CERCETĂRI PRIVIND PROCESUL DE USCARE ÎN FLUX CONTINUU AL FRUCTELOR ÎN INSTALAŢII CU MICROUNDE
EXPERIMENTAL RESEARCHES REGARDING THE CONTINOUS FLOW DRYNG OF FRUITS IN MICROWAVE INSTALATIONSS

Adriana Muscalu[1], Mihai Marin[1], Valer Turcin[2]
[1]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest
[2]National institute of Research – Development for Electric Enginery ICPE-CA, Bucharest

Abstract

The competitive capitalization of Romanian food products both on internal and external market has imposed the elaboration of new and efficient technologies, based on modern and state-of-the art equipment, which is also environmental - friendly equipment. The conventional drying technologies for fruits are not enough for maintaining their colour, flavour, texture, vitamin contents, etc. Therefore, alternative methods, also named non-conventional methods have been developed, being designed to reduce the effects that time and temperature factors have on these products. The paper comprises an overview of same non-conventional drying technologies of fruits and, at the same time, it presents the results achieved by the authors' team in the field of these products conserving technology by dehydration with non-ionized radiations (microwave field), by using an installation designed to continuous - flow processing.

Cuvinte cheie: uscare, microunde, fructe, flux continuu
Keywords: drying, microwave, fruits, continuous flow.

1. Introduction

Duration to keep in fresh state while maintaining commercial-quality food-technology is limited by the vital processes taking place in fruits stored under different thermohydric and aero kinetic conditions. To make possible domestic fruit consumption along the year and les to avoid important quantitative losses, many of these products are dehydrated (artificially dried). Fruit drying methods have continuously developed, the aim being that the resulted final product to keep his properties which during his preparing in view of consumption to encourage the return to the natural state. Therefore have developed alternative methods for drying, known as nonconventional methods, aiming at elimination of chemical treatment and application of ecological processes.

For unconventional food preservation are used methods including all wavelengths of the electromagnetic spectrum, from radio waves to gamma rays, depending on product and process. For unconventional dry fruit, from the electromagnetic spectrum are used mainly the infrared radiation, microwaves or their combinations with conventional methods.

2. Material and methods

Infrared radiation (IR): the term *infrared* is electromagnetic radiation whose wavelengths lie in the range from 0.75 or 0.8 micrometer (the long-wavelength limit of visible red light) to 1000 micrometers (the shortest microwaves), hence solid bodies will generally absorb the radiation in a narrow layer at surface. IR drying offers high efficiency of conversion of the electrical energy into heat (average 80% efficiency). The limitations of these applications are more or/less limited to the thin layers of material. IR dryers are commonly designed to be integrated with conventional dryers (conveyer hot air dryers), where standard IR radiators are used in order to ensure that the IR radiation is directed on the product being dried.

The treatment with Vacuum Cooling Infrared Rays Drying System (V-CID) was developed for mainly fresh food materials (seafood, meat, vegetables, fruits, etc). These products can be stored in frozen/chilled condition for around 1-2 months and they keep quality and freshness.

Another alternative method is the use the Kreyenborg infrared rotating drum IRD. The most important components of the infrared rotating drum IRD are the radiator module within a horizontal rotating drum, which has an integral, welded, conveyor screw. The material to be processed is fed continuously, by a volumetric metering unit, into the integral screw of the rotating drum, distributing it evenly through the dryer. The dwell time depends on the rotational speed of the drum and is adapted precisely to the operational parameters. The warm, humid air is extracted and discharged from the rotating drum through an exhaust pipe.

Microwaves are electromagnetic oscillations (no ionizing radiations) with frequencies ranging between $3x10^8$ and $3x10^{10}$ Hz. The mechanism of heating plant materials in no ionizing radiation fields (microwave fields) is based on complex phenomena of polarization and dielectric losses in conductivity due to dissipation of energy in these materials.

