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EFFICIENT TECHNOLOGICAL REGIMES FOR DEHYDRATION OF PEARS BY COMBINATION OF CONVECTION AND MICROWAVES

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Abstract: *The aim of this work is to determine the efficient technological regimes for dehydration of pears by combining convection and microwaves. In order to achieve the proposed aim, an experimental dryer has been developed, which specifically applies the combined fruit treatment process. Pears in particular were selected as the object of the research, as these fruits are more sensitive than others to both the technological processing and storage processes, and their dehydration by currently used methods is less efficient. The main results of the carried out research, obtained by applying the crafted pears dehydration plant, are: increase of the process speed and quality of the processed fruit, reduction of electricity consumption and processing costs. The significance of the research's results includes the solution to a number of pressing problems currently faced by companies specializing in fruit processing, in particular by significantly increasing the efficiency of the pear dehydration process, based on the establishment of optimal technological parameters and treatment regimes by combining convection and microwaves, with a predominant increase in productivity, energy efficiency, quality of final products and profitability.*

Key words: *pear drying, experimental plant, technological process, combined treatment, dehydration regimes, microwaves, convection.*

1. INTRODUCTION

Currently, fruit processing enterprises use equipment and technologies, which have low efficiency and primarily require a long time for processing. This fact contributes directly to the reduction of the quality of the finished products and to the increase of electricity consumption, especially in the case of the fruit dehydration process [1, 2, 3]. Thus, in order to make the dehydration process more efficient, it is necessary to implement installations based on new technological treatment methods [4, 5, 6].

At the same time, the improvement of dehydrators has always been in the sights of researchers from different countries, and the targeted problems have always been the increase in productivity, the quality of finished products, energy efficiency, constructive simplicity, operational safety, etc. [7, 8, 9, 10]. Although multiple studies have been carried out in the respective field, the above-mentioned problems have still not been definitively solved, and are currently addressed in many research examples and in specialized literature [11, 12, 13, 14].

The mentioned problems are exacerbated in the case of dehydration in the round slices of pears, because these fruits are sensitive to the heat treatment process, and the low speed and long duration of the process cause adverse effects, which reduce the quality of the final products [15, 16].

As mentioned by specialists in the field of research, increasing the speed of dehydration and reducing the duration of the process directly prevents the occurrence of adverse effects during processing (Pagotto and Halog, 2016; Kaya et al., 2009).

The research until now has not sufficiently evaluated the efficiency of the process of pears dehydration using combined method and the technological particularities of processing these fruits by the respective method have not been thoroughly studied. Thus, until now, effective regimes of microwave treatment in combination with convection have not been established, as such the optimal values of the technological parameters to ensure the maximum efficiency of the process have not been specified. Based on

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the above, increasing the efficiency of the pear dehydration process can only be achieved through extensive studies, both quantitatively and qualitatively.

Therefore, the aim of this work is to determine the dehydration regimes of pears by combining convection and microwaves. In order to achieve the goal of the research as well as to solve the described problems, an experimental installation for pears dehydration was developed, which applies the treatment process by combining microwaves and convection.

The obtained results demonstrated that the application of the elaborated installation allows to increase the efficiency of the process, namely by: increasing the speed of dehydration and reducing the time of technological processing, increasing the quality of the finished products and reducing the consumption of electricity. Achieving these results was possible based on the establishment of the optimal regimes of combined technological treatment, with the increase of product's moisture evacuation rate during heat treatment, by intensifying the heating input of the product, both from the inside and from the outside.

At the same time, the crafted installation allows the automation of the process with the rigorous monitoring of the technological parameters of the process, and during the research carried out, both in laboratory conditions and in real conditions within a specialized company in the field, that demonstrated a high level of reliability.

Thus, it can be highlighted that the obtained results have contributed to the solution of some current problems faced by companies in the field, by increasing the efficiency of the dehydration process of fruits of seeded species, such as in the case of this study – the pears, because they are extremely sensitive to both heat tratment and storage processes.

2. MATERIALS AND METHODS

The experimental installation developed to research fruits dehydration process by combined method is presented in Figure 1. Thus, the proposed installation offers the possibility of applying simultaneously microwaves and convection in the treatment process, and during the processing of the fruits it offers the possibility of directing the technological parameters and treatment regimes.

