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

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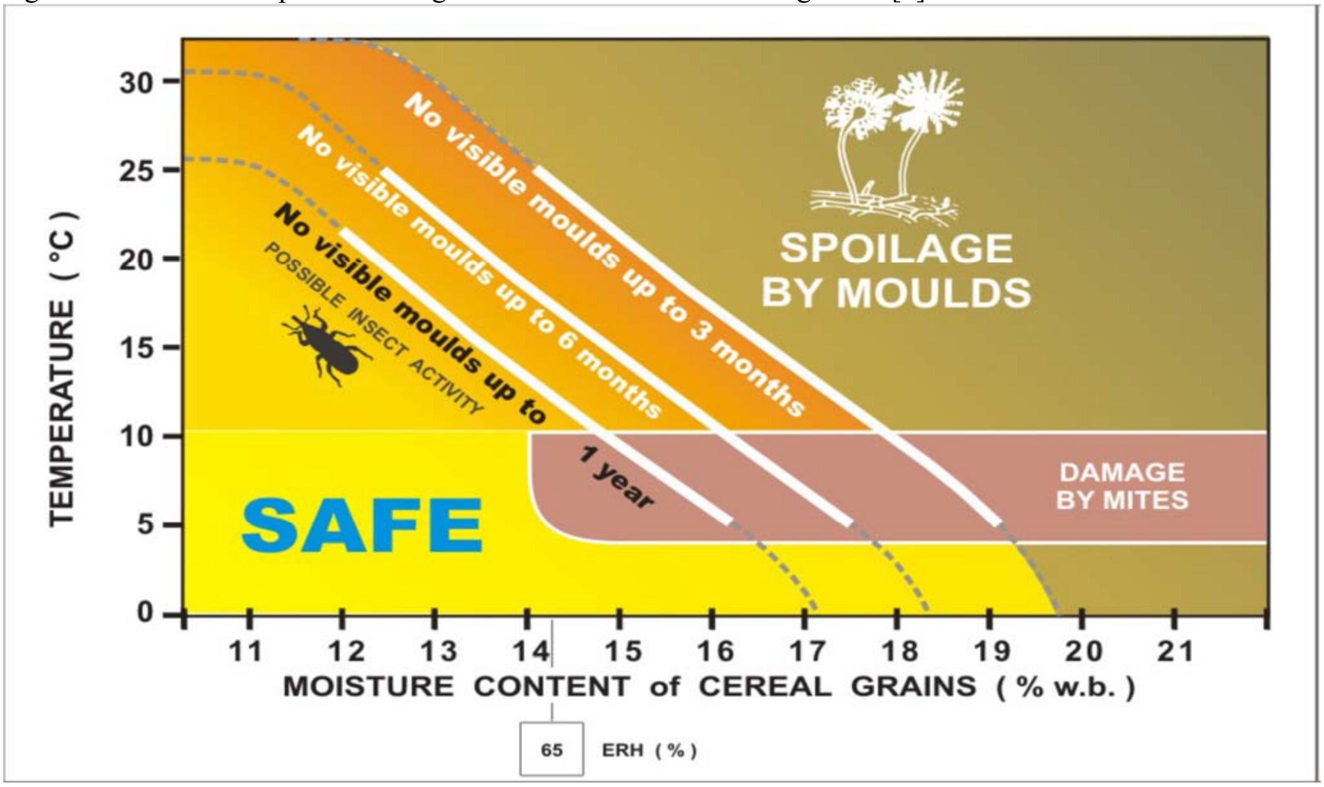
Abstract: This paper deals with the topic of drying maize grain and potential energy savings. The measurements were carried out at LIPONOVA, a. s. (the farm established in Lipoltice in the Pardubice region) in the period from 6th October to 31st December 2012, with a total sown area of 655.7 hectares 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.

$$TARH = \frac{\sum TYwg_i \cdot RHh_i}{\sum TYwg_i}, [\%] \qquad (1)$$

Where:

TYwg – Total yield per field of wet grain [kg]

RHh – 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.

$$TAGYHwg = \frac{\sum TYwg_i}{\sum A_i},$$

$$TAGYHdg = \frac{\sum TYdg_i}{\sum A_i}. [kg.ha^{-1}] \qquad (2)$$

Calculation of total dry matter, relative humidity of grain (RH), total water content at harvest and during storage describe for example Kováč (2012).

