Vedlegg 2

Northern Cereals – New Opportunities
A project supported by The Nordic Atlantic Cooperation (NORA)

NORA
Nordic Atlantic Cooperation

norden
Nordic Council of Ministers

Northern Cereals – New Opportunities

Final Report

29.04.2016

Partners

Matís ohf (Coordinator)
Agricultural University of Iceland
Norwegian Institute of Bioeconomy Research (NIBIO), Norway
Agronomy Institute, Orkney College (University of the Highlands and Islands), Scotland
Agricultural Centre, Faroe Islands
Government of Newfoundland and Labrador, Forestry and Agrifoods Agency, Canada
Greenland Agricultural Consulting Services

Northern Cereals – New Opportunities
A project supported by The Nordic Atlantic Cooperation (NORA)

Northern Cereals – New Opportunities

Final Report

Ólafur Reykdal[1]

Sæmundur Sveinsson[2]

Sigríður Dalmannsdóttir[3]

Peter Martin[4]

Jens Ivan í Gerðinum[5]

Vanessa Kavanagh[6]

Aqqalooraq Frederiksen[7]

Jónatan Hermannsson[2]

[1] Matís ohf
[2] Agricultural University of Iceland
[3] Norwegian Institute of Bioeconomy Research, Norway
[4] Agronomy Institute, Orkney College (University of the Highlands and Islands), Scotland
[5] Agricultural Centre, Faroe Islands
[6] Government of Newfoundland and Labrador, Forestry and Agrifoods Agency, Canada
[7] Greenland Agricultural Consulting Services

Cover photo: Jónatan Hermannsson standing in a NORA field in September 2015, Reykjavík Iceland.

Table of Contents

Summary

A project on the cultivation of cereals in the North Atlantic Region was carried out in the period 2013 to 2015. The project was supported by the Nordic Atlantic Cooperation (NORA). Partners came from Iceland, Northern Norway, Faroe Islands, Greenland, Orkney and Newfoundland, Canada. The purpose of the project was to support cereal cultivation in rural northern regions by testing barley varieties and providing guidelines for farmers and industry. To be able to do this, the most promising barley varieties were tested in all partner regions for growth and quality characteristics. The project established cooperation in the field of cereal research, production and utilization in the NORA region.

The project was divided into three parts: (1) Study of the status of cereal cultivation in the North Atlantic region. Results were reported after the first year of the project. (2) Field trials in all partner regions comparing five barley varieties. Trials were carried out in 2014 and 2015. (3) Quality evaluation of barley from field trials.

Weather conditions were very variable between the years 2014 and 2015 and also between locations. Conditions were difficult in 2015 due to heavy precipitation in most locations (Iceland, Faroe Islands and Orkney). Due to a cold season in Greenland during 2015, barley production was not possible, but some barley was produced in 2014. The variable conditions were valuable for testing the potential of the selected barley varieties.

The selected barley varieties (Kria, Tiril, Saana, Bere and NL) gave grain yields between 2.1 and 3.1 tons dry matter per hectare on average for all locations. Grain yield was highest in Iceland. Visual inspection of barley samples gave useful information on defects and maturity. Average starch content of grain was about 58% which is sufficient for the baking industry. Mycotoxins, toxins formed by certain species of mould, were not detected in selected samples. Results were compared to existing specifications and guidelines.

Early sowing was concluded to be the most important factor for a successful cereal production in the North Atlantic region. Seasonally frozen ground can delay sowing in some countries. Timing of the harvest in the autumn is equally critical. Most of the regions in this project experience wet autumns, which are problematic for harvesting. Early harvest is recommended in order to secure the harvest before it becomes vulnerable to wind and bird damages, even though the grain will be slightly less mature. This may lessen the prospect of getting grains with good enough quality for seed and malting.

1. Introduction

Agriculture in the North Atlantic area is characterized by a cool and short growing season. However, cereal cultivation has been successful in some areas in recent decades because of progress in breeding, increased experience and know-how among farmers. Climate change has affected the cultivation within the area and higher temperatures have both made the production more reliable and increased yield. Until now, the cereal production has been used mostly for feed.

Growing cereals in the cool climate of northern areas has both advantages and disadvantages. Among the advantages are the generally low levels of contaminants in the harvest and the products are therefore expected to be wholesome. Insects and other pests are relatively few and use of pesticides is limited. The relatively low temperature means that some of the mycotoxin producing moulds do not survive. Global warming is of concern as it may bring new pests and diseases to the area. Research is therefore needed to ensure food safety. Food safety should be the cornerstone of cereal production in northern areas. Also cereal production contributes to food security in the northern areas where agriculture mainly delivers animal products. Among disadvantages in cereal cultivation in the most northern areas are that the grains usually are harvested before they are fully mature and consequently they contain too much water for storage. For food and drink uses, it is therefore necessary to dry the grain after harvest for proper storage and high quality.

Cereals are important in feed concentrates, particularly for dairy cows. Cereals are also raw materials for a high proportion of foods for human consumption. The bakery industry is based on cereals, and barley is an important raw material for the production of alcoholic beverages.

1.1 A NORA project on northern cereals

In the autumn 2013, NORA funded a project on new opportunities for northern cereals. Partners came from Iceland, Faroe Islands, N-Norway, Orkney and Newfoundland (Canada) and from 2014 Greenland participated in the project. The purpose of the project was to support economic growth and sustainable communities in rural northern regions by developing cereal production and utilization. The project provided a unique opportunity to obtain a range of varieties well-suited to north Atlantic conditions and for these to be tested locally for growth and quality characteristics. The project has established cooperation in the field of cereal research, production and utilization in the

NORA region. In the project, cereals were confined to grains obtained from barley, wheat, rye and oats. Barley was prioritised because it is well-suited to northern regions.

The NORA region has the potential to produce cereals for feed and food and it is important to exploit this potential to create jobs and enhance economic growth within the area. In Iceland, for example, cereal production has been identified as the agricultural sector that has the most potential for expansion. Regional use of cereal grain crops for food and feed will mean less reliance on imported grain. It therefore has the potential to reduce carbon footprint and can support policy makers to obtain the overall goal of the future bio-economy by incrementally decrease the use of petroleum based products.

Expanding the cultivated area of cereals into new regions will enlarge the market for cultivars that are bred specifically for the unique environment in the north and this will secure such breeding efforts and give better economic returns.

Tourism is increasing considerably in various northern areas. This means that more food is needed in regions visited by tourists and here regional products are of special interest. This opens up new opportunities for local farmers and companies to increase their production with benefits for the regional economy. Foods from northern cereals have a healthy image because of low contaminant levels and few pests. Introduction of northern cereals for local foods and new Nordic food will increase the demand for cereals.

Regional markets for cereal products are not well developed in the northern areas. Development of regional niche markets will be valuable and would increase economic benefits for local communities. Introducing new cereal varieties at the regional level would increase the possibilities of developing new products.

1.2 Partners

The following partners were involved in the NORA project on new opportunities for northern cereals.

Matis – Icelandic Food and Biotech R&D (http://www.matis.is) coordinated the project. Matis is a non-profit institute under the Ministry of Industries and Innovation. Matis employs about 100 people, and has grown from approximately 70 employees in 2007. The role of Matis is to engage in food research, innovation and safety to increase the value of food through research, development, dissemination of knowledge and consultancy. The activities of Matis include innovation and R&D regarding consumers, food analysis (chemical analysis and microbiology), food processing, biotechnology and genetics. In recent years Matis has been developing knowledge and food production clusters all around Iceland to support local food production. Matis has helped farmers and companies to develop products and has also participated in cereal development projects together with the Agricultural University of Iceland.

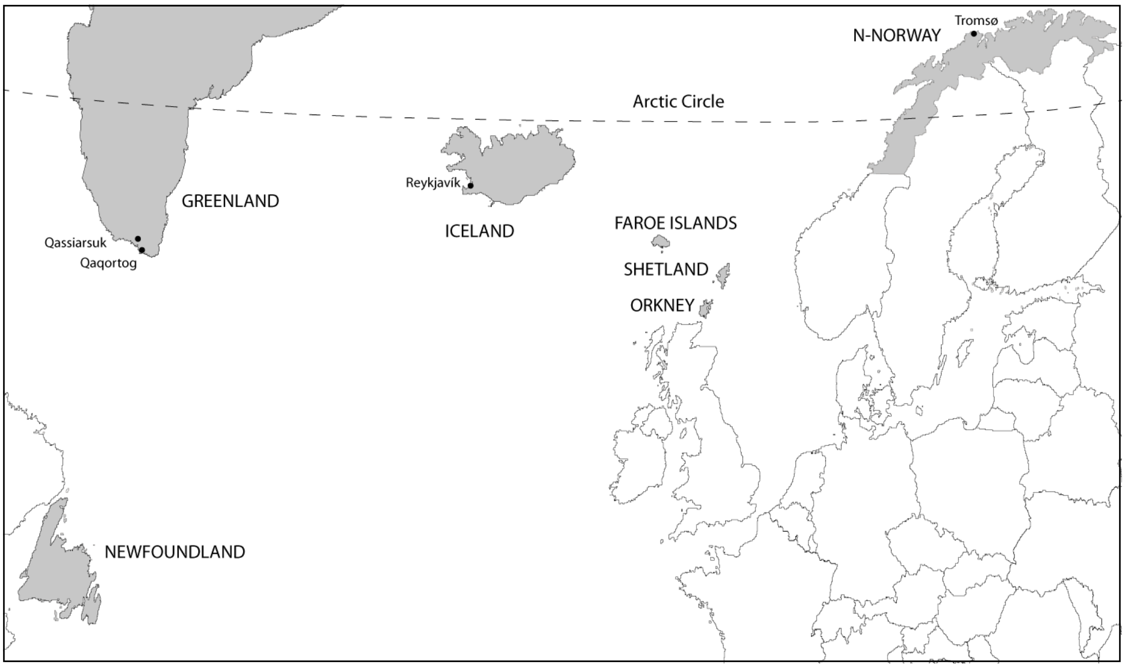

Figure 1-1. The partner regions (indicated with grey colour).

Agricultural University of Iceland (AUI, Landbúnaðarháskóli Íslands, http://www.lbhi.is) is an educational and research institution in the field of agriculture, land resources and environmental sciences under the Ministry of Education, Science and Culture. The main focus is on natural sciences, i.e. natural history, the conservation and sustainable use of land and animal resources, including traditional agriculture, horticulture and forestry, environmental and landscape planning, restoration sciences, and sustainable development. The overall role of the university is to pursue high quality education in the academic fields supported by competitive nationally and internationally oriented research programs. AUI plays an important role in its local community and for the country as a whole as it is a vital pillar for rural development in Iceland. It has a unique position among universities in Iceland since it has a number of sites distributed in rural communities around the country and thus offers a close proximity to the people it serves and the natural resources on which they base their livelihood. The university has a long history in cereal research and has helped farmers to improve their cultivation techniques.

The Norwegian Institute of Bioeconomy Research (NIBIO, www.nibio.no), formerly Bioforsk, Norway. NIBIO was formed by a merger and the new institute has been operative since 1st July 2015. NIBIO is a national research institute with headquarters in Ås. In this project, activities in Tromsø represent the three northernmost counties in Norway: Nordland, Troms and Finnmark, stretching from latitude 65°N to 71°N, including both coastal and continental climates. NIBIO in Tromsø focuses on arctic agriculture and conducts research and development activities linked to northern growing conditions, food products and recreational services with a distinct northern profile. NIBIO works to document how the special climate conditions in Northern Norway affect taste, healthy compounds and other qualities in the products. There is also a focus on northern production systems and the interaction between business development and environmental considerations. Through the Holt Division of the Northern Norway Competence Centre in Tromsø, NIBIO is laying the foundation for development and innovation.

