest drying time was registered in the case of drying at 60^{0}C, when a final humidity value of ***8.204%*** was reached after ***10 hours***.

In Figure 9 the influence of the drying agent temperature on the drying time in the case of tomatoes (slices of 5 mm in thickness) with the diameter of 60 mm and the regression equations of the sample masses are presented. As in the case of tomatoes with a 30 mm diameter, the shortest time was registered, in the case of drying, at 60 ^{0}C, when product humidity was of ***11.23%*** after ***33 hours***.

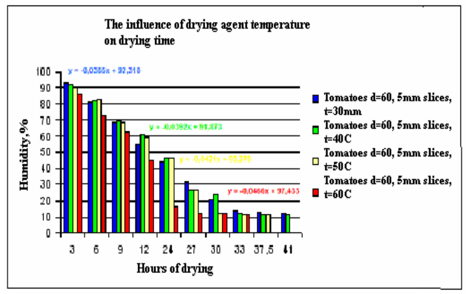

Fig. 9. *The influence of the drying agent temperature on drying time in the case of tomatoes with a 60 mm diameter*

For tomatoes (slices with a 5 mm thickness) with 80 mm in diameter, the influence of the drying agent temperature on the total drying time is presented in Figure 10.

Similarly with the used variants, in the case of slices with a 10 mm thickness, the shortest time was registered in the case of drying at 60 ^{0}C, when humidity reached the value of ***13.52%*** after ***33 hours***.

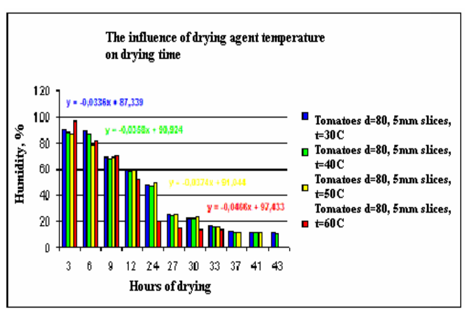

Fig. 10. *The influence of the drying agent temperature on drying time in case of tomatoes with an 80 mm diameter*

3.3.3. Energy optimization by choosing the initial dimension of tomatoes (slices with a 5 mm thickness)

For tomatoes from all size categories, the shortest time was registered in the case of drying at 60 ^{0}C, cut in slices of a 5 mm thickness, as presented in the chart from Figure 11. Even if the slicing system and the temperatures are the same, the drying time varies depending on the initial dimensions of tomatoes from which the samples are obtained.

From the analysis of the chart in Figure 11, it can be concluded that the most appropriate samples for drying, from the point of view of final humidity, drying time and of course energy consumption, are tomatoes with a 30 mm diameter, or cherry tomatoes, cut in slices with a 5 mm thickness, which have reached the final humidity of ***8.204%*** in only ***10 hours*** of drying at 60 ^{0}C.

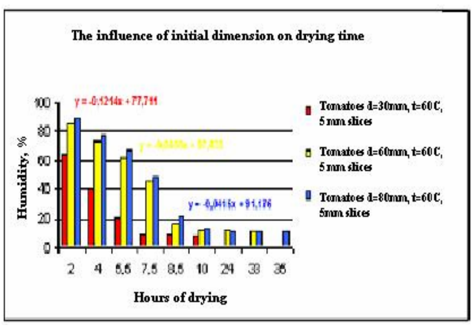

Fig. 11. *The influence of the initial dimension of samples on drying time for tomatoes with a 30, 60 and 80 mm diameter, dried in slices with a 5 mm thickness*

4. Conclusions

1. The experimental research objects from this paper were tomatoes of three dimensions (30, 60 and 80 mm) and a drying equipment powered by electrical energy (mini-laboratory dryer Precisa AC60).

2. The general methodology of research from the paper was designed so as to permit the analysis of the tomato drying process parameters. As parameters of the drying process, the drying time, the vitamin C content both in fresh and dried products, the color and the energy consumption for every sample that was researched were taken into account.

3. The experimental research made in the specialized laboratory from the Food and Tourism Faculty of the *Transilvania* University of Bra□ov have been conducted in the period January-July 2012 and had as an objective the energy optimization of the drying process of tomatoes, using a mini-laboratory dryer Precisa AC60 as a drying equipment.

4. The products to be dried were prepared by successive sectioning in halves, quarters and slices with a 5 and 10 mm thickness.

5. The used temperatures were 30 ^{0}C, 40 ^{0}C, 50 ^{0}C and 60 ^{0}C, and the experiment time was variable, depending on the moment when the humidity was closest to the optimal humidity for long keeping. Every sample that was analyzed weighed 100 g.

6. For tomatoes with a 30 mm diameter, at 30 ^{0}C, after 48 hours we discovered that: halves had 16.297% water, quarters had 13.291% water, 10mm slices had 17.809% water, and 5 mm slices had 12.791% water. Obviously the 5 mm slices represent the optimal solution for drying at this temperature.

7. A representative chemical component for fresh and dried products was the vitamin C content, and as a physical aspect, the way that the color was preserved.

8. Regarding the vitamin C content, this was of 0.528 g/100 g product at fresh products, and of 1.584 g/100 g product at dried products at 30 ^{0}C. A vitamin C concentration of 2.2…2.4 times higher is obtained in similar masses of fresh and dried products, even if, by drying, there is a global loss of vitamin C.

9. The color of dried products was significantly influenced by the temperature used for drying: at 30 ^{0}C, the color had a pleasant aspect and close to the color of fresh products, while at 60 ^{0}C, the color of the products had a depreciation trend towards browning.

Acknowledgements

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