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

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)* 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

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

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

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

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

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

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

where:
VNG – Volume of burned natural gas [m^3]
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].

Table 1 Plot areas and yields

Plot	Area [ha]	Variety	Total yield per field of wet grain [kg]	Wet grain yield per hectare [$kg.ha^{-1}$]	Harvest moisture Content [%]	t% actually dried	Total maize DM [kg]	Amount of water in grain at 14% [kg]	Dry maize stored at 14 % [kg]	Dry (RH 14 %) grain yield per hectare [$kg.ha^{-1}$]
	A		TYwg	GYHw	RHh	t%d	TYDM	GWCs	TYdg	GYHd
Za Peckova	46	MERIDIEN	582930	12770	31	8123	405136	65952	471089	10320
Zlá paměť	30	MERIDIEN	430510	14495	30	5784	301357	49058	350415	11798
V okliku	18	MERIDIEN	129440	7272	30	1739	90608	14750	105358	5919
U letiště	35	BEATUS	309860	8778	29	3853	220001	35814	255815	7247
Černá skála	7	ATLETIKO	81920	12412	31	1182	56525	9202	65727	9959
Dolce	9	ATLETIKO	132000	15529	31	1905	91080	14827	105907	12460
Za Petrusem	25	ATLETIKO	319770	12740	31	4616	220641	35918	256560	10222
Před cyklosem	12	KAIFUS	190760	15384	30	2563	133532	21738	155270	12522
U hájovny	25	KAIFUS	433380	17546	30	5822	303366	49385	352751	14281
Mokř	15	KAIFUS	212400	14351	30	2854	148680	24204	172884	11681
Smejtenec	19	MERIDIEN	309340	16196	30	4156	216538	35250	251788	13183
Kadavovo	7	KAIFUS	117420	16538	30	1577	82194	13380	95574	13461
Kouty	4	KAIFUS	67140	16376	30	902	46998	7651	54649	13329
Za drůbežárnou	9	KAIFUS	141080	16216	30	1895	98756	16077	114833	13199
Za Nalezinkem	19	KAIFUS	263060	13845	30	3534	184142	29977	214119	11269
Za kůlnou	4	SYMBOL	52600	13150	32	812	35768	5823	41591	10398
Za Slavíkova	11	KAIFUS	140160	12627	27	1463	102317	16656	118973	10718
Ohrada	34	KAIFUS	407410	12161	30	5473	285187	46426	331613	9899
Na horách	31	KAIFUS	478120	15676	24	3555	363371	59153	422525	13853
Jedousov	3	BEATUS	33780	11260	30	454	23646	3849	27495	9165
Padesátka	34	DELITOP	363960	10705	22	1978	283889	46214	330103	9709
Křemena	11	BEATUS	98560	8895	28	1127	70963	11552	82515	7447
U Starkoče I	11	MERIDIEN	144400	13115	30	1940	101080	16455	117535	10675
Brložská	29	BEATUS	574540	19609	27	5995	419414	68277	487691	16645
U Lovčic	41	MERIDIEN	492930	12052	30	6622	345051	56171	401222	9810
Výborná	49	BEATUS	725010	14766	28	8290	522007	84978	606985	12362
Na černé	40	DELITOP	586020	14614	26	5529	433655	70595	504250	12575
Pod Borkem	17	DELITOP	183880	10816	22	999	143426	23348	166775	9810
Ryntířovo	21	MERIDIEN	238650	11641	30	3206	167055	27195	194250	9476
U hráze	41	MERID/BEAT	544020	13400	30	7309	380814	61993	442807	10907
U májovky	2	mix	17180	11453	30	231	12026	1958	13984	9322
Celkem	**656**		**8802230**	**12832**		**105489**	**6289224**	**1023827**	**7313051**	**11152**

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.

