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The harvest home and dry – key figures for grain drying

The drying of grain is a proven and reliable process for maintaining its quality and creating storage stability. Wet harvests preventing long term storage of the resultant grain and the even narrower harvesting windows expected in the future mean that higher capacity harvesting machinery and use-related conservation systems, including drying to ensure product quality, are required. High drying costs due to increasing energy prices increasingly limit grain growing profitability. In Europe fossil fuel fired hot air drying plants currently dominate. At the moment the target in farming is to keep specific drying costs as low as possible whereby the secondary effects such as CO_2 reduction, grain protection and quality maintenance becoming increasingly important.

Keywords

Grain drying, grain harvest, grain storage

Abstract

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If grain is not fully mature at harvest its quality can be compromised. It goes into store with a higher moisture content with resultant increased temperatures promoting respiration losses and fungi, microorganism and store pest development. Physiologically, grain moisture content should not exceed 14.5 % for long-term storage, a target that might mean some form of prior conservation. This includes reducing pH through acid application, airtight storage or cooling. Drying is also often used for grain conservation. The main advantage of the latter method is that the grain remains usable for food. This also applies to cooling whereby here the grain still has to be dried before sale to produce a marketable commodity.

Agricultural drying plants for cereal or maize grain are often used over a limited period, typically approximately 100 to 1 000 working hours, whereby the utilisation profile has been on:

Drier capacity
- Ease of operation
- Drying energy requirement.

On cost grounds, optimum technically-achievable performance is mostly not sought.

The expected continued increase in dryer fuel costs and raw material costs in the medium term have led to a marked change in the requirement profile of grain dryers. The above three – almost equally important - main criteria are only achievable through complete optimisation of the entire process which in turn is only possible if the effective, product-specific, drying energy requirement can be successfully decoupled from the total applied energy requirement, then evaluated and optimised.

In practice, energy requirement for moisture evaporation on its own (kWh/kg) within the drying process is approx. 50 to 200 % higher than theoretical requirements **(table 1)**. Mainly responsible for this are product-specific diffusion resistance of moisture, its binding and its internal distribution. There are also technical factors or deficits to consider, e. g. sub-optimum air and heat distribution within the dryer, losses, non-adjustment for required drying times, unsuitable heat and air adjustments or wrong dimensioning of performance-determining dryer component groups.

Influence of drying material

Quite apart from the dryer itself, an up to 20 % variation in specific drying energy requirement is caused by grain variety, maturity, vegetation and weather conditions (location factors) and grain shape and development.

Efficient and well-designed grain dryers permit wide adjustment of warm air temperature and airflow. Limitations in this respect are mainly determined by the scale of regulation for the respective heating technology. In practice, adjustment variance is around 60 °C (**figure 1**). Drying air temperature should be adjustable to suit the respective stage of the process and this means that drying material specific influences remain important.

Understanding the process technology in the light of the dryability of the respective materials is particularly important where product quality requirements demand a particular drying speed. Ignoring such requirements and going for maximum drying speed is unwise.

Table 1

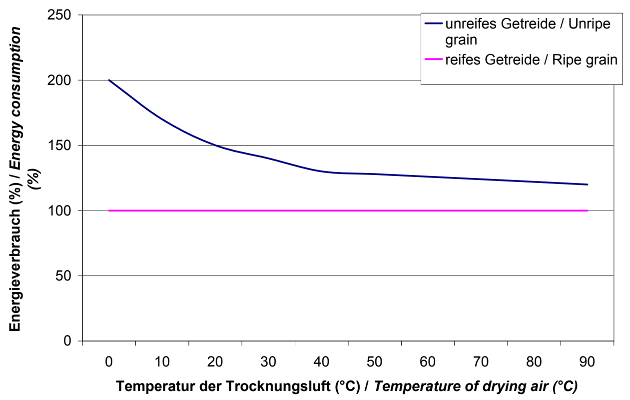
Overview of parameters influencing specific drying energy requirement

