Böhner, Martin; Barfuss, Isabel; Heindl, Albert and Müller, Joachim

Optimisation of the air supply of a multibelt conveyor dryer by fluid flow simulation

Uneven drying often occurs in belt dryers which leads to an increase in energy consumption and a decreased throughput. To optimise the system a fluid flow simulation was performed aided by computational fluid dynamics (CFD), supported by actual measurements. The installation of guiding plates and the optimised adjustment of the flaps inside the air supply duct can provide an effective approach for a better air supply.

Keywords
Drying, belt dryer, air duct, fluid flow simulation, CFD

Abstract
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In view of the persistent increases in energy costs, there is a definite requirement to reduce energy consumption in agriculture and its related areas by employing efficient technological processes. Post harvest technology is an important step between agricultural production and the post processing industry. This amounts to 30-50% of the total production costs incurred during the production process of medicinal and spice herbs, whereby the oil or gas fuel required for heating the air contributes to a high fraction of the costs [1].

Research has shown that drying is uneven over the belt width in belt dryers. This means that in practice, there are areas of higher product moisture content. The presence of these wet spots was already observed at the first belt [2].

It is very difficult to correct for any wet spots inside a belt dryer by adequate mixing of the drying product until the end of the drying process has been reached. Due to the steps at the end of each belt the product is turned but no lateral mixing occurs across the width of the belts, which would be necessary for uniform drying over the belt width to take place. Wet spots inside the material can lead to microbial deterioration of the intermediate or final product. To avoid deterioration the product often gets over dried so that even the wet spots will eventually reach the desired final moisture content at the end of drying. Therefore by avoiding over drying higher throughputs can also be reached [3].

Consequently, it is the aim of this project to obtain even drying of the material over the belt width by homogenising the air velocity distribution. To minimize the dependence on empirical methods for the modification of the air duct geometry, fluid flow simulations were conducted using computational fluid dynamics (CFD), which visualises the flow behaviour to reveal any shortcomings of the air ducting system. As a result of former studies a close correlation between measurements and calculations has already been observed [4].

Material and methods

Drying technology. The fluidic studies were carried out in a five belt dryer, which features a belt length of 20 m and a drying area of 300 m². The dryer is divided in three temperature zones. The high temperature zone with 105 °C contains the first one and a half belt lengths, the middle temperature zone with 95 °C spans the next one and a half belt lengths and the low temperature zone with 80 °C spans the last two belts. The temperature values are applicable to the drying of parsley. The drying material is loaded via a slewing belt conveyor, which leads to an inclined belt conveyor to the upper belt. The drying material passes through the dryer from the top to the bottom and falls onto the next lower belt at the end of each belt. When the product reaches the first half of the first belt, the product is mixed using a spiked roller. There are three air supply ducts, which are divided into three pressure chambers at both sides of the dryer respectively. The temperature zones, vent the belts. **Figure 1** shows the air supply ducts, the arrangement of the pressure chambers on both sides, as well as the recirculating and exhaust air duct of the dryer. Directly underneath every belt along the dryer are altogether 20 adjustable air inlets, which can regulate the lateral inflowing air. These air inlets divide the dryer into 20 segments. Every second air inlet of the first belt is furnished with a 10 cm long guiding plate, leading inside the drying chamber to improve the transportation of the air into the belt middle. Seven exhaust fans, situated in the middle of the dryer ceiling, extract the moist exhaust air out of the drying chamber.

The last three fans operate such that the air is partially re-circulated, so that the exhaust air flows back to the ignition area of the air heater.

Fluid flow simulation. The CFD (Computational Fluid Dynamics) Software FLUENT was used to simulate the fluid flow. It is based on the finite-volume-method, which requires the subdivision of the dryer geometry into a limited amount of cells. In each of these cells the fluid flow is calculated employing the Navier-Stokes-equations including additional equations to define the models. The calculation takes place iteratively until an acceptable convergence of the results is reached.

