Drying and storing of harvested grain
A Review of Methods

Ólafur Reykdal

Skýrsla Matís 05-18
Apríl 2018

ISSN 1670-7192

Skýrsluágrip Matís ohf
Icelandic Food and Biotech R&D

Report summary

ISSN: 1670-7192

Titill / Title	**Drying and storage of harvested grain** / Þurrkun og geymsla á korni		
Höfundar / Authors	Ólafur Reykdal		
Skýrsla / Report no.	05-18	*Útgáfudagur / Date:*	Apríl 2018
Verknr. / Project no.	2001-2352		
Styrktaraðilar /Funding:	Northern Periphery and Arctic Programme		
Ágrip á íslensku:	Á norðurslóðum er korn að öllu jöfnu skorið það rakt að það skemmist fljótt ef það er ekki þurrkað eða votverkað í fóður. Þurrkun korns er kostnaðarsöm og því þarf að vanda val á tækjabúnaði og orkugjöfum. Mælt er með notkun jarðhita þar sem þess er kostur enda ætti jarðhiti að vera ódýrasti orkugjafinn. Blandaðar lausnir geta reynst vel, t.d. jarðhiti og dísilolía. Landbúnaðurinn þarf að stefna að aukinni sjálfbærni og þá eru jarðhiti og rafmagn góðir kostir. Sumir myglusveppir á akri eða í geymslum geta myndað mýkótoxín (sveppaeiturefni) við rök og hlý skilyrði. Mýkótoxín geta skaðað heilsu fólks og búfjár. Hætta á mýkótoxínmyndum er í lágmarki á köldum norðlægum slóðum. Samt sem áður er nauðsynlegt að fylgjast með gæðum korns í geymslum og vakta mögulega myndun mýkótoxína. Þessi skýrsla gefur yfirlit um þurrkunaraðferðir, orkugjafa og öryggi korns og er grundvöllur ráðgjafar og athuguna á kornþurrkun.		
Lykilorð á íslensku:	*Korn, þurrkun, geymsla, matvælaöryggi*		
Summary in English:	In the Northern Periphery Region, grains are usually harvested at moisture contents too high for safe storage. Therefore the grain should be dried (or wet processed) as soon as possible. The drying process is expensive and the selection of equipment and fuel should be studied carefully. Where available, the use of geothermal water is recommended. In Iceland, geothermal energy has been found to be the cheapest energy source for grain drying. The use of mixed solutions, e.g. geothermal energy and diesel, is possible. Grain producers should aim at increased sustainability. Excellent solutions are geothermal energy and electricity. Mould in the field or in stores can produce mycotoxins under humid conditions and quite high temperature. Mycotoxins can harm the health of humans and animals. The existence of mycotoxins in grain grown under the cool conditions of northern regions is likely to be minimal but the situation should be studied and monitored. This report reviews grain drying methods, possible energy sources, safety aspects and is the basis for guidelines and case studies.		
English keywords:	*Cereals, drying, storage, safety*		

Northern Periphery and Arctic Programme

Northern Cereals – New Markets for a Changing Environment

Deliverable T2.2.1

Drying and Storage of Harvested Grain

A Review of Methods

Matis Report

April 2018

Ólafur Reykdal

Contents

1. Introduction

In the Northern Periphery Region, grains are usually harvested at moisture contents too high for safe storage. The harvested grain can then either be wet processed for feed (airtight storage or acidification) or dried. Drying of grain makes several higher value uses possible, including milling for baking flour, malting for the beverage industry and seed for sustainable agriculture. Drying of the grain has to be completed before microbial deterioration occurs.

Although grain will dry fully in the fields in southern regions, loss of harvest at the last stages might be considerable. This loss can be due to birds, insects, moulds or other pests. Therefore, it might be reasonable to harvest early even though drying of the grain would be needed. The CBH Group in Australia has published detailed guidelines on high moisture harvest management (CBH Group 2006). Even though the guidelines do not take northern conditions into account, the general principles are very useful for consulting.