Technical equipment factors	*Reduces or influences drying energy requirements by:*
Dryer insulation *Reduction of heat radiation losses*	*approx. 8 % (cereal grain) up to 20 % (grain maize)*
Automatic final moisture content control	*approx. 3 to 10 %*
Arranging for homogenous moisture content of material at input or through mixing of product in dryer	*approx. 5 to 15 %*
Performance-oriented matching of dryer plant components air heating system, dryer column, air fans, dust extraction, controls and grain transport technology for efficient operation as a whole	*approx. 5 to 30 %*
Aggregates within the drying plant (for heating air, dryer column, air fans, dust extraction) adjusted for working efficiently together	*up to 15 %*
Dryer designed to fit efficiently into the grain production infrastructure on the individual farm	*up to 8 %*
Correct positioning of measurement sites for main factors in control of drying operation (drying air temperature, temperature – or moisture content – of discharged grain)	*up to 20 %*
Adapted process operation within dryer (e. g. variable (modulated) warm air temperature production, material throughput speed, drying speed, frequency controlled fan, process air flow)	*approx. 5 to 20 %*
Precleaning before dryer (wind/cyclone separator)	*approx. 3 to 5 %*
Sieving before drying process	*approx. 5 to 8 %*
Indirectly powered hot air producer	*approx. + 4 bis 16 %*

If grain is dried for conservation, the drying applies as a complete procedure whereby main governing factors for throughput, moisture extraction and the energy required for this are:

- Dryer design and operation
- Whether control and operation of the plant is manual or automatic

Fig. 1



Comparison of energy consumption in drying unripe grain with that needed for ripe grain in relationship to temperature of drying air. The description "unripe grain" is to be understood in this case as a general term for grain where moisture is present in different associations (Source RKL, adjusted).

- Product-specific drying characteristics

Although a recognised description, there is no precise definition of the word dryability as used here in describing physical and procedural product-specific characteristics. Dryability describes the capacity of the drying material in question for releasing attached and integrated moisture down to a target moisture content.

This capacity depends on two factors:

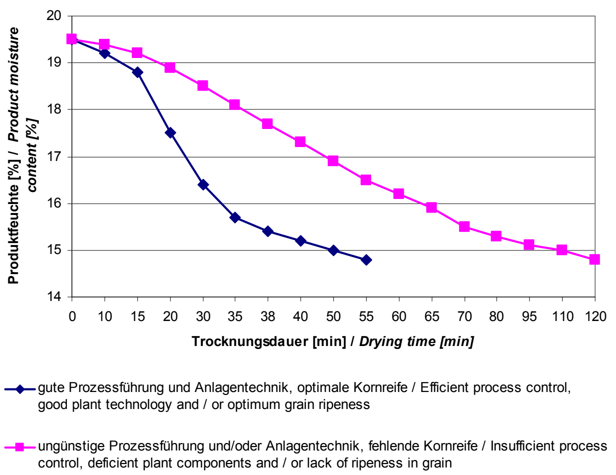
- Dryability in association with the technology applied. Important here, too, is construction and process efficiency of the technology in exploiting the moisture release capacity, or requirement, at lowest practicable drying energy consumption. This is decisive when selecting a drying process.
- Dryability as a direct product-specific characteristic factor. Hereby it is, in simplified terms, also possible in a physical description of dryability to avoid establishment of product-specific internal measurements in practical application. Instead, the same physical measurements can be applied in transferable relationship parallel to the effect in the dryer. After all, these are the units upon which financial performance is judged, i. e. first the thermal energy requirement and the electrical energy requirement for transport or movement of process air and drying material. The geometrical, biological and physical grain interior dimensions are required in the evaluation of drying. Dryability as a characteristic and comparable factor of the product is a description containing all the variants involved in grain dryer operation.

Process requirements

Drying time required for extraction of a certain amount of moisture is the characteristic factor with regard to product quality. This required, or resultant, time indicates how well the moisture release capacity of the drying material can be exploited by the grain dryer.

Typical farm grain dryer extraction of from 19 to 14 % moisture content takes place without any notable diffusion resistance on the part of the grain. However, due to the interaction of the initially required energy input for increasing vapour pressure for forcing moisture onto the grain surface where it can then be removed by the drying air, the speed of the drying process is not constant. On the farm dryer this typically slows the process. Where a system has a slower drying speed (e.g. in-store bulk aeration, bulk drying in silo) the influence of this interaction also sinks. Individual grain drying takes place more uniformly although movement of the drying horizon can occur in static heaps of bulk grain (**figure 2**).

