Laboratory equipment for the measurement of cereals drying on Mendelu

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Abstract: The report focuses on the drying of cereals in connection with the laboratory equipment designed at Mendel University in Brno and used for drying samples of wheat and barley grain. The samples were placed in six cartridges thus forming a high layer of the dried material. Hot air was the drying medium and was blown through the high layer of grain by means of a fan. Samples in each of the cartridges were weighed and the grain temperature was sensed at periodical intervals. Drying of the material in the high layer at a constant flow direction of the drying medium was unevenly, with the highest rate of drying occurring at the bottom layer; subsequently, drying continued in other layers. The measured data were used for producing drying rate curves and the results were compared with the results of measurements achieved with a similar apparatus at a foreign university. The data make it apparent that the drying device is functioning and the measured data match the foreign references. A minor deviation occurred in the resulting values (a large increase in drying rate at the beginning of measurements) and was caused by using grain harvested after the rain. The subsequent heating in a drying facility resulted in a significant evaporation of the surface water between the grains. Subsequently, when measuring was done within the next time interval, the drying rate returned to expected values. The small possibility of regulating air flow is a certain drawback of the current unit. The high layer of the material creates too much resistance for the fan, the device subsequently ensuring maximum air velocity of 0.3 metres per second even at the highest speed. Enhancing the unit with a suction pump to suck the air might be some sort of way out in that this would turn the unit from a high-pressure unit into a vacuum device. Save the weakness described above, the apparatus allows creating suitable settings for scientific measurements and is capable of providing measurement in even more complex areas in the field of drying.

Key-Words: drying, cereals, quality, energy intensiveness

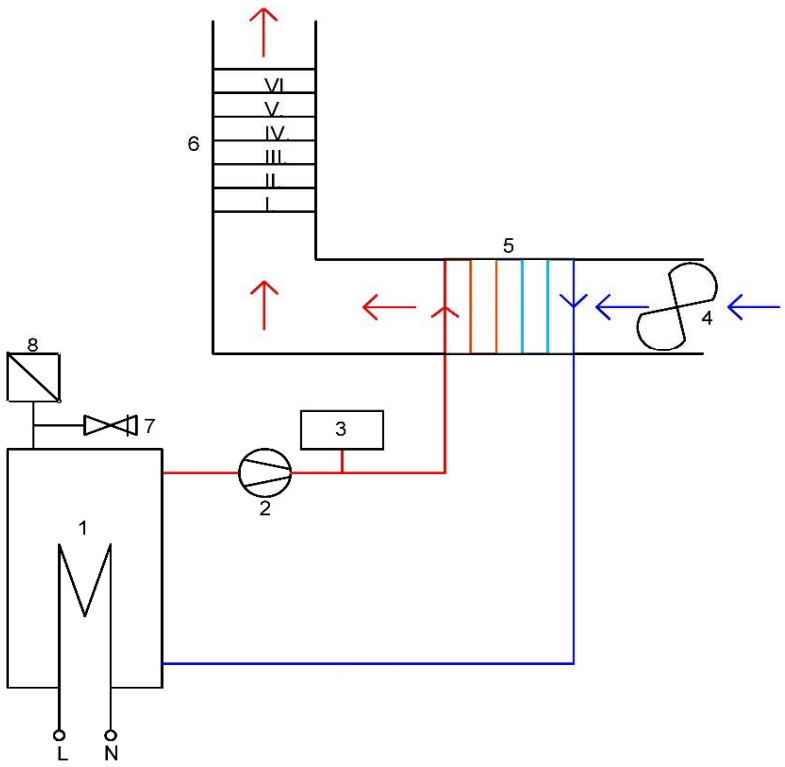
Introduction

Drying is a physical process, in which the water content of the dried product is reduced through the effect of heat, and any change in the chemical composition of the product is not desirable [1]. Since moisture (i.e. water) is removed by evaporation, drying involves a change in the water phase, from liquid to gas (vapour) [2]. This makes drying fundamentally different from other means of reducing moisture of products, which particularly involves mechanical methods such as centrifuging, pressing, etc. [3]. The gradual development of drying technology in each of the industry and farming sectors and related requirements as to drying plant parameters and quality is closely linked to deepening knowledge of the general theory of drying [4]. For this reason, we decided to construct a drying laboratory apparatus at Mendel University. Its function and the potential of using the measured parameters within rather complex experiments in the field were validated by measuring basic parameters in drying cereals, particularly wheat and barley. In future measurements, the apparatus may be possible to use e.g. for measuring materials with drying pauses (phase drying), drying with cyclic changes in the medium flow rate, for new representation of weight and thermal flows in drying, for constructing the modified i-x-w diagram of moist air, and designing draft specifications of and additions to technical standards. This makes the range of use of the lab system widely broad.