In the UK, detailed guidelines on grain storage have been published (Agriculture and Horticulture Development Board 2011). A chapter on grain drying is included. The guidelines are very descriptive and give concrete recommendations but they do not cover the special conditions in northern regions. In Norway, guidelines in Norwegian have been published on the drying and storage of grain (Norsk Institutt for Bioøkonomi, 2016). These guidelines were developed for southern and central Norway and might not cover fully the conditions in Northern Norway.

Grain drying as practiced in Iceland was studied by Hjörvar Halldórsson (2004). Many of his observations are still valid, particularly regarding the use of geothermal energy for grain drying and the comparison of drying methods.

The safety of cereals is a key issue for farmers and consumers. Cereals can become infected by fungi that form mycotoxins under certain weather conditions. Due to climate change mycotoxins in cereals should be monitored carefully. This is the task of food and feed inspectors but farmers and researchers should also be involved. In Norway a detailed risk assessment of mycotoxins in cereals has been carried out (Norwegian Scientific Committee for Food Safety 2013).

This report reviews grain drying operations and will be used to support project case studies and guidelines for farmers.

2. Basics of drying

Drying is the addition of thermal energy under controlled conditions to remove water from a material. Many methods use large quantities of air to remove moisture from the material.

2.1 Water content

Water in living creatures is an essential element and can be classified as follows:

- Free water
- Bound water
- Water of hydration

Free water is easiest to remove during drying. Bound water is more difficult to remove due to internal forces. Water of hydration is a part of compounds and usually not removed during drying. As more water is removed from foods or feed, the more energy intensive will the process be. It is not necessary to remove all the water to prevent grain spoilage. Here, water activity is a key property.

2.2 Water activity

Water activity (a_w) is a property that indicates the availability of water for microbes. By drying, the aim is to remove enough water to prevent the growth of microbes for safe storage. Removing more water will not be helpful but will be costly. The storage life is prolonged by reducing water activity. The growth of bacteria is inhibited even though the bacteria have not been killed.

Figure 1 shows the relationship between water activity and the progress of spoilage. The most important points are as follows:

- Growth of most spoilage bacteria is inhibited at about a_w 0.9.
- Growth of most spoilage yeast is inhibited at about a_w 0.88.
- Growth of most spoilage moulds is inhibited at a_w 0.7-0.8.

Water activity is in the range 0.0 to 1.0. Water activity of 1.0 corresponds to clean water. There is not a relationship between water content and water activity since water interacts with other components in food and feed. Water activity is measured at chemical laboratories.

