Microwaves in the food industry

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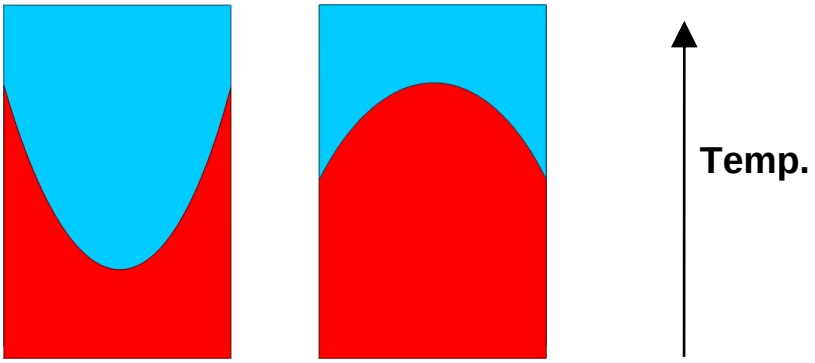
In the food industry microwave heating technology is used for heating, pre-cooking, thawing, drying and for killing of bacteria. Microwaves usually heat food very well, as food generally has a high water content and water is readily heated by microwave energy.

Microwaves

Microwaves are electromagnetic waves, similar to radio waves, which can be used for drying and heating. The advantage of microwaves, in comparison to many other heating methods, is that microwaves can penetrate into the product where they induce heating inside the product. As a result, microwave processes avoid the slow heating times that are characteristic of conventional processes as a result of the slow conduction of heat from the surface to the inside of the product.



Picture 1 Inverse Temperature Profile

As microwaves can penetrate into the product, they heat up the complete volume of the product at the same time, so that a very homogeneous heating is achieved as compared to conventional heating methods. The temperature profile generated in a material by the microwaves is inverse to that achieved by conventional heating. During microwave heating, the inside of the product has the highest temperature and the surface has a lower temperature. As a result, the heating times can be reduced significantly and damage to the product avoided due to a shorter exposure to high temperatures and less overheating of the surface. In the food technology, microwaves are mainly used for drying, heating and sterilisation.

Baking of crust-less bread

In a microwave oven, food is heated up mainly by the interaction of the electromagnetic field with the water molecules inside the food. The non-uniform distribution of electrons in the water molecule creates a dipole moment. Inside an alternating electrical field, the water molecules are rotated with changing the orientation of the field. This movement creates heat. The high dielectric loss factor of water is the reason for fast heating of food inside a microwave oven.

The penetration depth of the microwave field in food is limited by the water content frequency, power. In pure water at 20 ˚C, 66 % of the microwave energy is absorbed inside

the first 14 mm. When the temperature increases to 75 ˚C, the absorption zone is expanded to 59 mm. At the start of the process, the center of large parts is heated only by the flow of energy effected by the temperature difference between the microwave heated surface and the cold core. During the heating process the penetration depth increases because of vaporisation of water at higher temperatures.

It is possible with microwaves to cook food and also bread. The microwaves heat a product from the center toward the surface, while conventional ovens are work in the other direction. Typical baked bread, which is baked in 28 min in a conventional furnace, has the right structure and stability within only 10 minutes processing with a microwave. This microwave technology has been used for more than 8 years by a Linn High Therme customer in Thailand for baking of white crust-less bread. Eight Linn microwave continuous flow units (picture 1) with a length of 11 m and a width of 1, 5 m have a bread capacity up to 1200 kg / h. They output a total microwave power of 96 kW (8 microwave units at 12 kilowatts each). This corresponds to a total energy consumption of 165 kW by the unit at full power. This results in a savings of up to 40% of energy in comparison to conventional technologies.

Normally the crustless bread is baked and then the crust is removed, which is a waste of raw material and energy. The microwave baked bread is “normal” bread, but without a crust. The surface of the bread has thin white film, which is as smooth and elastic as the center of the bread. The bread is baked in microwave transparent (PP, PTFE) boxes. The boxes are placed on a special holding system, which is put on a conveyor belt for feeding into the microwave chamber. Next, the boxes loaded with bread dough travel continuously on the conveyor belt through the microwave furnace. The patented microwave chamber with a round shape and the magnetrons placed helically around the chamber leads to a homogeneous heating, not only from the sides, but also from below.

There are other uses of this technology in the cakes and pastries industry: These include the baking of small cakes and the baking of dough for the production of the dry bread crumbs.

Pic. 2: Continuous Microwave Baking Ovens (Linn High Therm GmbH Model MDBT 12)

Close-up of microwave baked crust-less bread

Use of microwaves for the production of fast cooking rice

Conventional pre-treatment processes are used for the production of the three forms of fast-cooking rice: parboiled rice, fast cooking rice and instant rice. The general pre-treatment

process for all three forms of rice is similar. First, the still un-hulled rice is hydrated to increase the water content to 30-40 %. Then, the surplus water is removed and the rice is allowed to rest to homogenise the humidity. Next, a heat treatment is performed, usually by cooking at approx. 100 °C. Finally, the rice is dried until it has a final humidity of approx. 14 %. These processes are all very time consuming and have a high energy consumption for the cooking and drying processes; in addition, there is considerable water consumption for the cooking process.
As an alternative to these conventional processes, a new process based on the use of microwaves for heat treatment has been developed. The use of microwaves for the production of fast cooking rice is not new, but most of the previous methods only substituted the use of microwaves as the source of energy for the conventional heat treatment step; in this method, the other process steps are largely the same, and as a result, the advantage of the microwave process is minimal. However, by using the newly developed microwave process, the whole production process is significantly shortened, which results in a great improvement of the process.

