The energy performance of the drying process according to maize harvest time

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Abstract: This paper deals with the topic of drying maize grain and potential energy savings. The measurements were carried out at LIPONOVA, a. s. (the farm established in Lipolice in the Pardubice region) in the period from 6th October to 31st December 2012, with a total sown area of 655.7 hectares of agricultural land. The average yield was 12.832 kg per hectare with the moisture content of 29.86%. Drying was under way in two phases: the grain was first pre-dried to reduce moisture from the average of 29.9% to 19.6%. Then there was final drying to reach storage moisture of 13.7%. The dried samples of maize were subjected to the measurement of (1) relative grain moisture using a hygrometer and the measurement of (2) temperature using a digital thermometer with a measurement probe. A review testing was done for several samples in a laboratory at Mendel University in Brno. The values of relative humidity and temperature of ambient air were also recorded. In addition, notes were taken of grain-dryer parameter settings, i.e. drying medium temperature and dryer emptying delay. The data acquired make it apparent that ambient air temperature is a major factor for the energy demand of drying; the higher the temperature, the less energy is needed. Other important parameters include the target temperature of the heated air in the dryer and dryer outlet air humidity. It is possible to achieve the energy savings in the drying process if the parameters above are set properly and their level is considerable with regard to the quantity of the dried material.

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

Introduction
Grain crops possess the important position in the national economy as they are grown on more than half of the total area of arable land and cover about 40 % of calories intake in the population's diet [1]. Grain crops include maize. Since maize is a seasonal product, it must be stored once harvested until it is used for processing into final products or directly consumed. After harvesting, maize is a living matter and its life processes must not be restricted by the crop being treated, stored and managed improperly to ensure the required shelf life with minimised storage losses. When storing pre-conditioned maize, i.e. with removed excess water, impurities and pests, the storing requirements are not extensive; protection from additional moisture, pest infestation and undesirable micro flora are sufficient. [2] The most important variables influencing the storage period can be seen in (Fig. 1) and involve temperature and grain moisture content. Drying is the very action to reduce the water content of maize to the value at which storing the crop is possible over the long-term. It 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 desirable. Since moisture (i.e. water) is removed by evaporation, drying involves a change in the water phase, from liquid to gas (vapour) [3]. This makes the drying fundamentally different from other means of reducing moisture of products, which particularly involves mechanical methods such as centrifuging, pressing, etc. With the grain shape and higher relative moisture (over 30 %), maize drying is much more complex than with other grain crops. If grain is heated to a high temperature and then suddenly cooled, it exhibits a higher susceptibility to mechanical damage [4, 5]. In the Czech Republic,
the issue of drying maize grain is particularly up to
date because of new hybrids, as well as new maize
drying plants [6, 7]. New post-harvest lines include
that in Lipoltice, the Pardubice region, which
became the site for measuring energy requirements
of drying and evaluating installation’s operating
parameters.

Fig. 1 The effect of temperature and grain moisture content on storage time [9]

Material and methods
The measurements were carried out at LIPONOVA,
a. s. - the farm established in Lipoltice in the
Pardubice region. Grain maize was harvested from
6th October to 31st December 2012. The post-
harvest line consists of a system of conveyors (screw
and bucket conveyors), the grain cleaner Schmidt-
Seeger TAS 154A-4, the mobile drying plant
Schmidt-Seeger EcoDryFlex18, natural gas
powered, and three grain storage tanks. Maize was
first pre-dried to reduce moisture from the average
of 29.9% to 19.6%. Then there was final drying to
reach storage moisture of 13.7%. During the drying
period, hourly consumption of electricity and the
quantity of natural gas were being deducted using
a sub-meter and gas flow meter, respectively. The
dried samples of maize were subject to the
measurement of (1) relative grain moisture using the
hygrometer Pfeuffer HE 50 and (2) temperature
using a digital thermometer with a measurement
probe. A review testing was done for several
samples in a laboratory at Mendel University in
Brno. Values were also recorded of relative
humidity and temperature of ambient air. In
addition, notes were taken of grain-dryer parameter
settings, i.e. drying medium temperature and dryer
emptying delay. The plot areas, yields and computed
values are shown on Tab. 1.

Establishing the average relative humidity of all
harvested grain (TARH) by using the method of
weighted average.

\[
TARH = \frac{\sum TYwg_i \cdot RHh_i}{\sum TYwg_i}, \text{[\%]} \tag{1}
\]

Where:
- \(TYwg_i\) – Total yield per field of wet grain [kg]
- \(RHh_i\) – Relative humidity of grain at field at harvest
time. [%]

Average grain yields per hectare (TAGYH) were
calculated from sum of wet (at harvest RH) grain or
dry (storage RH) divided by total sown area \(A\).

\[
TAGYHwg = \frac{\sum TYwg_i}{\sum A_i}, \text{[kg.ha}^{-1}\text{]} \tag{2}
\]

\[
TAGYHdg = \frac{\sum TYdg_i}{\sum A_i}, \text{[kg.ha}^{-1}\text{]} \tag{3}
\]
Calculation of total dry matter, relative humidity of grain (RH), total water content at harvest and during storage describe for example Kováč (2012).

\[
RHg = \frac{Mg - MDMg}{Mg} \cdot 100 = \frac{Mw}{Mg} \cdot 100, \% \quad (3)
\]

where:
- \(Mg\) – Total mass of grain at given humidity [kg]
- \(MDMg\) – Mass of dry matter of the grain [kg]
- \(Mw\) – Amount of water in grain at given RH.

