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Study of the parameters' variation in the vegetables drying process

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Abstract

The aim of the paper was the study of the parameters' variation of the vegetables drying process. As materials there were used vegetables with hard texture (celery, carrot, red beet) and as methods there were used the conventional drying (with air convection) and unconventional drying (with microwave and infrared radiations). It pursues the parameters variation as: mass, product's core temperature, humidity, drying time. It was used the hydration as an estimation method of the drying products' texture modification.

The experimental determinations had pointed out the diminution of drying duration with 50 - 88% using the unconventional methods. Also, it was found that the microwave drying method had affected the vegetable texture the least. The unconventional drying assures constant water excluding from the product in comparison with the conventional one, an important factor for the textural characteristics of the dried products. The vegetable yield to the drying process both conventional and unconventional is celery.

Keywords: air convection, microwave, infrared radiations, vegetables drying, texture

1. Introduction

To study the parameters' variation which influence the taproot vegetables drying process, three types have been used – celery (*Apium graveolens*), carrot (*Daucus carota*), red beet (*Beta vulgaris*) – from the taproot vegetables class, because these are representative for the Romanians' nutrition, especially in the winter months, because they have a rich vitamin content, special sensorial qualities and a good preserving capacity. Although, like the other classes of vegetables, the taproots are pretentious regarding the humidity and the oxygen content of the storage space.

The preservation method chosen was the vegetable dehydration, the oldest used technique and one of the most efficient, knowing that, after drying, the water content of the vegetables is eliminated (the main responsible for the development of and reproduction of microorganisms, which causes the perishable or damaging effect of the vegetables characteristics) with direct implication over the preservation period. To be able to ultimately choose the best drying method for taproots, three techniques have been tested: one conventional (with warm air convection) and two unconventional (with microwave and infrared radiations).

Through vegetables dehydration it seeks the step by step water evaporation from the surface, depending on the type of the heat applied. The conventional thermal treatment has been chosen because it is the most widespread drying method at industrial scale. The warm air is the vector which feeds the products` surfaces with energy and pushes off the water vapours.

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The dry product volume decreases as the air temperature increases and the air is the drying agent.

Because the energy conservation is one of the key factors for the unit's operation profitability and its success, there was also chosen alternative drying processes, using infrared radiations and microwave. The infrared radiations are characterized by a wavelength between 0.75- 2.5 µm (short), 2.5-25 µm (medium) and respectively 25 µm - 100 µm (long), that can be viewed in the Figure 1.

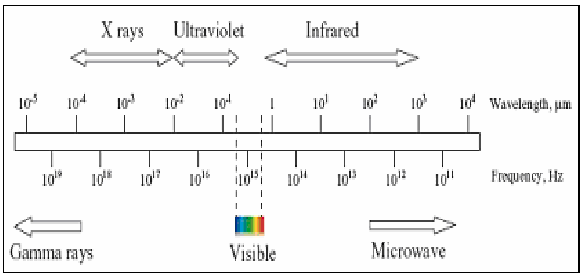

Figure 1. Electromagnetic wave spectrum (Kathiravan *et al*, 2008)

The infrared radiation is favoured because of the thermal efficiency correlated with the reduced exposure period of the product in comparison with the conventional thermal treatment. Therefore, the infrared thermal treatment is successfully applied in food industry for drying operations, frying and pasteurization [1,2].

The drying operation using infrared radiations has the added benefit of enzyme inactivation, which are responsible for the vegetables degradation and the alteration [3] and also the inactivation of bacteria, yeasts and moulds presented in their vegetative microbiota.

Regarding the drying taproot vegetables with infrared radiations, it is important to take into consideration the sensorial changes which can affect the products submitted to the treatment, such as the colour reduction with 18.1-37.6% for potato and carrot. [6]. Microwaves are high frequency electromagnetic radiations varying between 300 MHz and 300 GHz, with wavelengths between 1m and 1mm. The microwave heat is influenced by some physical and thermal properties of the material, such as: the product's shape, the surface area, the product's weight, and the water content. [4, 12-15].

Microwave drying is superior to conventional drying, if it was taken into account that the heat is directly generated by the transformation of electromagnetic energy into molecular kinetic energy, thus the heat is generated in the profundity of the product that needs to be dried. [16-19].

