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Microwaves for Grain Maize Drying

Drying Maize through a Combination of Warm-Air and Microwave Application

Drying grain maize preserves grain quality and stabilizes storage conditions. In practice, high drying capacities at low specific costs are being strived for, whereby maintaining quality is becoming more and more important. Conventional convection warm-air driers are by and large technically mature. For further development, possibilities for optimizing the process combination of warm-air drying and microwave were tested, as well as under which conditions a drying combination process is meaningful.

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Literature

References can be retrieved under LT 05507 at http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm.

The timely, gentle conservation of grain maize and other agricultural grain crops is an important task of agricultural engineering in practice, given the high food losses in the post-harvest area worldwide. Since raw materials produced in agriculture are also increasingly being used as a basis of utilizable raw materials in industry, energy or medical technology, the application of adapted drying techniques is gaining in importance.

Ultimately, convection drying under conditions which remain invariable during the drying process cannot provide the systematic advantages of drying adapted to the individual drying properties.

Microwave application is a fundamentally different possibility of improving the input of energy into the crops to be dried and accelerating the process of moisture extraction. The physical property used in this technique is the direct conversion of energy into heat in the water molecules.

Based on both theoretical considerations and drying tests with potato slices [3], Lücke found that supplementary microwave application in combination with convection drying has advantageous effects if the input of microwave energy is adapted both under design-technological aspects and with regard to the drying profile.

Combined Convection- and Microwave Drying

Superficially, moist crops and grain maize in particular tolerate high hot air temperatures during the first part of the drying process. However, this only applies as long as the cooling limit temperature is adjusted. As soon as heat input and the resulting extraction of moisture from the grain are no longer equivalent, grain damage and overheating may occur. In contrast to convection drying, supplementary microwave drying causes evaporation where the grain contains moisture, i.e. also directly in the interior of the grain. If the two techniques are combined, the water-permeable outer layers and shells remain more capable of diffusion until the end of the drying process.

Design of the Experimental Drying System

For the realization of the tests, a batch dryer was designed instead of a continuous-flow drying system. This allows all relevant process conditions of the batch dryer to be set and balanced separately during the drying process.

The metallic dryer consists of a standing cylindric mixer with a level grille and the exhaust-air space underneath. Near the fresh-air supply point, a stainless steel grid is installed in the container wall so that the drying room is supplied with a virtually even flow of hot air. At the same time, the stainless steel grid is intended to prevent microwaves from escaping. The drying air is heated steplessly by two electrically operated resistance heating registers arranged in series with a thermal output of 1,700 W each.

The cover consists of a metal ring on which the hollow-core conductor with an industry magnetron on top is installed eccentrically. At a frequency of 2.45 GHz, the magnetron has a transmitting power of 1,200 W, which can be controlled steplessly. The magnetron used has an efficiency of ~ 70%, which results in an electric power draw of 1,800 W.

For the energy balancing of the drying processes, the electric energy consumption of hot air generation and dielectric heating was measured by separate electricity meters.

The power required to generate the transmitting power of the microwaves corresponds to the consumption of power from the electric supply network, which must actually be paid for. However, it must be considered that the effective conversion of microwave energy in the grain is actually only possible up to the level of magnetron efficiency. During the drying process, the maize is mixed three-dimensionally by two agitators.

While in operation, the entire dryer unit is positioned on a digital scale. Therefore, both the mass of the moist crops and moisture extraction during the drying process can be recorded continuously.

Fig. 1: Batch mixing drier

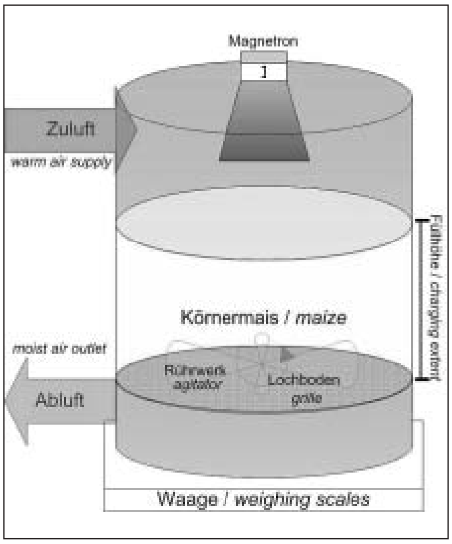

Fig. 2: Scheme of experimental drying plant

Experimental Techniques and Methods

The actively usable dryer volume is 0.08 m^3. In preliminary tests of grain maize drying, a batch size of 10 to 30 kg has proven itself in this system. If the flow thickness of the bulk can be adapted to the filling, drying processes in static layer dryers, band dryers, inverting dryers, or systems of mixed-flow dryers can be adjusted and recorded.