Non ordinary used symbol is \(t\%\), which mean amount of percent of water, have to be remove from 1 ton of grain. For example drying 100 ton of grain from RH 30% to 14% is \((30–14)\ast 100 = 1600 \ t\%\). It determines the fee for drying during buying or selling of grain.

If the RH of grain is known, the mass of dry matter (MDM) of the grain can be calculated by

\[
MDMg = \frac{Mg \cdot (100 - RHh)}{100} \quad [\text{kg}] \quad (4)
\]

If we need calculate mass of water at corn at known RH, we use this equation (Ružbarský et al., 2004)

\[
Mw = MDMg \cdot \frac{RH}{(100 - RH)} \quad [\text{kg}] \quad (5)
\]

Hourly energy consumption of dryer was calculated from volumes of burned natural gas and electricity energy.

\[
q = \frac{VNG \cdot HNG \cdot 3600}{Mwrem} \quad [\text{kJ.kg}^{-1}] \quad \text{and}
\]

\[
q_{el} = \frac{ELE \cdot 3600}{Mwrem} \quad [\text{kJ.kg}^{-1}] \quad (6)
\]

where:
- \(VNG\) – Volume of burned natural gas [m³]
- \(HNG\) – Energy content of natural gas 10.55 kWh.m⁻³
- \(3600\) – is constant for convert kWh to kJ
- \(Mwrem\) – mass of water removed during measurement [kg].

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<th>Total maize DM [kg]</th>
<th>Amount of water stored at 14% [%]</th>
<th>Dry maize yield per hectare [kg]</th>
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Results and discussion
A total sown area was 655.7 hectares of agricultural land (Tab. 1). The yield of maize ranged from 7.274 to 16.645 kg per ha; the variance was generally caused by the different time of harvest and over-reproduced wild boars. Grain losses on late-harvested plots in combination with losses from lodging of whole plants are estimated at 20% by the farm management. The average yield was 12.832 kg per ha with the moisture content of 29.86%. Stored after drying was a total of 7.313 tonnes of grain with a moisture content of 14%. which is an average yield of 11.152 kg per ha. The drying was under way in two phases. with ambient air being the drying medium. heated in a heat exchanger through burning natural gas.

Measurements within drying phase 1 took place on 22nd and 23rd November 2012 with the outdoor air temperature ranging from 6 to 12°C. the temperature of the drying medium being 120°C and the dryer performance amounting to 4.850 kg per hour. The average grain moisture reduced from 31.6% to 19.6%. In the afternoon. the achieved average specific heat consumption was 3.603 kJ per kg. while at night with the outdoor temperature dropping to 6°C it was 4.049 kJ per kg.

For drying phase 2 measurements were carried out on 14th January 2013 at outdoor air temperature of -2°C. The temperature of the drying media: 90°C. the dryer facility performance: 8.023 kg per hour. The average grain moisture decreased from 16.7% to 13.7%. Specific heat consumption: 5.380 kJ per kg.

The measured and computed values of specific heat consumption fall within the range commonly reported by other manufacturers of dryer plants. [6]

As can be noticed. grain moisture decreased by 2.8% between the phases. which is due to forced ventilation and thermal inertia of the grain. This phenomenon brings savings in the energy required for drying and is a common feature of two-stage drying technologies. In terms of average consumption per 1%, the quantity of natural gas needed was 1.275 cubic metres for phase 1 and 1.563 cubic metres for phase 2.

Fig. 2 The drying process in the form of Mollier diagram, Brno, CR, 2014

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*Fig. 2 The drying process in the form of Mollier diagram, Brno, CR, 2014*
Conclusion

It results from the data acquired by measurements that ambient air temperature is a considerable factor for the energy demand of drying [8]. The energy demand of the heating of the drying medium is determined by the selected temperature of the same at the inlet into the drying compartment (point B: 120/130°C) and by the temperature of ambient air (point A: 0 to 20°C), more specifically, by their different enthalpy. To improve the drying economy, choosing a higher temperature of the drying medium is preferable. As it can be seen in Fig. 2, when the temperature reaches 130°C instead of 120°C, the air can hold more water (point C), which is specified through the yellow line segment (the difference between the levels of specific humidity), which is extending while the saturation of the moist air exiting the dryer does not have such an effect. As can be seen in Fig. 2, point C, the yellow line segment shortens only slightly at the humidity of 90%, 8% and 70%. The combined two-stage drying method applied in Lipoltice and the measurements also showed some risks. High grain moisture (over 30%) causes problems with clogging of transportation routes and vault effects in silos, which was manifest in the measurements as well. There was also an incorrect (low) final cooling of grain at the dryer outlet when the grain temperature at the dryer outlet was 33°C during the first measurement, and 42°C during final drying, which definitely does not comply with technological requirements (max. 5°C difference compared with the ambient temperature). As a result, there was locally a rise in grain temperature inside the storage bin (to as much as 50°C), which was resolved by aeration fans being operated on a continuous manner and the grain being transferred between the silos, which however leads to greater mechanical damage to the grain. When combined with relative grain moisture around 20%, such a level of high temperature also forms an ideal setting for mould to develop and storage pests to propagate.

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