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Northern Cereals – New Markets for a Changing Environment

GRAIN QUALITY CRITERIA FOR MALTING BARLEY

Project Report

Activity 6.1.1

By

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1 Introduction

With growing interest in North Atlantic areas in using local cereals for beer or spirit production, it is important to summarise some of the grain quality criteria which need to be considered by both growers and cereal end-users if a high quality product is to be made. Given that barley is the cereal which is best adapted to growing in the North Atlantic region, it is most likely that it will be malting barley which will be used for beverage production. Malting barley is a term which is used to cover many different varieties of barley which have been specially bred for their suitability for brewing or distilling. Before these varieties can be used for beverage production, they must first be made into malt. This is a separate process, usually carried out by specialist malting companies, and involves the initiation of germination of the barley grains and its premature termination by drying.

Malting barley is a specialised crop and a number of quality criteria have now been adopted, in areas where it is commonly grown, which determine whether a batch of grain is suitable for this purpose. It is, however, worth stressing that several of these criteria are aimed at obtaining a product which maximises the production of alcohol, and failure to meet all criteria does not necessarily mean that the barley cannot be made into malt or that the malt will be unusable. Growing conditions in northern areas may make it difficult to consistently produce malting barley which meets the criteria used in more southerly areas. Provided this does not have a large detrimental effect on alcohol yield or taste and does not create food safety issues, malting barley which does not have the optimum specification can still be valuable for making high provenance beverages. It may, however, be more expensive for end-users to work with and require adjustment to normal practices to be able to make good malt from this barley. Since there is not currently a market in most of the Norther Cereals project region for malting barley, the crop is only likely to be grown where a farmer has a collaborative agreement with an end-user and it is recommended that both parties discuss and agree the quality criteria which are acceptable to the end-user.

The sections below summarise some of the most important considerations and quality criteria which would normally be considered when growing or purchasing malting barley in areas where it is an established crop.

2 Initial Considerations

2.1 Market

In Scotland, where a lot of malting barley is grown for distilling, some varieties are recommended just for distilling, some just for brewing and others are recommended for both end-uses. One of the main differences between varieties suitable for distilling and brewing is that the former are capable of producing a lower grain nitrogen than the latter. It is therefore important to identify a suitable variety (see below) for the intended market.

2.2 Variety

Since malting barley varieties have been bred for a range of characteristics which tend to maximise the production of alcohol during brewing or distillation, growers should select a recognised variety of malting barley and one which is suitable for their location. It is often found that different varieties of barley need to be treated in different ways during malting to optimise their performance. It is therefore important that growers do not mix varieties together for malting or it will be difficult to produce a homogeneous malt. There are sometimes valid reasons, however, for not using recognised malting varieties – for example, where an old or heritage variety of cereal is being grown for a niche product. This is the case in Orkney where the Scottish landrace, Bere, is grown for both brewing and distilling although its malting characteristics compare very unfavourably with modern malting barley varieties.

Several countries publish lists of recommended malting barley varieties and, in some of the Northern Periphery regions, these lists may be useful in identifying varieties to grow. In other areas, however, the varieties listed are suited to more southerly areas or more continental climates and have not been tested under North Atlantic conditions. For each of the Northern Cereals project regions, the below paragraphs summarise information about national recommended lists of malting barley varieties.

Canada

In Canada, a list of recommended varieties is produced by the Canadian Malting Barley Technical Centre (CMBTC) (http://www.albertabarley.com/wp-content/uploads/2014/11/CMBTC-Recommended-Malting-Barley-Varieties-2015-16.pdf),

Iceland

The Agricultural University of Iceland publishes annually a list of recommended barley varieties for feed production. Varieties for malting have not been included, however, since these have seldom been grown specifically for this purpose in Iceland. However, a local brewery (http://www.olgerdin.is/en/) and a related microbrewery (http://www.borgbrugghus.is/) use small amounts of an early Icelandic variety, called ‘IS-Kria’, in a couple of their beers. The grain is treated with enzymes in order to make it fermentable. Experimental malting of ‘IS-Kria’ (700 kg) was carried out in an Icelandic project on barley for food. The malting was successful and the malt was used for small scale production of beer. Since then, malt has been produced from Icelandic barley on a laboratory scale. Low germination rates have been a problem with Icelandic barley and more testing is needed on the malting properties of locally grown barley.