Electric field interaction with a dielectric generates the displacement of particles load from equilibrium positions inducing the growth of induced dipole in it. Besides the induced dipoles some dielectric, known as polar dielectric, was containing permanent dipoles due to matchlessly distribution of load with contrary sign, which tend to focus under the influence of electric field, thus giving the origin of orientation of polarization. Figure 1 shows a schematic representation of Maxwell-Wagner and orientation of the polarization due to an alternative electric field. These two mechanisms, together with the DC conductivity, represents the base of the heating in high frequency. For heating with microwaves dipolar dielectric materials present interest due to hysteresis in time in variable electric fields, which has the effect of converting electromagnetic energy into heat. Dielectric losses are the source of energy. The dielectrics with high values of loss factor, ensure a good yield for the transformation of incident energy into heat, according to the known relation:

$$P_v = 2\pi \cdot \varepsilon_0 \cdot f \cdot E^2 \cdot \varepsilon_r \cdot tg\delta \cdot V \qquad (1)$$

where: E is the effective local value of the electric field; $\varepsilon'' = \varepsilon_r \cdot tg\,\delta$ is the dielectric loss factor.

If $10^{-5} < \varepsilon'' < 5$, microwave heating is possible.

Mechanisms of loss depend on the frequency. In Figure 2 are represented schematically different mechanisms contributing to the loss factor in an moist material. Because industrial heating at high frequency take place in the frequency band $10^7 < f < 3\ 10^9$ Hz, mechanisms would be particularly dipoles, represented by *b* and *w* in Figure 2, depending on the degree of water absorption in the material, Maxwell-Wagner effect and conductivity in DC. (Areas outside the band are due to loss of polarization distortion, which don't play an important role in the high frequency heating).

Further drying improvement can be obtained by using combination based on microwaves-MW. When microwaves and vacuum (sub atmospheric pressure) are used simultaneously, the drying is friendly and gentle for the product. The main purpose of vacuum drying is to enable the removal of moisture at a much lower temperature than the boiling point under ambient condition. For example the boiling point of water is reduced to 29^0 C at 40 mbar. Mw-vacuum drying determines good qualities of the product (colour, rehydration potential, density, nutritional value and textural properties). Combination of osmotic dehydration with microwave drying appears as a promising possibility of receiving in short time and with reasonable energy consumption dried fruits with a suitable shelf life and quality.

The material for the experimental researches was the microwave drying installation of fruits in continous flow and fruits (apples *Golden Delicious,* pears *Bergamotte* and wood fruits berries, rosehip).

The our installation (Figure 3) comprises the following:

a) Desiccation Module: desiccation precinct; supporting frame; microwave generators; wave guides; ventilation system of microwave generators; wet air evacuation system from the desiccation precinct;

control system of processed material temperature by temperature transducer without contact, in infrared.

b) Feeding/Evacuation System of Processed Material:
- transport system with conveying band;
- supporting frame of feeding/evacuation system;
- microwave recovering tunnel (at dehydrating module entrance);
- conveying band drum;
- stretching drum of conveying band;
- guiding elements of conveying band; microwave recovering tunnel (at dehydrating module exit);
- electric engine of transmission driving to conveying band.

c) Main technical and functional characteristics of installation:
- Type of desiccation installation:……………...................with continuous flow;
- High frequency effective power…...10.2 KW;
- Microwave source type:…………….2M 107 A – 795 magnetrons (Toshiba);
- Number of magnetrons/ installation ………………………………..12 pieces;
- Operating frequency:……………………………………………….2450 MHz ;
- Microwave power/ magnetron:…………………………………………850 W;
- Supply voltage:………………………………………………………380 V;
- Temperature control range:…………………………………………20…100 ^{0}C;
- Type of conveyer………………………with band PTFE with glass fibber insert;
- Linear speed of conveying band.....................................0.04...0.10 m/min.;
- Installation desiccating capacity...30...50 kg/h;
- Dimension of drying precinct: ....(3430x500 x522) mm;
- Personnel servicing:…………...max.3 people;

3. Results and discussion

The wave directories of a rectangular shape represent the entrance port and are placed at a distance λ (h = 122,4 mm) between them and the wall of the applicator. The work frequency of the applicator is f = 2450 MHz in accordance with ISM (Industry, Science, Medicine); norms for EU. The installations which have been performed are equipped with multi-mode applicators of cavity type.