For energy- and output balancing, the following measurement data are recorded during dryer operation:

- sample weight and weight change due to drying
- temperature, moisture content, and flow speed of the ingoing and outgoing air
- crop temperature
- pressure difference
- hot air energy
- microwave energy
- power requirements for process air conveyance
- operating time of the agitator

Results and Discussion

For practical reasons, the drying trials with the experimental drying system were carried out with freshly harvested moist maize. In this contribution, two batch mixer trials are presented.

Trial 1: convection drying

Trial 2: microwave-convection drying

At the beginning, trial 2 was carried out with the same drying parameters as the pure convection drying trial described above. In contrast to trial 1, however, convection drying was supported by microwave application, which was activated after a drying time of 75 minutes.

Figure 3 shows water extraction during the two trials plotted over the drying time. It is shown that pure convection drying from an initial moisture content of 29% to a target moisture content of 14% requires a drying time of 210 minutes (3.5 hours). Thermal energy consumption is 1.98 kWh per kg of extracted water. This curve confirms the typical course of convection drying known from practice. Due to the comparatively low initial moisture content of 29%, heat input into the maize grains by means of conduction is slower than at an initial moisture content of 35%. This lack of thermal pre-drying is one reason for the high specific energy demand in this trial set-up.

Under comparable process-air conditions in the trial with microwave support, the extraction of the same quantity of moisture requires a drying time of 135 minutes (2.25 hours). In this trial, the specific energy demand also decreases considerably to 1.25 kWh per kg of water. Here, microwave application for supporting drying was activated after a drying time of 75 minutes. The drying process which leads to target moisture is completed significantly earlier. Water extraction remains virtually constant over the entire drying time.

The advantage of a short drying time during which only as much thermal energy as is needed for the extraction of a certain quantity of moisture becomes effective in the interior of the grain due to microwave application is a big drying-technological benefit. With regard to temperature and volume flow, the supply of warm air follows the level actually required for moisture transport from the outer layers of the grain.

With regard to a combination of techniques, dielectric heating was activated based on thermodynamic considerations during this trial. Further studies will show to what extent process combinations designed with drying-technological considerations (e.g. binding enthalpy) in mind will have an accelerating effect on a high-quality drying process.

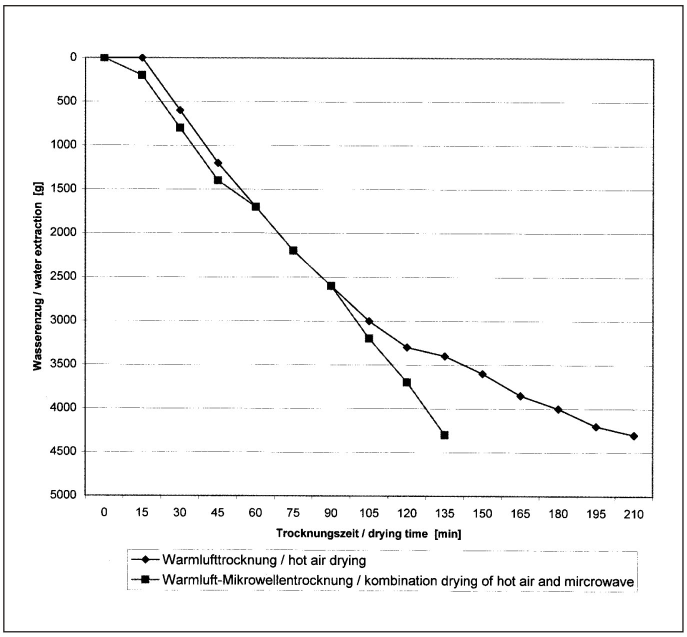

Fig. 3: Convection drying and microwave-convection drying of grain-maize, initial moisture (w.b.) 29 %, target moisture (w.b.) 14 %, inlet air temperature 125 °C, air velocity 0.40 m/s, microwave power 0.24 kW for 30 min.