Material and methods

Fig. 1 shows the drying laboratory equipment. It consists of a primary heat exchanger (1) in which water is heated via a heating element. Water circulation is provided by a centrifugal pump (2). Proper functioning is ensured by an expansion vessel (3).

Fig. 1 Drying lab apparatus, Brno, CR, 2014



Heated in the primary heat exchanger to 90 °C, the water is transported to the secondary heat exchanger (5) using the pump. The fan (4) sucks the ambient air that flows through the secondary heat exchanger, while the heat from the water passes through the heat-exchange surface of the secondary heat exchanger into the air (60 °C), which then flows upward with the velocity being 0.3 metres per second to pass through the cartridges filled with samples designed for drying (6). After passing through the system of cartridges, the air is discharged back into the environment; its temperature is lower than that at the input and its relative humidity is higher. This is the mode in which the apparatus was working. The unit includes an air-relief valve (7) and a safety valve (8). Exact doses of dried samples were put into each of the cartridges, wheat first, followed by barley. After the start of the measurements, each of the cartridges was removed and weighed, this followed by measuring the temperature of the grains which was firstly done every 30 minutes and subsequently every 60 minutes. The relative humidity of the input material was determined using three cups filled with the material measured by weighing and subsequently dried in an oven at 105 °C. The temperature and relative humidity of the hot air were measured behind the cooler straight prior the inlet into the cartridges.

Measurement apparatus

-Thermometer (to measure grain temperature) - VOLTCRAFT DUAL-LASER LR-SCAN-350 RH, temperature range: -50 to 350°C
- Thermometer/hygrometer (measuring the temperature and relative humidity of hot air) - COMMETER D 3121 Temperature range: -30 to 105 °C, resolution of 0.1 °C, accuracy of 0.4°C. Relative humidity: range 0-100%, resolution 0.1%, accuracy 2.5%.
-Scale RADWAG WAS 220/C/2, range 10-220 g, resolution 1 mg, accuracy 0.1 mg
-Weight JADEVER LPW-1260, range up to 6,000 g, resolution 0.5 g.
Used formulas
Relative humidity

$$w = \frac{Mv}{Mm} = \frac{Mm - Mms}{Mm} \cdot 100 \quad [\%]$$

Mv – water weight [kg]
Mm – the weight of the moist material [kg]
Mms – the weight of dry matter [kg]

Results and discussion

Drying of the material in the high layer at a constant flow direction of the drying medium was unevenly, with the highest rate of drying occurring at the bottom layer; subsequently, drying continued in other layers. This is seen in a way that the area of the dried material gradually increases in the direction of airflow. Drying curves (decrease in relative humidity over time) of barley and wheat are shown in Figs. 2 and 3 (the top section). Sample numbering is from I to VI depending upon the place the cartridge with samples was located (see Fig. 1). As the air passes through the lower, moist layers, its relative humidity increases until the equilibrium relative humidity of the initial moisture content of the wet material. Thus, drying occurs in the higher layers (II-VI) with a gradually increasing time delay, which reaches the maximum for the uppermost layer, hence the uneven final moisture of the dried material in continuous drying when it is over dried in the bottom layer, while drying is not complete in the top layer. For these reasons, drying should take place with low layers of the material (1 metre is the maximum). This adverse effect can be eliminated by cyclic changes in the flow direction of the drying medium.