Agricultural Centre, Faroe Islands (AC, Búnaðarstovan, http://www.bst.fo) is an institution belonging to the Ministry of Fisheries and Agriculture. Different services for farmers are located at the Centre: (1) Administration of financial agricultural support for farming, (2) Agricultural consultancy, (3) Education in agriculture and (4) Research in Agriculture and Horticulture. For this purpose the Centre has access to cultivated land for field trials as well as uncultivated areas for animal grazing. Experiments are carried out in collaboration with local farmers on their fields.

Agronomy Institute, Orkney College (University of the Highlands & Islands). The Agronomy Institute (AI, http://www.agronomy.uhi.ac.uk) is a research centre of the University of the Highlands and Islands (UHI) and is based at Orkney College, one of the academic partners in UHI. The AI works with growers and end-users to develop crops, plant products and their markets in Scotland's Highlands and Islands region. The AI has access to land and machinery for running agricultural field trials and has good collaborative links with local growers, cereal stakeholders (including distilleries, breweries, water mills, bakeries and a seed merchant) and the Orkney office of SAC Consulting which is the main advisory organisation for farmers in Scotland. Apart from cereals, the AI is also active in research on crops for biomass and natural products. AI has experience in developing local markets for cereals and has access to research and quality criteria which have been developed in the UK.

Agrifoods Development Branch -Forestry & Agrifoods Agency (Government of Newfoundland and Labrador). The Agrifoods Development Branch of the Forestry and Agrifoods Agency (http://www.nr.gov.nl.ca/nr/agrifoods), is responsible for promoting the continued development, expansion and diversification of competitive and sustainable primary and value-added agriculture and agrifoods businesses. The Branch provides programs and services as follows: (1) Technical advice on the production, processing and marketing of food and other agricultural products in a manner that maximizes profits while also acting responsibly towards food safety, animal welfare and sound land and environmental stewardship. (2) Professional veterinary assistance in the prevention and treatment of disease as well as the avoidance of residues in food products. (3) Analytical services from the Animal Health Laboratory and the Soil, Plant and Feed Laboratory. (4) Operation of mandatory food safety programs. (5) Support of research into new agricultural products and practices, as well as animal diseases of economic and public health importance. (6) Funding opportunities to encourage growth and diversification in the agrifoods industry.

The Agricultural Consulting Services, Greenland (http://www.nunalerineq.gl/english/raad/index-raad.htm). The Agricultural Consulting Services is an institution with relations to the Farmers' Association. The institution is under the Greenland Department of Fisheries, Hunting and Agriculture. The Consulting Services aim to support Greenland´s agricultural development and serves all sectors of agriculture in Greenland. Among the tasks are research in agriculture, horticulture and forestry, public relations and cooperation with foreign institutions. The Agricultural Consulting Services is located in Qaqortoq, South Greenland.

1.3 Staff

The following staff members have worked on the project:

- Iceland: Ólafur Reykdal, Sæmundur Sveinsson, Jónatan Hermannsson, Þórdís Anna Kristjánsdóttir, Áslaug Helgadóttir.
- Norway: Sigríður Dalmannsdóttir, Hilde Halland.
- Faroe Islands: Rólvur Djurhuus, Jens Ivan í Gerðinum.
- Orkney: Peter Martin, John Wishart.
- Newfoundland: Vanessa Kavanagh.

2. Status of cereal cultivation in the North Atlantic Region

The status of cereal cultivation differs between the countries in the North Atlantic region. In Orkney, Iceland and Newfoundland cereal cultivation is well established while Faroe Islands and Northern-Norway are restarting cultivation. Cereal cultivation in Greenland is in an experimental phase. Barley is the most important cereal, particularly in the northernmost regions. The following paragraphs summarize the situation in Iceland, Faroe Islands, N-Norway, Orkney and Newfoundland. A detailed report on the status of cereal cultivation in the North Atlantic Region was prepared during the first year of the NORA Cereal Project (Reykdal et al. 2014).

Iceland. Barley was grown in Iceland from the time of settlement but was discontinued through the middle ages. Barley has now been grown uninterrupted in Iceland for about 50 years. Barley cultivation has increased considerably during the last 20 years and the harvest was 10,000 – 16,000 tons per year in the period 2009-2014. In 2014, the number of farmers growing barley was 436 and barley fields were about 4,100 hectares. Some farmers have been successful in growing wheat when weather conditions have been favourable. Oats and rye have also been grown successfully on a small scale.

Because of the short and cool growing season the grain needs to be dried after harvest to make it a viable commercial commodity. A few small scale drying facilities are available for farmers, most of which are located on farms. Farmers have also the possibility to process silage (wet feed) for cows.

Most of the barley production is used as concentrates for cows and for pigs to a limited extent. In recent years the interest in barley as food has increased but still only a very small proportion of the production is used for food. Three farmers are marketing cereals on the consumer and food industry markets. Eymundur Magnússon, a farmer at Vallanes, East-Iceland, has for about 25 years sold barley products in supermarkets (Mother Earth, http://www.vallanes.net). Ólafur Eggertsson, a farmer at Þorvaldseyri, in close vicinity to the Eyjafjallajökull glacier South-Iceland, has for a few years sold barley flour to the baking industry and breakfast cereal industry (http://www.thorvaldseyri.is). Haraldur Magnússon, a farmer at Belgsholt West-Iceland has supplied barley to the brewery Ölgerðin Egill Skallagrímsson, which has used it unmalted through enzyme technology to produce beer.

Northern-Norway. Barley was grown in N-Norway in the old days but most of the old barley varieties used at that time have apparently been lost. Because of political and economical reasons barley cultivation has been limited in N- Norway since 1940 and the skills to cultivate barley has been lost in some areas. However, a few farmers in Alta and South Varanger in Finnmark, in Inner-Troms and parts of Lofoten cultivate barley for animal feed production. At the Helgeland coast in Nordland County, there are farmers growing barley for full maturity and some of those farmers are experimenting with their own breweries. Most of these farmers are localized in the municipality of Sømna. A few breweries are operated in N-Norway, Mack in Troms being the largest company. There is an increasing interest in N-Norway in microbreweries. The farmers growing barley in N-Norway are both organic and conventional farmers. The short growing season is a limiting factor for barley cultivation. Therefore, an extended growing season as an effect of climate change, may create new opportunities for annual crop production in N-Norway. Likewise, use of new varieties with early maturation could improve the cultivation and increase yields.

Faroe Islands. Cereals have not been grown in the Faroe Islands for more than 50 years, and all cereals for feed and food are now imported. However, farmers grew barley for centuries and baked their own bread. Normally the barley did not fully ripen outdoors but was harvested and then stored indoors for drying, and subsequently threshed indoors. All the work was carried out by hand. As the labour and money moved from agriculture towards fisheries and fish industries in the first half of the 20th century, barley production in Faroe Islands gradually decreased and finally came to an end about 50 years ago. The end of barley cultivation was also a result of competition from cheaper imports from areas with a more suitable climate and more efficient production due to modern machinery for cultivation and harvesting.

In the Faroe Islands it will be important to restart cereal cultivation, especially barley. In addition to brewing and baking it is important to introduce Faroese barley as feed on dairy farms similar to what Icelandic farmers have done in recent years. Farmers growing barley in the Faroe Islands will face many challenges and one of them will be how to cope with the high precipitation at the end of the growing season.

Orkney, Scotland. For hundreds of years, Bere, a barley landrace was grown for milling, malting and as animal feed on Orkney. During the 20th century Bere was almost completely displaced by modern barley varieties (about 4,300 ha are now grown annually) which are harvested at high moisture content, treated with a preservative and used for animal feed. Oats were commonly grown as an animal feed and for human consumption on Orkney from the Iron Age but there has been a dramatic decline in the area grown since the 1940's (when tractors replaced horses on the farm) and now only about 100 ha are grown, almost entirely for animal feed. Very little wheat has ever been grown in Orkney. The Agronomy Institute (AI) is developing several new higher value markets for Orkney-grown cereals and has also tested a number of different varieties. Amongst these, North European varieties have often been very suitable. Some of the AI's most successful cereal projects have included collaborations with distilleries (malting barley and Bere), a brewery (Bere) and a local water mill (oats and wheat) which produces stone ground flour. The main challenges restricting progress are a lack of suitable varieties, grain quality for some end uses and the high cost of small-scale grain drying.

Shetland, Scotland. As in Orkney, cereal cultivation in Shetland started in the Neolithic and expanded considerably during the Iron Age and Norse settlement, especially in coastal areas. In Shetland, however, the harsher climate and poorer soils create greater challenges for cereal cultivation so that the islands have seldom been self-sufficient in cereals, even for animal feed. During the 20th century there was a gradual decline in the area of cereals grown – from about 3,400 ha in 1912 to about 70 ha for grain in 2000. The reasons for this decline are complex but include an expansion of sheep farming and decline in cattle rearing. This has partly been driven by a need for easier farm management systems as many small farmers (crofters) have taken on jobs away from their crofts. Cereal cultivation in Shetland is still important, however, in the south of the mainland where farms and fields are larger and the soils and climate are more conducive for earlier sowing and harvesting. These are also the areas where it is easiest to use larger farm machinery. Although there are a number of potential higher value outlets for locally grown cereals (bakeries, breweries and plans for a distillery), the majority of the cereal crop is used for animal feed. The main cereals currently grown are barley (c. 60 ha) and oats (c. 25 ha).

Newfoundland, Canada. The agriculture/agrifoods sector of Newfoundland and Labrador provides direct and indirect employment for 4,000 persons on farms and in the food and beverage manufacturing sectors. Value of farm production has grown in 27 of the last 30 years with sales of $111 million in 2008, while Agrifood processing reached $501 million. The dairy industry has led this growth with expansion on farms and in dairy processing of value-added milk products such as cheese and novelty ice creams. Higher energy costs are having an effect on agriculture operations, with significant impacts on livestock production. These impacts are direct, such as equipment operations, and indirect, such as higher feed costs due to the demand on grain for ethanol.

Historically, barley was grown on the island, however over time Newfoundland became dependent on the rest of Canada for its grain requirements. In today's economy, increasing fuel prices and biofuel diversions has increased the cost of importing grain so it is no longer economical to import substantial quantities. Unfortunately, there are no commercial cereal operations in Newfoundland to supply its livestock industries. The province's short season ends with a rainy period that makes harvesting dry grain problematic. A high moisture grain system appears promising to accommodate these challenges allowing earlier harvest at higher moisture contents. Newfoundland is in the beginning stages of a cereal program which will be assessed for animal feed production.

3. Barley growing – Field trials 2014 and 2015

3.1 Basis of field trials

The purpose of the field trials was to test promising varieties within the North Atlantic region with the aim to increase the diversity of available varieties for farmers and promote collaboration within the region. Field trials were set up in ten locations, spanning an area of about 80 longitudinal degrees and 20 latitudinal degrees, ranging from Finnmark in the East to Newfoundland in the West (see Table 3-1). Five common barley cultivars were grown in all ten locations, in order to map cereal growing potential for each area (see section 3-2). A few extra barley cultivars were grown in some locations, in order to obtain information about their cultivation potential.

Table 3-1. Details on the location and the soil type of the NORA field trials, including information about the year of trials.