Northern Norway

In Norway, the Norwegian Institute of Bioeconomy Research (NIBIO) is cooperating with Graminor Ltd., a plant breeding company, responsible for the development and testing of cereal varieties. Since 2012, the testing of varieties for malting has been carried out as part of ongoing projects. Testing has included old and newer varieties, some developed for malting, in relation to yield and other quality characteristics like time to maturity and malting quality. A number of varieties have proven suitable for malting. Although the Norwegian varieties are mainly 6-row barleys, one 2-row barley ‘Domen’ has been found suitable for the south of Norway. In general, the older cultivars have a lower yield, but the highest yielding of these are ‘Arve’, ‘Olsok’ and ‘Varde’. Generally, 2- row cultivars have higher yields and larger grains than 6-row cultivars. The best of the 2-row cultivars were ‘Marthe’ and ‘Quench’ and, of the newer varieties, ‘Quench’ had the best malting quality. In the northern part of Norway, varieties need to be early-maturing to ensure that they reach maturity in the very short growing season. Here, two of the most successful varieties have been ‘Tiril’ and ‘Arve’; both of these should be acceptable for malting.

Scotland

Scotland’s Rural College (SRUC) publishes, annually, a list of recommended varieties for brewing and distilling (http://www.sruc.ac.uk/downloads/file/2276/sruc_cereals_recommended_list_2015). This is based on a larger UK-wide list produced by the Home Grown Cereals Authority (HGCA) (http://cereals.ahdb.org.uk/media/537554/spring-barley-2015-v2.pdf). The SRUC list is the best available starting point for identifying varieties which may be useful in the north of Scotland and the Northern Isles (Orkney and Shetland). In trials on Orkney run by the Agronomy Institute, some of the varieties on the 2015 list have successfully reached grain maturity (e.g. ‘Moonshine’, ‘Concerto’, ‘Belgravia’). Nevertheless, it is thought that, over a longer time frame, earlier-maturing varieties are more likely to be reliably harvested because of the Northern Isles’ short growing season. Early-maturing varieties are not well-represented on the recommended list because they usually have lower yields than later varieties and this precludes them from becoming a recommended variety. Varieties which have been grown recently in Orkney for malting include the landrace ‘Bere’, ‘Golden Promise’ (a variety first released in the 1960’s) and ‘Tartan’ (a variety which was given provisional approval for distilling in 2007).

Where lists of recommended varieties are not available for specific parts of the North Atlantic region, it will be necessary for growers to carry out their own screening trials on a range of varieties before starting commercial growing. It would be preferable for this to be done in collaboration with regional cereal research centres. If this is done, agronomic characteristics like earliness of harvesting, disease resistance, lodging and grain yield should be considered as well as the grain quality characteristics described below. It would also be advisable to send grain samples of the different varieties for micro-malting analyses (see section 3.7).

2.3 Purchase Contracts

End-users normally specify the terms under which they will purchase malting barley in a formal contract with growers. The contract will usually cover most of the criteria described in later sections and, importantly, identifies factors which may cause the barley to be rejected for purchase. Typically the contract will specify:

- Purchase price at a specific grain moisture content
- Grain moisture content at delivery
- Grain nitrogen content and any premiums for low nitrogen or deductions for high nitrogen
- Maximum levels of screenings acceptable
- Germination % required
- Acceptable agrochemicals which can be applied to the crop. In the UK, these can only come from an approved list (http://www.ukmalt.com/pesticides)
- Barley variety to be grown
- Payment terms
- Conditions of crop rejection

2.4 Regulations Concerning Movement of Grain Off-Farm

In some countries, movement of grain off-farm may require a grain passport which is designed to facilitate traceability and provide some assurance that the grain is safe and fit for purpose. In the UK, for example, grain passports are issued under farm quality assurance schemes and therefore provide the end-user with some assurance that the crop has been grown in an approved way. The passport also covers the hygiene of the vehicle transporting the grain and requires any post-harvest treatment of the grain to be specified.