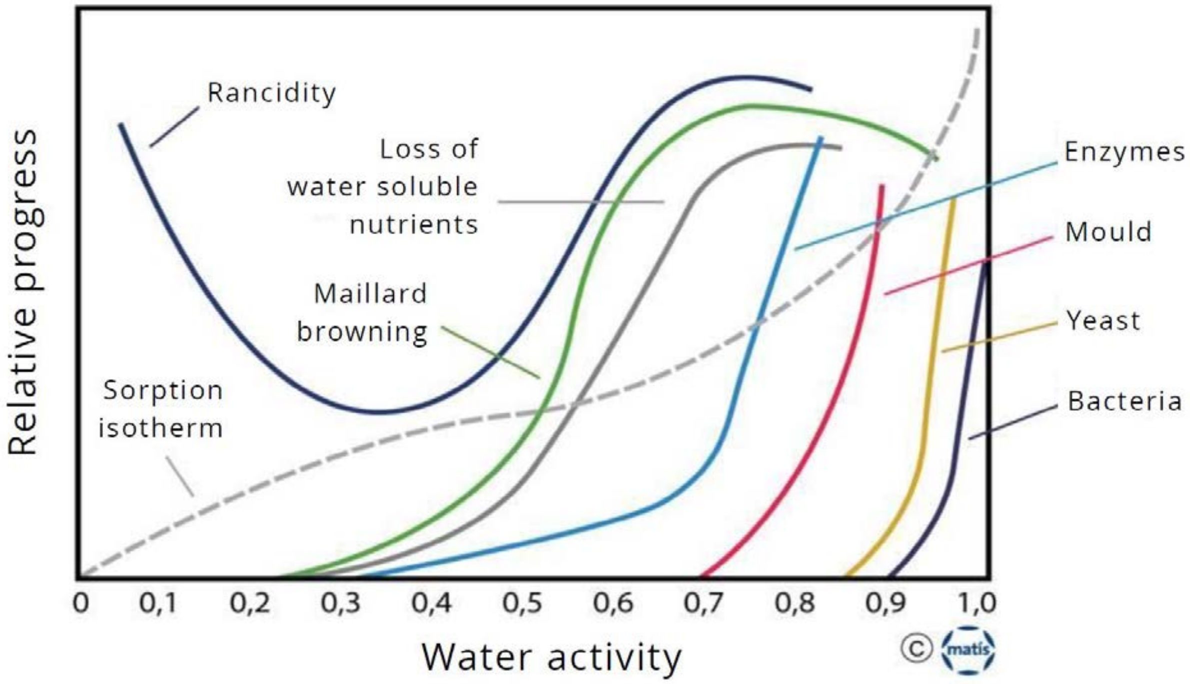

Figure 1. The relationship between water activity and progress of microbial and chemical spoilage.

2.3 Equilibrium moisture content

Grain is constantly interacting with its surrounding air space. The internal moisture content of the kernel changes to be at equilibrium with the moisture level in the surrounding air. This moisture level is known as the equilibrium moisture content (EMC). EMC of grain is dependent on both the humidity and temperature of the air.

Moisture migration into or from a product is dependent on the difference in vapour pressure between the atmosphere and the product. If the atmospheric vapour pressure is greater than grain vapour pressure, grain absorbs moisture from the atmosphere.

Drying air in a mechanical drying system carries the necessary energy to the grain to evaporate the moisture and carries the evaporated water out of the grain mass. The air used for drying should have low humidity.

2.4 The effects of drying

With overheating or prolonged heating of the grain, grain kernels can form cracks during the drying process (stress cracking of grain). This will affect the germination and milling characteristics. The cracks are possible points for attacks by mould, fungi and insects. The stress cracking will increase with higher drying temperatures and rapid cooling rates. The lower the moisture content of a grain kernel the more susceptible it is to cracking and damage. After drying, grain is more prone to damage during moving than before drying. Rapidly cooled grain also tends to be more brittle and prone to damage (CHB Group 2006). To prevent stress cracking of grain it is important to monitor grain temperatures according to the dryer operation manual.

According to the CBS Group Report (2006), the drying of grain occurs in three stages:

1. The moisture inside the grain kernel must move to the surface of the grain. The greater the moisture level the more freely the water can move to the surface. This is generally the slowest part of the drying process.
2. The moisture must evaporate from the surface into the surroundings.
3. The airflow must be sufficient to carry the moisture out of the grain mass.

3. Grain drying

Grain drying is very specific to the geographic location, kind of drying system and the type of grain (Gunasekaran 1986). The optimal system should be selected based on careful evaluation of the alternatives.

Grain drying refers to the removal of some of the moisture from grain by mechanically moving air through the grain after it has been harvested (Hellevang 2013). In southern regions grain, in the fields dries naturally as the crop matures, until the grain moisture is in equilibrium with the moisture in the air (equilibrium moisture content). However, in the Northern Periphery Region, grain does not usually dry in the field to a moisture content safe for storage. Therefore, the drying of northern cereals is crucial to prevent grain spoilage.