Country, location	Latitude, Longitude	Soil type	Years of trials
Norway, Alta	69°96‘N, 23°29‘E	Gravel	2014
Norway, Holt	69°68‘N, 18°94‘E	Sandy loam	2015
Norway, Vestvågøy	68°22‘N, 13°78‘E	Sandy loam	2014 and 2015
Orkney, Orkney College	58°59‘N, 02°57‘W	Clay loam	2014 and 2015
Shetland, Bigton	59°58‘N, 01°19‘W	Sandy loam	2014
Faroe Islands, Sandur	61°50‘N, 06°48‘W	Sandy soil	2014 and 2015
Faroe Islands, Hoyvik	62°02‘N, 06°47‘W	Humus	
Newfoundland, Pynn’s Brook	49°07‘N, 57°56‘W	Loam	2014 and 2015
Geenland, Qinngua	61°16‘N, 45°30‘W	Sandy soil	2014
Iceland, Korpa	64°09‘N,21°45‘W	Andosol	2014 and 2015

3.2 Weather conditions in regards to cereal cultivation

The three main challenges of cereal cultivation in the North Atlantic area are: (1) Low summer temperature in regions characterized by oceanic climate, (2) short growing season in regions with continental climate and (3) wet harvesting period. The relatively longer summers in the regions with oceanic climate partially compensate for the cool summers and warmer summers promote barley maturation in the short growing season of regions with continental climates in the North Atlantic area. In addition, the long days at these latitudes further facilitate barley growth. Still, the marginal growing conditions are further challenged by heavy autumn rains at the end of the growing season which makes harvesting problematic. The continental climate in Newfoundland and Norway causes seasonal soil freezing resulting in a shorter growing season since this prevents early sowing (see Table 3-2).

3.2 Material and Methods

3.2.1. Cultivars

The five barley cultivars grown in both years at most locations, were chosen based on performance in their country of origin. In addition to these five common varieties, several others were included in individual field trials based on the interest of each partner. Below is a description of the five common varieties.

Bere is an old six-rowed landrace from Orkney. Its production has increased in Orkney in recent years as a result of the development of new food and drink markets for the crop.

Saana is a two-rowed, early maturing malting variety from Finland. It was chosen based on its malting qualities and earliness, since it is the best candidate for producing local malt in the North Atlantic area.

Tiril is a Norwegian six-rowed, early maturing variety. It was released on the market in 2004 and is still recommended for farmers in the northernmost part of the country.

Kría (Iskria) is a two-rowed Icelandic variety. It is about ten years old and was bred to be very early maturing in regions with relatively long but cold growing season.

NL is a synonym for three breeding lines from Canada which were submitted to the field trials by the partner in Newfoundland. In 2014, a single six-rowed breeding line was tested and is designated NL in this report. In 2015 two new NL varieties were tested which were designated NL-1 (two-rowed) and NL-2 (six-rowed). In Table 3-3 results for NL are shown for 2014 but NL-2 for 2015 in Table 3-4.

3.2.3. Locations and experimental setup

In each location, trials consisted of three replicates of each variety that was sown in 10m^2 plots. Most partners used a commercial seed drill and harvested using a combine. In 2015 some plots were harvested by hand and those cases are noted in table 3-4. Establishment of the 2015 trials in Orkney was poor because of very wet conditions in the early part of the growing season and therefore, in addition to harvesting the entire plot by combine, a well-established area of 1 m^2 was selected from each plot for hand-harvesting. This was to estimate the highest possible yield potential. In the Faroe Islands, plots were badly damaged by birds. This caused problems for yield estimates, which were not possible in 2014 but were attempted in 2015. Small samples of harvest were received from Greenland for 2014 but the trial in 2015 was destroyed by drought.

Six countries, or regions, took part in this project (see Table 3-1):

Northern-Norway, includes the three northernmost counties in Norway: Nordland, Troms and Finnmark. In 2014 three experimental locations were chosen to represent different climate and latitudes. The experiments were setup at a farm site with ongoing barley cultivation. The farm was chosen in collaboration with the advisory service and the advisory service assisted in performing the experiment, using the equipment on site. The experimental design was a random block design with three replicates and size of plots ranging from 12,5m^2 to 20m^2 depending on the available equipment on each location. Oats (var. Ringsaker) was seeded around and between plots for protection and to reduce border effects. The northernmost location was in Alta (Norway A) Finnmark, which has a continental subarctic climate. The second location was in Vestvågøy in Nordland (Norway V), which is characterised by a typical oceanic climate. The third one was in Sømna in Nordland, southernmost part of N-Norway with milder coastal climate. Because of heavy machinery, establishment of the experiment in Sømna failed. In year 2015 the experiment in Vestvågøy (Norway V) was repeated and in addition a small plot experiment was hand sowed at the NIBIO experimental station at Holt in Tromsø (Norway H). The climate at Holt is a mixture between the oceanic – and subarctic climate.

Faroe Islands: There were two experimental sites on separate islands, one in Hoyvik on Streymoy Island and the other in Sandur on Sandoy Island. These sites are quite close to each other and are characterised by a typical oceanic climate. Summers are wet, with very little sunshine. Both field trials suffered damages from birds and no harvest was recorded in Hoyvik.

Northern Islands of Scotland: These consist of two groups of islands, Orkney and Shetland, and research on cereals in both locations was carried out for the project by the Agronomy Institute at Orkney College UHI. Cereal cultivation is much more developed in Orkney, where about 4,400 ha of barley is sown annually for grain compared with about 60 ha in Shetland. Both archipelagos have a similar maritime climate, although the growing season is slightly warmer in Orkney.

Newfoundland: The experimental location was in Pynn's Brook, located on the Western part of the island. It is by far the southernmost site of all experimental locations in the project. It is also the coldest, due to a continental climate and severe frosts during the winters. These winters cause soil to freeze that makes sowing difficult until middle of June. Summers of Newfoundland are warmer than in any of the other participating countries of this project, which makes up for the short growing season.

Greenland: The climate is continental and winters very cold. Summers are also quite cold, except inside the deep fjords of the South-West coast.

Iceland: Most of the country is characterized by a typical oceanic climate. Winters are cold enough to generate considerable frozen ground, and summers are relatively cool compared to the other locations in this project (see figure 3-1).

3.2.4. Measurements and recordings

Three different measurements were made on the barley grain, which indicated its maturity: Dry matter (DM) content at harvest, thousand grain weight (Tgw) and specific weight. Specific weight is the easiest of the three to measure and has been used to get a temporary estimation of maturity in dried barley grain in Iceland.

3.2.5. Statistical analysis

The results from field experiments were evaluated with a simple analysis of variance (ANOVA) using Genstat (VSN, 2011). Before the statistical test was preformed, the data were visually inspected to make sure that variance among sites and cultivars were similar and that the data were approximately normally distributed.

3.3 Results

3.3.1. Timing of sowing and harvest.

Table 3-2 shows the timing of sowing and harvest of the field trials conducted in this project. The time of sowing, harvest and the total number of growing days varied extensively between years and location. The earliest sowing was in Orkney 21st of April 2014 which also resulted in the earliest harvest observed, the 15th of August. The latest sowing date was in 2014, the 17th of June in Newfoundland which resulted in the latest harvest date, 13th of October. The barley in the field trials in Iceland had the highest number of growing days in 2014 and the second highest in 2015. The average number of growing days was 120.3 in 2014 and 127.3 in 2015 (see figure 3-1b).

Table 3-2. Timing of sowing and harvest of the field trials.

	2014			2015		
Date of:	Sowing	Harvest date	Growing days	Sowing	Harvest date	Growing days
Location						
Norway, Alta	4.6.	10.9.	98			
Norway, Holt				16.5.	17.9.	124
Saana					24.9.	131
Norway, Vestvågøy	10.6.	25.9.	97	8.6.	28.9.	112
Orkney College	21.4.	15.8.	117	30.4.	5.10.	158
Saana		26.8.	128			
Shetland, Bigton	30.4.	29.8.	121			
Saana, Bere		14.9.	137			
Faroe Isl, Sandur	14.5.	19.9.	128			
Faroe Isl, Høyvik						
Newfoundland, Pynn‘s Brook	17.6.	13.10.	117	3.6.	9.9.	98
Saana					13.10.	132
Greenland, Qinngua				28.6.		
Iceland, Korpa	29.4.	16.9.	140	30.4.	21.9.	144
Mean			120.3			127.3

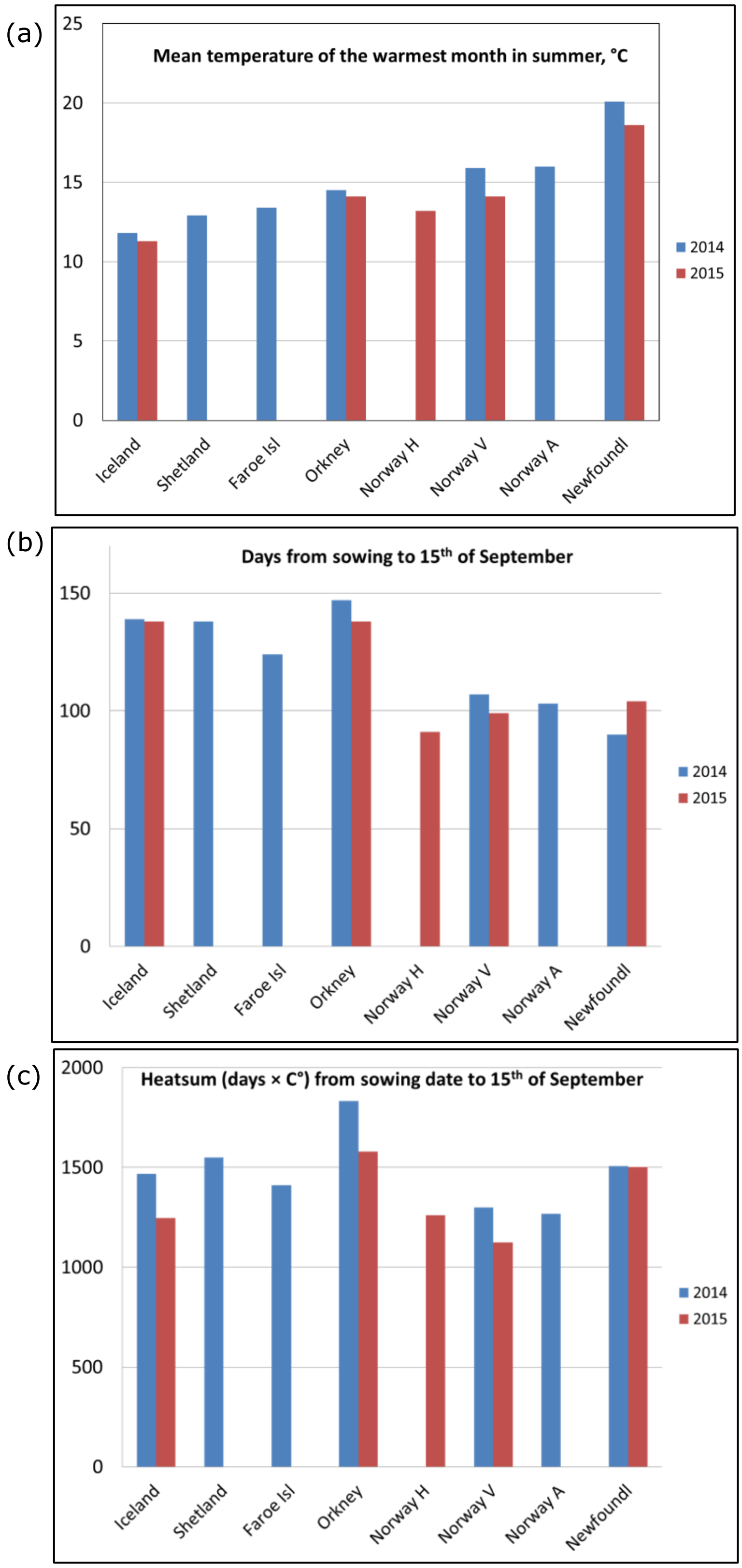

Figure 3-1. Bar charts showing temperatures in the growing season (a), number of growing days (b) and heatsum (c) in locations of the field trials in 2014 and 2015. The three locations in Norway are: Holt (Norway H), Vestvågøy (Norway V) and Alta (Norway A). The summer of 2014 was much warmer in the North Atlantic regions than 2015.