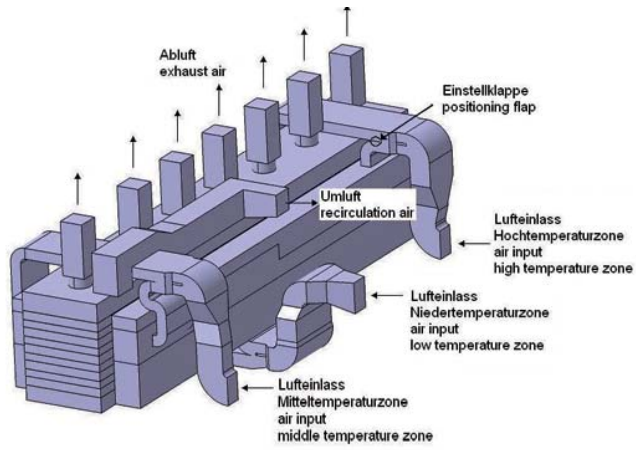
Firstly the geometry of the air duct system was digitized with the CAD-Software CATIA.

To generate the grid for further calculations with FLUENT the software Gambit was used. The grid took the form of a hybrid grid comprising pyramids and prisms with 860,000 cells, created by pre-meshing of the geometry edges. The boundary conditions for the calculations were determined by taking measurements directly from the dryer. At the inlet to the air supply duct, an air velocity of 13 m/s for example was measured. The high temperature zone of the belt dryer was simulated with the realisable k-ε-model. This demonstrates an improvement on the standard k-ε-model which is often used in industry for flow and heat transfer calculations. This model, consisting of the transport equation for turbulent kinetic energy (k) and an extensively modified equation for the dissipation rate (ε), resulted in an improvement by employing a new method for calculating the turbulent viscosity and an exact equation for the dissipation rate.

The advantage of the modified k-ε-model is its suitability for separated and secondary flows as they appear during the simulation of the dryer [5]].

Experimentation. The drying material was Parsley (*Petroselinum crispum*), which was directly cut after harvesting (cutting length around 3-5 cm) and was air classified and loaded with an

Fig. 1



Air duct system of the investigated five belt dryer

average bulk height of 10 cm,.

To identify the amount of moisture content, coarse, material samples were taken at the feeder, in the middle of the first belt and at the end of each of the five belts providing mixed samples over the belt width, which were then analysed using the furnace method (103 +/-2 °C, 24h). Measuring points underneath the first, third and fourth belts as well as inside the air supply duct, enabled the measured air temperatures and velocities to be compared with those calculated using FLUENT.

The instruments used were thermo anemometers from (Ahlborn MT8635TH4) and NiCr-Ni and thermocouples (Ahlborn FT015L0500).

Altogether five sensors were installed on tripods positioned at a distance of 0.5m relative to each other across the belt width, these being located between the transportation and return side of the belt. These tripods were installed at the beginning, in the middle and at the end of the first belt. Furthermore, each exhaust stack was furnished with a moisture and temperature sensor from (Ahlborn FHA646-E1C).

Results

Spatial differences of the product moisture content and the air temperatures over the belt width are illustrated in **figure 2**. These measurements were taken halfway along the length of the first belt. They show a temperature drop of around 30°C from the sides to the middle of the belt.

Because the product moisture content behaves oppositely to this, the bulk on the sides will dry at a faster rate. The fluid path length is not sufficient to lead the hot drying air as far as the middle of the belt. Another reason for the faster drying rate on the sides can be explained by the radiation effect on the pressure chamber walls. Furthermore, due to the uneven feeding of the drying material, the bulk height on the sides will usually be lower than at the belt middle, this accelerating the drying process even further.

The fluid flow simulation supports this explanation. The temperature distribution, visualised in **figure 3**, shows higher temperatures at the side areas whilst the air temperature decreases in the direction of the belt middle.

