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EVALUATING THE PARAMETERS OF A MOBILE MAIZE DRYER IN PRACTICE

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Abstract

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The method of drying maize for grain has been recently employed on a large scale in the Czech Republic not only thanks to new maize hybrids but also thanks to the existence of new models of drying plants. One of the new post-harvest lines is a plant in Lipoltice (mobile dryer installed in 2010, storage base in 2012) where basic operational measurements were made of the energy intensiveness of drying and operating parameters of the maize dryer were evaluated. The process of maize drying had two stages, i.e. pre-drying from the initial average grain humidity of 28.55% to 19.6% in the first stage, and the additional drying from 16.7% to a final storage grain humidity of 13.7%. Mean volumes of natural gas consumed per 1t% for drying in the first and second stage amounted to 1.275 m^3 and 1.56 m^3, respectively. The total mean consumption of electric energy per 1t% was calculated to be 1.372 kWh for the given configuration of the post-harvest line.

drying, maize, quality, energy intensiveness

Drying of maize for grain has become recently a much discussed topic in the Czech Republic not only thanks to the emergence of new maize hybrids but also due to the existence of new types of maize dryers. One of the new post-harvest lines is a plant in Lipoltice in the Pardubice region (mobile dryer installed in 2010, storage base in 2012) where basic operational measurements were made of the energy intensiveness of drying, and operating parameters of the maize dryer were evaluated. Drying of maize is much more complex than drying of other cereals. The reason is not only the high content of water at the time of harvest when the relative grain humidity is usually higher than 30%, but also the size and shape of the grain of individual maize hybrids. With the rapidly changing temperatures (grain heat-up to high temperature and subsequent quick cool-down), the grain is also more susceptible to the mechanical damage (Vitázek, 2011).

MATERIAL AND METHODS

The experimental measurements took place at the LIPONOVA, a.s. farm in Lipoltice, Pardubice region. The farm is situated at an altitude of about 350 m a.s.l. The Claas Lexion combine Model 550 with a 6-row adapter for maize was used for the harvest, which started on 6 October 2012. The last maize was harvested on 31 December 2012. The post-harvest line installed by AGROING BRNO, s. r. o. was equipped with a grain cleaner and a mobile dryer Model Schmidt-Seeger EcoDryFlex 18 designed for natural gas (Fig. 1).

The drying of maize had two stages: pre-drying from the initial mean grain humidity of 29.9% to 19.6%, and final drying from 16.7% to the final mean grain storage humidity of 13.7%. During the process of drying, records were taken of natural gas hourly consumptions and of the consumption of electric energy on a submeter. Samples of dried maize were collected, in which relative humidity (RH) was measured by the moisture content indicator Pfeuffer Model HE 50 on the dryer plant output as well as grain temperature by the digital thermometer with a measuring probe. Relative humidity of several grain samples was tested also in the laboratory of Mendel University in Brno.

Concurrently, relative ambient air humidity and temperature were measured and records of the adjustment of dryer parameters by the operator were taken such as adjusted temperature of the drying medium and the time-out for emptying the dryer, which directly predetermined the plant performance.

An overview of plot acreages, sown hybrids and yields based on the weighing daily of the plant is presented in Tab. I; all other values were calculated by using standard procedures (Los, Pawlica, 2010; Vitázek, 2006).

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

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

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).

$$RHg = \frac{Mg - MDMg}{Mg} \times 100 = \frac{Mw}{Mg} \times 100, [\%] \qquad (3)$$

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 = 1 600 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