3.3.2 Yield and maturity of grain

The main results from these two years of field trials are shown in Tables 3-3 and 3-4. The genotype by environment interaction for yield, thousand grain weight and specific volume were significant ($p < 0.01$). We therefore calculated the average values of the measurements for cultivars in each location separately (see Tables 3-3 and 3-4).

In 2014, the highest grain yields were in trials in Iceland and Orkney, while in 2015 they were in Iceland and Newfoundland. There was a large variation in yields between locations, the yield in Iceland in 2014 being more than twice that of the Norwegian sites. The highest yielding variety varied from site to site but was commonly Tiril (especially in Norway) or Iskria. In Orkney and Shetland in 2014, Tiril was badly affected by mildew (*Blumeria graminis*) and this probably reduced its yield at these sites. At most sites, Bere was usually amongst the lowest yielding varieties in both years.

Grain dry matter at harvest was highest at Vestvågøy and Orkney (77-79%) in 2014 and in Orkney and Newfoundland (75-77%) in 2015. At the other locations it was between 49 and 66%. The varieties Tiril and Iskria usually had the highest dry matter content. There were considerable differences in the average height of varieties at the different locations in 2014, varying from 52 cm at Vestvågøy to 98 cm in the Faroes. At all sites, Bere was the tallest variety and at most sites Kria was the shortest. Lodging was most severe in Shetland and the Faroes. At most sites, Bere was most sensitive to lodging, probably as a result of its height. With the exception of Shetland, there was not too much variation in the average (TGW) at each site (range, 34 to 41 g, but 23 g in Shetland). The two 6-row varieties, Bere and Tiril, had the lowest Tgw and usually lower in Bere.

Table 3-3. Analysis of the common varieties for all trial sites in **2014**. Dashes indicate missing data. List of acronyms: DM (dry matter), Tgw (thousand grain weight), weight (specific weight).

		Iceland	Orkney	Shetland	Newfound-land	Norway Vestvågøy	Norway Alta	Faroe Islands	Mean
Grain yld., t DM/ha	Bere	3.96	3.49	2.2	2.72	1.43	1.7	-	2.55
	Iskria	3.78	4.05	3.81	3.1	1.63	2.14	-	3.06
	NL	4.24	-	-	2.72	-	2.05	-	2.90
	Saana	4.62	4.13	3.41	2.25	1.4	2.08	-	3.00
	Tiril	4.57	3.51	1.66	2.75	1.62	2.42	-	2.73
	Mean	4.23	3.79	2.77	2.71	1.52	2.08		
	S.e.d.	0.44	0.168	0.264	0.64	0.43	0.396		
	p-value	0.375	0.006	<0.001	0.771	0.918	0.535		
DM, %	Bere	59	69	-	67	78	61	-	67
	Iskria	67	77	-	73	82	63	-	72
	NL	60	-	-	56	-	62	-	64
	Saana	57	81	-	61	78	58	-	68
	Tiril	67	81	-	70	77	68	-	73
	Mean	62	77		66	79	62		
	S.e.d.	1.7	0.5		2.2	5.3	1.3		
	p-value	0.012	<0.001		<0.001	0.811	<0.001		
Stem %	Bere	56	49	63	52	52	50	-	53
	Iskria	54	48	54	42	50	47	-	49
	NL	54	-	-	56	-	51	-	56
	Saana	53	48	55	56	60	50	-	53
	Tiril	55	48	71	51	46	39	-	52
	Mean	54	48	61	51	52	47		
	S.e.d.	0.6	1.3	1.9	4.8	2.7	7.7		
	p-value	0.044	0.89	<0.001	0.107	0.011	0.605		
Height, cm	Bere	115	102	76	92	61	76	127	93
	Iskria	75	69	66	61	45	50	83	64
	NL	88	-	-	68	-	63	-	75
	Saana	90	76	74	70	48	49	87	70
	Tiril	92	83	50	64	54	54	93	70
	Mean	92	82	66	71	52	58	98	
	S.e.d.	3.3	4.2	5.4	5.6	3.5	7.4	2.7	
	p-value	0.002	<0.001	0.011	0.005	0.016	0.031	<0.001	
Lodging, 0-10	Bere	1	8	10	0	10	7	6	6.9
	Iskria	0	0	2	0	0	3	4	1.3
	NL	0	-	-	0	-	2	-	1.9
	Saana	0	0	9	0	0	0	5	1.9
	Tiril		0	5	0	0	0	2	1.1
	Mean	2	-	6			2	4	
	S.e.d.	0.7	-	0.5			2.4	1	
	p-value	<0.001	-	<0.001			0.103	0.043	
Heading, days after June 30	Bere	14	30	-	39	-	20	43	29
	Iskria	12	28	-	37	-	22	43	28
	NL	20	-	-	47	-	23	-	34
	Saana	24	36	-	42	-	25	41	34
	Tiril	13	27	-	39	-	23	42	29
	Mean	17	30		41	-	23	-	
	S.e.d.	0.8	-		1.6	-	1.2	-	
	p-value	<0.001	-		0.003	-	0.033	-	

Table 3-3, cont.

		Iceland	Orkney	Shetland	Newfound-land	Norway Vestvågøy	Norway Alta	Faroe Islands	Mean
Thousand grain weight, g	Bere	33	31	22	29	39	35	-	31
	Iskria	36	36	28	37	42	44	-	37
	NL	42	-	-	39	-	44	-	39
	Saana	38	40	27	42	42	45	-	39
	Tiril	37	27	17	32	42	39	-	32
	Mean	37	34	23	36	41	41		
	S.e.d.	0.9	1.6	1.1	1.3	2	1.3		
	p-value	0.003	<0.001	<0.001	<0.001	0.565	<0.001		
Weight, g/100ml	Bere	73	-	-	69	64	68	-	69
	Iskria	74	-	-	75	67	70	-	71
	NL	70	-	-	80	-	65	-	70
	Saana	73	-	-	76	61	69	-	69
	Tiril	68	-	-	67	64	69	-	67
	Mean	72			73	64	68		
	S.e.d.	0.7			1.2	1.5	1.4		
	p-value	0.007			<0.001	0.026	0.071		

Table 3-4. Analysis of the common varieties for all trial sites in **2015**. Dashes indicate missing data. List of acronyms: DM (dry matter), Tgw (thousand grain weight), weight (specific weight).

		Iceland	**Orkney**	**Newfound-land**	**Norway Vestvågøy**	**Faroe Islands**	**Mean**
Grain yld., t DM/ha	Bere	2.51	2.98	2.34	-	0.74	2.05
	Iskria	3.69	2.65	3.04	2.29	1.14	2.56
	NL-2	3.48	2.3	3.16	1.96	-	2.31
	Saana	3.53	-	2.55	1.65	0.4	2.10
	Tiril	4.77	2.85	3.3	2.38	0.53	2.77
	Mean	3.6	2.7	2.88	2.07	0.7	
	S.e.d.	0.305	0.26	0.5	0.116	0.24	
	p-value	0.001	0.147	0.324	0.003	0.081	
DM, %	Bere	52	80	74	-	-	52
	Iskria	58	80	78	51	-	58
	NL-2	52	67	66	49	-	52
	Saana	51	-	74	45	-	51
	Tiril	59	81	80	51	-	59
	Mean	54	77	75	49		
	S.e.d.	0.9	0.8	4.6	3.6		
	p-value	<0.001	<0.001	0.105	0.394		
Thousand grain weight, g	Bere	34	31	-	25	-	31
	Iskria	37	40	43	32	-	38
	NL-2	36	40	40	-	-	38
	Saana	-	42	36	23	-	36
	Tiril	31	34	42	27	-	34
	Mean	34	38	40	27	-	
	S.e.d.	0.68	1.28	1.59	0.83	-	
	p-value	<0.001	<0.001	0.021	<0.001	-	
Weight, g/100ml	Bere	69	69	66	-	-	66
	Iskria	71	69	74	71	-	69
	NL-2	74	65	71	67	-	67
	Saana	68	-	75	64	-	65
	Tiril	66	62	69	69	-	63
	Mean	70	66	71	68		
	S.e.d.	0.8	0.8	0.9	1.4		
	p-value	<0.001	<0.001	<0.001	0.013		

3.4 Discussion

Grain yields are very variable across the region, both within the same year and between different years (see tables 3-3 and 3-4). We believe that weather is the most important factor contributing to this variation. The weather varied considerably between locations and years, illustrated by heatsums in figure 3-1c. Differences between years are especially noticeable in the European locations. The differences in the weather, from site to site and year to year, is the most likely reason for there being no single variety which performed best at all sites. This suggests that it would be wise to encourage growers to plant a range of varieties, rather than just one or two. For grain yield, Iskria, Saana and Tiril appeared to be the most promising varieties in the trial. However, Saana does not mature in the northernmost locations, reflected by relatively low dry matter content (tables 3-3 and 3-4). There were also quite large location and variety differences in the dry matter content of grain at harvest, demonstrating the need for farmers to have robust strategies for dealing with grain of high moisture content at harvest. Depending on end-use, this could involve making silage, treating grain with a preservative or drying it.

The trials also demonstrated some of the main challenges of growing cereals in northern areas, for example: the difficulty of achieving early planting, crop lodging (Shetland in 2014), bird damage (Shetland and the Faroes in 2014). We conclude that barley cultivation is difficult in Greenland, since no barley harvest was recorded in either year of the field trials.

Oceanic climate is dominating in Iceland, Faroe Islands, Shetland and Orkney. The climate in Iceland stands out, since the winters are cold enough to cause soils to freeze, which can delay sowing. This is important, since an early sowing can compensate for the cool growing season in Iceland (see figure 3-1a and 3-1c). In Orkney and Shetland, where spring temperatures are higher, temperature is not such a critical factor and spring sowing time is largely determined by the onset of sufficiently dry soil conditions. The average temperature in the coldest month is 4°C in the Faroe Islands, 5°C in Shetland therefore frozen soil is not a common problem. Figure 3-1a compares the average temperature in the warmest month among the different locations.

When growing barley in cool oceanic climates, the most important factor for successful cereal production is early sowing. Seasonally frozen soil can delay sowing, but that is only a problem in certain regions of the North Atlantic area. In Orkney, the Faroe Islands, Vestvågøy and Shetland, frozen soil is not a problem. However, early planting in those regions is limited by wet soils due to heavy precipitation. To get a better idea of the potential for cereal production in these areas, sowing should be done as early as possible. Same can be said for the continental regions of Alta and Newfoundland. Delayed sowing in Vestvågøy in 2014 was not because of bad climatic conditions, but practical problems on farm.

Timing of the harvest in the autumn is equally critical. All the regions in this project, experience very wet autumns, which are problematic for harvesting. Under these conditions, early harvesting is important to minimise damage, especially lodging, from wind, rain and birds and also to reduce the risk of poor quality as a result of pre-germination. While early planting will help to achieve an early harvest, the use of early maturing cereal varieties is also critical. These are particularly important where dry grain is required (e.g. for malting or milling). Where grain is being grown for feed and germination is not important, harvesting before the grain is fully mature may be a useful strategy for improving the security of the harvest. In Alta, some plots suffered from droughts during early summer, this may have affected the yield potential. Furthermore, low yields in Alta and Vestvågøy can partly be explained by the size of the combine, which is not designed to harvest small plots. Therefore a part of the harvest can be lost, but relative comparison between varieties is realistic.

4. Quality evaluation of barley

Quality of barley from field experiments was evaluated. The following methods were used:

- Visual inspection based on definitions of defects and impurities.
- Microbiological measurements.
- Measurements of mycotoxins.
- Measurements of nutrients.

Methods and results are described within the relevant sections.

4.1 Visual inspection of barley

Visual inspection can give valuable information about quality and might be needed for trade. Any indication of mycotoxin producing moulds is a food safety aspect. Inspection is particularly important for barley intended for malting since requirements of the beverage industry are very strict (Martin 2015).