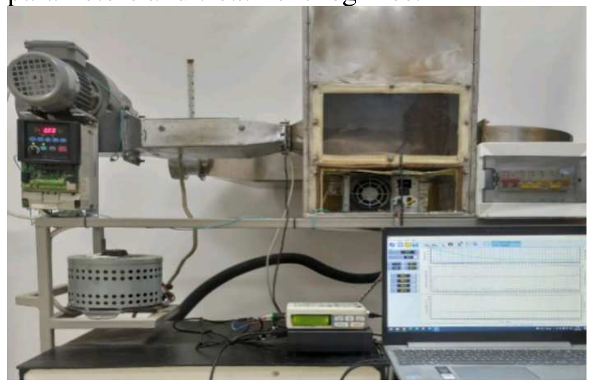

Fig. 1. The experimental installation developed for the dehydration of fruits with the application of the combined treatment method

In order to monitor all the technological parameters important to pear dehydration process, the crafted installation is provided with a connection to the computer, which applies a specialized software (Figure 2) developed for recording and processing experimental data. Thus, the computer connected to the installation receives and processes the information received from the installation's transducers, which monitor the parameters of the technological process.

So the developed system allows automatic monitoring of the temperature and humidity of the drying agent at the input and output of the processing chamber, the decrease in the mass of the product subjected to drying, the microwave frequency and the temperature of the product. All these parameters are recorded in real time and are visualized on the computer screen (Figure 2).

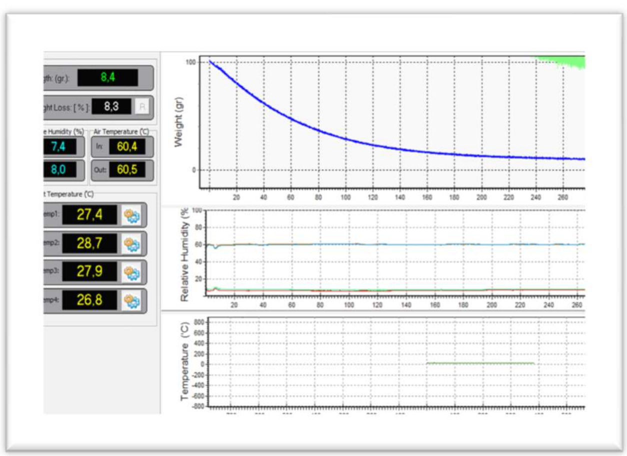

Fig. 2. Computerized monitoring of technological process parameters

The researches results were focused on the example of the examination of seed-bearing fruits species, but in particular, pears were selected as the main object of the research, because these fruits are extremely sensitive to the dehydration process, ultimately resulting in a reduced quality because of the adverse effects that inevitably occur while heat treatment occurs especially when applying a convective traditional method.

When conducting the experiments, the pears were cut into rounds slices (Figure 3) and processed for comparison, using both methods – the traditional convective method and the proposed method – with the application of treatment by combining microwaves and convection.

Fig. 3. Preparation of pears samples for processing

In order to establish the effective technological regimes, a series of experiments were carried out for different slices thicknesses – 2, 3, 4, 5, 6 mm, for different temperature regimes – 50, 60, 70, 80, 90 °C, and different velocities of the treatment agent 1.0, 1.5, 2.5 and 2 m/s.

The weight of the samples subjected to drying was 100 ± 0.87g, with the initial moisture of the product of 89 ± 0.5 %, the final humidity of 19 ± 0.5 %.

For each method examined, the following parameters of the technological process were monitored: dehydration speed, technological processing time, electrical energy consumption and quality of the final products.

3. RESULT AND DISCUSSION

Thus, based on the experiments carried out, it was found that, in order to increase the speed of dehydration of pears and to reduce the duration of the process, it is necessary to increase the rate of moisture evacuation from the product during processing. To accomplish this, the heating input of the product was intensified, both from the inside and from the outside, by applying simultaneous treatment with microwaves in combination with convection.

Thus, in order to establish the optimal technological processing parameters, the process of dehydration of pear samples was examined, carrying out multiple series of repeated experiments for: different temperature regimes of the thermal agent in the range of 50-90 °C, different speeds of the flow of air in the range 1.0-2.5 m/s, different slices thicknesses in the range 2-6 mm and different microwave regimes 100-500 W.

During the series of experiments carried out, for all the fruit samples examined, it was highlighted that the efficiency of the process and the quality of the finished products directly depend on the speed of dehydration and the duration of processing, which are directly dependent on the intensity of the technological parameters, which in their turn depends on the variety and the moisture content of the pears being processed.