Fig. 2



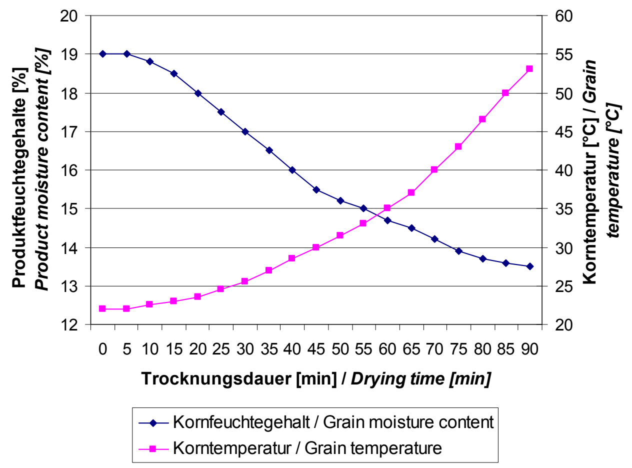
Comparison of different drying times (milling wheat)

In well designed on-farm grain drying plants the rate of moisture release achieved with cereal grain and rapeseed in the moisture content range mentioned here is about 3.5 to 4.5 % per hour. This means the active drying operation from 19 down to 14 % takes approx. 1.25 hours and also indicates that grain volume within the active drying range are in direct relationship to possible dryer performance regarding rated dryer performance at predetermined, or resultant, moisture extraction rates.

Figure 3 presents the typical drying process in a cascade recirculation dryer taking wheat down from 19 to 14 % moisture content with a constant air temperature of 75 °C.

It became clear in terms of the KTBL work programme calculation literature for this investigation that there remained substantial reserves in this respect as demonstrated by very strongly differentiating specific dryer energy requirements.

Fig. 3



Wheat drying procedure using a cascade recirculation dryer as example

In practice, the installed performance potential of grain dryers is often not optimally exploited because adjustments made to meet actual operational requirements are not optimally carried out, or the correct reactions are simply not known (**table 2**).

Usually, the outcome of manual adjustments to operational parameters can be very difficult for the operator to estimate on a cause and effect basis, resulting in performance penalties or increased drying energy requirement.

Together, however, altered operational conditions (increased throughput and increased quality requirements for the grain to be dried), and higher energy costs in "expanded" drying plants through to failure in maintaining the level of technology and operational skill can all negatively influence product quality.

The product-specific characteristics of moisture release during drying are especially evident where initial moisture content is high or where grain is not ripe. Where ripening to maturity on the stalk has not taken place, this can only be carried out in the dryer to target moisture content through extra energy input.

Specific moisture release behaviour during drying is also an important aspect with seed, bread or brewing grain and,

Table 2

Overview of drying energy requirement evaluations

Specific heat requirement KJ/kg	*Performance*	*Specific heat requirement calculated in* kWh/kg
< 4000	*very good*	< 1,1
4000–4500	*good*	1,1–1,25
4500–5000	*satisfactory*	1,25–1,38
5000–6000	*sufficient*	1,38–1,66
> 6000	*unsatisfactory*	> 1,66

in terms of results, can only be partly characterised through the typical dryer data, e.g. installed heat performance (or required air temperature), active throughput or capacity of the dryer, process air flow and drying time required. In such cases the performance and operational figures from the dryer manufacturer do not always supply all the information required. Based on 1 000 kg grain with ideal dryer performance – but with unavoidable heating of the grain - around 8.2 to 8.5 kWh/kg moisture extraction (kWh/kg) is required for realisation of the required moisture extraction within the typical grain dryer moisture range. In practice, the required range for this of approx. 0.98 to 2 kWh/kg moisture extraction on thermal energy is sufficient.