Grain has to be dried to 10-15% moisture content for safe storage. For barley, Hellevang (2013) recommended 14% moisture content for short term storage (less than 6 months) and 12% for long term storage (more than 6 months). Grain with damaged kernels needs to be stored at 1-2% lower moisture content. Grain can be stored at a higher moisture content when storage temperatures are low.

The removal of moisture from grain during drying causes a considerable reduction in grain weight referred to as moisture shrink. In the Australian report from the CBH Group (2006) a detailed table on weight loss from drying grain is presented on page 51. For example, 1 tonne of barley at 20% moisture contains 200 kg or 200 L of water. To reduce this down to 12% moisture, about 90 kg of water will need to be removed from each ton of barley.

The higher the oil content of grain (e.g. rapeseed), the lower should its storage moisture be.

Low moisture level of grain at harvest is important for the energy management process because it affects the total drying time and energy required. This is important from a quality standpoint because kernel damage increases rapidly when grain is harvested at moisture levels above 25% (Gunasekaran 1986).

Many farmers have moisture meters that measure moisture indirectly by electrical conductance or capacitance. The accuracy of these meters is often about ± 0.5% moisture content. The results could be compared to laboratory moisture measurements which are direct methods.

It is recommended that farmers monitor moisture content of dried grain. The results for moisture immediately after drying might be in error so rechecking 12 hours after drying is recommended. The moisture content of several samples of a grain lot should be measured.

Samples should not be handled with hands (this adds moisture) and exposure to air should be minimised because this causes drying or wetting of the grain depending on humidity.

An alternative method is to seal a sample in a closed container and allow 1-12 hours until temperatures and moisture distribution within the kernels equalize. Then measure moisture content.

3.1 Drying methods and types of dryers

The simplest classification of grain drying methods is based on the temperature of the air used for drying.

Natural air – Low temperature drying refers to drying grain using little or no additional heat. The humidity and temperature of the outdoor air will influence the degree of drying. Drying takes place in a drying chamber where a fan blows the outdoor air in at the bottom of the chamber. With this method there is a limit on the initial grain moisture content that can be effectively dried.

This drying method is likely to be unsatisfactory in northern regions except under the most favourable weather conditions.

High temperature drying can be used to dry wet grain, but grain damage may occur due to overheating and stirring in the dryer. Germination of seed drops rapidly if the seed kernel temperature goes above 49 °C (Hellevang 2013). For this reason, 43 °C is recommended for drying of seed. The same temperature (43-49 °C) is recommended for malting barley. Grain to be used for baking should not be dried at air temperatures above 66 °C. High temperatures can severely damage baking quality even though grain kernels appear undamaged. In extreme conditions burning spots might be found on the kernels.

Martin (2015) recommended malting grain temperatures of 35-38 °C during drying in Orkney. Drying of high moisture grain should be carried out carefully at not too high a temperature.

It is important to monitor the operating temperatures of grain dryers. Most dryers are equipped with thermometers but location of meters varies and so does the information provided to the operator. The most common places to measure temperature in a dryer are as follows (CHB Group 2006):

- Plenum temperature is the temperature of air after it has passed the burner but is still inside the machine. Plenum temperature is used to monitor the heating of the air and burner operation. Maximum plenum temperature is usually reported in dryer operation manuals. For cross flow – static grain

  dryers, the maximum plenum temperature might be 55 °C for malting / seed grains, 60 °C for milling grains and 75 °C for feed grains. For dryers with moving grain, the temperature is a bit higher.

- Grain temperature can be estimated by measuring the hot air passing through the grain mass. This is often done with a simple probe thermometer in the side of the machine.
- Actual grain temperature. The only way to test the true grain temperature is to isolate it from the dryer‘s airflow. Grain is removed from the dryer and placed in a container. The temperature is allowed to stabilize for several minutes and measurement carried out by a thermometer. Ideally, grain should be sampled from the hottest spot in the drier. In continuous flow-dryers this will be at the end of the heating section. In cross flow dryers grain will be hottest close to the plenum.

