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MICROWAVE TREATMENT OF MATERIALS IN LOW PRESSURE

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Uniquely favourable characteristics of biological product can be obtained through the use of the microwave method in vacuum heating process. Microwave-vacuum drying is superior to other methods in terms of dried products' structure, flavour, colour and biological active compounds contents. But applications of such a methods seems to be much wider: drying of fruits and vegetables for consumption, drying of herbs for extraction of valuable biological compounds, for modification of seed structure (sunflowers seeds, pumpkin seeds), for pasteurisation etc.

A universal system was designed for testing such processes in laboratory scale and several industrial scale system have been developed.

The most important advantages of this method are:

- possibility of heating the dried material in its entire volume (however, it requires special solutions of process chambers),
- very short drying time,
- relatively low temperature of the material due to the lowering of the boiling point of water at low pressure,
- favorable structure of the dried material caused by the effect of "loosening" the material as a result of water heating in capillaries and inside cell structures (puffing effect).

Process of thermal treatment can be carried out with plastic drum installed inside of multi-mode microwave cavity and cavity which is connected by microwave line with reflectometer and circulator - to microwave generator. In laboratory unit generator 2.45 GHz with controlled power (from 50W to 800W) was applied. System was equipped with vacuum pump with pressure control and is controlled by computer. Most important technical parameters, like: microwave power, time of treatment, pressure inside of drum, temperature of steam – are controlled and recorded. Laboratory scale unit is shown below.

Fig. 1. Photo of a laboratory microwave vacuum station for testing drying processes. The device has been ordered by Institute of Fruit Farming in Skierniewice, Poland. Similar units have been delivered to several universities and research institutions and to industrial laboratories as well. Are mainly used for drying, but also for pasteurization and recently for seed structure modification. Very promising research has been carried out for drying of hemp before extraction.

Basing on laboratory scale test several technologies in industrial scale was developed. Industrial scale unit equipped with 8 generators of 3 kW (2.45 GHz) was constructed and for last 8 years has been successfully used for "production" of crispy chips which are now popular in Polish market. Exemplary industrial scale installation is shown in photo below.

a)

b)

Fig. 2. a) Two cavity microwave industrial drier, b) Multi – drum microwave drier

Another system for modification of seed is now constructed – ordered by big industrial producer of batons and sweet snacks. Process will be carried out inside of dielectric drum in low pressure and reactor will be equipped with 8 generators of 3 kW (2.45 GHz). Treatment time will be reduced to 3-4 minutes and next material (seeds) will be cooled down.

Last project which now is realized connected with drying of scobs(wood chips) applied in composite material production. System will work continuously with two airlocks and with dielectric drum and will be connected with 4 microwave generators (3 kW, 2.45 GHz). In next step planed installation will be equipped with microwave high power generator ca. 60 kW with frequency 915 MHz.

1. Microwave vacuum installation in technical scale – two-chamber version

The above, briefly described process of drying vegetables, fruit and herbs has for many years been applied in technical scale at PAULA company in Kalisz, Poland. To meet the company's needs, four separate lines were constructed, consisting of pulse-and-fluidization driers for initial drying of fruit and vegetables, as well as two-chamber microwave vacuum driers. The functional system of microwave driers is illustrated by the block diagram in figure 3 and 4.

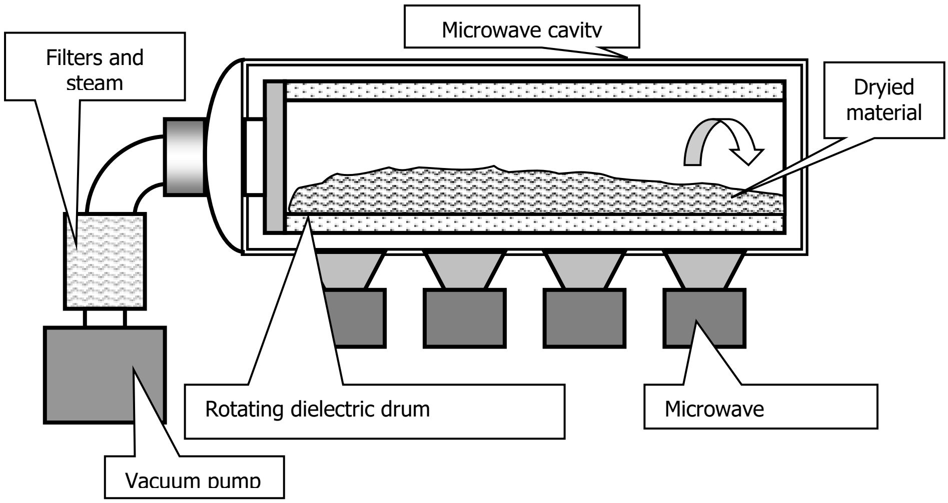


Fig. 3. Simplified diagram of the industrial microwave vacuum drier.