As such, figure 4 shows, as an example, the dehydration speed curves by the traditional convective method, for "Conference" variety pears, with the optimal thickness of the slices set at 4 mm, at the optimal air speed of 2.0 m/s, for 5 temperature regimes selected for exemplification – 50 °C, 60 °C, 70 °C, 80 °C, 90 °C, from the series of those examined.

Thus, analyzing the dried pears dehydration kinetics by traditional method, for different temperature regimes, a uniform reduction of moisture was observed over time, and the duration of dehydration from the initial maximum value to the final one, varies depending on the temperature regime examined.

For the optimal slices thickness set at 4 mm, it was established that: for the thermal regime of 50 °C – the duration of dehydration is 257 minutes, for the regime with the intensity of 60 °C – the duration of dehydration is 214 minutes, for the regime of 70 °C – the duration is 172 minutes, for 80 °C – the duration is 151 minutes and respectively for the regime with the maximum intensity of 90 °C – the dehydration duration is 106 minutes.

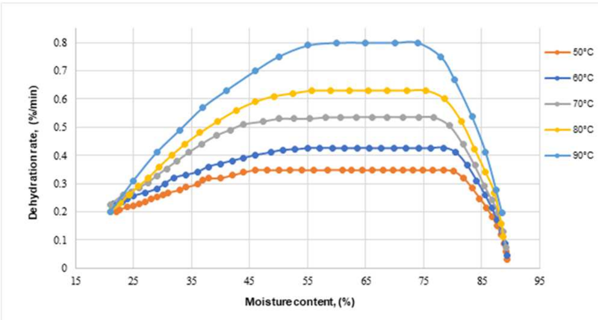

Fig. 4. Dehydration kinetics curves of pears dried by the traditional method

The kinetic studies carried out showed that the duration of the dehydration of these samples from the initial humidity of 89 ± 0.5 % to the final humidity of 19 ± 0.5 %, is inversely proportional to the intensity of the thermal regime and varies between 106 minutes and 257 minutes, and the maximum dehydration rate varies between 0.34 %/minute and 0.79 %/minute.

At the same time, it was observed that at low dehydration speeds for regimes with reduced intensity and higher degree of thermal processing, obvious adverse effects appear that especially affect the superficial layer of the product. Increasing the dehydration speed with the aim of increasing productivity and therefore for regimes with increased intensity and shorter processing time, pronounced defects appear as well. Thus, no regime was shown to be effective in terms of final quality, however, it can be mentioned that more satisfactory results were obtained for the thermal regime of 60 °C.

Apart from these, analyzing the drying process with different air speeds in the range of 0.5-3.0 m/s, it was confirmed that, with the increase in air speed, the drying speed also increases, but the optimal value of the air speed for effective dehydration, is 2.0 m/s, because at higher speeds, the quality of the products is again reduced and at the same time the energy efficiency of the process is reduced, due to the intensification of the evacuation of thermal energy from the drying chamber together with the evacuation of moisture.

Examining the drying process for different pears slices' thicknesses in the range of 2-10 mm, it was confirmed that the thinner the slices' thickness, the faster the process and the shorter the processing time, but the optimum thickness was found to be 4 mm, because at a lower thickness, the quality of the products decreases and adverse reactions occur, especially carbonization.

In order to eliminate the shortcomings mentioned above, at the next stages of the conducted research, the kinetics of dehydration of pears was examined, with the application of the proposed method of microwave treatment in combination with convection.

Therefore, figure 5 shows, as an example, the curves of the dehydration speed of pears with the application of the combined method (for similar samples of pears and under the same conditions applied as in the case of the traditional method). The figure shows the results for 5 regimes selected for exemplification – 180 W, 225 W, 270 W, 315 W, 360 W, from the series of those examined in the 100-500 W range. The other established technological parameters of the process with maximum efficiency in the given case were: optimal air speed 2.0 m/s, optimal air temperature 60 °C, optimal slices' thickness 4 mm.

