Journal of Integrative Agriculture 2016, 15(10): 2203–2214

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Characterization of A- and B-type starch granules in Chinese wheat cultivars

ZHANG Yan[1], GUO Qi[1], FENG Nan[1], WANG Jin-rong[2], WANG Shu-jun[2], HE Zhong-hu[1, 3]

[1] *Institute of Crop Science/National Wheat Improvement Center, Chinese Academy of Agricultural Sciences, Beijing 100081, P.R.China*

[2] *Key Laboratory of Food Nutrition and Safety, Ministry of Education/Tianjin University of Science & Technology, Tianjin 300457, P.R.China*

[3] *International Maize and Wheat Improvement Center (CIMMYT) China Office, Beijing 100081, P.R.China*

Abstract

Starch is the major component of wheat flour and serves as a multifunctional ingredient in food industry. The objective of the present study was to investigate starch granule size distribution of Chinese wheat cultivars, and to compare structure and functionality of starches in four leading cultivars Zhongmai 175, CA12092, Lunxuan 987, and Zhongyou 206. A wide variation in volume percentages of A- and B-type starch granules among genotypes was observed. Volume percentages of A- and B-type granules had ranges of 68.4–88.9% and 9.7–27.9% in the first cropping seasons, 74.1–90.1% and 7.2–25.3% in the second. Wheat cultivars with higher volume percentages of A- and B-type granules could serve as parents in breeding program for selecting high and low amylose wheat cultivars, respectively. In comparison with the B-type starch granules, the A-type granules starch showed difference in three aspects: (1) higher amount of ordered short-range structure and a lower relative crystallinity, (2) higher gelatinization onset (T_o) temperatures and enthalpies (ΔH), and lower gelatinization conclusion temperatures (T_c), (3) greater peak, though, and final viscosity, and lower breakdown viscosity and pasting temperature. It provides important information for breeders to develop potentially useful cultivars with particular functional properties of their starches suited to specific applications.

Keywords: bread wheat, A- and B-type starch granules, short-range molecular order, relative crystallinity, gelatinization and pasting properties

1. Introduction

Starch is the major component of wheat flour and serves as a multifunctional ingredient in food industry. Starch occurs as granules in the endosperm of wheat grain. The granule shape, size and its hierarchical structure are important determinants of starch functionality (Lindeboom *et al*. 2004; Park *et al*. 2004). Wheat starch consists of two distinct forms of granules: A- and B-type granules. The A-type starch granules are disk-like or lenticular in shape with a

Received 29 September, 2015 Accepted 20 January, 2016
Correspondence HE Zhong-hu, Tel: +86-10-82108547, E-mail: zhhecaas@163.com; WANG Shu-jun, Tel: +86-22-60912486, E-mail: sjwang@tust.edu.cn

doi: 10.1016/S2095-3119(15)61305-3

diameter of >10 μm, while the B-type starch granules are less than 10 μm in diameter and spherical or polygonal in shape (Vermeylen *et al*. 2005; Ao and Jane 2007; Kim and Huber 2008; Wang *et al*. 2014). In wheat, A-type granules contribute to more than 70% total weight of the starch (Bechtel *et al*. 1990; Peng *et al*. 1999; Shinde *et al*. 2003), whereas B-type granules comprise up to 90% of granules in number (Raeker *et al*. 1998).

The proportions of B- and A-starch granules, by weight, volume and number, differ among genotypes (Raeker *et al*. 1998; Li *et al*. 2001). A wide range of variation (17–50%) for B-starch granule volume was observed in bread wheat, suggesting possibilities of genetic manipulation of granule size distribution (Stoddard 1999). The B-granules occupied volumes in a range of 28.5–56.2% for hard red winter and hard red spring wheat (Park *et al*. 2009). The volume percentages of A- and B-type starch granules were 52.7–65.5% and 34.5–47.3% in seven Chinese wheat cultivars (Dai *et al*. 2009). In several studies, environmental stress such as temperature (Liu *et al*. 2011), water deficit (Dai *et al*. 2009; Zhang *et al*. 2010), nutrient supplementation (Ni *et al*. 2012; Li *et al*. 2013), and light intensity (Li *et al*. 2010) significantly changed starch granule size distribution and amylose content in wheat.