In the described process, the humidity of the inserted material is usually approx. 15-25% (per weight), and as a result of the microwave drying, the humidity is reduced to about 2-4%. The efficiency of an installation operating in such a way is approx. 30-45 kg of dried material an hour.
Photographs in fig. 4 present two lines made by PROMIS-TECH: one with manual loading and unloading of material, and a line with a set of automatic loading and unloading of the material from drums in both chambers.

a) b)

Fig. 4. Photographs of microwave vacuum driers (installation made for PAULA company in Kalisz, Poland): a) version for manual loading, b) version with automatic loading and unloading of the material.

2. Multi-drum vacuum drier

The previously described structure of a drier is relatively expensive and requires complex control system with the so-called switch throw enabling to switch power supply of a set of microwave generators installed on both chambers. Moreover, for quite a long time the devices remain inactive when the process of stabilizing the product in the chamber takes place, after previous heating up with microwaves.

These inconveniences have been removed in a new, largely modified structure defined as the multi-drum vacuum drier. The structure utilizes only a single set of microwave generators instead of two sets installed in the previously described system; in addition, specially developed chargers for microwave generators were applied, which provide low power rippling with a simple and inexpensive structure.

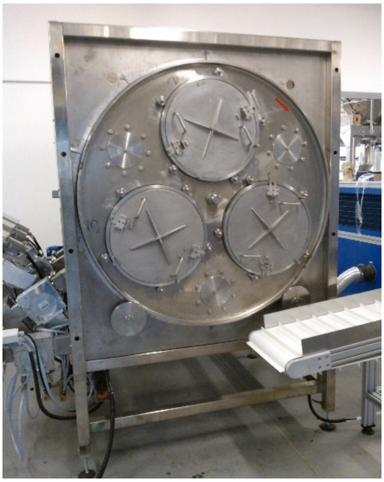
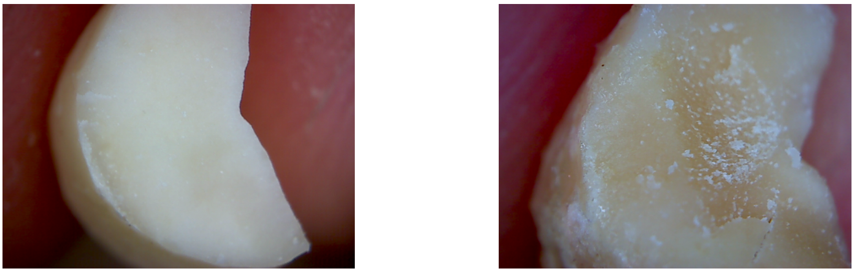


Fig. 5.

Other example for the use of microwave vacuum system is industrial installations analogous to two-chamber designs used to change the structure of pumpkin seeds, sunflower seeds and nuts to reduce their hardness and to obtain a more fragile structure. This process was used to modify these seeds and nuts used in the production of bars.



a) b)

Fig. 6. Photographs of cracked peanut a) before and b) after the process under microscope.

Another project based on the use of microwaves in drying processes under reduced pressure is the technology of drying scobs. This product, after drying to a relative humidity below 1%, is used for the production of special composites with resins.

As part of laboratory tests, the rate of scobs drying was compared by conventional method with microwave drying. In both cases, the process was carried out at reduced pressure (about 60 hPa).

Conventional drying of scobs to achieve a very low final relative humidity (about 1-2%) is a difficult and potentially dangerous process. With conventional drying in a stream of hot air, the limitations are:

- dust removal effects (fine fractions from finely divided shavings),
- possibility of dust explosion (eg due to a spark between electrostatically charged particles).

In addition, as a result of the conventional drying of scobs, the drying product can be characterized by significant differences in relative humidity (some, for example, larger fragments may remain more moist than the smallest fractions).

It is intended that these drawbacks can be removed by using a drying process under reduced pressure, heating the dried material with microwave energy and through the hot walls of the process chamber.

The application of a reduced pressure in the dryer chamber results in a lower water evaporation temperature, and the lack of oxygen in the chamber prevents the explosion of dry scobs. However, it is necessary to supply energy to the dried material and in this process it is preferable to use microwave energy properly emitted to the dryer chamber. In addition, partial energy transmission to the dried material can be provided by heating scobs by contact with the hot wall of the feeder.