4.1.1. Methods

The visual evaluation was carried out according to definitions for barley and wheat developed in the UK (Agriculture and Horticulture Development Board, 2013). Items for barley inspection are listed in Table 4-1. A template for barley inspection based on this method can be found in Appendix 1 of this report. Samples were photographed close-up using high resolution. This allowed study of enlarged pictures on screen to detect defects. Grains from replicate 1 out of 3 replicates were photographed for each variety and location. For debatable questions, replicates 2 and 3 were studied and in some cases a stereoscope was used.

Certain training and experience is needed for inspection of grain. The following defects need particular attention:

- Splitting (is. Hefur rifnað). Cracks can be seen through outer grain tissues. This should not be confused with the natural slots found on all barley grain.
- Skinning (is. Afhýðing). Separation and loss of barley husk.
- Gape (is. Op). A gap between husk tissues.

- Care should be taken when damaged grain is inspected. Do not sniff mouldy grain. Wear gloves and a mask. Spores present possible health hazard and must not be inhaled.

Table 4-1. Items for visual inspection of barley.

Items for inspection	Details
Sample information	Variety, origin, harvest time, water content
Description of sample	General information. Broken grain?
Smell and other defects	Unusual smells.
Damage	1. Overheating: Bronze to dark brown. Hull over germ is golden brown. 2. Splitting. Deep cracks due to weakness. 3. Skinning. Loss of husk due to weather, rough harvest, handling. 4. Gape: Gap between husk tissues. 5. Lost embryos. 6. Pre-germination. 7. Discolouration due to weather, spores or moulds.
Mould	Dullness / Visible mould. *Fusarium* mould is discoloured by pink, orange, black + white. Mildew fungal condition is grey. Ergot is purplish-black but grey / white inside. Sclerotia is black to grey.
Foreign bodies	Straw, unthreshed grain, insects, faeces, glass, stones, foreign seeds etc.

4.1.2. Sample material

The following barley varieties from field experiments were inspected:

- Bere 6 row
- Iskria 2 row
- Saana 2 row
- Tiril 6 row

For reference, three samples were obtained from the Agricultural University of Iceland. These samples were grown in Sweden and imported to Iceland as seed. The quality of these samples was expected to be high.

- Iskria, 2 rows, thousand grain weight 33 g
- X06-72, 6 rows, thousand grain weight 44 g

- Kannas, 2 rows, thousand grain weight 33 g

Table 4-2 reports the availability of samples from NORA field trials in 2014 and 2015. Samples from the Faroe Islands and Greenland were very small.

Table 4-2. Barley samples available for quality evaluation.

Country	Location	Samples 2014	Samples 2015
Iceland	Korpa	Bere 6r	Bere 6r
		Iskria 2r	Iskria 2r
		Sanna 2r	Sanna 2r
		Tiril 6r	Tiril 6r
Norway	Alta 2014 & Holt 2015	Bere 6r	Bere 6r
		Iskria 2r	Iskria 2r
		Sanna 2r	Sanna 2r
		Tiril 6r	Tiril 6r
Norway	Vestvågøy	Bere 6r	
		Iskria 2r	Iskria 2r
		Sanna 2r	Sanna 2r
		Tiril 6r	Tiril 6r
Newfoundland		Bere 6r	Bere 6r
		Iskria 2r	Iskria 2r
		Sanna 2r	Sanna 2r
		Tiril 6r	Tiril 6r
Orkney		Bere 6r	Bere 6r
		Iskria 2r	Iskria 2r
		Sanna 2r	
		Tiril 6r	Tiril 6r
Shetland		Bere 6r	
		Iskria 2r	
		Tiril 6r	
Faroe Islands		Bere 6r	Bere 6r
		Iskria 2r	Iskria 2r
		Sanna 2r	Sanna 2r
		Tiril 6r	Tiril 2r
Greenland			
		Iskria 2r	
		Sanna 2r	
		Tiril 6r	
Number of samples		30	22

4.1.3. Results

Results from visual inspection of barley samples are reported in Tables 4-3 to 4-6. The tables provide a description of the grain and list the damage seen in the barley samples from field experiments. Defects were detected for all cultivars (Bere, Iskria, Saana, Tiril) in 2014 and 2015. Skinning was the most common defect but broken grains and gape were sometimes reported. Greenish colour of grain was reported for some samples, particularly samples from Greenland, Faroe Islands and N-Norway. The green colour indicates that grain is not fully mature. Generally, samples from Orkney had fewer defects than samples from other regions.

The following defects were not found in any of the samples: Ergot (the fruiting body of the fungus *Claviceps purpurea*), insect damage, rodent droppings, stones, soil. Smell was not found from the samples.

Figures 4-1 and 4-2 show close-up pictures for two reference samples where grains are normal and have few defects. Figures 4-3 and 4-4 compare Bere grain from Orkney and Vestvågøy. More defects are seen in the sample from Vestvågøy.

It can be concluded that close-up high resolution photographs are very useful for inspecting quality of grain samples. Possible infection can be detected for further studies. Inspection by use of a stereoscope (see Figure 4-6) is very useful but might not be needed for screening.

Table 4-3. Results from visual inspection of Bere.

Country	Year	Variety	Description	Damage
Faroe Islands	2014	Bere	Brown, grey and yellow.	Partly burned. Gape.
Faroe Islands	2015	Bere	Pale green colour.	Splitting. Skinning. Gape. Loss of husk. Deep cracks. Some grains are dark brown.
Iceland	2014	Bere	Yellowish-brown	Gape.
Iceland	2015	Bere	Yellowish-brown	Gape. Some grains grey or dark-brown.
Newfoundland	2014	Bere	Brown. Yellowish. Grey. Burned (few).	Skinning. Broken.
Newfoundland	2015	Bere	Brown.	Skinning.
Norway-Alta	2014	Bere	A part is pale green. A part w broken ends.	Gape. Partly dull. Partly skinning.
Norway-Holt	2015	Bere	Considerable part of the grains are pale green	Gape.
Norway-Vestvågøy	2014	Bere	Pale brown, green, dark brown.	Skinning and dark brown grains. Husk very much broken.
Orkney	2014	Bere	Yellowish-brown	Gape.
Orkney	2015	Bere	Yellowish-brown	Gape.
Shetland	2014	Bere	Brown. Greyish.	

Figure 4-1. Reference sample Iskria.

Figure 4-2. Reference sample 06-72.

Figure 4-3. Sample of Bere from Orkney 2014.

Figure 4-4. Sample of Bere from Vestvågøy Norway 2014.

Table 4-4. Results from visual inspection of Iskria.

Country	Year	Variety	Description	Damage
Faroe Islands	2014	Iskria	Grey-Yellow. Some grains are burned.	Skinning. Broken.
Faroe Islands	2015	Iskria	Brown-Yellow.	Skinning (considerable). Splitting (some).
Greenland	2014	Iskria	Green-Brown.	Gape (few).
Iceland	2014	Iskria	Brown-Grey.	Skinning (few). Gape (few). Broken (few).
Iceland	2015	Iskria	Brown.	
Newfoundland	2014	Iskria	Brown.	Skinning (some).
Newfoundland	2015	Iskria	Brown.	Gape (few). Skinning (few). Broken (few).
Norway-Alta	2014	Iskria	Brown. Green (few).	Broken. Gape.
Norway-Holt	2015	Iskria	Brown. Greenish (some).	Skinning. Broken (few).
Norway-Vestvågøy	2014	Iskria	Pale-brown.	Skinning. Gape.
Orkney	2014	Iskria	Brown.	
Orkney	2015	Iskria	Brown.	Skinning (few)
Shetland	2014	Iskria	Pale-brown. Dark-brown.	Skinning. Gape.

Table 4-5. Results from visual inspection of Saana.

Country	Year	Variety	Description	Damage
Faroe Islands	2014	Saana	Pale-brown.	Skinning (considerable).
Faroe Islands	2015	Saana	Variable colour. Dark spots and brown grain => Possible mould infection.	Looks damaged.
Iceland	2014	Saana	Pale-brown. Dark-brown. Yellowish-green.	Skinning (considerable). Splitting (few).
Iceland	2015	Saana	Brown.	Skinning (few).
Newfoundland	2014	Saana	Greyish. Pink => possible mould infection. Black.	Skinning. Lost embryos.
Newfoundland	2015	Saana	Brown.	Skinning (some). Broken (few).
Norway-Alta	2014	Saana	Green. Pale to dark brown.	Skinning (considerable).
Norway-Holt	2015	Saana	About 1:1 Greenish : Light-brown.	Skinning.
Norway-Vestvågøy	2014	Saana	Greenish. Dark-brown (some).	Skinning.
Orkney	2014	Saana	Brown.	

Faroe Islands 2014

Greenland 2014

Iceland, Korpa 2014

Newfoundland 2014

Norway, Alta 2014

Orkney 2014

Figure 4-5. Saana from 6 field experiments in 2014.

(a) Saana from Newfoundland 2014

(b) Saana from Orkney 2014

Figure 4-6. Examples of stereoscopic pictures.

Table 4-6. Results from visual inspection of Tiril.

Country	Year	Variety	Description	Damage
Faroe Islands	2014	Tiril	Brown. Burned (few).	Skinning. Splitting (few). Gape.
Faroe Islands	2015	Tiril	Brown-Yellowish. Dark (few).	Skinning. Splitting (few). Gape.
Greenland	2014	Tiril	Pale-brown. Greenish.	
Iceland	2014	Tiril	Brown. Greyish. Dullness. Moulds?	
Iceland	2015	Tiril	Brown.	
Newfoundland	2014	Tiril	Variable colour. Greyish. Dullness. Spots. Infection?	Skinning. Splitting. Gape. Broken.
Newfoundland	2015	Tiril	Brown.	
Norway-Alta	2014	Tiril	Brown. Green.	Gape.
Norway-Holt	2015	Tiril	Brown-Greenish.	Skinning (few).
Norway-Vestvågøy	2014	Tiril	Pale-brown. Other seeds (few).	Broken. Skinning. Gape.
Orkney	2014	Tiril	Brown.	
Orkney	2015	Tiril	Brown.	Skinning (few).
Shetland	2014	Tiril	Brown-Greyish. Grey spots.	Lost embryos.

4.2 Microbiological data

Moulds, yeasts and bacteria can contaminate cereal grains in the field and during storage. The microflora of cereal grains are generally representative of the environment in which they grow. Since harvested grain is usually dried by heating to less than 15% moisture content, the low water content prevents bacterial growth. After rehydration, bacteria will grow. Fungi will slowly die off in grains properly dried (moisture content below 13%). Inadequate drying or improper drying will allow moulds to grow. Normal microbiological profiles for cereal grains are: Moulds 10^2-10^4 /g, yeasts 10^2-10^4 /g and plate count 10^2-10^4 /g (Beuchat & Cousin, 2001). In Iceland food inspection regards dry cereal-based foods with moulds above 10^4 per g as unacceptable. Some mould species can form toxic mycotoxins and therefore knowledge about the microbial profile is important.

Table 4-7. Microbiological data for NORA composite samples 2014. Composite samples are made from equal amounts of 3 replications.

Country	Location		Mould per 1 g	Yeasts per 1 g	Total Count per 1 g
Iceland	Korpa	Bere 6r	9800	2200	
		Iskria 2r	2000	1600	1500000
		Sanna 2r	5400	2800	
		Tiril 6r	6200	2400	1700000
Norway	Alta	Bere 6r	4200	360000	
		Iskria 2r	2400	17000	3800000
		Sanna 2r	4400	61000	
		Tiril 6r	8400	380000	8500000
Norway	Vestervågøy	Bere 6r	3000	120000	
		Iskria 2r	2600	140000	8300000
		Sanna 2r	2800	150000	
		Tiril 6r	3400	10000	9500000
Newfoundland		Bere 6r	260000	160000	
		Iskria 2r	100000	20000	3800000
		Sanna 2r	80000	40000	
		Tiril 6r	320000	120000	9100000
Orkney		Bere 6r	200	3600	
		Iskria 2r	1000	2600	300000
		Sanna 2r	1200	1800	
		Tiril 6r	5200	6200	460000
Shetland		Bere 6r			
		Iskria 2r	9200	2000	2100000
		Sanna 2r			
		Tiril 6r			
Faroe Islands		Tampar	22000	15000	11000000

Moulds, yeasts and total viable counts were determined in samples from field experiments 2014. Measurements were carried out at Matis and methods were as follows: Moulds: NMKL 98, 4th ed. 2005. Yeasts: MNKL 98, 4th ed. 2005. Total bacterial count 30 °C: NMKL 86, 5th ed. 2013.

