Field Crops Research 179 (2015) 95–102

Contents lists available at ScienceDirect

Field Crops Research

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

Evaluation of common and durum wheat rheological quality through Mixolab® analysis after field damage by cereal bugs

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ARTICLE INFO

Article history:
Received 27 February 2015
Received in revised form 23 April 2015
Accepted 24 April 2015

Keywords:
Common wheat
Durum wheat
Proteins
Gluten
Eurygaster maura

ABSTRACT

The pre-harvest damage of wheat by sunn pests decreases flour quality. Mixolab® is a recent instrument that can be used to accurately describe the technological behaviour of flour dough, since it is able to evaluate both protein and starch components at the same time. Two-year field experiments were carried out to study the effect of *Eurygaster maura* (Heteroptera: Scutelleridae) feeding on the quality traits of common and durum wheat, recorded using different protocols, in comparison to the traditional sodium dodecyl sulphate sedimentation test (SSV). In 2012–13 growing season, a damage rate between 16% and 21% of damaged kernels led to a greater reduction in dough stability for common (−65%) than for durum wheat (−32%), while the protein strength was affected more by insect activity in durum wheat (−56%). In 2013–14 growing season, *E. maura* feeding (on average 32% of damaged kernels) reduced SSV by 5% and 66%, dough stability by 12% and 30%, and protein strength by 12% and 16%, for common and durum wheat, respectively. The increasing percentages of damaged kernels in both crops led to a clear decrease in dough stability and protein strength; a significant change in the rheological parameters was noticeable at a 2.5% level of damaged kernels. SSV resulted to be significantly correlated to Mixolab® dough stability, the protein strength, the protein network wakening rate (α) and Change in Mixolab Consistency (CMC, "Wheatbug" protocol) for both common and durum wheat. Therefore, Mixolab® can be considered a suitable tool for a quick detection of damage caused by sunn pests in common and durum wheat flour.

1. Introduction

Grain protein content (GPC) and gluten quality are key traits that influence the end-use of wheat market classes throughout the world (Foca et al., 2007). High levels of proteins as well as gluten quantity and strength are the predominant factors associated with superior bread- and pasta-making quality. Therefore, these traits are desirable for the marketability of both common and durum wheat in several supply chains (Brown and Petrie, 2006; Kovacs et al., 1997). Although the environmental conditions and the genotype, i.e. the choice of variety, are fundamental for the technological behaviour of the derived dough, the agricultural practices, and in particular nitrogen nutrition, also influence the flour quality to a greater extent.

Considerable modifications of wheat quality can also be produced by several species of insects, in particular cereal bugs, which are also known as sunn pests, belonging to Scutelleridae (shield-backed bugs) and Pentatomidae (stink bugs) (Critchley, 1998). *Eurygaster maura* (L.) (Heteroptera: Scutelleridae) is the most noxious species in western Europe, in terms of reduction in grain quality (Pansa et al., 2015; Vaccino et al., 2006). Sunn pests feed on wheat during the different stages of developing grains; in case of early attacks, the damage mainly concerns losses in kernel weight and consequently in grain yield; late attacks during the grain filling period, which are more frequent, lead to a reduction in technological quality. In this case, the insects suck the milky nutrients from the immature grain by piercing it and injecting proteolytic enzymes, via their saliva, which persist in the flour after milling and cause the breakdown of the gluten structure in the

Abbreviations: CMC, Change in Mixolab Consistency; DDT, dough development time; GPC, grain protein content; GS, growth stage; SSV, sodium dodecyl sulphate sedimentation volume; WA, water absorption.

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http://dx.doi.org/10.1016/j.fcr.2015.04.014
0378-4290/

dough (Olanca et al., 2009). Thus, the rheological properties of the dough obtained from bug-damaged wheat are characterized by lower farinographic development time and stability, lower alveographic strength, tenacity and extensibility, and a lower gluten index (Karababa and Ozan, 1998).

In the case of common wheat, the result is the production of bread with poor volume and texture (Aja et al., 2004; Pérez et al., 2005), while in the case of durum wheat, bug damage can negatively affect the cooking potential, especially in varieties with poor gluten quality (Petrova, 2002). Ozderen et al. (2008) have demonstrated that the semolina properties and spaghetti quality of durum flour obtained from bug-damaged wheat decreased significantly as the damage levels increased. Although there are several reports on the effects of bug damage on common wheat in the literature, limited information is available related to its effects on durum wheat, and in particular a direct field comparison of the bug feeding effect on both crops is missing.

The relevant reduction in technological quality of both common and durum wheat underlines the necessity of bug damage control before batch processing. The practical tolerance for bug-damaged kernels in industry, regardless of the wheat type (common or durum) or variety, is 2–3% (Canhilal et al., 2006). The damage caused by sunn pests can be detected through a visual inspection of the kernels which are characterized by a discoloured halo around the stylet penetration point (Critchley, 1998). Unfortunately, visual damage detection is often not completely reliable, since it is strongly related to the operator's experience and sensitivity. Moreover, similar symptoms can be sometimes due to the activity of pathogens or the abnormal starch deposition. As a consequence, visual inspection should be associated with complex biochemical analyses which assess protein degradation due to insect attack, such as reverse-phase or size-exclusion high performance liquid chromatography and free zone capillary or gel electrophoresis (Sivri et al., 1999; Aja et al., 2004; Rosell et al., 2002a; Vaccino et al., 2006).