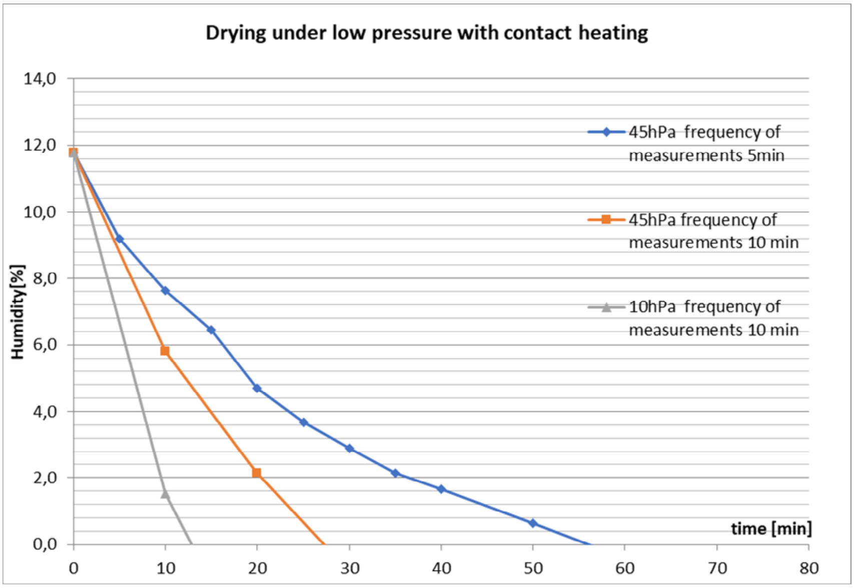


Fig. 7.

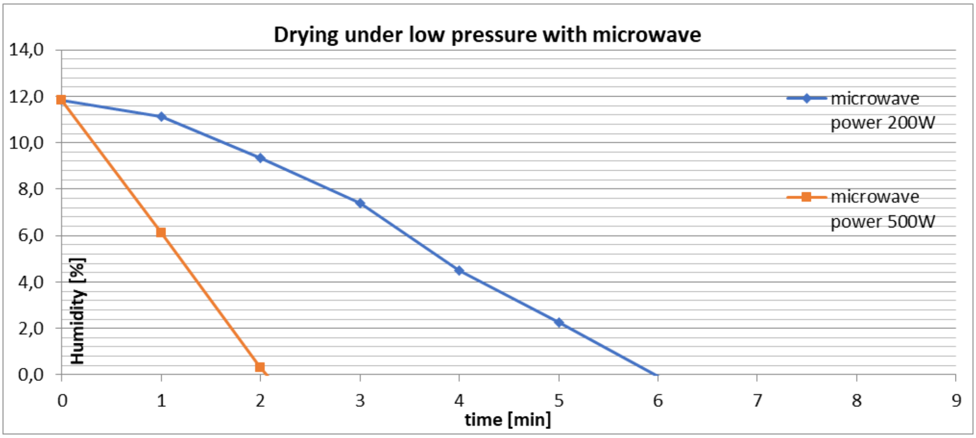


Fig. 8.

The use of microwaves has allowed the drying process to be accelerated many times from about 20-40 minutes with contact heating to 2-6 minutes in the case of microwave heating.

3. Conclusions

The process of microwave vacuum drying has found its valuable use in technical scale, enabling to obtain dried material with unique qualities, impossible to be obtained with the use of conventional methods. All quality research carried out so far has shown very favourable characteristics in dried material obtained this way: preserving valuable biologically active components and very good organoleptic assessment.

The quality of obtained dried material is comparable to the material dried through sublimation methods, which methods are costly, require long time for drying and large spaces.

In both mentioned cases of industrial application of microwave vacuum driers, the investment process was preceded by tests with the use of laboratory driers. Such driers are also very useful during operation of industrial installations, as they allow to seek optimal technological parameters with the use of small amounts of raw material, and they eliminate the risk of significant losses caused by improper selection of process parameters.

However, it should be stressed that the described designs both in laboratory scale and industrial installations allow optimal process of drying by applying adequate technical solutions resulting from the specificity of the microwave technology: special radiators emitting microwaves to the material being dried, their proper location in the chamber, and microwave generators with low power rippling. Proper selection of working pressure values and the use of special microwave generators also enables elimination of the threat of spontaneous discharges.

To sum up, vacuum microwave driers are a technological solution with very large application potential; however, their implementation requires design works and starting such lines taking into account the specificity resulting from wave-related phenomena, characteristic for the microwave band.