The dried products rehydration is influenced by: the desired rehydration period, the rehydration temperature, the physical structure of the drying products, the rehydration water *p*H, the ionic strength of the product and the rehydration of the water used. [5, 7-11].

2. Materials and Methods

2.1. Materials. The materials used were: taproot vegetables with hard texture (celery, carrot, and red beetroot), watch glasses, Berzelius glasses, aluminium (Al) foil, knife, paper towel, ruler, distilled water, scissors, and marker.

Used gear: oven type MEMMERT UNB 400, microwave oven type SAMSUNG /GRILL SELECTION P=900 W, thermometer type bore AMPROBE TPP1-C1 used for the measurement of the vegetable's core temperature, AND series AD 4714 digital scale for humidity, digital scale Partner type AS110/C/2.

2.2. Methods. The vegetables have been bought from supermarket, washed under cold spray water and dried off with a towel of paper. The taproot vegetables had their crust peeled off, subsequently being cut into sample pieces with 10 cm edge. It was laid 5-6 pcs on aluminium foil or glass watch and then it have been used the digital scale Partner type AS110/C/2 in order to set the initial weight of the samples.

Conventional drying with convection of warm air has been done in an oven type MEMMERT UNB 400. The duration of the thermal treatment at 100°C was 2 hours, with a systematic check, every 30 minutes, of the product's weight with the digital scale and the temperature in the core of the product, with the weight thermometer type bore AMPROBE TPP1-C1 and. In the case of the unconventional microwave method it was used a microwave oven type SAMSUNG/GRILL SELECTION (900 W).

The vegetables were dried with a microwave oven at 30% power 2 minutes at a time.

For IR treatment it was used the digital scale for humidity type AND series AD 4714, the drying had been done at 100°C and the loss of weight and humidity through evaporated water from the vegetables were measured using the same equipment.

The IR equipment allows the drying treatment development, the product's initial and final weight measurement and to set the treatment time interval.

After the thermal treatment the samples were dried, kept for 2 days in drying equipment and after that they were rehydrated. 20 ml of distilled water for each vegetable were necessary for vegetables rehydration. They were weighed again, immersed in water, and from time to time they were taken out and reweighed with the digital scale; these operations were repeated until saturation.

3. Results and discussion

The aim of then study was to determine some parameters which influence the behaviour of vegetables during drying such as: weight, product's core temperature, humidity, drying duration. Rehydration was used as a method of evaluation for the drying products` texture.

In the Figure 2 it can be seen the product's core temperature variation as a function of time for warm air convection drying.

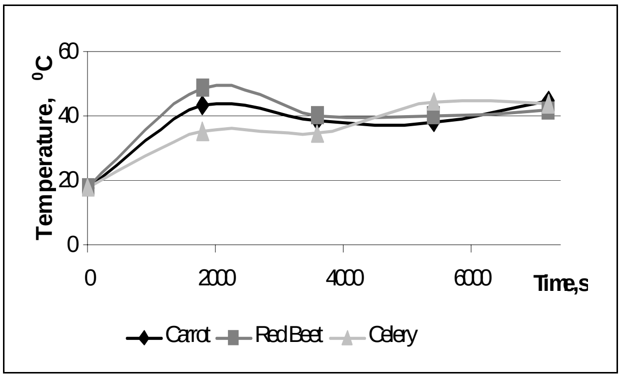

Figure 2. The product's core temperature variation as a function of time for warm air convection drying

The products` core temperatures have increased rapidly in the first 30 minutes, followed by a temperature stabilization plateau, and then it can be observed that the temperature decreases, because of the accelerating evaporation speed of the vegetables` surface water.

The maximum temperature reached in the samples centre was registered by the red beet and at the other pole by the celery. After the rehydration of the oven dried vegetables, one could observe that the red beet is the one which needs the longest rehydration time, which can be explained by the destruction of this vegetable's capillary structure during the drying process.

This observation is not valid for the carrot. The largest evaporated water content was eliminated by the red beet, but equal humidity losses have been registered for celery and carrot. The evaporated water quantity as a function of time is exponential for all types of vegetables.