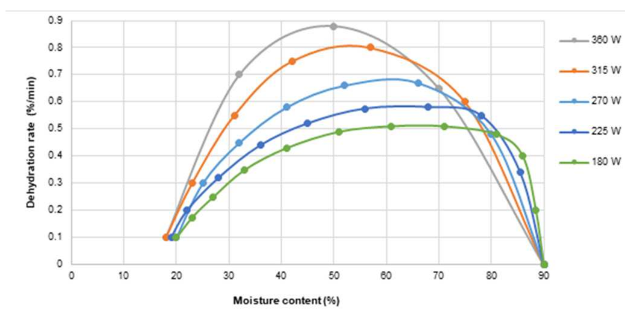

Fig. 5. Dehydration kinetics curves of pears dried by the combined method

The results of dehydration based on the combined method, demonstrated that the duration of dehydration of these samples from the initial humidity of 89 ± 0.5%, to the final one of 19 ± 0.5 %, depends on the technological regime of treatment in the following way: for 360 W - the duration of dehydration is 73 minutes, for 315 W - it is 114 minutes, for 270 W - 153 minutes, for 225 W - it is 196 minutes, and for 180 W - the duration of dehydration is 254 minutes.

So, when dehydrating by microwave treatment in combination with convection, according to the kinetics studies carried out, it was highlighted that the duration of dehydration is inversely proportional to the intensity of the regime and varies between 73 and 254 minutes, being significantly lower compared to the traditional method, and the maximum dehydration rate varies between 0.52 %/minute and 0.88 %/minute.

At the same time, it was observed that, when intensifying the treating regime to increase the speed of the process, adverse effects appear, which worsens the quality of the final product, and the optimal microwave regime for efficient processing was determined to be 315 W.

Thus, following the realization of multiple series of experiments, the regimes with maximum efficiency and the optimal technological parameters of the process were established: the optimal thickness of pears slices – 4 mm, the optimal air speed – 2.0 m/s, the optimal temperature – 60 °C, optimal microwave power – 315 W, optimal processing time – 114 minutes.

More than that, it should be highlighted that, comparing the consumption of electricity when dehydrating pears by both examined methods, it was established experimentally that, using the traditional method, with maximum efficiency regime (with the optimal thickness of the slices of 4 mm, at an optimal air speed of 2.0 m/s and at an optimal temperature of 60 °C), the electricity consumption is about 23% higher than in the case of drying similar samples and under the same conditions, but with the application of the combined treatment method, using the established optimal parameters of the maximum efficiency regime (optimal slices thickness – 4 mm, optimal air speed – 2.0 m/s, optimal temperature – 60 °C, optimal microwave power – 315 W).

The lower consumption of electricity, in the case of the combined method, was confirmed by all the experiments carried out and for all the samples examined, compared to the traditional method. This fact is due to the efficiency of the technological treatment process, with the increase in the rate of moisture removal from the product during the technological processing and by increasing the efficiency, intensifying the heating input of the product, both from the inside and from the outside, due to the application of microwave treatment in combination with convection.

At the same time, for the comparative analysis of the quality of the finished products, the samples dehydrated by both researched methods were initially examined from the point of view of organoleptic properties.

Figure 6 and figure 7 show, as an example for comparison, samples of pears dehydrated by both examined methods (packaged in food film envelopes).

Fig. 6. Samples of pears dehydrated by the traditional method

Fig. 7. Samples of dehydrated pears by the combined method

To determine the organoleptic indices, a panel of expert tasters was drawn up, who analyzed 3 samples, as follows: Sample I – fresh pears, Sample II – pears dehydrated by the traditional method, and Sample III – pears dehydrated by the combined method. As an example, the analysis results for pear samples of "Conference" variety are shown in tables 1, 2.

The determination of the organoleptic indices in tables 1 and 2 was carried out in accordance with the active rules, and following the analysis, the commission assigned the highest score to fresh pears (4.9 points), after which pears dehydrated by combined method were ranked second (4.7

points), and pears dehydrated by traditional method were ranked third, with 4.2 points.

Table 1

Organoleptic analysis of pear samples (fresh - sample I and dried by the traditional method - sample II and the combined method - sample III)

Fresh pears - sample I		Dehydrated pears – sample II, III		Note
Index	Comments	Index	Comments	
1) Texture	No small particles of foreign substances were detected, the surface is smooth and rough	1) Texture	No foreign particles were detected, the surface is rough. Sample II is a bit dry	Sample I = 5.0 Sample II = 3.8 Sample III = 4.5
2) Color	Color is characteristic of the variety	2) Color	Sample II is a bit dark. The color is attractive in Sample III	Sample I = 4.9 Sample II = 3.8 Sample III = 5.0
3) Aroma	Characteristic aroma of pears	3) Aroma	The aroma at Sample III is sweet-caramelized but at Sample II it is less pronounced	Sample I = 5.0 Sample II = 4.6 Sample III = 4.7
4) Taste	Characteristic of pears	4) Taste	The taste is sweet-caramelized in Sample II and III	Sample I = 5.0 Sample II = 4.8 Sample III = 4.8