The drying speed of barley and wheat is obvious from Figs. 1 and 2 at the bottom. The first phase reveals a clear increase in the drying rate (0-0.5 h); it is the initial interval in which the dried material adapts to the new conditions of thermal and material equilibrium during drying. Extreme increase in time (0.5-1 h) is affected by the use of grain harvested after the rain. It is obvious that in the areas between the grains there remained surface water, which quickly evaporated at the beginning of the experiment due to the hot air. The following section (1.5-2.5h) is known as one of constant speed, in which prevailing is the evaporation of surface water, moisture loss is directly proportional to time. This section ends with a critical point (2.5 hours). The last part of the graphs shows a decreasing rate of drying. The loss of moisture is no longer proportional to the time; there is the evaporation of inner moisture inside the material. This section ends with an equilibrium point - the material reaches equilibrium with the drying medium.

Making a comparison of the measured data with the results of measurements at the Slovak Agricultural University in Nitra can lead to a conclusion that we managed to reach a consensus [4], [5], [6]. The difference can be seen only in the drying rate curve that reaches large extremes; the reason why this is so is described in the previous paragraph.

Fig. 2 Drying barley, Brno, CR, 2014

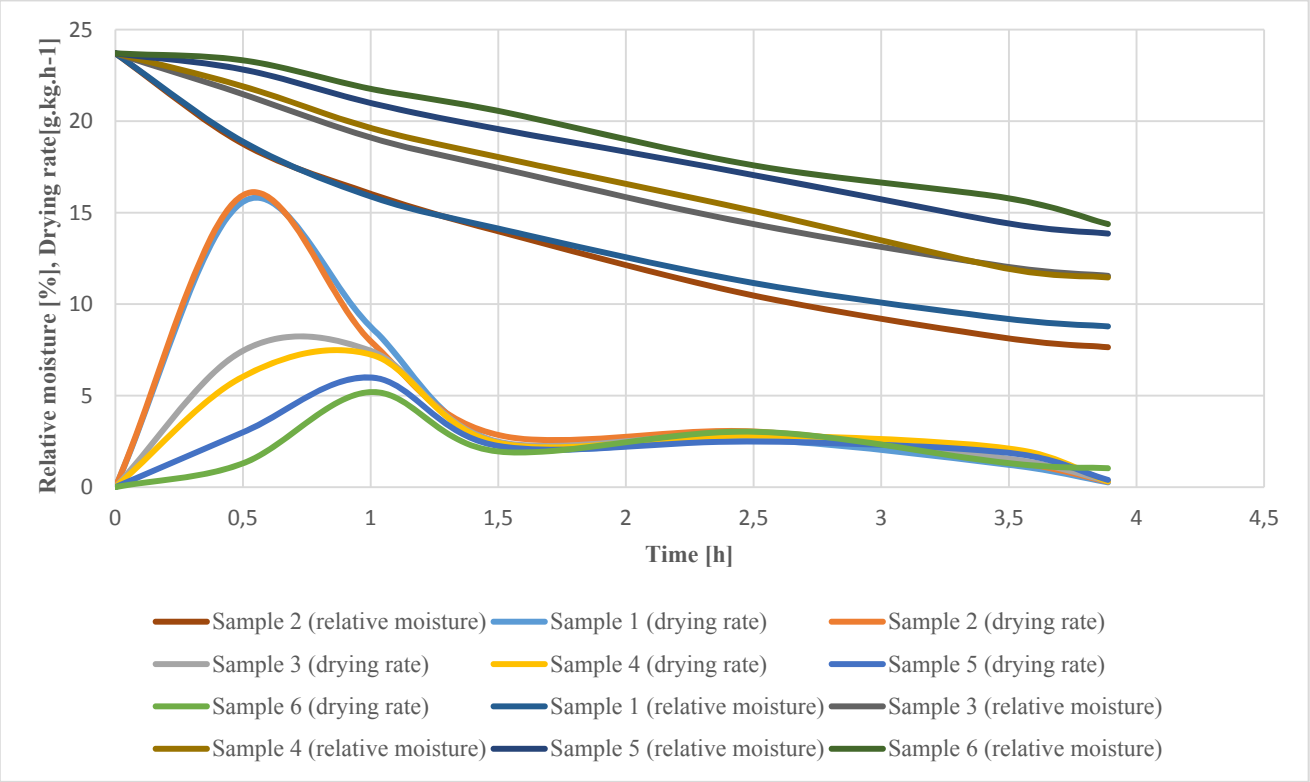
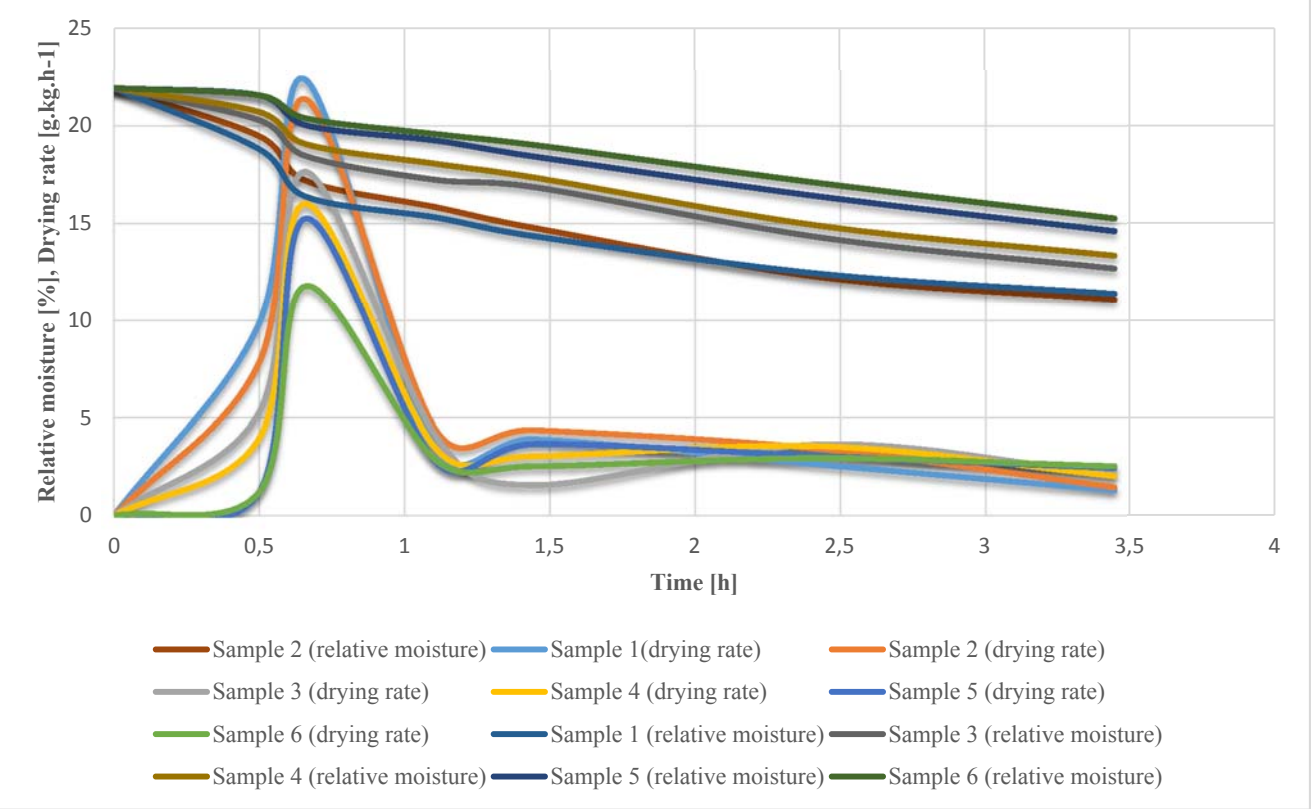


Fig. 3 Drying wheat, Brno, CR, 2014



Conclusion

The measurements showed that the laboratory apparatus constructed at Mendel University is capable of creating the proper conditions for measuring a cereal drying process; certain improvements of existing equipment are possible. The measurements showed the need to increase air flow rate. This can be controlled by a fan with adjustable speed. Due to the large layer of material (large flow resistance), this regulation is little effective and air velocity can be changed only slightly. The solution is to connect the suction pump via the piping and remove the fan. The air then would not be injected into the cartridge, but sucked with a vacuum pump and the system would turn from a high-pressure type into a vacuum type [7]. Once these adjustments are implemented, the device makes it possible to solve even rather challenging scientific problems of drying.

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