Wheat starch A- and B-type granules differ in composition, chain length distribution of amylopectin, relative crystallinity, microstructure (e.g., surface pores, channels, cavities), and they have been summarized in details (Soulaka and Morrison 1985; Fortuna *et al*. 2000; Chiotelli and Le Meste 2002; Bertolini *et al*. 2003; Shinde *et al*. 2003; Van Hung and Morita 2005; Geera *et al*. 2006; Kim and Huber 2008; Kim 2009; Salman *et al*. 2009). The differences in these structural characteristics lead to variations in swelling, gelatinization, retrogradation and pasting properties of the two types of starch granules (Eliasson and Kaelsson 1983; Fortuna *et al*. 2000; Chiotelli and Le Meste 2002; Shinde *et al*. 2003; Geera *et al*. 2006; Soh *et al*. 2006; Kim 2009). A-type granules have higher gelatinization enthalpy, amylose content, pasting parameters such as peak, trough, breakdown, final and setback viscosities, and lower gelatinization onset and peak temperatures, whereas B-type granules have higher lipid-complexed amylose content and swelling power, broader gelatinization ranges, and lower gelatinization enthalpy (Sahlström *et al*. 2003; Geera *et al*. 2006; Soh *et al*. 2006; Kim and Huber 2010a; Yin *et al*. 2012). Shinde *et al*. (2003) and Soh *et al*. (2006) observed that peak and final viscosities of wheat starch reduced with increasing proportion of B-type granules. Thus, the proportion of A- and B-type granules impacts wheat starch structural characteristics and functional properties. However, there are yet inconsistent reports on amylopectin chain-length distribution, relative crystallinity, and microstructure of A- and B-type wheat starch granules (Vermeylen *et al*. 2005; Liu *et al*. 2007; Salman *et al*. 2009). Much of this inconsistency is likely attributable to the different genotypes used in previous reports. In addition, there are very little information available on amylopectin chain-length distribution, relative crystallinity and microstructure of A- and B-type starch granules in Chinese cultivars.

The objective of the present study was to investigate starch granule size distribution in Chinese wheat cultivars, and to assess A- and B-type starch granule characteristics of four leading cultivars in morphology, amylose content, chain length distribution of amylopectin, short-range molecular order, relative crystallinity, and gelatinization and pasting properties. The results of this study will help breeders to develop potentially useful cultivars with particular functional properties of their starches suited to specific applications.

2. Materials and methods

2.1. Experimental materials

A total of 345 Chinese leading cultivars and advanced lines, including 66 from the Northern China Plain zone, 251 from the Yellow and Huai Valley zone, 12 from the middle and low Yangtze Valley zone, 3 from the southwestern China zone, and 13 introductions from other countries were grown in Anyang, Henan Province in two seasons, including 245 and 208 genotypes in 2010–2011 and 2011–2012 cropping seasons, respectively. Only 108 genotypes were grown in two consecutive cropping seasons. They were used to determine the distribution of A- and B-type starch granules. Among them, four leading cultivars Zhongmai 175, CA12092, Lunxuan 987, and Zhongyou 206 collected from the same field in 2012–2013 season in Beijing were used to analyze morphology, amylose content, chain length distribution of amylopectin, short-range molecular order, relative crystallinity, and gelatinization and pasting properties of the A- and B-type starch granules. Zhongmai 175, Lunxuan 987 and Zhongyou 206 have been released in the Northern China Plain zone, and CA12092 is an advanced line currently including in the regional yield trials. Zhongmai 175 is characterized by high yielding potential and broad adaptation, soft kernel, excellent noodle, and steamed bread qualities, and is currently a leading cultivar and also serves as a check cultivar in the regional yield trials. Zhongyou 206 possessed hard kernel, strong gluten and excellent breadmaking quality. CA12092 and Lunxuan 987 showed high yielding potential and broad adaptation, hard kernel, but poor gluten quality, and averaged qualities for noodles and steamed bread.

2.2. Flour milling

Grain hardness was measured on 300-kernel sample with a