Table 2

Results of organoleptic analysis of pear samples

Sample	Points
Sample I - fresh pears	4,9 points
Sample II - traditionally dried pears	4,2 points
Sample III - pears dehydrated by the combined method	4,7 points

Thus, examining multiple samples of finished products, it was found that the combined method increases the quality of dehydrated pears compared to the traditional method, with the improvement of the main organoleptic properties, such as: texture, color of the finished products, their aroma and taste.

Based on the results obtained in this study, it was found that the use of the developed dryer for the dehydration of pears with the application of microwave treatment in combination with convection, reduces the degree of occurrence of adverse effects, because it increases the speed of the process and reduces the duration of thermal processing, contributing to the increase in productivity and the quality of processed products.

At the same time, as it was highlighted, the combined treatment process allows to reduce electricity consumption by about 23% compared to the traditional processing process, a fact that offers the possibility of reducing processing costs.

The reduction of electricity consumption, when processing with the combined method, in relation to the application of the traditional method, is due to the fact that, in the process of technological processing, the contribution of convection to thermal processing is supplemented by the contribution of microwaves, a fact that increases the efficiency of the process, and the processing requires a shorter time to reach final moisture.

This happens thanks to the fact that, the processing of slices under the combined action of heat treatment agents, essentially allows the technological process to be made more efficient, with the increase in the degree of dehydration intensification, which directly contributes to increasing the speed and reducing the duration of the process.

Moreover, the facility developed for the dehydration of fruits, allows the automation of the process with the rigorous monitoring of the technological parameters of the dehydration process, and during the experiments carried out, both in laboratory conditions and in real operating conditions within a specialized company from the field of fruit dehydration has demonstrated a high level of safety in operation.

4. CONCLUSION

The results of the researches carried out allowed to establish the optimal dehydration regimes of pears with the application of microwave treatment in combination with convection and demonstrated that the dryer

crafted for fruit dehydration based on the combined method, allows to make the technological process more efficient, especially with the increase of dehydration speed and the reduction of processing time.
2) At the same time, it was confirmed that the combined method of treatment allows to increase the quality of dehydrated pears in comparison with the traditional method, and furthermore, the developed installation allows the automation of the process with strict monitoring of the technological parameters of the dehydration process and during the experiments carried out, both under laboratory and real operating conditions in a company specialized in fruit dehydration, demonstrated a high level of safety in operation.
3) Therefore, thanks to the efficiency of the dehydration process, with the increase of the dehydration speed and the reduction of the technical processing time, the electricity consumption in the dehydration of pears with the combined method is about 23% lower than in the traditional method, and this allows a significant reduction of the technological processing expenses and the cost of the processed products.

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REGIMURILE TEHNOLOGICE EFCIENTE DE DESHIDRATARE A PERELOR PRIN COMBINAREA CONVECȚIEI ȘI A MICROUNDELOR

Scopul lucrării constă în determinarea regimurilor tehnologice eficiente de deshidratare a perelor prin combinarea convecției și a microundelor. Pentru atingerea scopului propus, a fost elaborată o instalație experimentală, care aplică anume procedeul de tratare combinată a fructelor. Au fost selectate în calitate de obiect al cercetărilor în mod special perele, deoarece aceste fructe sunt mai sensibile în comparație cu altele, atît la procesul tehnologic de prelucrare cît și la cel de păstrare, iar deshidratarea lor prin metodele utilizate în prezent are o eficiență redusă. Rezultatele esențiale ale cercetărilor efectuate, obținute în baza aplicării instalației elaborate la deshidratarea perelor sunt: creșterea vitezei procesului și a calității fructelor procesate, reducerea consumului de energie electrică și a costurilor de prelucrare. Semnificația rezultatelor obținute în cercetare constă în soluționarea la o serie de probleme stringente cu care se confruntă actualmente întreprinderile specializate în procesarea fructelor, îndeosebi prinvind creșterea semnificativă a eficienței procesului de deshidratare a perelor, în baza stabilirii parametrilor tehnologici optimali și a regimurilor de tratare prin combinarea convecției și a microundelor, preponderent cu sporirea productivității, a eficienței energetice, a calității produselor finite și a rentabilității.

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