Optimal and maximum grain temperatures during drying are provided in Table 1 based on several references.

Table 1. Optimal and maximum grain temperatures during drying processes.

Grain type	Optimal	Maximum	Reference
Malting / seed barley	40 °C	43 °C	CBH Group 2006
Malting barley	35-38 °C		Martin 2015
Malting / seed barley		45 °C	Hjörvar Halldórsson 2004
Food barley		55 °C	Hjörvar Halldórsson 2004
Feed grains	60 °C	65 °C	CBH Group 2006
Feed barley		80-100 °C	Hjörvar Halldórsson 2004
Rapeseed (Canola)	40 °C	43 °C	CBH Group 2006

Icelandic quality specifications for dried barley specify maximum drying air temperature as 55 °C for malting and milling barley but 80 °C for feed barley (Ólafur Reykdal et al. 2012; Ólafur Reykdal et al. 2016). Bústólpi feed production company in Iceland requires barley to have a maximum of 14% moisture content. Otherwise, farmers will be paid less.

Barley intended for malting needs particular care (CBS Group 2006):

- Do not overheat the barley. Temperatures above 45 °C will reduce the ability of barley to germinate and can denature enzymes in the grain needed for brewing.
- Do not over dry the grain since this might lead to germination loss and mechanical damage.
- Properly cool barley after drying and keep in a cool store.

Hjörvar Halldórsson (2004) divided grain drying methods into:

- Thin-layer drying (0.2-1.5 m thickness of grain) is either batch-drying or continuous-flow drying. Batch-drying is used for small-scale grain drying. Continuous-flow drying is used on an industry scale, e.g. in the fish meal industry.
- Deep-bed drying (0.5-6 m thickness of grain). Air for drying can be heated or not heated. Grain or other material can be dried in the store. This method was commonly used in Iceland for drying of hay. Another version would be repeated addition of a wet layer on the top of a dried layer (layer drying). Finally, Batch-In-Bin is similar to layer drying except layers are thin. For northern regions heated air would be needed but for these simple methods air temperature should not be above 27 °C, otherwise grain moisture would be variable.

The most common grain dryers are:

- Cross-flow dryers
- Mixed flow dryers.

Both types can be used for batch-drying or continuous-flow drying.

Thin-layer dryers can be small and transportable.

Drying plants would be a good choice where geothermal energy is available. The plant could serve farmers within a reasonable distance. The transport of wet grain is costly and grain has to be dried within a relatively short time.

3.2 Energy sources

The possible energy sources for grain drying are:

- Diesel
- Geothermal water
- Electricity
- Natural gas
- Straw for combustion
- Biodiesel

Most farmers in Iceland use diesel for grain drying but a few of them use geothermal water only or together with diesel. The use of electricity has been considered, but so far it has been regarded as too expensive. At one farm in Iceland straw is used as fuel for a grain dryer. A few fish meal drying plants in Iceland have been upgraded to use electricity as the only energy source. These factories have switched between electricity and diesel during the last years depending on prices. The fish meal factories use continuous-flow drying which differ from the usual grain drying methods. Normally grain in the northern regions is dried using batch-drying where drying of each portion is completed before the next portion is added to the dryer.

Hjörvar Halldórsson (2004) compared energy cost for grain drying based on different energy sources. The relative costs were as follows (calculations based on ISK/kWh): Electricity > Diesel > Heat pump (is. varmadæla) > Geothermal water. The cheapest energy source was geothermal water. In 2004 the use of diesel was 3 times more expensive than geothermal water, while electricity was 5 times more expensive. Where geothermal water is insufficient for drying operations, a mixed solution might be possible, e.g. supplementing geothermal water with diesel.

The smoke from diesel burners is about 9-13% carbon dioxide, and the rest is mostly nitrogen oxides (NO_x) and water vapour. The smoke contains contaminants (dioxins etc.) and the contaminated exhaust air should not be allowed to come into contact with the drying grain. Pollution from the use of geothermal water is minimal. Geothermal water is recommended for high quality dried grain free from contaminants.