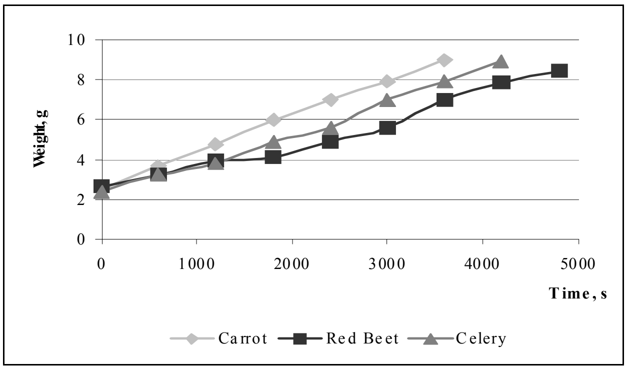

Figure 3. The vegetables weight evolution as a function of time for conventional drying

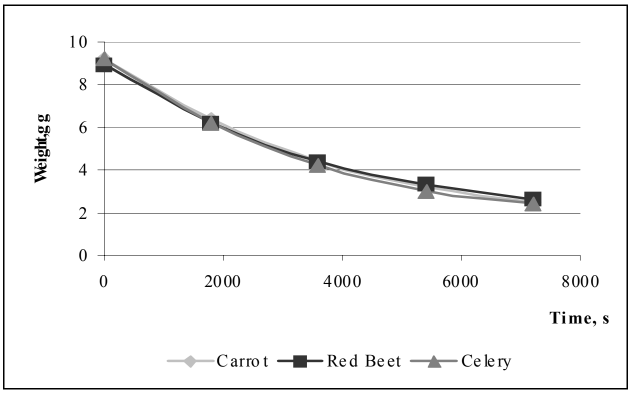

Figure 4. Vegetables' hydration process dynamics dried with warm air convection

In the microwave drying experiment, at 30% power, one could see that for a 16-18 minute interval, the carrot has a constant temperature (80ºC), and that it can lead to the degrading of proteins and vitamins. In the first part of the drying process, the water from the vegetables evaporates rapidly, indicated by the temperature increment, and towards the end, the evaporation speed values were still growing, but at a slower rate.

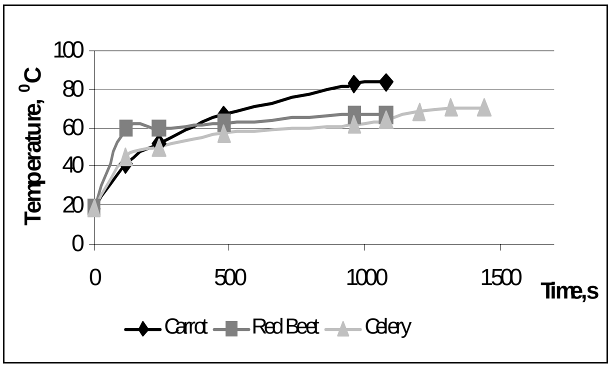

Figure 5. The product's core temperature variation as a function of time for the microwave drying

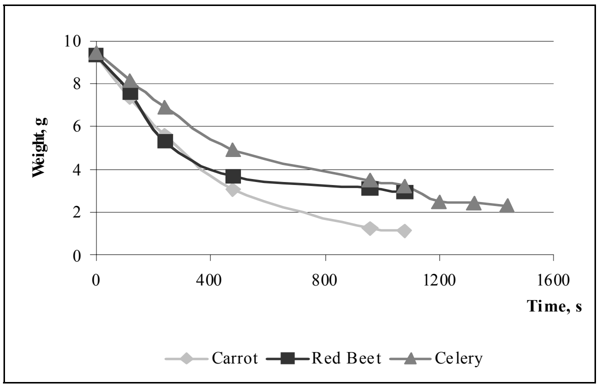

Figure 6. The vegetables weight evolution as a function of time for microwave drying

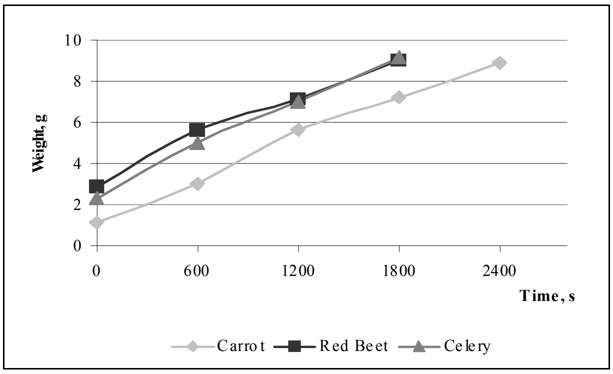

Figure 7. Vegetables' hydration as a function of time process dynamics dried with microwave