The trial framework of the DLG for assessment of the specific heat requirement of warm air drying plants is based on the following evaluation scheme: (**table 3**)

Because of the differing moisture release speeds over the drying process depending on initial moisture content and moisture binding in the product, the specific drying energy requirement for each percentage point of moisture extraction in the case of cereal grain or maize is seen differently. Arriving at an average value is only practicable where based on the total drying process, e.g., in the case of cereal grain from approx. 22 to 18 % initial moisture content to an end figure of 15 to 14 % and for maize grain from an initial 30 to 37% to the same end values.

There is a target conflict between performance maximised and energy input optimised grain drying. From the required, or the resultant, drying time can be seen how well the moisture release capacity of the grain can be exploited by the dryer.

Energy requirement

The reference value for drying energy requirement [kWh] is moisture withdrawal in kilogrammes [kg]. The moisture withdrawal required for drying is calculated via the Duval formula as follows:

$mH_2O = mNaßww \cdot \{(FA - FE)/(100\ \% - FE)\}$

FA = Initial moisture content in %

FE = Final moisture content in %

mH_2O = Mass of the removed moisture

mNaßww = Mass of the drying material

The information on average specific thermal energy requirement represents the thermal energy requirement that can be typically expected, or has been measured in trial plants, in dryers configurated and powered according to the present standard of technology and average product quality (**table 3**).

Table 3

Energy requirements of drying systems

Type of dryer	*Average specific thermal energy requirement* kWh$_{th}$/kg	*Variance of specific thermal energy requirement* kWh$_{th}$/kg	*Average specific electrical energy requirement* [2] kWh$_{el}$/kg	Bemerkungen *Comments*
		Grain drying – Moisture reduction from 19 to 14 %		
Cascade batch	1,5	1,3–2,0	0,14	*warm air temperature limited to 60 °C*
Cascade recirculating dryer	1,3	1,1–1,7	0,08	*warm air temp. 80 °C*
Cascade continuous dryer	1,2	0,98–1,5	0,07	*warm air temp. 80 °C*
Tower dryer (batch dryer) [1]	1,4	1,28–1,9	0,14	*warm air temp. 60 °C good self-insulation with internally circulated warm air*
Tower dryer (recirculating dryer) [1]	1,25	1,12–1,6	0,10	*warm air temp. 80 °C good self-insulation with internally circulated warm air*
Belt dryer	1,35	1,15–1,7	0,05	*uniform drying, multiple belt dryers perform better than single band ones*
Feed-and-turn dryer	1, 45	1,25–1,9	0,09	*great flexibility regarding function with an associated slightly higher specific energy requirement*
Drum dryer	1,7	1,5–2,2	0,06	*small current importance in agriculture*
Trailer dryer	1,75	1,5–2,5	0,09	*overtaken system, new solutions for using heat from biogas plants increasing grain load height < 1 m*
Container dryer	1,8	1,5–2,5	0,1	*as with trailer dryer, in load height of around 1.5 m*
Silo batch dryer	1,1	1,0–1,25	0,12	*warm air temp. 60 °C*
In-store aeration dryer	0,85	0,8–1,7	0,3–1	*lower warm air temp., higher energy requirement for process air through grain pile height + aeration time, max. product moisture content 19 %*

[1] *Different systems are described under this name: centre-pipe dryer, crossflow etc.*
[2] *Electrical energy requirement for process air and powering minimal grain moving requirements i.e. loading and unloading dryer, powering existing recirculating or product movement systems; given as kilowatt hours electricity requirement per kilogram moisture removal.*

Conclusions

The process sensors typically installed in a grain dryer for steering the plant enable efficient operation for achieving a particular final moisture content. Nevertheless, the dryer has still not lost its “black box” character. Achieving the required final moisture content still does not permit a statement on the energy input required for this, and whether the product moisture distribution is homogenous. Possible energy saving potential while producing a quality dried product, or applying performance reserves, is first clearly apparent through a sufficiently comprehensive recording of the process (air) condition, the corresponding product moisture content in the dryer and the energy input. Momentary recording of basic physical data may be sufficient for preliminary estimation of cost saving or optimising strategies. But reliable and sustainable evaluations are only possible through continuous longer-term recording with graphic representation of results.

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