$$MDMg = \frac{Mg \times (100 - RHh)}{100}. [kg] \qquad (4)$$

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

$$Mw = MDMg \times \frac{RH}{(100 - RH)}. [kg] \qquad (5)$$

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

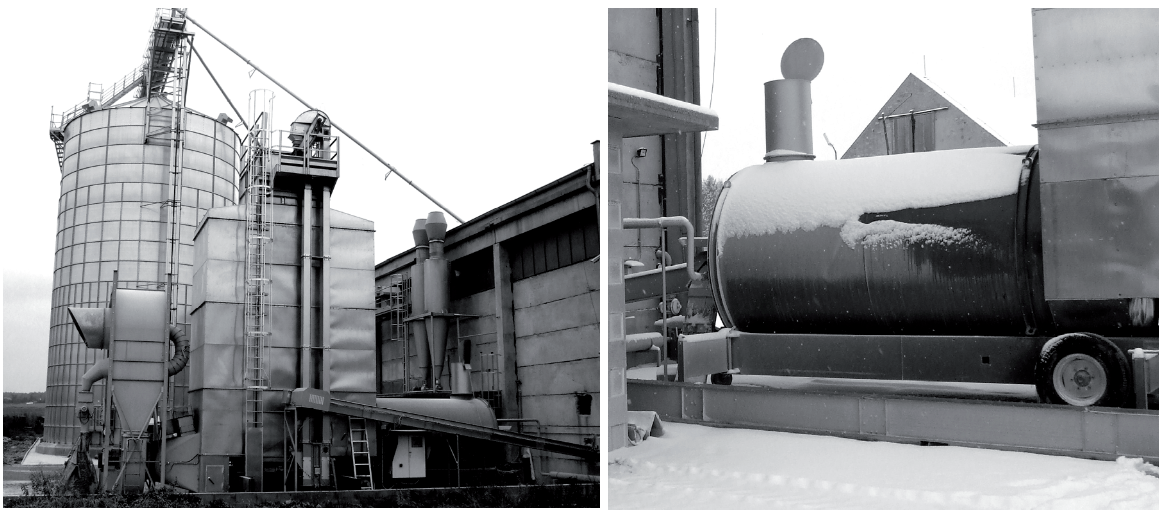
$$q = \frac{VNG \times HNG \times 3600}{Mwrem} [kJ.kg^{-1}]$$

and

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

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].



1: *Mobile dryer Schmidt-Seeger Model EcoDryFlex 18 – General view (left) and a heat-exchanger detail (right) during the measurement – 14 January 2013*

I: *Maize plots and yields*

Plot	Area	Variety	Total yield per field of wet grain	Wet grain yield per hectare	Harvest moisture content	t% actually dried	Total maize DM	Amount of water in grain at 14%	Dry maize stored at 14 %	Dry (RH 14 %) grain yield per hectare
	A		TYwg	GYHw	RHh	t%d	TYDM	GWCs	TYdg	GYHd
	[ha]		[kg]	[kg.ha^{-1}]	[%]	t%	[kg]	[kg]	[kg]	[kg.ha^{-1}]
Za Peckova	45.65	MERIDIEN	582 930	12 770	31	8 123	405 136	65 952	471 089	10 320
Zlá paměť	29.7	MERIDIEN	430 510	14 495	30	5 784	301 357	49 058	350 415	11 798
V okliku	17.8	MERIDIEN	129 440	7 272	30	1 739	90 608	14 750	105 358	5 919
U letiště	35.3	BEATUS	309 860	8 778	29	3 853	220 001	35 814	255 815	7 247
Černá skála	6.6	ATLETIKO	81 920	12 412	31	1 182	56 525	9 202	65 727	9 959
Dolce	8.5	ATLETIKO	132 000	15 529	31	1 905	91 080	14 827	105 907	12 460
Za Petrusem	25.1	ATLETIKO	319 770	12 740	31	4 616	220 641	35 918	256 560	10 222
Před cyklosem	12.4	KAIFUS	190 760	15 384	30	2 563	133 532	21 738	155 270	12 522
U hájovny	24.7	KAIFUS	433 380	17 546	30	5 822	303 366	49 385	352 751	14 281
Mokř	14,8	KAIFUS	212 400	14 351	30	2 854	148 680	24 204	172 884	11 681
Smejtenec	19.1	MERIDIEN	309 340	16 196	30	4 156	216 538	35 250	251 788	13 183
Kadavovo	7.1	KAIFUS	117 420	16 538	30	1 577	82 194	13 380	95 574	13 461
Kouty	4.1	KAIFUS	67 140	16 376	30	902	46 998	7 651	54 649	13 329
Za drůbežárnou	8.7	KAIFUS	141 080	16 216	30	1 895	98 756	16 077	114 833	13 199
Za Nalezinkem	19	KAIFUS	263 060	13 845	30	3 534	184 142	29 977	214 119	11 269
Za kůlnou	4	SYMBOL	52 600	13 150	32	812	35 768	5 823	41 591	10 398
Za Slavíkova	11.1	KAIFUS	140 160	12 627	27	1 463	102 317	16 656	118 973	10 718
Ohrada	33.5	MIX	407 410	12 161	30	5 473	285 187	46 426	331 613	9 899
Na horách	30.5	KAIFUS	478 120	15 676	24	3 555	363 371	59 153	422 525	13 853
Jedousov	3	BEATUS	33 780	11 260	30	454	23 646	3 849	27 495	9 165
Padesátka	34	DELITOP	363 960	10 705	22	1 978	283 889	46 214	330 103	9 709
Křemena	11.08	BEATUS	98 560	8 895	28	1 127	70 963	11 552	82 515	7 447
U Starkoče	11.01	MERIDIEN	144 400	13 115	30	1 940	101 080	16 455	117 535	10 675
Brložská	29.3	BEATUS	574 540	19 609	27	5 995	419 414	68 277	487 691	16 645