A multimode applicator is a close metallic cavity connected to a microwave generator. The cavity dimensions are bigger than the wavelength of microwaves propagated through the guide to the respective cavity, propagation modalities $E_{l,m,n}$ (transversal magnetic TM) and $H_{l,m,n}$, (transversal electric TE). The field distribution has as a result multiple mode reflections on the metallic cavity walls and on the product meant to be heated.

For a load possessing the features of table1 the effective variation of the electromagnetic field intensity on the load surface is presented in fig. 4.

Technological process of microwave drying of fruits is carried out in accordance with preset flow technology and includes the following operational phases:

a) preparing the material for drying – this operation involves, in case of fruits, several important steps: fruit reception (quality separation of components and foreign bodies), washing, splitting into pieces - where appropriate, whitening - if applicable.

b) feed of the installation with material in continuous flow – fruits, placed on the conveyor band as uniform, in a layer whose thickness varies depending on the physicochemical characteristics of the material;

c) application of microwaves treatment - the act of starting switches for microwave generators, the power emitted is regulated according to load chart which characterizes the work for each type of product.

d) discharging dried material is done by free fall, in continuous flow.

Microwave treatment can be discontinued at any time to control the evolution process of dehydration, and then continuing until the completion of it.

The development of the desiccation process of fruits is done in three successive stages as follow:

a) the preheating period during which the heat is consumed almost in totality for the heating of the material until the establishment of the regime temperature, at which there is established an equilibrium between the transmitted heat quantity and that which is consumed for the water evaporation.

b) the desiccation period with constant speed which represents the dehydration period for that matter;

c) the desiccation period with decreasing speed (the final period), in which the desiccation speed is gradually reduced;

The state parameters which define the desiccation process are as follow: the temperature (°C); humidity (%); desiccation speed (% humidity/min.)

The microwaves power regime can be continually adjusted starting from zero to the maximal power.

The working drying conditions for apples (Fig. 5): the working temperature for a constant speed drying process was about. 60^0C, the drying process from 81,2% to 19,8% humidity, dehydrating speed for constant speed drying period, has the average value of 9,72 % humidity/min. The results of the laboratory analysis, highlighted the quality of the finished product, expressed by organoleptic and physico-chemical properties (2.0% total ash, soluble solids concentration in 69.80 Brix) determined based on the samples taken from experiments.

The working drying conditions for pears are similar to apples: the working temperature for a constant speed drying process was about 60°C, the drying process from 80,5 % to 17.2% humidity, dehydrating speed for constant speed drying period, has the average value of 9.74 % humidity/min. Laboratory findings highlight the quality of the finished product, expressed by organoleptic and physico-chemical properties (1.3% total ash, soluble solids concentration in 50.10 Brix) determined from samples taken from experiments.

The working drying conditions for rosehip and hawthorn fruits (Fig.6): the working temperature for a constant speed drying process was about 90^0C, the drying process from 42.24 % to 12.39% humidity, dehydrating speed for constant speed drying period, has the average value of 1.34 % humidity/min.

Working regime of the installation is determined according with the plant species that are dried. Initial moisture of the fruit can vary between 90-40% and the final between 25-5%. Operating temperature at constant drying regime can range between 50-90ºC, the rate of drying for the period with constant speed rate, ranging between 1-15 % humidity/min.

4. Conclusion

The utilization of the fruits drying installation with microwaves in continuous flow presents the following advantages:

1. Electro-thermal conversion of high frequency electromagnetic waves result in a rapid heating of load in his whole volume, from the inside to outside, opposite as to the conventional heating;

2. The heat generated by the microwaves field is manifested constantly in all of the product's mass, during passing through the drying precinct;

3. The electro-thermal conversion of the electro-magnetic waves of high frequency, determines a rapid heating of the product in its entire volume; but with different absorption rates;

4. Rapid heating of the product to over 60ºC in its whole volume allow removal of treatments for the inactivation of oxidative enzymes with acidic solutions, while reducing the risk for darkening and burning;

5. Focus and resonance phenomena, favored by the shape of product fragments subjected to dehydration, determine the development of some areas (points) for high temperature, in which occurs the local combustion of the product;

6. Percentage of losses caused by fragments which are burned is reduced (about.1-2%), they expunged with the sort of losses, after drying process;

7. The results are appropriate both from the point of view of drying process efficiency and of the final product's quality;

8. The favourable impact on the environment, the technology for drying with this plant being unpolluted, no affecting the ecological equilibrium and conserving the biodiversity of the environment factors.