In Australia the relative cost of energy sources based on heat energy were as follows: Liquid bottled propane gas > Diesel > Natural gas (CBS Group 2006).

3.3 Cost of grain drying

Drying grain is an energy intensive operation. There is no single solution to cost reduction, rather the situation at each farm should be studied. Drying cost is made up of capital cost (equipment) and operating cost (fuel, electricity, labour cost). Investment in equipment should be studied carefully.

When grain drying is started, make sure that the dryer is performing optimally. There should be no unnecessary obstructions in the system and it should be as clean as possible. Decide your safe moisture level and avoid overdrying as this is a waste of money. When little water is left in the grain, it is energy intensive to remove this water and this will consume extra energy. The lower the outdoor air temperature is, the more energy is needed to heat the drying air.

Hjörvar Halldórson (2004) considered recirculation of air to reduce drying cost. He found that humidity of exhaust air might be too high for using it again without a heat exchanger.

Use of geothermal energy to dry grain is interesting from the point of sustainability. The temperature of geothermal water available for drying might be about 60 °C. This water would be used for a heat exchanger which might return water at about 30 °C. A fan is used to deliver hot air from the heat exchanger to the drying chamber. Heaters using geothermal water pay for themselves in a short time.

When attempts are made to reduce grain drying costs, the following should be considered:

- The drying process should be controlled as precisely as possible. Air temperature should be measured at the intake and output of the dryer. The drying progress is monitored by comparing temperature at intake and output, when the temperature difference is small the drying process should be complete. Also the actual grain temperature should be measured.
- The final moisture content of the dried grain should not be lower than needed for safe storage.
- The choice of energy source should be as economical as possible.

It should be considered to use the energy in the output air. A heat exchanger is needed to heat fresh air to be used.

4. Storage of grain

4.1 Storage of harvested grain before drying

Storage time for harvested grain depends on moisture and temperature. In the Northern Periphery Region barley is often harvested at 30% moisture content. This means that the barley can only be stored for a very short time. It should be stored in a dry and clean store free from insects, mice and mould and drying should start within 12 hours.

When capacity of the dryer is too small compared to harvested grain, aeration can be used to partly dry the grain and keep it from spoiling until the dryer is available. Aeration enables safe storage of high moisture grain by passing small volumes of air through the grain. Aeration drying (fixed bed drying) makes it possible to dry low moisture grain over time. Aeration spears are also useful for helping to keep freshly harvested grain cool for a short time until it can be dried. (As an example see: http://martinlishman.com/trouble-dry-aeration-spears-and-fans/ - retrieved 15.09.2017).

Figure 2 shows the facilities at Laxárdalur Iceland used to extend shelf life of wet harvested barley before drying. By pumping cold air through the pipes the barley is kept cold and the moisture content will be reduced to a limited degree. At low temperature, storage of wet barley has been possible for one week.

Figure 2. Facilities for aeration storage or drying.

4.2 Storage of dried grain

Before storing grain, it is important that its moisture is checked to make sure that this is sufficiently low for storage. Low grain moisture and suitable storage conditions are the key to ensuring high grain quality.

Kernels of grain are living organisms that respire as other living things. They use oxygen and together with grain carbohydrate produce carbon dioxide, water and heat. This process is ongoing in dried grain but low moisture content and low temperature make the process slower. Viable dried grain can germinate under the right conditions, but low moisture content and low temperature will reduce the risk of this and minimise bacterial and insect growth.

The main causes of spoilage in stored grain are:

- Fungi and mycotoxins
- Insects
- Mites

Regardless of whether the grain moisture and temperature have been determined as safe, problems may yet occur. Therefore it is advisable to examine the grain at least every two weeks.