3 Grain Quality Criteria

3.1 Visual Evaluation

A visual assessment of grain is often the first step that an end-user will take in determining the suitability of a barley sample for malting. Although it is a non-quantitative method, it can still provide a very useful quick assessment of barley quality when carried out by trained, experienced staff. Barley for malting should be visually bright, free from disease and fully matured. Samples should also be free of insects, weed seeds, ergot and should not have smells of mould or other contaminants. Photographs of a range of undesirable grain conditions can be seen at http://www.ukmalt.com/reasons-rejection . If a visual assessment of barley is favourable, the barley will then be analysed against the criteria mentioned below.

3.2 Viability And Germination

In order for barley to be made into malt it has to be viable and to have reached the stage where it will germinate readily. A tetrazolium test on the cut grains (http://www.ukmalt.com/barley-requirements) provides a rapid test for grain viability and is normally carried out before malting barley is purchased. Usually, in the UK, at least 98 % of the grains are required to be viable to be acceptable for malting. Tests are also normally carried out for germination to determine the stage at which grains are ready for malting; this is discussed further below.

Viability

Poor viability of grains may be caused by either field or post-harvest factors.

The most likely field-related causes of poor viability are:

- *Pre-germination of grains* caused by wet conditions at harvest or harvesting too late. Lodged crops are particularly susceptible to pre-germination because they take a long time to dry out after rain.
- *Immaturity of barley at harvest.* This may result when a variety is grown in a growing season which is not sufficiently long and may reflect a poor choice of variety, a poor growing season or both. It could also result from late planting.
- *Frost damage.* This may occur if sowing is late or if early frosts occur before harvest.
- *Peeled ("skinned") and broken grains.* Both of these conditions may be caused by excessive handling of grain but are most commonly caused by incorrect combine settings. Usually, there is a requirement for there to be no more than 2-5 % broken grains in a sample of malting barley (HGCA, 2003; Canadian Malting Barley Technical Centre, 2012)

Post-harvest factors affecting viability include the following:

- *Inadequate grain drying.* For safe storage, the moisture content of grain needs to be reduced to about 12-13 % after harvest and so cereals grown in northern areas require drying if they are to be used for malting. If grain is not dried adequately, areas of high moisture content may develop during prolonged storage which can result in grain overheating and the development of moulds and associated toxins or storage pests. All of these factors can have an adverse effect on the quality or acceptability of grain for malting and also on its viability.
- *Excessively high drying temperature.* Another very important factor during drying is the temperature at which this is done since high drying temperatures can kill the grain. There is an important distinction between the air temperature within the dryer and the grain temperature. Air temperature is sometimes referred to as plenum temperature and is usually shown by a dial on the side of the dryer. Most dryers also show grain temperature which is measured by a probe. Although there appears to be a divergence of opinion on the recommended temperature for drying malted barley, most recommendations advise dryer operators to refer to their dryer's operator manual for specific settings. For the batch dryer (Master 120 D) used by the Agronomy Institute in Orkney a grain temperature range of 35-38 ^{o}C is recommended during drying. In Western Australia, the optimal and maximum grain temperature for malting/seed barley is considered to be 40 ^{o}C and 43 ^{o}C, respectively (CBH Group and South East Premium Wheat Growers Association, 2006), but this may be because the grain is harvested with a lower moisture content than in northern Europe. If a dryer does not display grain temperature, this can be checked by collecting a grain sample from the dryer and measuring its temperature with a thermometer (CBH Group and South East Premium Wheat Growers Association, 2006). After drying with hot air, it is very important to allow a period of cooling before the grain is stored. If using a batch dryer, this will mean continuing the circulation of the grain but without any heat.