At the technological level, one of the most specific methods to detect bug damage on grains and flour is the sodium dodecyl sulphate sedimentation volume test (SSV) proposed by Every (1992).

According to the European ISO605 and the United States Department of Agriculture (USDA) standards, the food supply chain requires practical and reliable screening procedures in order to ensure the technological quality and marketability of wheat kernels and flour. Mixolab® (Chopin Technologies, Villeneuve la Garenne, France) is a recent instrument that is used to determine the rheological quality of flour and to more accurately describe its behaviour during bread making. This device provides, in one single test, a complex analysis of the rheological properties of wheat flour dough, considering dough behaviour during mixing, protein coagulation, heating-up behaviour at enzyme activity intensification, and starch gelatinization and retrogradation during the final cooling. The instrument has also proved useful to analyze the quality of durum wheat (Moscaritolo et al., 2008). Kahraman and Köksel (2013a) have recently suggested a new and specific Mixolab® analytical protocol to estimate bug damage in flour.

The aims of this study were to make the direct field comparison of the bug feeding effect on both common and durum wheat and to evaluate the potential of Mixolab® to detect bug damage on the two crops considering different analysis protocols.

2. Material and methods

2.1. Agronomic information

Field trials were carried out in Carignano, Piedmont, NW Italy (44°53′8.69″ N, 7°41′16.75″ E, 232 m a.s.l.), in a medium-texture fertile soil, during the 2012–13 and 2013–14 growing seasons. Common and durum wheat were cultivated side by side in the same field, according to the normal crop management programme applied to wheat in the growing area.

The common wheat cultivars were Generale (Consorzio nazionale sementi, Conselice, RA, Italy) in 2012–13 and Arrocco (Limagrain Italia S.p.A., Busseto, PR, Italy) in 2013–14, which are classified, according to the Italian bread-making quality grade (Foca et al., 2007), as superior bread making-quality wheat. The durum wheat cultivars were Colombo (Apsovsementi S.p.A., Voghera, PV, Italy) in 2012–13 and Saragolla (Produttori Sementi Bologna S.p.A., Argelato, BO, Italy) in 2013–14, which are classified as high quality wheat. Planting was conducted in 12 cm wide rows at a seeding rate of 450 seeds m^{-2} on the last decade of October. The previous crop was maize for grain every growing season. The weed control was conducted with isoproturon and diflufenican at wheat tillering (growth stage, GS 23; Zadoks et al., 1974), while fungicide treatments were performed to avoid the development of foliar and head fungal diseases at stem elongation (GS 35, a.i. azoxystrobin and cyproconazole applied at 0.2 kg ha^{-1} and 0.08 kg ha^{-1}, respectively) and at heading (GS 58, a.i. prothioconazole applied at 0.250 kg ha^{-1}). A total of 170 kg N ha^{-1} was applied as a granular ammonium nitrate fertilizer, split 50 kg N ha^{-1} at wheat tillering (GS 23), 80 kg N ha^{-1} at stem elongation (GS 32) and 40 kg N ha^{-1} at booting (GS 46).

2.2. Collection and rearing of cereal bugs

During spring 2013 and 2014, large quantities of *E. maura* were collected in several wheat fields in Piedmont, and transferred to laboratories. There, they were reared on kernels and small wheat plants inside 3 L plastic boxes. The lid of these boxes (265 mm × 175 mm) was cut in the middle and closed with a net. Mass rearing was conducted in climatic chambers maintained at 25 ± 1 °C, 70 ± 5% RH and a 16L:8D photoperiod.

2.3. Exposure of wheat to bug feeding

Two parallel experiments were performed in order to evaluate the effects of bug feeding on common and durum wheat quality. These experiments involved comparing the rheological parameters of the flour derived from: (i) grain samples obtained in the presence or absence of *E. maura* in field conditions (first experiment); (ii) grain samples with different percentages of bug-damaged kernels (second experiment).

The first experiment was conducted during two growing seasons using large net cages (4 m × 4 m × 3.5 m) which were placed at early milk stage (GS 73) for both crops, after a careful check for the absence of bugs. Two treatments, that are the presence of *E. maura* and control without insects, and three replications for each treatment and crop were performed according to a completely randomized experimental design. In 2013, 48 individuals (i.e., 3 individuals m^{-2}) were introduced into each cage and left until the end of wheat ripening (July 2). In 2014, 45 individuals were introduced into each cage and left until the end of wheat ripening (July 1). At this stage, in both years, all the bugs were removed and recorded through an accurate inspection of the cage contents.

On July 22, 2013 and July 11, 2014, the grain was obtained by harvesting with a Walter Wintersteiger cereal plot combine-harvester, and 2 kg grain samples were taken from each cage for the qualitative analyses. Damaged kernels, i.e. the percentage of seeds showing, on visual inspection, the typical discoloured area around the point of bug stylet penetration, were determined on three 100-kernel randomly selected samples for each treatment and replication.

In the second experiment, carried out in 2012–13 growing season, white sleeve polythene fine mesh net cages were positioned