Microbiological data are presented in Table 4-7. These samples were not dried at as high a temperature as commercial barley and therefore more moulds, yeasts and bacteria are expected. There is considerable difference between countries, reflecting different treatments. High values were found for microbes in samples from Newfoundland while the lowest values were found for samples from Orkney. Quite high values were found for moulds, indicating the importance to inspect possible existence of mycotoxins.

4.3 Mycotoxins and grain safety

4.3.1 Grain safety

Humid weather conditions are often common during harvesting of cereals in the North Atlantic region. The possibility that mycotoxin producing moulds grow on the grain should therefore be taken seriously. Mycotoxins can harm the health of animals and humans. An EU regulation (No 1881/2006) sets limits for levels of some mycotoxins (aflatoxins, ochratoxin A, deoxynivalenol (DON) and zearalenone (ZEA), fumonisin, T-2 and HT-2) in foods.[1] In most countries, mycotoxins in cereals are included under food safety inspection programmes.

A risk assessment of mycotoxins in cereal grain has been carried out for Norway (Norwegian Scientific Committee for Food Safety, 2013). The mean concentration of DON has increased in crude grain of oats during the period 2003 – 2013 in Norway. Mycotoxins in wheat grains have also been increasing. Mycotoxin producing moulds have been found at higher levels than previously, the reason could partly be the increased precipitation.

Mycotoxins can form both in the field and in storage rooms for feed or food. DON is the most commonly found mycotoxin in agricultural fields in Norway and is therefore often detected in cereal grain samples. Ochratoxin A is the storage mycotoxin of most concern. The mycotoxins T-2 and HT-2 can also be widespread.

Limited data is available for mycotoxins in food and feed in Iceland (Reykdal, 2008). Mycotoxins have generally not been detected when these compounds have been analyzed in domestic barley. It has been hypothesized that some of the mycotoxins do not form in Iceland in the fields due to low temperature.

The north Atlantic region benefits from the cool climate when mycotoxins are considered. Aflatoxins and fumonisins will only form when temperatures are 20-30 °C. However, ochratoxins can form under cool conditions. If temperature rises and precipitation increases in the region, mycotoxins should be inspected carefully. Under current conditions mycotoxins in cereal grain should be inspected regularly although the mycotoxins might not be detected in surveys.

---

[1] Commission regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Retrieved 21.12.2015 from: https://www.fsai.ie/uploadedFiles/Consol_Reg1881_2006.pdf

4.3.2 Measurements

Three mycotoxins, ochratoxin A, deoxynivalenol (DON) and zearalenone (ZEA), were analyzed in selected barley samples. Samples were sent to Eurofins, Germany for analysis. The method for Ochratoxin A was CEN 14132, mod., CON-PV-00850, IAC-LC-FLD. Deoxynivalenol (DON) and zearalenone (ZEA) were measured by CON-PV-00854, LC-MS/MS.

Large samples (about 1 kg) were required so it was not possible to use the available samples from the NORA experiments for analysis. Samples were collected in Iceland from the harvest in 2014 and 2015, and they were analysed for mycotoxin. In 2015 barley was harvested under wet conditions late in the autumn which might increase the risk of mycotoxin formation. Samples are listed in Table 4-8.

Table 4-8. Three mycotoxins in barley samples and maximum allowable levels according to regulation EU 1881/2006.

Variety	Year	Origin
Iskria	2015	Belgsholt a
Iskria	2015	Belgsholt b
Skeggla	2015	Belgsholt c
Iskria	2015	Thorvaldseyri a
Iskria	2015	Thorvaldseyri b
Iskria	2015	Thorvaldseyri c
342-1	2014	AUI-Korpa
342-1	2015	AUI-Korpa
Iskria, pearled	2014	Vallanes

The three mycotoxins measured were not detected in any of the samples (results were below the quantification levels). The quantification levels were 0.5 µg/kg for ochratoxin A, 20 µg/kg for DON and 10 µg/kg for ZEA. The maximum levels set in regulation 1881/206 are much higher than the quantification levels. The maximum levels are 5.0 µg/kg for ochratoxin A, 1250 µg/kg for DON and 100 µg/kg for ZEA.

4.4 Nutritional composition of barley

Water, starch and protein are the most important components of barley when quality for food and feed use is evaluated. These components were measured in samples from the field experiments in N-Norway, Iceland, Orkney and Newfoundland. Additionally, more detailed analysis were carried out at the Rowett Institute in Scotland.

4.4.1 Methods

Protein was determined at Matis by the Dumas method and was calculated as Nitrogen multiplied by 6.25 (prEN ISO 16634-1 2008 modified for rapid measurements). Water was determined at Matis by drying at 103 ± 2 °C for 4 hours (ISO 6496-1999 E). Starch was determined by Agrolab Group in Kiel Germany (method §64 LFGB L 17.00-5). The method is based on a double determination. In the first determination the sample is treated by diluted HCl solution and heated (boiling). After clarification (Carrez) and filtration the optical rotation of the solution was measured by a polarimeter. In the second determination the sample was extracted by 40% ethanol. After treatment of the filtrate with HCl, clarification (Carrez) and filtration the solution is measured in the same way as with the first determination. The difference in optical rotation between both preparations was multiplied by a known calculation factor, resulting in the starch content of the sample.

4.4.2 Results

For each variety and location, samples from 3 replicates were combined into one composite sample. Table 4-9 presents data for four barley varieties at the Korpa experimental station in Iceland. Table 4-10 compares data for the Iskria variety grown in four regions. The average composition of all samples is reported in table 4-11.

The chemical composition of 6 barley varieties from field experiments of the Agricultural University of Iceland in 2006 and 2007 was as follows (Reykdal et al. 2008):

- Starch 57.5 (54.4 – 60.7)%, n = 48
- Protein (N×5.83) 10.3 (7.5 – 13.2)%, n = 48
- Water 9.4 (7.4 - 10.6)%, n = 48
- Total fibre 18.2 (17.1 – 19.1)%, n = 18
- Fat 2.4%, n = 1
- Ash 2.4%, n = 48
- Sum 100.1
- Beta-glucans 2.6 (1.6 – 3.5)%, n = 48

Table 4-9. Chemical composition of 4 barley varieties at Korpa, Iceland.

Variety	Year	Starch %	Protein %	Water %
Bere	2014	55.7	10.0	7.6
Iskria	2014	58.6	10.0	7.6
Saana	2014	60.3	8.7	7.7
Tiril	2014	58.0	8.2	7.5
Bere	2015	56.3	9.1	5.8
Iskria	2015	59.5	8.2	6.1
Saana	2015	58.1	7.3	5.2
Tiril	2015	60.3	6.8	6.0
Average 2014		58.2	9.2	7.6
Average 2015		58.6	7.9	5.8
Average both years		58.4	8.5	6.7

The outermost layers of the barley (about 15% of grain weight) were removed for some of the samples. Total fibre dropped to 9.4% (7.9–10.0%, n=6) and starch increased to 61.4% (60.4 – 63.9%, n=6). However the concentration of beta-glucans did not change. Results for beta-glucans were 2.6 % (1.7 – 3.5%, n=12).

Table 4-10. Chemical composition of the barley variety Iskria in 4 regions.

Region	Location	Year	Starch %	Protein %	Water %
Iceland	Korpa	2014	58.6	10.0	7.6
N-Norway	Vestervågøy	2014	55.9	13.0	7.7
Orkney		2014	54.3	10.5	10.9
Newfoundland		2014	56.8	14.6	7.2
Iceland	Korpa	2015	59.5	8.2	6.1
N-Norway	Vestervågøy	2015	56.6	12.3	7.0
Orkney		2015	57.4	10.2	6.4
Newfoundland		2015	58.1	12.4	4.2
Average 2014			56.4	12.0	8.4
Average 2015			57.9	10.8	5.9
Average both years			57.2	11.4	7.1

Generally starch is expected to increase when grain matures and consequently protein concentration decreases. In Iceland, starch content has been measured as low as 34.2% in poorly matured barley.

Starch was highest and protein lowest in the samples from Iceland (Table 4-10), the same result are found when data are calculated on dry weight basis. In all cases, starch content was higher and protein content lower in samples from 2015 when compared to 2014. As mentioned before, 2015 was a difficult year for barley growing due to rain and low temperature.

Table 4-11. Average composition of 14 barley samples reported in Tables 4-9 and 4-10.

	Starch %	Protein %	Water %	Starch % in DM	Protein % in DM
Samples 2014	57.1	10.7	8.0	62.1	11.6
Samples 2015	58.0	9.5	5.8	61.6	10.1
All samples	57.6	10.1	6.9	61.8	10.9

DM: Dry matter

Barley samples from the field experiments in 2014 were provided to the Rowett Institute of Nutrition and Health at the University of Aberdeen. The samples were used for studies on nutrient value of cereals. The institute carried out a big UK project on cereals and health. Results from the samples of the NORA experiment were presented at the Northern Periphery and Arctic Cereal Project Conference in Orkney, October 23rd, 2015 (Scott, 2015). Measurements were carried out by Near-Infrared Spectroscopy Analysis. Results are shown in Figures 4-7 and 4-8. The locations are listed from north to south: Alta N-Norway, Vestvågøy N-Norway, Iceland, Shetland, Orkney and Newfoundland.

Starch content decreased and sugar content increased by the distance from the Arctic Circle. The barley varieties Iskria and Saana had higher starch content and lower fibre content than Tiril and Bere. Mineral content of barley varied between locations. The concentrations of beta-glucans (water soluble dietary fibre) were 1.5 – 2.5%.

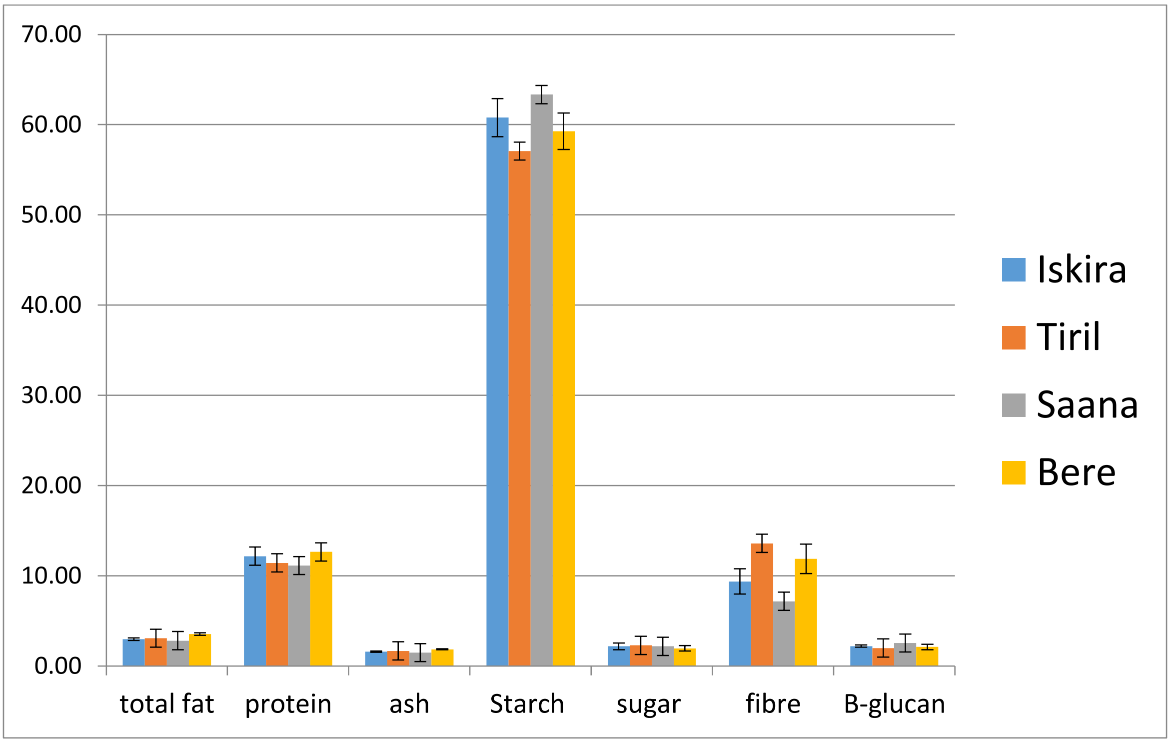

Figure 4-7. Nutrients in 4 barley varieties grown in Iceland, N-Norway, Orkney and Newfoundland. From Scott (2015).