Grain Dormancy

Most varieties of malting barley exhibit some degree of dormancy after harvest (Briggs, 1998). This has been bred into modern varieties to reduce the risk of grain germinating in the head prior to harvest (pre-germination). After harvest, dormancy gradually declines over the winter. Although the loss of dormancy can be artificially hastened by warm storage conditions, often the barley is simply stored, and not malted until dormancy declines to an acceptable level. In the Northern Cereals project region, this means that growers, or the end-users with whom they are collaborating, will need to provide grain storage facilities for their malting barley for several months.

Germination tests are usually carried out on replicated 100-grain samples in petri dishes with i) 4 ml and ii) 8 ml of water. The difference between % grain viability (measured by a tetrazolium test) and the germination % with the 4 ml water test provides a measure of dormancy while the difference in germination % between the 4 ml and 8 ml test provides a measure of the grain's "water sensitivity" which is another aspect of dormancy (Briggs, 1998). In the early stages of grain storage, there is often a much higher germination % in the 4 ml test than in the 8 ml test which is related to the presence of excess water around the grain and possibly to the failure of oxygen reaching the embryo. Water sensitivity declines with storage and malting is usually delayed until the % germination in the two tests is similar.

3.3 Grain Nitrogen And Protein

Grain nitrogen analyses are used as a measure of the amount of crude protein in the grain which is calculated from the nitrogen content by multiplying it by 6.25. For malting barley, a low % grain protein is preferred because this means a higher % of carbohydrate and therefore, most importantly, a higher alcohol yield on fermentation. A lower level of grain protein is generally required for distilling than for brewing and the following are typical requirements in the UK (http://www.ukmalt.com/barley-requirements):

Distilling – the optimum is considered 1.50 % nitrogen (9.4 % crude protein), but grain is usually accepted up to 1.65 % nitrogen (10.3 % crude protein).

Brewing (ales/beer) – 1.60-1.75 % nitrogen (10.0-10.9 % crude protein)

Export brewing (especially for lager beers) – 1.70-1.85 % nitrogen (10.8-11.6 % crude protein)

Higher grain nitrogen is required for brewing to match the needs of the types of yeast used in brewing and also, especially in lager beers, to produce additional enzymes to break down starch in non-malt additives which may be included in the mash.

Provided a recommended modern variety of malting barley is grown, the main factors affecting grain nitrogen content are likely to be field conditions, growing practices and the growing season. Some of these factors are considered below

Field conditions

With malting barley in Orkney, high grain nitrogen has been associated with high levels of available soil nitrogen. This is particularly high in fields which have just come out of grass and, to allow for this, considerably reduced levels of nitrogen fertiliser are usually applied to such fields for the first 2-3 years to prevent grain nitrogen levels from rising excessively. Approximate rates currently used are 25-30 kg/ha N for the first couple of years after ploughing out of grass, rising to about 40-50 kg/ha of N by about the fourth year. Differences have also been found in Orkney between soils with a high % of sand (>50%) and those with a lower % (<30%). On soils with the lower % sand, grain nitrogen seems to increase more rapidly in response to the application of nitrogen fertiliser and consequently smaller amounts of fertiliser nitrogen are applied on these soils. In Orkney, there appears to be a delicate balance, especially on heavier land, between the amount of fertiliser nitrogen (organic or inorganic) which will produce a reasonable grain yield and the amount which results in excessively high levels of grain nitrogen.

Growing practices

In the UK, high grain nitrogen has been associated with late planting of spring barley (HGCA, 1998/9) and with nitrogen top-dressing. In the north of Scotland, however, the earliest possible planting is still "late" in comparison with more favoured areas, making it particularly important to plant as early as possible. Low plant populations which can result from low seed rates or poor establishment may also give rise to increased levels of grain nitrogen (HGCA, 2003).

Growing season

Variations in grain nitrogen are seen between years. Higher than usual grain nitrogen levels have often been associated with years when the crop is subject to heat or water stress during grain filling.

3.4 Grain Size

Plump grains give a higher alcohol yield than small grains and malting barley is usually tested for size by passing it over a 2.5 mm screen. Standards vary from country to country, but in Scotland it is expected that a sample of barley for malting should have no more than 10% of grains by weight passing through the screen ("screenings").