Plot	Area	Variety	Total yield per field of wet grain	Wet grain yield per hectare	Harvest moisture content	t% actually dried	Total maize DM	Amount of water in grain at 14%	Dry maize stored at 14 %	Dry (RH 14 %) grain yield per hectare
	A		TYwg	GYHw	RHh	t%d	TYDM	GWCs	TYdg	GYHd
	[ha]		[kg]	[kg.ha^{-1}]	[%]	t%	[kg]	[kg]	[kg]	[kg.ha^{-1}]
Plot	Area	Variety	Total yield per field of wet grain	Wet grain yield per hectare	Harvest moisture content	t% actually dried	Total maize DM	Amount of water in grain at 14%	Dry maize stored at 14 %	Dry (RH 14 %) grain yield per hectare
	A		TYwg	GYHw	RHh	t%d	TYDM	GWCs	TYdg	GYHd
	[ha]		[kg]	[kg.ha^{-1}]	[%]	t%	[kg]	[kg]	[kg]	[kg.ha^{-1}]
U Lovčic	40.9	MERIDIEN	492 930	12 052	30	6 622	345 051	56 171	401 222	9 810
Výborná	49.1	BEATUS	725 010	14 766	28	8 290	522 007	84 978	606 985	12 362
Na černé	40.1	DELITOP	586 020	14 614	26	5 529	433 655	70 595	504 250	12 575
Pod Borkem	17	DELITOP	183 880	10 816	22	999	143 426	23 348	166 775	9 810
Ryntířovo	20.5	MERIDIEN	238 650	11 641	30	3 206	167 055	27 195	194 250	9 476
U hráze	40.6	MIX	544 020	13 400	30	7 309	380 814	61 993	442 807	10 907
U májovky	1.5	MIX	17 180	11 453	30	231	12 026	1 958	13 984	9 322
	Σ655.7		Σ8 802 230	ϕ13 423	ϕ28.5	Σ105 489	Σ6 289 224	Σ1 023 827	Σ7 313 051	ϕ11 152

RESULTS AND DISCUSSION

Many factors condition the economy of the drying process. One of them is a correct technology of drying, i.e. dryer type and performance adequate to the plan of crops rotation and size of sown plots, heating medium, drying medium, drying schedule, adequate mechanization and automation of the whole post-harvest line, as well as a proper synchronization of the harvest and post-harvest parts of the line. In addition to energy consumption (natural gas and electric energy), total costs of drying include also some other items of which we can mention labour costs, depreciation or overhead costs; these may amount to as much as 40% of total costs (Los, Pawlica, 2010).

Deciding upon the purchase of a dryer we have to analyze these many factors and we should be able to compare various types of dryers. Perhaps the most important parameters to be compared include the specific heat consumption q (kJ.kg^{-1}) for the evaporation of 1 kg water (Mühlbauer, 2009), and the specific consumption of air for the diversion of 1 kg humidity *l* (kg.kg^{-1}). In this respect, stationary high-performance dryers are preferred, which are usually equipped with heat recuperation and drying medium recirculation (Vitázek, 2011). However, the building permission is sometimes difficult to obtain and the dryer has to be of a mobile type as it is in Lipoltice. Vendors of farm machines and agricultural operations very often use derived units – costs and consumption values converted to t%. Their informative value is much higher for them because an alternative to purchasing a dryer is the sale of wet grain to the vendor with the costs of drying to be detracted from the purchasing price and the purchased quantity to be converted to storage humidity. Deductions for humidity are expressed in CZK per 1 t% and usually range from 50–75.00 CZK per t%. The humidity deduction for a ton (1,000 kg) of maize at 30% RH will be (30% – 14%) × 50.00 CZK.t%$^{-1}$ = 800.00 CZK. The purchasing weight at 14% humidity is 814 kg.

At the Liponova, a.s. farm, the average yield of grain per hectare from 656 hectares sown with maize was 13,423 kg. Grain humidity was 28.55%. After drying, 7,313 tons of grain with 14% humidity was put in store, i.e. an average yield was 11,152 kg.ha^{-1}. As shown in Tab. I, the lowest and highest yield was 7,274 kg.ha^{-1} and 16,645 kg.ha^{-1}, respectively. The range of grain yields was rather large even in individual hybrids due to different plots and the harvest times. The year 2012 was very favourable for wild boar in the locality and the farm estimates losses on the late-harvested plots combined with losses due to the lodging of whole plants to amount to 20%.