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Table 1 (E. Popa et al. 2004)

Dielectric constant εr at % humidity			Losses factor tg δ at % humidity		
0	20	80	0	20	80
1.7	3.5	7.0	0.04	0.22	0.18

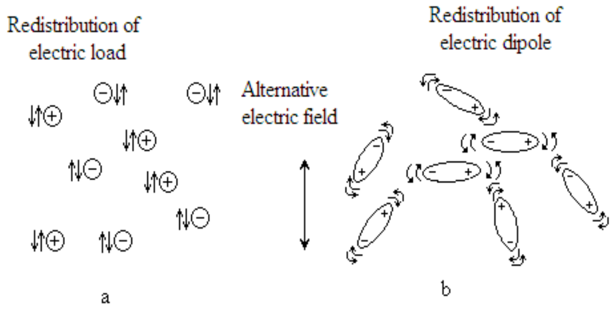

Fig. 1. Interface polarization (spatial load) (a) and shift polarization(b). (Hantila, 2002)

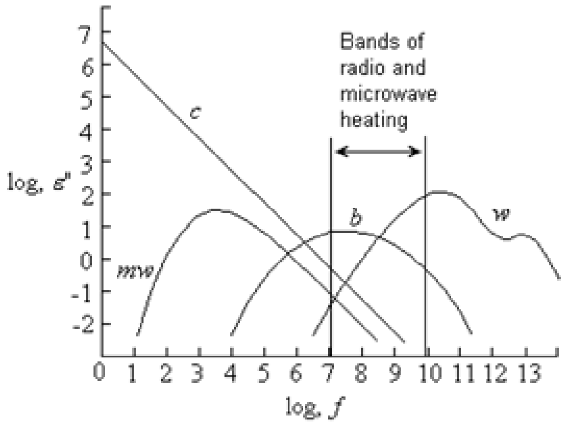

Fig.2. Loss factor in a wet material is a function of frequency in Hz. (Hantila, 2002)
c -conductivity c.c.;
mw - Maxwell-Wagner effect;
b - edge of the water relaxation;
w - free water relaxation

Fig. 3. The continous flow installation and the conservation of fruits aspect

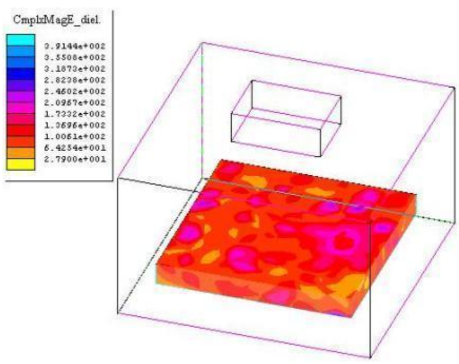

Fig. 4. Effective variation of the electromagnetic field intensity on the load surface (E. Popa and co., 2004)