If grain storage tanks are exposed to outdoor weather conditions, special attention should be paid to possible effects on the grain. Warm or cold conditions outside the store cause convection currents inside the grain store. This will cause moisture migration within the grain mass (CBH Group 2006). In cool weather the outer grain layers in the store will have a downward convection current. The reverse is found in warm weather.

Moisture migration can be further explained as follows. At the beginning of storage the grain moisture content is fairly uniform throughout the storage tank. With time, localized high moisture zones may develop due to changes in outdoor temperatures. If the storage tank is not within a building, low outside temperature cools the grain close to the tank wall. This results in a downward air flow through the grain and upwards towards the centre of the tank. As the air moves through the grain it becomes warmer and begins to pick up moisture from the grain. Condensation occurs when the warm moist air hits the cool surface of the grain near the centre of the tank. This can lead to grain spoilage (Alberta Agriculture and Forestry 2010). The reverse airflow may occur due to warming actions of the sun on outdoor tanks.

Moulds, insects and mites that can cause grain to heat are inactive at low temperatures (below 8 °C for moulds and insects and below 3 °C for mites). Grain moisture contents below 13% arrest the growth of most moulds and mites. Moisture contents below 10% limit the development of most insects and pests. The ideal storage conditions would be a moisture content of 12% or less and a temperature of 3 °C or less (Alberta Agriculture and Forestry 2010).

Aeration is the process of ventilating stored grain at low air flow rates (1-2 L/second/cubic metre) with the purpose of maintaining a fairly uniform grain temperature throughout the bin to prevent moisture accumulation in the top or bottom layers of the bin due to natural convection (Alberta Agriculture and Forestry 2010).

Storage tanks should be equipped with an aeration system to control grain temperature during storage. Grain should be cooled during storage to control insects and reduce moisture migration.

5. Safety of grain

The safety of cereals is a key issue for farmers and consumers. Of most concern is the formation of mycotoxins in moulds. Mycotoxins can harm the health of humans and animals. Cereals can become contaminated in the field or during storage. Only some of the mould species form mycotoxins and climatic conditions have to be suitable. Wet conditions are needed and formation of some of the mycotoxins only occurs at quite high temperatures. In the Northern Periphery Region, the cool climate might reduce the formation of mycotoxins.

In Norway a detailed risk assessment of mycotoxins in cereals has been carried out (Norwegian Scientific Committee for Food Safety 2013). Deoxynivalenol (DON) and ochratoxin A are the mycotoxins of most concern in cereals in Norway. Mould (*Fusarium* species) infections of cereal have increased by more than 100% in oats, barley and wheat in Norway. *Fusarium graminearum*, which produces DON, has been detected at much higher levels than before. This indicates changes in the mould flora. It should be noted that precipitation during harvesting promotes the occurrence of mycotoxins in cereals.

Food and feed inspectors monitor the occurrence of mycotoxins but the activities differ between countries. Farmers should be aware of this problem and observe mould contamination in the fields. Some cereal farmers in northern regions have not used fungicides to control mould growth. However a warming climate might bring more pests and a different mould flora which may require a more frequent use of fungicides.

Because of climate change the occurrence of mycotoxins in cereals and cereal products should be monitored carefully. More research is needed in this field in northern regions.

6. Conclusions and recommendations on grain drying

In the Northern Periphery Region, grains are usually harvested at moisture contents too high for safe storage. Therefore the grain should be dried (or wet processed) as soon as possible. The safe storage period from harvest until drying is only about 12 hours, but may be extended slightly with aeration.

The drying process is expensive due to equipment, fuel, electricity and labour cost. The selection of equipment and fuel should be studied carefully. The drying process should be as economical as possible, otherwise domestic grain products will not compete on the market.

Where available, the use of geothermal water is recommended. In Iceland, geothermal energy has been found to be the cheapest energy source for grain drying. In many cases diesel might be the fuel of choice. The use of mixed solutions, e.g. geothermal energy and diesel, is possible. Grain producers should aim at increased sustainability. Excellent solutions are geothermal energy and electricity, however electricity might be too expensive in many locations.