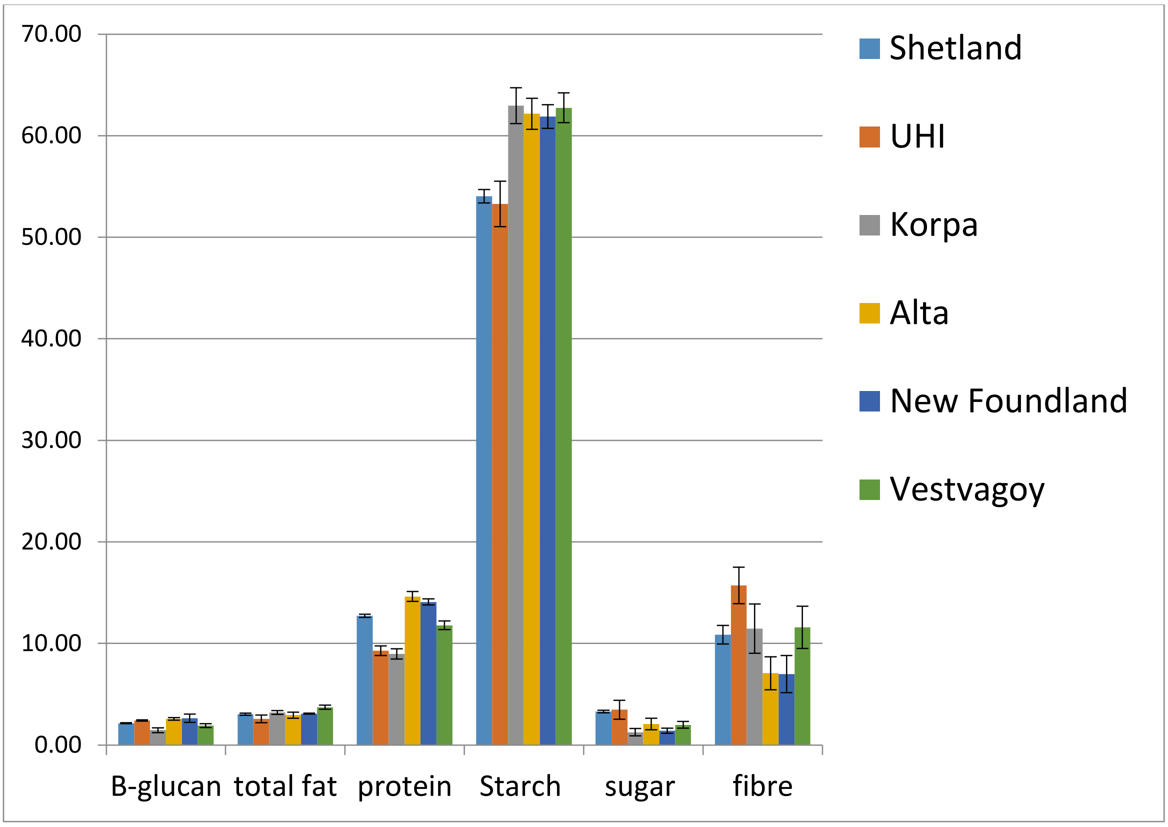

Figure 4-8. Nutrients in 4 barley varieties grown at 6 locations, Shetland, Orkney (UHI), Iceland (Korpa), N-Norway (Alta) and N-Norway (Vestervågøy). From Scott (2015).

5. Quality specifications and guidelines for barley

Quality specifications for cereals are important as a reference for trade and communication regarding cereal quality. Some businesses have their own specified requirements and will reject cereals when requirements are not met.

5.1 Available specifications and guidelines

Information on available cereal specifications was collected. A considerable part of the specifications and guidelines came from the United Kingdom. The specifications are reviewed in the sections below.

United Kingdom. Several Guidelines on cereals have been published by the Agriculture and Horticulture Development Board (AHDB).[2]

- HACCP explained: a supplement to the HGCA Grain Storage Guide

AHDB Cereals and Oilseeds (http://cereals.ahdb.org.uk/), formerly HGCA, have a valuable website and have published guidelines:

- HGCA Grain Storage Guide for Cereals and Oilseeds.
- HGCA Grain Sampling Guide.
- The Barley Growth Guide 2006.
- Malting Barley – Quality Criteria and Tests.
- Milling Wheat - Quality Criteria and Tests.
- Feed grains – Quality Criteria and Tests.

The Maltsters' Association of Great Britain (http://www.ukmalt.com/barley-requirements) has published requirements for barley.

- Barley Requirements.

BSPB have published information to support farmers:

- FAQ on Farm-saved seed

Food and Environment Research Agency (Fera, http://fera.co.uk/) has published guidelines on seed:

[2] Agriculture and Horticulture Development Board. http://www.ahdb.org.uk/

- A brief Guide to Seed Marketing.

Iceland. The first edition of the Icelandic specifications for barley was published in March 2011.[3] The specifications were printed in a report about possibilities to increase barley cultivation in Iceland.[4] Specifications are available for (a) Barley for food products, (b) barley for production of malt and (c) dried barley for feed. The specifications are written in Icelandic but an English translation can be found for barley for foods in Appendix 2 of this report.

Norway. In Norway NIBIO (formerly Bioforsk) has published detailed guidelines for the 7 steps from seed to feed.[5] The guidelines are in Norwegian and include quality aspects. The Norwegian seed supplier Felleskjøpet supplies guidelines to farmers.[6] Finnish guidelines (in Swedish) for malting barley are used in Norway.[7] The guidelines set limits for germination rate, protein, moisture, mould and more.

Canada. Several guidelines and regulations apply to barley in Canada. The Official Grain Grading Guide[8] defines required characteristics for barley. Malting barley methods used to measure quality have been published.[9] Quality requirements for malting barley have been published by Alberta's Agriculture Industry.[10]

---

[3] Retrieved on 15.12.2015 from: http://www.matis.is/media/frettir/Gaedakrofur_fyrir_bygg_2011.pdf

[4] Sjávarútvegs- og landbúnaðarráðuneytið, 2011. Tillögur starfshóps um eflingu kornræktar á Íslandi. Retrieved on 15.12.2015 from: https://www.atvinnuvegaraduneyti.is/media/Skyrslur/Skyrsla-um-kornraekt-a-Islandi-mai-2011.pdf

[5] Bioforsk, 2013. Økt norsk kornproduktion. Retrieved 10.12.2015 from: http://www.bioforsk.no/ikbViewer/page/prosjekt/tema?p_dimension_id=97355&p_menu_id=97364&p_sub_id=97356&p_dim2=97357

[6] Norwegian supplier Felleskjøpet. Retrieved 10.12.2015 from: http://www.felleskjopet.no/landbruk/Plantekultur/saavare/Sider/Dyrkingsrad---hostkorn.aspx

[7] Finnish growth guide for malt barley (Mauritz og Tove Sundgren). Retrieved 10.12.2015 from: http://www.vyr.fi/multimagazine/web/mallasohraopas/liitteet/odlingsguide_maltkorn_web_120227.pdf

[8] Official Grain Grading Guide, 2013. Canada.

[9] Malting barley methods. Retrieved 10.12.2015: http://www.grainscanada.gc.ca/barley-orge/method-methode/bmtm-mmao-eng.htm

[10] Alberta Ag-InfoCentre, 2009. Malting Barley. Agdex 114/20-2. www.agriculture.alberta.ca

5.2 Specifications for barley – Food, malt and feed

Specifications for barley can be divided into three groups depending on the use of barley: (a) Barley for food products, excluding malt and beverages, (b) barley for malt production and alcoholic beverages and (c) barley for feed.

Barley for food products

In the Icelandic specifications requirements are set for composition, microbes, purity, maturity and air temperature during drying. Moisture content of barley shall not be above 15% and air temperature during drying shall not be above 55 °C. Mould count shall be below 1000 per gram, *Bacillus cereus* below 100 per gram, faecal coli below 10 per gram and *Salmonella* not found. Barley shall be free from visible mould. Specific weight (grain weight, g/100 ml = kg/hl) is used as a measure of maturity. Specific volume of 6-row barley shall be at least 60 g/100 ml and 65 g/100ml for 2-row barley. Purity refers to grain on weight basis and shall be at least 98%. Requirements for protein and starch are presented for de-husked barley (10-15% of grain weight removed as outermost husk layers). Protein in de-husked barley shall be at least 11 g/100g dry matter and starch at least 65 g/100g dry matter.

In the Norwegian guidelines 14-15% moisture content is recommended. However it is indicated that this is too high if the cereals are kept at a warm temperature. It is recommended that cereals are dried without delay to reduce possible mycotoxin formation.

In the HGCA guidelines on grain storage it is recommended that grain should be dried below 18% moisture content within the shortest possible time to prevent the risk of mycotoxin formation.

Barley for malt production

The Icelandic specifications for malting barley state that the barley shall be dried carefully and grain temperature shall not exceed 38 °C. It is recommended that air temperature does not exceed 40 °C. Grain temperature should be measured in a sample removed from the dryer.

At the Agronomy Institute in Orkney, a grain temperature of 35-38 °C is recommended during drying. However there are different recommendations on drying temperatures. In Australia the optimal and maximum grain temperature for malting / seed barley is considered to be 40 °C and 43 °C respectively. For malting barley, grain temperature is critical since high drying temperatures can kill the grain (Martin 2015).

Barley for feed

The Icelandic specifications for feed barley are less detailed than for food barley. Moisture content shall not be above 15% and air temperature up to 80 °C is allowed during drying. Specific weight shall be at least 60 g/100 ml. Requirements for microbes include that *Salmonella* shall not be found. Mould should not be visible on grain or on plants at fields. Pesticides shall not be applied in the two last months before harvest.

According to HGCA guidelines for feed grains, grains with more than 15% moisture might be rejected by buyers. In the UK, grain contracts often require specific weight. Failure to meet the specific weight requirement leads to price deduction or rejection. A typical specific weight for barley is 63 g/100 ml. Presence of moulds*, Fusarium* and ergot may lead to rejection of grain. Detection of ergot or *Fusarium* means automatic rejection with no tolerances.

5.3 Suggested quality specifications for northern cereals

Results for barley samples from the field trials can be compared to the Icelandic specifications. The tested barley meets the requirements for specific weight in most cases. The moisture content of samples is below the limit of 15%. However mould count is above the limit of 1000 per gram except for barley from Orkney. It should be noted that barley marketed for food is processed according to strict cleanliness criteria which are not the case for experimental samples.