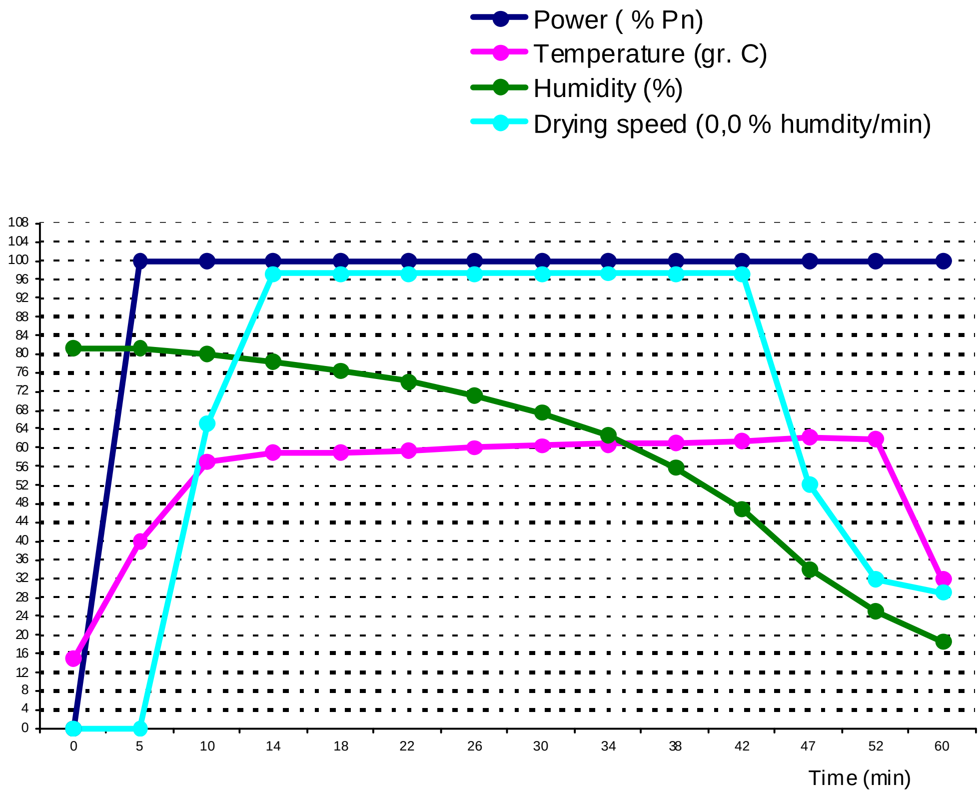

Fig. 5 Variation of condition parameters during drying process of apples ('Golden Delicious' cv.) and variations in microwave power emissions.

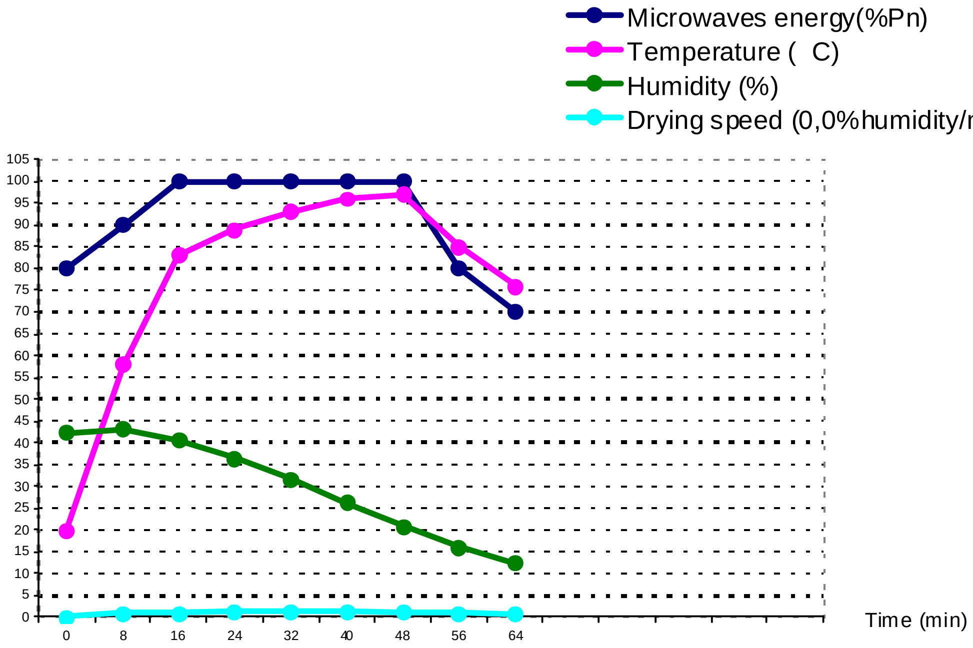

Fig. 6 Variation of condition parameters during drying process of rosehip and changes in microwave emission power