Screenings are affected by a number of field factors and tend to be increased particularly by high levels of fertiliser or conditions which restrict grain filling (e.g. drought or disease). The use of fungicide therefore often helps to reduce screenings. Six-row barley varieties produce smaller grains than two-row varieties and so will also have a higher proportion of screenings. Although six-row varieties are not often used for malting in Europe, they are much more common in North America (http://www.probrewer.com/library/malt/a-comparison-of-north-american-two-row-and-six-row-malting-barley/).

3.5 Mycotoxins

Mycotoxins are toxic chemicals which can be produced by a wide range of fungi, including species of *Fusarium, Aspergillus and Penicillium*. Since malting barley is entering the food chain, it is important that it is not contaminated by mycotoxins. Currently, the mycotoxins of greatest potential concern are Aflatoxins (AFs), Ochratoxin A (OTA) and several toxins derived from *Fusarium* spp (DON, NIV, ZEA, T-2 and HT-2). Legal limits or indicative levels for these mycotoxins have been set by the European Union (European Union Commission Regulation No. 1881/2006 and Commission Recommendation 2013/165/EU). In the UK, the occurrence and levels of these mycotoxins in malting barley is assessed by a series of annual surveys of grain samples provided by members of the Maltster's Association of Great Britain (MAGB, http://www.ukmalt.com/mycotoxins).

Mycotoxin-producing fungi often develop under poor storage conditions, especially when grain moisture increases. The presence of damp grain often gives a characteristic mouldy smell to cereals and any barley samples with this smell are usually rejected by malting companies.

Contamination of grain with mycotoxins may occur in the field or during storage. The most serious field problems are caused by a range of *Fusarium* species which are associated with Fusarium Head Blight (FHB). The occurrence of this disease varies from year to year, probably as a result of weather-related factors, and it is thought that reduced tillage systems help the disease to overwinter on crop debris. Another possible source of inoculum could be seed, if fungicide-treated seed is not used. While some varieties are recognised as having more resistance than others to FHB, control strategies in the field are poorly developed with, for example, conflicting reports about the value of the application of fungicide.

It is recognised that grain storage is the key post-harvest stage in the development of mycotoxins (Latila, 2015) as moisture is the main factor determining growth of the fungi which produce them. Grain should be dried immediately after harvest, and for prolonged storage it should be dried down to <13% moisture. During storage, grain moisture should be checked periodically to verify that it has not risen excessively – this should not happen if the grain has been dried well initially and storage conditions are cool and dry. Grain store sanitation is also important and, after emptying stores, they should be cleaned of crop debris and dust to reduce the carry-over of mycotoxin producing fungi and periodically fumigated to control storage insects and mites which can spread these fungi and create suitable growing conditions for them (HGCA, 2011).

3.6 Glycosidic Nitrile And Ethyl Carbamate

Ethyl carbamate (EC) is a compound which may occur naturally in fermented foods and beverages, including spirits and beer (EFSA, 2007). As a probable human carcinogen, some national Governments have set upper limits for their occurrence in beverages. In distilled spirits, one of the main precursors of EC is epiheterodendron (EPH), a glycosidic nitrile (GN). Considerable research by the Scottish whisky industry has identified several ways to reduce the occurrence of EPH. Probably the most important of these is the recognition that some barley varieties do not produce EPH precursors. Consequently, the Scottish whisky industry has now specified that all new barley varieties entering trials for distilling should be non-GN producing varieties (GN < 0.5 mg/tonne malt) (Bringhurst and Brosnan, 2014). It is likely that distillers in other countries may also require the adoption of such varieties.

3.7 Micro-malting

Before malting a large quantity of barley it is usual to assess its likely malting quality by malting a small sample (0.1-1.0 kg) using specialised micro-malting equipment. This can help to identify the optimum conditions which will be required for larger scale malting but also produces a sample of malt which can be analysed for important malt characteristics like extract, the amount of solubilised protein in the extract and the amount of enzymes in the malt (especially its diastatic power).

Micro-malting can also be used as a very useful tool for comparing different malting barley varieties and identifying those which will produce the best quality malt. This would be important for areas where malting barley is not commonly grown.

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