To limit drying cost, grain should not be dried more than needed for safe storage. For barley, the final moisture content should be in the range 12-14%.

It is very important that farmers monitor moisture content of dried grain. Since grain moisture may change immediately after drying, it is recommended that it is re-checked 12 hours after drying. The moisture content of several samples of a grain lot should be measured. Samples should not be handled with hands (this adds moisture) and exposure to air should be minimised because this causes drying or wetting of the grain depending on humidity.

During storage, grain constantly interacts with the surrounding air space. If conditions in the store are too humid, the grain moisture will increase and damage might occur due to bacteria, mould or insects. Therefore, temperature and humidity should be monitored in the store, together with grain temperature and moisture.

Mould in the field or in stores can produce mycotoxins under humid conditions and quite high temperature. Mycotoxins can harm the health of humans and animals. The existence of mycotoxins in grain grown under the cool conditions of northern regions is likely to be minimal but the situation should be studied and monitored.

7. References

Agriculture and Horticulture Development Board, 2011. HGCA Grain storage guide for cereals and oilseeds. 3rd edition. Retrieved 30.06.2017 from: https://cereals.ahdb.org.uk/media/178349/g52_grain_storage_guide_3rd_edition.pdf

Alberta Agriculture and Forestry, 2010. Cereal Grain Drying and Storage. Retrieved 9.07.2017 from: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/crop1204

CBH Group and South East Premium Wheat Growers Association, 2006. The WA Guide to High Moisture Harvest Management, Grain Storage and Handling. ISBN: 0-646-46990-8.

Gunasekaran, S., 1986. Optimal energy management in grain drying. Crit. Rev. Food Sci. Nutr. 25 (1): 1-48.

Hellevang, K.J., 2013. Grain drying. NDSU Extension Service, North Dakota, USA. Report AE701 (Revised).

Hjörvar Halldórsson, 2004. Kornþurrkun. B.Sc. ritgerð í véltæknifræði. Tækniháskóli Íslands TD – vt – 04 – 03. (Report on Grain Drying, in Icelandic).

Martin, P., 2015. Grain quality criteria for malting barley. Agronomy Institute. Northern Periphery and Arctic Programme. Retrieved 30.06.2017 from: http://cereal.interreg-npa.eu/resources/

Norsk Institutt for Bioøkonomi, 2016. Korndyrkning. Temaark 6. Kornet er i hus. (Cereal growing guidelines, No. 6. In Norwegian). Retrieved 30.06.2017 from: https://kornforum.nlr.no/nyhetsarkiv/2016/temaark-korn/

Norwegian Scientific Committee for Food Safety, 2013. Risk assessment of mycotoxins in cereal grain in Norway. ISBN: 978-82-978-82-8259-090-7. Retrieved 30.06.2017 from: http://www.vkm.no/dav/eee04d10c4.pdf

Ólafur Reykdal, Sæmundur Sveinsson, Sigríður Dalmannsdóttir, Peter Martin, Jens Ivan í Gerðinum, Vanessa Kavanagh, Aqqalooraq Fredrikssen, Jónatan Hermannsson, 2016. Northern Cereals – New Opportunities. Matis Report 05-16. 55 p. Retrieved 30.06.2017 from: http://www.matis.is/media/matis/utgafa/05-16-Northern-Cereals.pdf

Ólafur Reykdal, Þóra Valsdóttir, Þórdís Anna Kristjánsdóttir, Jón Þór Pétursson, Jónatan Hermannsson, 2012. Íslenskt matkorn – Gæði, innihald og viðhorf / Icelandic cereal grain crops for food – Quality, chemical composition and consumer view. Matis Report 01-12, 55p. (In Icelandic). Retrieved 30.06.2017 from: http://www.matis.is/media/matis/utgafa/01-12-Matkorn-Lokaskyrsla.pdf