The farm employs the method of combined two-stage drying with burnt natural gas as a source of heat and ambient air heated in the exchanger as a drying medium. The first stage of drying took place at a drying medium temperature of about

120 °C and with a dryer output of ca. 4,850 kg.h^{-1}; the average grain humidity was reduced from 31.6% to 19.6%. Measurements were made from 22–23 November 2012 at ambient air temperatures ranging from 12 °C to 6 °C. Average specific heat consumptions measured in the afternoon at higher ambient air and grain temperatures and in the night when the outdoor temperature dropped to 6 °C were 3,603 kJ.kg^{-1} and 4,049 kJ.kg^{-1}, respectively.

During the second stage of drying, when the drying air temperature was ca. 90 °C, the grain humidity was reduced from 16.7% to 13.7% at an outdoor temperature of about –2 °C and grain temperature ca. 3 °C. The specific heat consumption was measured and calculated to be 5,380 kJ.kg^{-1}.

The above measured and calculated specific heat consumption values are within the ranges stated by other manufacturers of dryers (M–C q = 2 991,2 kJ.kg^{-1}, LAW q = 3 977 – 4 186 kJ.kg^{-1}, MEYER q = 4 765 kJ.kg^{-1}) (Vitázek, 2011).

The two-stage technology of drying brings savings in the consumption of electric energy because the humidity of stored grain was reduced by about 2.8% with the help of active ventilation with making use of grain thermal inertia. If we calculate a total average heat consumption only for drying, we arrive at 3,002 kJ.kg^{-1} and 0.0967 kWh.kg^{-1} of electric energy.

If we express the average consumption per t%, then 1.275 m^3 and 1.563 m^3 of natural gas per 1 t% was consumed in the first and second stage of drying, respectively. The total average consumption of electric energy per 1 t% for the whole season was calculated to be 1.372 kWh. The total average consumption of natural gas per 1 t% for the given post-harvest line configuration was 1.119 m^3.

CONCLUSION

Maize for grain has come to the limelight in the agricultural sector thanks to new hybrids and financially more affordable technologies. Later sowing dates and yields over 10,000 kg.ha^{-1} make it a good alternative to classic cereals as well as a guarantee for the enterprise economic stabilization. This is however conditioned by effective and high-quality drying as well as by conditions suitable for the drying. Our experimental measurements show that interesting for farmers may become also smaller-sized, mobile dryers.

Another question is the technology of drying in connection with the final product quality. The two-stage combined method of drying applied in Lipoltice and the taken measurements revealed also some risks. The high grain humidity (over 30%) causes problems in blocked transport routes and bridging in storage silos, which showed also during the experimental measurements. Another disadvantage was poor (low) final cool-down of grain on the dryer output where the temperature on the dryer output was 33 °C at the first measurement and 42 °C at the final drying, which was in direct contradiction with the technological requirements (max. by 5 °C as compared with the ambient temperature). The consequence was a locally increased grain temperature in the silo sometimes even up to 50 °C. The problem was solved by the continual operation of aerating fans and by exchanging the grain between the silos, which usually leads to the mechanical damage of grains. Furthermore, the high temperatures in combination with the high relative grain humidity (ca. 20%) form an ideal environment for moulds and storage pests.

SUMMARY

Evaluating of corn drying process energy consumption is very important due to high contents of water at harvest time in corn ordinarily 30% and higher. One of the new post-harvest lines is a plant in Lipoltice (mobile dryer installed in 2010, storage base in 2012) where basic operational measurements were made of the energy intensiveness of drying and operating parameters of the maize dryer were evaluated. The process of maize drying had two stages, i.e. pre-drying from the initial average grain humidity of 28.55% to 19.6% in the first stage, and the additional drying from 16.7% to a final storage grain humidity of 13.7%.

During the process of drying, records were taken of natural gas hourly consumptions and of the consumption of electric energy on a submeter. Samples of dried maize were collected, in which relative humidity (RH) was measured on the dryer plant output as well as grain temperature by the digital thermometer with a measuring probe. Relative humidity of several grain samples was verified also in the laboratory. Concurrently, relative ambient air humidity and temperature were measured and records of the adjustment of dryer parameters by the operator were taken to determine the plant performance.

Mean volumes of natural gas consumed per 1 t% for drying in the first and second stage amounted to 1.275 m^3 and 1.56 m^3, respectively. The total mean consumption of electric energy per 1 t% was calculated to be 1.372 kWh for the given configuration of the post-harvest line. During the drying process 1,515,539 kg of water was removed, 270,040 kg (17.8%) from this by using active ventilation system. Its correspond to save 22581 t% haven't been dried and theoretically save 58650 m^3 of natural gas. Measurement show energy consumption dependency on ambient temperature too. The differences between day (12 °C) and night (6 °C) values are about 12%.

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