Also the un-uniform temperature distribution of the right compared to the left side is significant. The explanation for this can be found in the air supply duct. Where the air is separated into the left and right pressure chambers a flap is installed. This flap is marked in **figure 1** and divides the flow volume into each chamber. The original horizontal setting of the flap resulted in a higher air volume inside the left pressure chamber and therefore at the left part of the dryer.

Significant is the uneven temperature profile at the air inlets with the guiding plates. This demonstrates the effect of the guiding plates on the air distribution. This phenomenon can be explained by considering the air velocity of the flow simulation, which shows the same profile as the temperature. This suggests that with higher velocities the air flow travels further in the direction of the belt middle and provides it with higher temperatures. Furthermore the air up-streaming from underneath is deflected at the guiding plates, which guide it in the direction of the belt middle where it causes an additional temperature rise.

Conclusions

The uneven air distribution of belt dryers presents a formidable problem. With the help of measurement techniques and simulations, imperfections in the system may be revealed and counteracted accordingly. Due to the strong drying at the belt sides it is our aim to lead the hot air as far as possible into the drying chamber.

The installation of longer guiding plates at the air inlets, or increasing the inlet velocity are possible improvements. Additionally, the hovering speed of the drying material has to be considered so that the product does not exhaust with the air.

The findings of the measurements and simulations should lead to constructive improvements of belt dryers. The aim is to obtain an optimised flow through the duct with a homogenous temperature distribution over the drying area.

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Authors

Dipl.-Ing. Martin Böhner, **M.Sc. agr. Isabel Barfuss** and **Dr.-Ing. Albert Heindl** are research assistants at the institute of agricultural engineering of the Universität Hohenheim, department of agricultural engineering in the tropics and subtropics (**head Prof. Dr. J. Müller**), Garbenstraße 9, 70599 Stuttgart, E-Mail: martin.boehner@uni-hohenheim.de

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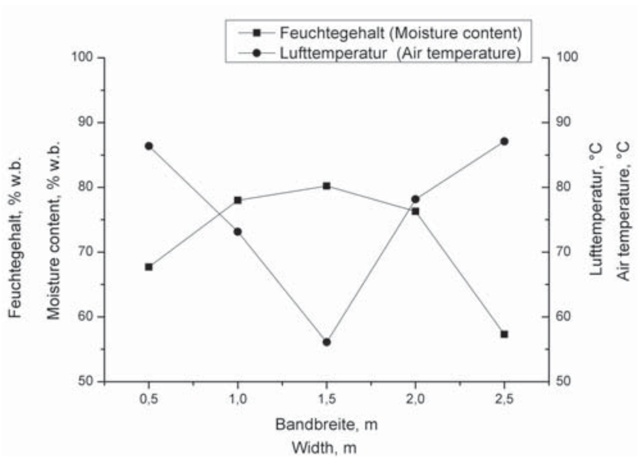
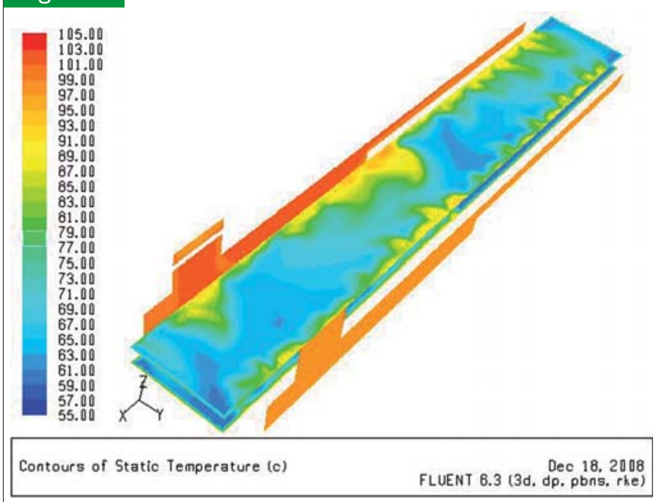
Fig. 2



Moisture content and air temperature across the belt width in the middle of the first band

Fig. 3



CFD simulation of the temperature distribution above the first dryer band