Journal of Cereal Science 74 (2017) 1–10

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

The agronomic performance and nutritional content of oat and barley varieties grown in a northern maritime environment depends on variety and growing conditions

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ARTICLE INFO

Article history:
Received 7 July 2016
Received in revised form
23 November 2016
Accepted 8 January 2017
Available online 10 January 2017

Keywords:
Nutritional content
Maritime environment
β-glucan
Variety

ABSTRACT

Warmer temperatures and increasing interest in high provenance food and drink products are creating new opportunities for cereal growing in northern Europe. Nevertheless, cultivation of oats and barley in these areas for malting and milling remains a challenge, primarily because of the weather, and there are few reports of their nutritional content from this region. In this study, trials in Orkney compared agronomic characteristics and nutritional content of recommended UK oat and barley varieties with Scandinavian varieties over three years. For a subset of varieties, nutritional content was compared with samples cultivated in more southerly sites. For Orkney, barley was considered a more suitable crop than oats because varieties matured earlier. In both crops, Scandinavian varieties matured earlier than UK varieties and some produced comparable yields. The range of values for macronutrients and minerals in oats and barley in Orkney were similar to those reported previously for other locations, but there were some significant differences attributable to variety and year. Compared with grain samples from more southerly locations, oats in Orkney had a significantly lower β-glucan and higher sodium content. The lower β-glucan may have resulted from higher rainfall and lower temperatures during the months of grain filling and maturation.

1. Introduction

Diets high in whole grain cereals are thought to be beneficial for health and several large scale epidemiological trials have shown their consumption to be associated with a reduction in the risk of type 2 diabetes, obesity, cardiovascular disease (CVD) and colorectal cancer (Murphy et al., 2012; Cho et al., 2013). The fibre component of cereals is thought to be largely responsible for these actions through a variety of mechanisms, including: reducing low density lipoprotein (LDL) cholesterol and blood pressure; influencing glucose homeostasis; increasing satiation from a meal; increasing faecal transit time and lowering the exposure of colonocytes to faecal mutagens and carcinogens; and providing the colonic microbiota with growth substrates to produce beneficial short chain fatty acid metabolites (Beck et al., 2009; Othman et al., 2011; Louis et al., 2014).

Both oats and barley are high in the soluble fibre (1-3)(1-4) β-D-glucan. Mixed link β-glucan has been shown to reduce LDL cholesterol and reduce the risk of CVD in clinical trials and currently has several endorsed health claims worldwide including the European Food Standards Agency (EFSA, 2006).

Barley and oats are both important crops in northern areas and their production in this region is likely to expand with the warmer growing seasons projected to occur as a result of climate change

Abbreviations: NDF, Neutral detergent fibre; TKW, housand kernel weight; β-glucan, (1-3)(1-4) β-D-glucan Mixed Link β-glucan; AHDB, Agriculture and Horticulture Development Board; EFSA, European Food Standards Agency; DEFRA, Department for Environment and Rural Affairs; ANOVA, Analysis of variance.

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http://dx.doi.org/10.1016/j.jcs.2017.01.005
0733-5210/

(Bindi and Olesen, 2011). Northern maritime areas, like Iceland, coastal Norway and parts of Scotland, are also likely to benefit from these effects, and recent years have seen considerable expansion of barley cultivation in Iceland (Martin, 2016). Nevertheless, growing barley and oats in such areas remains very challenging as gales and high winter rainfall often prevent the use of autumn-sown varieties, while high soil moisture or frozen ground delays cultivation and the planting of spring crops. With cool growing seasons and the risk of high rainfall at harvest, these areas have a particular requirement for early maturing varieties, especially if fully mature, dry grain is required for milling or malting.

Located about 10 km off the north coast of Scotland, the Orkney archipelago has a hyper-oceanic climate (Crawford, 2000) and currently grows about 4500 ha of cereals. Most of this is feed barley for the local livestock industry, but the expanding market for high provenance food and drink products (Martin, 2016) has increased interest in local cereals for this purpose. Spring oat and barley varieties in the United Kingdom's (UK) lists of recommended varieties produced by the Agriculture and Horticulture Development Board (AHDB, 2016) show only a small variation in days to maturity. Consequently earlier maturing varieties sourced from Scandinavia are being tested in Orkney by the Agronomy Institute of the University of the Highlands and Islands (UHI).

The environment in which cereals are grown is known to affect their nutritional composition, and studies have found differences in the protein, fat and β-glucan content of oats and barley grown in different environments (Zhou et al., 1999; Redaelli et al., 2013). There are no detailed reports on the composition of oats and barley grown in hyper-oceanic climates like Orkney's. The present study reports the chemical composition and agronomic performance of early and later maturing varieties of oats and barley grown in Orkney between 2012 and 2014. For a subset of varieties, nutritional composition in Orkney was compared with that of the same varieties grown in more southerly parts of the UK.