The use of specific weight as quality indicator is debatable according to HGCA guidelines. However the cereal industry continues to use this measure because of long experience and easy measurements.

It can be concluded that:

- Guidelines for cereals reported in this project are useful in the North Atlantic Region. The Grain Storage Guide for Cereal and Oilseeds from HGCA in the UK is particularly valuable. However the special conditions in the region should be kept in mind.
- The Icelandic specifications for barley will still be useful. However they should be modified regarding drying temperatures and should always be referred to whole grain rather than de-husked grain.

6. Conclusions and guidelines

6.1 General conclusions

The work concentrated on barley since this cereal is best suited for the North Atlantic Region.

All five varieties (Bere, Kria, NL, Saana and Tiril) were grown successfully in field trials in Iceland, Orkney, Newfoundland and North Norway. Problems occurred in Greenland and Faroe Islands due to weather conditions and lack of experience. The field trials served well as a basis for developing guidelines for farmers.

Grain yields in field trials were 2.1-3.1 tons dry matter per hectare on average for all locations. Dry matter of harvested barley was 64-73% in 2014 but only 51-59% in 2015. The year 2015 was difficult for cereal growing due to heavy precipitation.

Although weather conditions and dry matter of barley differed between the years 2014 and 2015, the concentration of starch was similar for barley from both years. This indicates that barley can be used in the baking industry even though conditions for cultivation are variable.

Due to wet weather conditions in the North Atlantic Region, inspection of mould and mycotoxins in cereals should be a part of feed and food control programmes in all regions.

Early sowing is the most important factor for successful cereal production in the North Atlantic region. Seasonally frozen ground can delay sowing, but that is only a problem in certain regions. Timing of the harvest in the autumn is equally critical. All the regions in this project, experience wet autumns, which are problematic for harvesting. Where grain is not going to be used for seed or for malting, damage from birds, wind and rain may be reduced by harvesting before the grain is fully mature.

6.2 Guidelines for farmers

The two main challenges of cereal cultivation in the North Atlantic Region are low summer temperatures and short growing season. Also heavy precipitation is problematic during the harvest period.

- Because of the short growing season in the North Atlantic Region, farmers should sow as early as possible. The time for sowing depends on frozen ground and how wet the fields are. In some regions (e.g. the Faroe Islands, Orkney and Shetland) there should be no frozen ground, but fields might be too wet for tractors early in the spring.
- The selection of appropriate varieties is also very important – in all regions, there are advantages from early maturing varieties, but they are especially important where the heat sum from sowing to 15 September is lowest (Fig. 3-1c).
- It is equally important to consider the best harvesting time. Where barley is grown for feed, it may be advantageous to harvest before the grain is fully mature to prevent grain loss due to wind or birds. The use of early maturing varieties and early planting will help to achieve an early harvest.
- Heavy precipitation is of particular concern. Under wet conditions moulds may develop in the field and some mould species can form mycotoxins which are harmful for animals and humans. Grain is also likely to suffer from pre-germination under protracted, wet conditions in the field.
- After harvesting, grain should be dried as soon as possible to prevent spoilage and to prevent the risk of mycotoxin formation.
- Where grain is being grown for seed or malting, particular care is required not to use an excessively high drying temperature as grain viability will be reduced.

Farmers should have hand-held moisture meters to measure moisture content of grain through the processing chain from field to storage.

6.3 Quality and food use

- Visual inspection of barley grain was useful to detect defects and limited maturity. Grain from some locations had green colour indicating limited maturity. The most common defect was skinning.
- Mould was detected on grain samples but the mycotoxins Ochratoxin A, deoxynivalenol and zearalenone were not detected in selected samples.
- Starch concentration in dried barley grain was on the average 58% and protein 10%.
- Quality specifications and guidelines were found useful for the North Atlantic Region.

7. Acknowledgements

This work was supported by the Nordic Atlantic Cooperation (NORA) for the project *Northern Cereals – New Opportunities*, project number 515-005. The financing of the work is gratefully acknowledged. The project is grateful to Karen Scott of the Rowett Institute of Nutrition and Health (University of Aberdeen) for arranging the nutritional analyses of grain samples from the trials and for providing the nutritional data.

8. References

Agriculture and Horticulture Development Board, 2013. Inspecting grain for defects and impurities. Retrieved 16.11.2015 from: http://cereals.ahdb.org.uk/media/248957/a2_hgca_grain_defects_poster_2013.pdf

Beuchaat, L.R. and M.A. Cousin, 2001. Cereal and cereal products. In: Compendium of Methods for the Microbiological Examination of Foods. 4th Edition. Frances Pouch Downes & Keith Ito (Eds.). American Public Health Association. Washington.

Martin, Peter, 2015. Grain quality criteria for malting barley. Project Report. Northern Periphery and Arctic Programme.

Norwegian Scientific Committee for Food Safety, 2013. Risk assessment of mycotoxins in cereal grain in Norway. Retrieved 23.02.2016 from: http://www.vkm.no/dav/eee04d10c4.pdf

Reykdal, Ólafur, 2008. Sveppaeitur og MYONET-verkefnið. (Mycitoxins and the MYCONET-project). Matis Report 41-08. (In Icelandic).

Reykdal, Ólafur, Jónatan Hermannsson, Þórdís Anna Kristjánsdóttir, Jón Óskar Jónsson, Aðalheiður Ólafsdóttir, Emilía Martinsdóttir, Birgitta Vilhjálmsdóttir, Jón Guðmundsson, Guðmundur Mar Magnússon, 2008. Íslenskt bygg til matvælaframleiðslu. (Icelandic Barley for food production). Matis Report 40-08. (In Icelandic).

Reykdal, Ólafur, Þórdís Anna Kristjánsdóttir, Jónatan Hermannsson, Peter Martin, Sigríður Dalmannsdóttir, Rólvur Djurhuus, Vanessa Kavanagh, 2014. Status of Cereal Cultivation in the North Atlantic Region. Matis Report 23-14. 47 p.

Scott, Karen, 2015. Nutritional content of barley (and oats) grown in diverse geographical regions. Presentation at the Northern periphery and Arctic Cereal Project Conference in Orkney, October 23rd, 2015.

VSN International, 2011. GenStat *for Windows*. VSN International, Hemel Hempstead, UK. Web page: GenStat.co.uk.

Appendix 1 – Template for visual inspection of grain

Cereal inspection

Date:

Cereal:

Sample: Origin and harvest time: Water content:
Description: (General information. Broken grain)
Smell and other defects: (Fishy smell indicates mould. Do not sniff mouldy grain. Wear gloves and a mask)
Damage: (1. Overheating: Bronze to dark brown. Hull over germ is golden brown. 2. Splitting: Deep cracks due to weakness 3. Skinning: Loss of husk due to weather, rough harvest or handling. 4. Gape: Gap between tissues. 5. Lost embryos. 6. Pre-germination. 7. Discolouration due to weather, spores or moulds)
Mould: (Spores present possible health hazard and must not be inhaled. Dullness / Visible mould. *Fusarium* mould is discoloured by pink, orange, black + white. Mildew fungal condition is grey. Ergot is purplish-black but grey / white inside. Sclerotia is black to grey)
Foreign bodies: (Straw, unthreshed grain, insects, faeces, glass, stones, foreign seeds etc.)

Appendix 2 – Quality specifications for dried Icelandic barley for food production and cooking

The quality specifications are intended to serve as a reference when barley is sold for food production.
Different requirements are presented for barley for food products and barley for malting / beverage industry. Specifications have also been presented for dried barley for feed. Regulation 301/1995 on seed is valid in Iceland. Further information is available from the Icelandic Food and Veterinary Authority (www.mast.is).

Definitions

A barley cultivar is plants belonging to the species *Hordeum vulgare* L. with measurable properties different from other cultivars and preserve their properties when multiplied by seed. A register of acknowledged barley cultivars on international markets is published by OECD.

Icelandic barley is barley grown in Iceland from Icelandic or foreign seed.

Malting barley is barley which meets the quality criteria for production of malt. Husk is not removed from malting barley.

Barley for food is barley with the outermost layers of husk removed. About 10-15% of the grain weight has been removed as husk. Barley for food meets the criteria set in these specifications.

Dried feed barley is barley that meets criteria for feed.

Barley seed are seed with high germination rate for sowing in fields. Requirements for production, import and trade of seed differ from one country to another. In Iceland the Food and Veterinary Agency (is. Matvælastofnun, www.mast.is) sets the rules / regulation. Criteria include germination rate and purity. A certificate is required.

Six row barley is a barley cultivar with 6 rows of kernels. Kernel weight is usually 30-40 mg and specific volume is 60-65 g/100ml, both for whole grain.

Two row barley is a barley cultivar with 2 rows of kernels. Kernel weight is usually 35-50 mg and specific volume is 65-70 g/100ml, both for whole grain.

Specific weight is the weight of grain in a particular volume. Weight of grain per volume is a measure of grain density and starch content. Specific weight can easily be measured and is a useful measure of grain maturity. Dried grain is weighted in a container with known volume (full container, minimum 100 ml). Specific weight is usually reported as g/100 ml.

Thousand grain weight is the weight for fully dried grain reported in grams. Grain (kernel) weight is the average weight per kernel reported in milligrams.

Moisture content of grain is determined at 103 $\pm$ 2 °C after homogenization.

Germination test. Recognized methods shall be used, e.g. the ISTA method.

Barley for food

Barley for food processing and cooking has been cleaned (loose husk and unwanted non-cereal matter removed) and a part of the husk has been removed (up to 15%). Barley can be grain, rolled flakes or flour or similar products. Estimations of maturity and purity are carried out on whole barley but other measurements are carried out on de-husked barley. The quality requirements are met when results and allowed deviations are fulfilled.

Requirements

1. Maturity. Barley shall be mature. Specific weight is used to indicate maturity. For 6-row barley specific weight shall be at least 60 g/100 ml and for 2-row barley specific weight shall be at least 65 g/100 ml.
2. Drying. Barley shall be dried and moisture content shall not be above 15%. Heated air should be used during drying. Exhaust air containing smoke from burners is not allowed for drying of barley. Suitable air temperature at the beginning of drying depends on the type of dryer but temperature equal to or below 55 °C can be used as a reference.
3. Purity. Unwanted non-cereal matter, damaged or green grain and straw should be removed. Whole grain should be minimum 98% clean grain (weight %). When husk has been removed barley should be minimum 99.5% clean grain (weight %).
4. Removal of husk. The outermost husk tissues (about 10 – 15% weight) are removed.
5. For dried de-husked barley (husk partly removed) protein shall be at least 11 g/100g dry matter (nitrogen factor 6.25) and starch at least 65 g/100g dry matter.
6. Microbes are measured in the barley product as it is sold for human consumption. Results shall be below the following values: Moulds 1000 per g, *Bacillus cereus* 100 per g, faecal coli 10 per g and *Salmonella* not found. Values refer to the product as it is sold with the water it contains. A farmer that plans to sell barley at consumer or industry markets shall buy analysis of microbes in his products.
7. Mould. Barley in field and barley grain shall be free from visible mould. Pesticides shall not be sprayed to barley fields for two months before harvesting.

Allowed deviations

Allowed deviations shall be as follows:

- Deviation for specific volume 0.5 g/100 ml
- Deviation for moisture content, starch and protein 1 g/100 g
- Deviation for minimum purity 0,5%

Barley not meeting criteria for food use can be considered for feed.

Homogeneity

The content of each package shall be homogeneous.

Packaging

Packaging for barley for food use shall be made from paper, cardboard or nylon. Packaging shall be food grade and fulfil regulatory requirements. Only clean packaging can be used.

Labelling and traceability

Packaging for consumer markets shall be labelled according to regulation. Large barley containers to be sent to suppliers shall be labelled at least with product name, producer name and lot number. Other information shall be available for the buyer. A lot number shall be related to information on barley cultivar, year of harvest and fields.