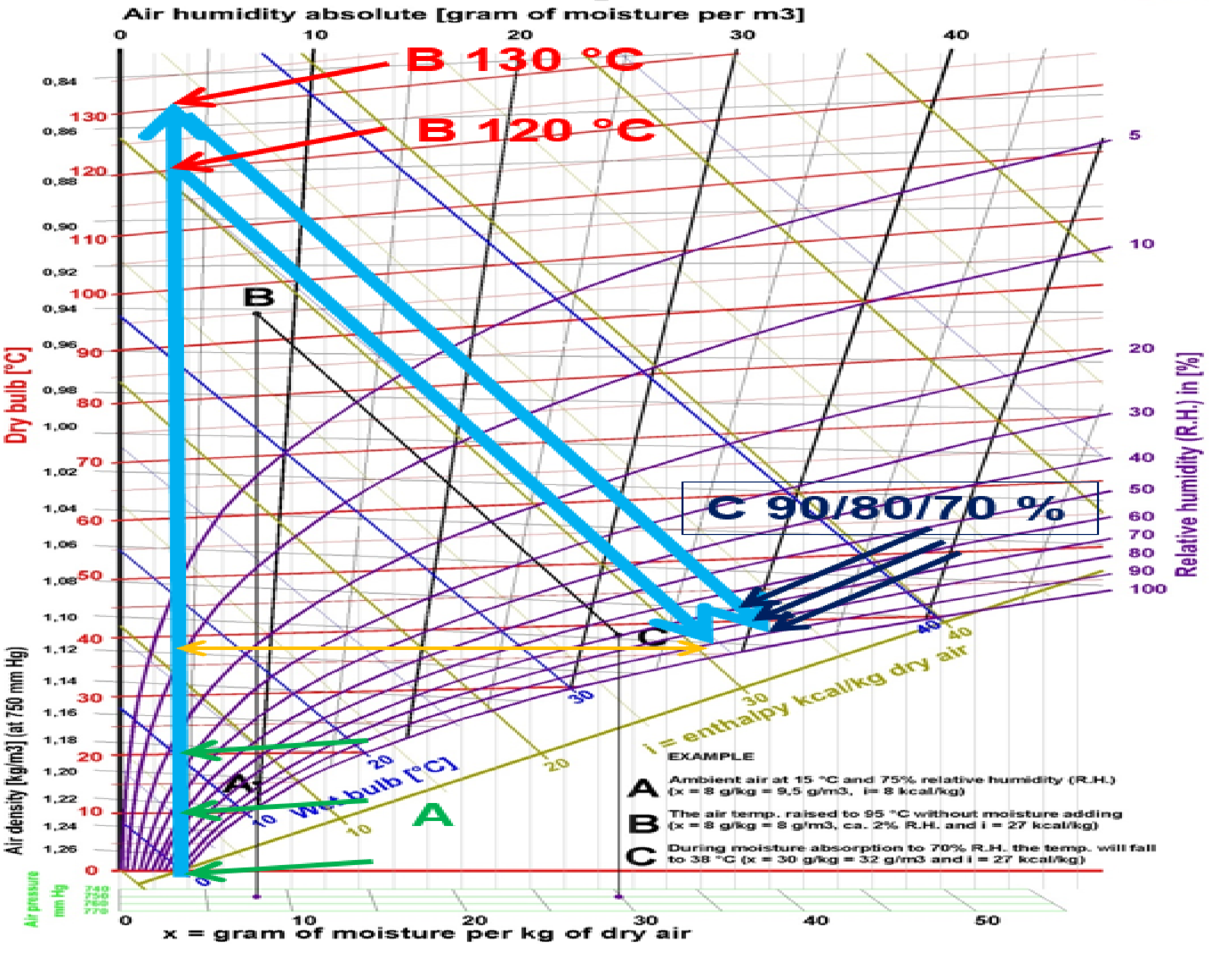
Measurements within drying phase 1 took place on 22nd and 23rd November 2012 with the outdoor air temperature ranging from 6 to 12°C. the temperature of the drying medium being 120°C and the dryer performance amounting to 4.850 kg per hour. The average grain moisture reduced from 31.6% to 19.6%. In the 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 t%, 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



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.

Acknowledgement

This study was financed by the Internal Grant Agency of the Faculty of Agronomy MENDELU in Brno No. TP 11/2013 and by the project CZ.1.02/5.1.00/10.06433, Acquisition of Instrumentation for BAT Center at MZLU in Brno for Categories of Food Processing Activities and Categories of Facilities for Disposal or Destruction of Animal Bodies and Animal Waste.

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