2. Materials and methods

2.1. Orkney field trials

Six oat and six barley varieties were grown in separate trials over three consecutive growing seasons from 2012 to 2014. The trials were located at Orkney College UHI (58° 59′ N and 2° 57′ W) on sandy loam soil. Trials used a randomised block design with five replicates. Barley varieties included Bere (an early maturing Scottish landrace), three Scandinavian varieties obtained from Lantmännen SW Seed AB (Vilde, Kannas and Vilgott), and two recommended (AHDB, 2016) UK varieties (Waggon for feed and Concerto for malting). Oat varieties included three Scandinavian varieties from Lantmännen SW Seed AB (Haga, Belinda, and Betania) and two recommended (AHDB, 2016) UK varieties (Firth and Canyon) and Lennon, a naked oat. Varieties were planted in plots 20 m long and 3 m wide with a plant population of 350 plants m^{-2} for barley and 400 plants m^{-2} for oats. Fertilizer was applied to both cereals at planting each year; oats received 50–60 kg ha^{-1} yr^{-1} of nitrogen and phosphorus (as P_2O_5) and 67–91 kg ha^{-1} yr^{-1} of potassium (as K_2O); barley received 65 kg ha^{-1} yr^{-1} of nitrogen and phosphorus (as P_2O_5) and 87–105 kg ha^{-1} yr^{-1} of potassium (as K_2O). The planting dates and inputs used are specified in Supplementary Table S1. Varieties were harvested when they reached senescence and usually when grain moisture content was below 25%. Plots were harvested with a Sampo combine with 2.3 m cutter bar and the weight of grain per plot measured. An 800 g sample of grain was collected from each plot and a 200 g subsample from this was used for determining grain moisture and thousand kernel weight (TKW) which was determined with a seed counter (Contador). TKW is often used as an indicator of grain quality in both barley and oats; in barley, it is correlated with grain plumpness and is a good indicator of starch in the kernel (Newman and Newman, 2008). The remaining 600 g sample was dried in an oven for 48 h at 35 °C and retained for the nutritional analyses. Grain yield (t ha^{-1}) per plot was calculated at 15% moisture content from the fresh weight of grain harvested and the laboratory determinations of grain moisture. Poor weather resulted in lodging of oats in the 2012 harvest and only Haga could be machine-harvested; all other varieties were hand-harvested to obtain samples for analysis.

One composite soil sample was collected from each of the oat and barley trials in February 2012, 2013 and 2014 and consisted of the mixed soil from 8 cores (0–30 cm depth). Samples were analysed by NRM laboratories (Bracknell, England) and results are summarised in Supplementary Table S2. Data for precipitation and temperature during each growing season were obtained for Kirkwall airport, about 6 km from the trial site from http://en.tutiempo.net/climate/europe.html and are summarised in Supplementary Table S3.

2.2. Other field trials

In additional trials in the same growing seasons, two recommended UK (AHDB, 2016) barley varieties (Waggon and Concerto) were grown by the James Hutton Institute at Balruddery near Dundee in Scotland (56° 28′N and 3° 4′W), and three recommended UK (AHDB, 2016) oat varieties (Lennon, Firth and Canyon) were grown by Aberystwyth University in Wales at Morfa (52° 54′N and 4° 32′W) and in the north of England at Berwick-upon-Tweed (55° 45′N and -2° 0′W). Weather data for Dundee were obtained from an automatic weather station at the trial site and for the other sites from the closest stations listed in the TuTiempo.net database (http://en.tutiempo.net/climate/europe.html). These sites were Gogarbank for Berwick-upon-Tweed and Aberporth for Morfa. For each site, total rainfall and degree days were calculated from the date of planting to that of harvesting. Degree days were calculated from each day's average temperature using a base temperature of 0 °C. From each site, a 100 g grain sample was obtained from each variety and used for the nutritional analyses.

2.3. Processing of oat and barley samples

Oat and barley grains of all varieties were processed in the same way and were first heat-treated to deactivate endogenous lipase and β-glucanase enzymes. Samples were placed in uncovered containers and steamed in an autoclave for 10 min and then incubated at room temperature for 48 h to allow moisture to equilibrate. They were then dehulled for 30 s using a laboratory thresher (Streckel and Schrader, Hamburg, Germany) and barley underwent a second dehulling to replicate pearling. After a 15 min cooling period, samples were milled into a fine flour using a freeze mill (Spex, Certi Prep 6800 Freeze Mill). Milling consisted of 2 min of milling followed by a 2 min cooling period and a final 2 min milling period. Flours were then stored refrigerated between 2 and 8 °C and analyses were completed within 6 months.

2.4. Nutritional analyses

2.4.1. Macronutrient analysis by near-infrared reflectance spectroscopy (NIRS)

Compositional analysis (Ash, Lipid, Protein, Starch, Sugar and fibre as Neutral Detergent Fibre (NDF)) was carried out at the Royal Zoological Society of Scotland (Edinburgh) using near-infrared spectroscopy (NIRS). Each flour sample was analysed in triplicate