In the new process, the rice is first hulled and then directly packed into cooking bags. Next, the microwave treatment is complete without addition of extra water. As a result of using microwaves and a special process technology, the normal water content in the rice of approx. 14 % is sufficient to achieve the rapid cooking effect. After the new microwave treatment, the rice only needs to be cooled down so that it can be packaged. The fast-cooking rice produced by this process has a cooking time of 10 - 11 min, which is comparable to the cooking time of rice made using conventional processes.

Reduction of energy consumption

In order to analyze the energy savings resulting from the new microwave process, it is useful to compare the microwave process with a conventional gas-fired process. The conventional rice pre-treatment process has an energy requirement of approx. 560 m^3/t gas for cooking/drying and approx. 70 kWh/t for transport/cooling. The 560 m^3/t gas is equal to an energy of approx. 5000 kWh/t, so the total energy requirement for the conventional process is about 5070 kWh/t rice. Please note that these values are general estimates and may vary depending on the efficiency of each process.

For the new microwave process, the energy requirement is about 130 kWh/t for microwave heating and about 15 kWh/t for cooling. Therefore, the total energy requirement for the microwave process is about 145 kWh/t. Comparison of the microwave process energy consumption with the conventional process shows that the microwave treatment reduces the energy requirement by about 60-85 %. When considering the different costs for gas and electrical energy, the microwave process reduces total energy costs by up to 90%.

In addition to energy reduction, there are also improvements in the taste and color of microwave processed rice as compared to conventional treated rice, as the process time and the potential for damage to the rice is reduced significantly. In addition, the fragility, which is the tendency of the rice to break, is not increased by the microwave treatment and is comparable to the values of non-treated rice.

Use in production
This new microwave process was developed in a research project with Pannon University, Veszprém, Hungary. The development time for the production-ready process was about 2 years. In August 2003, a first production line which uses the new process was operational at the company AboMill (formerly Alföldi Malomipari RT), Hungary, the industrial partner of the development project. This plant (see picture 3) has a microwave power of approx. 21 kW and has a production capacity of approx. 300 kg/h.

Picture 3: Microwave continuous belt furnace for rice MDBT 21
(Linn High Therm GmbH)

Sterilization of spices

Spices are mainly cultivated in countries with a humid atmosphere. This fact increases the growth of bacteria. Often at the material's arrival at the place of destination, the bacteria count can be above the legal limit. Therefore, in order to sell the spices, it is necessary to sterilize them. In some countries, this is achieved by radiation treatment with Co^{60}, but this method is not allowed in Germany. The disadvantage of conventional thermal processes is that the spices have relatively long holding times at high temperatures, which are necessary for sterilization, so that the desired temperature in the inside, e.g. of peppercorns, is reached. As a result of the long treatment, the taste and the appearance can be negatively affected. With microwaves, it is possible to reduce the treatment time and achieve a comparable or even better bacteria reduction to conventional processes. Thus, the quality of the spices is less affected as the taste and the colour are not negatively influenced.

Picture 4: Sterilization of spices (Thailand)

Drying of fruits

For the manufacturing of dried fruits, fresh fruits are cut into pieces and treated with sugar solvent. Next, the fruit parts have to be dried. This step of refining is mainly done in the country of origin of the fruits. The fruits are dried by the sun or treated in hot air driers, depending on the degree of the production technology. A long conventional drying process

at low temperatures is required in order to preserve the shape and colour of the fruits. Microwave drying has shown that comparable results can be achieved for taste, shape and colour at shorter processing times. Thus, it is possible to dry in a continuous process, which yields many advantages for the productivity of the process. Additionally, a sterilization effect can be obtained by microwaves, similar to the effect used with spices (see above).

Picture 5: Drying of fruits, herbs

Hulling of Seeds

Certain seeds are difficult to hull and need special processes to remove the edible seed and separate it from the inedible hull. For example, pumpkin seeds are very hard to hull with automatic devices, because the hull adheres very strongly to the seed. Sometimes after automatic processing of such seeds, hull pieces are still adhered to the seed. However, using a microwave treatment, it is possible to heat up the seeds for a short time which leads to a swelling of the hull. As a result, it is much easier to separate the seed from the hull, without the risk that some part of the hull sticks to the seed.

Microwave treatment of bottle corks

Bottle corks are made from the bark of the cork tree. The cork bark raw material is usually stored for some time before it is processed into corks. During storage, bacteria can enter the cork. These bacteria are not dangerous, but produce a chemical called TCA (trichloranisol) that is responsible for the bad taste of cork in the wine. In the conventional treatment process, the bottle corks are cooked and treated with steam to kill the bacteria and to reduce the TCA content. However, cork has a very low thermal conductivity, so it is not possible to reach the required temperatures in the inside of the cork in acceptable processing times. Therefore, the cork taste could not be avoided until the advent of microwave treatment processes. With microwave treatment, it is possible to kill the bacteria and to reduce the TCA content drastically in a single process step. This microwave treatment is done in large

continuous belt heaters, which have a power of 50 kW to 60 kW (picture 6). The contamination of wine can thus be easily avoided and the taste improved.

Picture 6: Microwave continuous belt dryer MDBT 60 kW / 15 m for treatment of cork stoppers

Résumé of
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