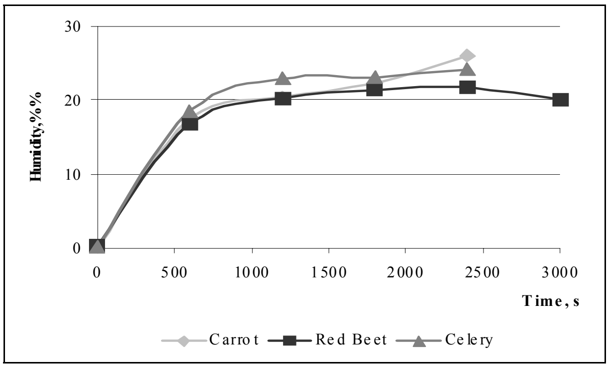

Figure 8. The humidity loses of the product as a function of time for the IR treatment

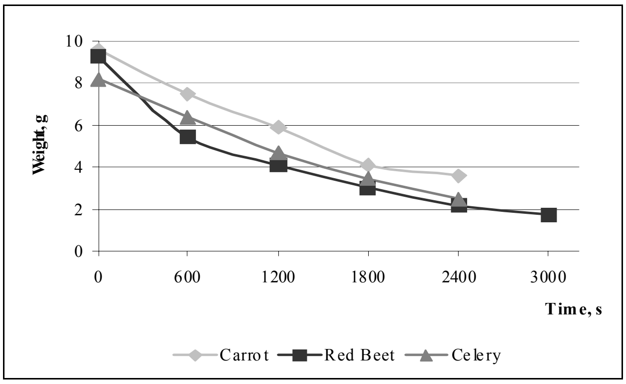

Figure 9. The evolution of the vegetables humidity elimination for the IR drying as a function of time

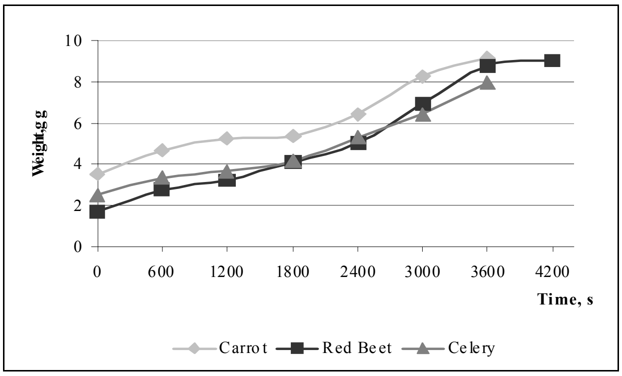

Figure 10. Vegetables' hydration process dynamics dried with IR radiations

For microwave treatment, we have found that the vegetable rehydration takes much less time (≈50%) than the conventional thermal treatment, but in this case, it can be observed that the carrot structure has suffered alterations through the microwave drying process, perhaps due to the way the electromagnetic radiations interact with the water's dipoles.Therefore, the drying process and the rehydration are very different for every vegetable from the three types.

The largest evaporated water content was eliminated by the red beet, but equal humidity loses have been registered for celery and carrot. The evaporated water quantity dependent on time is exponential for all types of vegetables. For the IR treated vegetables it can be observed that the rehydration time is longer, similar to that for the conventional treatment that denotes that the analyzed products` structure is affected.

From the graphic, it can be noticed that the succession of the analyzed processes are similar, the vegetable which is drying first is the carrot, the same vegetable being the first to rehydrate.

4. Conclusions

It can be asserted that the unconventional drying insures an almost a constant water elimination from the product in comparison with the conventional one, fact which aids the texture of the vegetables to not be altered in a major way.

The accelerated drying interval from the first period of the conventional drying, which has affected the dried products` quality, is replaced by a mild phase of humidity elimination in the unconventional drying case.

Celery is the vegetable which has been found to dry the best, but the one which is the most difficult to dry is the red beet. Analyzing the drying process applied to the vegetables, it can be concluded that:

- the carrot is the vegetable that dries the fastest;
- the red beet is the vegetable that has the slowest drying process;
- regarding the celery, it is a vegetable which has behaved very good to the drying processes, doing an exception for the microwave treatment, where the dehydration has occurred in the longest period of time in comparison with the other vegetables;
- regarding the microwave treatment, the most sensitive texture is the one of the red beet.

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