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Effects of heat stress during grain filling on the structure and thermal properties of waxy maize starch

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ABSTRACT

Clarifying the waxy maize starch physicochemical characteristics response to heat stress could modify starch quality. The effects of heat stress during grain filling (1–40 day after pollination) on starch structure and thermal properties of four waxy maize varieties were investigated. The mean day/night temperature during grain filling for heat stress and control treatments was 35.2/16.1 °C and 27.4/15.6 °C, respectively. Heat stress during grain filling increased the starch average granule size and the proportion of long chains in amylopectin. Starch granules under heat stress presented more pitting or uneven surfaces. X-ray peak intensities in response to heat stress were variety dependent. Heat stress during grain filling decreased the swelling power and increased the gelatinization temperature and retrogradation percentage, while the gelatinization enthalpy was not affected. In conclusion, heat stress during grain filling significantly affected structural characteristics of waxy maize starch and consequently, changed its swelling and thermal properties.

1. Introduction

Maize starch is the primary starch resource and accounts for the majority (80%) of the global market share (Jobling, 2004). Maize starch can be classified as waxy (0%), normal (∼25%), high amylose (50–70%), and sugary based on the amylose content (Singh, Inouchi, & Nishinari, 2006; Singh, Sandhu, & Kaur, 2005). Among them, waxy maize starch has high viscosity, low retrogradation tendency, and good clarity. Waxy maize starch is easy to digest and have advantages to produce stabilizer, thickener and adhesives, etc.

Temperature is an important environmental factor affecting maize yield and starch quality. Optimum temperature during maize grain filling is between 27 and 32 °C (Commuri & Jones, 1999). However, the growing temperature at this stage is often higher than 32 °C, which results in loss of grain yield especially in tropical and moderate zones (Cairns et al., 2012). The global temperature was predicted to increase by 1.8–4.0 °C at the end of this century (IPCC, 2007) and an increase of 2 °C could cause more than 10% maize yield lose (Lobell & Burke, 2010).

Heat stress not only decreases maize grain yield, but also changes starch quality. Lu, Jane, Keeling, and Singletary (1996) observed that heat stress from 15 days after pollination to maturity decreased the starch granule size, amylose content and short branch-chains and increased gelatinization temperature. Planting conditions and sowing dates were reportedly exerting significant effects on maize starch structure and properties (Lu, Guo, Dong, & Lu, 2010; Lu, Wang, Zhao, & Lu, 2009; Medic, Abendroth, Elmore, Blanco, & Jane, 2010). However, little is known on the effects of heat stress under controlled conditions on the structure and physicochemical properties of waxy maize starch. Starch quality variability necessitates continuous adjustments of many industrial processing parameters and carries over a potential quality control problem in various products (Lu et al., 1996). This study aimed to clarify the effects of heat stress during grain filling on the starch structural characteristics that may be related to the potential for variations in starch swelling and thermal properties of waxy maize

2. Materials and methods

2.1. Samples

Four genetically unrelated waxy maize varieties, Suyunuo5, Yunuo7, Lainongnuo11 and Huaikenuo3, were produced in Yangzhou University, Yangzhou, China. Seeds were sown on 1 July and transplanted to plastic pots on 5 July. Two plants were placed in each pot. One plant was retained at the jointing stage. Each plastic pot measured 42 cm in height and 38 cm in diameter and was loaded with 30 kg of sieved sandy loam soil. The plants were provided a basal dressing of 10 g per pot (commercial fertiliser, N:P_2O_5:K_2O = 15%:15%:15%) at transplanting and a top dressing of 6 g per pot (commercial urea, *N* concentration = 46%) at the jointing stage.

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Ten plants of each variety were grown in an environmentally controlled green house with a temperature about 35 °C from 6:00 to 18:00 after pollination to maturity (1–40 day after pollination), with plants grown in the natural environment were taken as control. Everyday from 18:00 to 6:00, the door and windows of the greenhouse were left open so that the indoor temperature during the night was the same as that outdoors. The average day/light temperature in the greenhouse was 35.2/16.1 °C. The outdoor condition was 27.4/15.6 °C.

2.2. Starch isolation

The plants were harvested at maturity (40 days after pollination). The grains (100 g) were steeped in 500 mL of distilled water containing 1 g/L sodium hydrogen sulfite (SO_2) for 48 h at room temperature. Starch was isolated following a method described previously (Lu & Lu, 2012). The samples were rinsed with distilled water, and then ground using a blender for 2.5 min. The suspensions were passed through a 100-mesh sieve. The materials left on the screen were again homogenised for 1.5 min, and then passed through the same sieve. The starch–protein slurry was collected in a 1000 mL wide-neck flask and allowed to stand for 4 h. The supernatant was removed through suction and the settled starch layer was collected in 50 mL centrifuge tubes and centrifuged at 3000*g* for 10 min. The upper non-white layer was scooped. The white layer was resuspended in distilled water and stirred for 30 min before centrifugation. The isolation procedures were repeated three times. The starch was then collected and dried in an oven at 40 °C for 48 h.

2.3. Granule morphology

Starch granules were mounted on circular aluminium stubs with double sticky tape, coated with gold, examined by scanning electron microscopy (SEM, XL-30 ESEM, Philips, Amsterdam, Netherlands) at an accelerating potential of 20 kV, and then photographed (Lu & Lu, 2012).

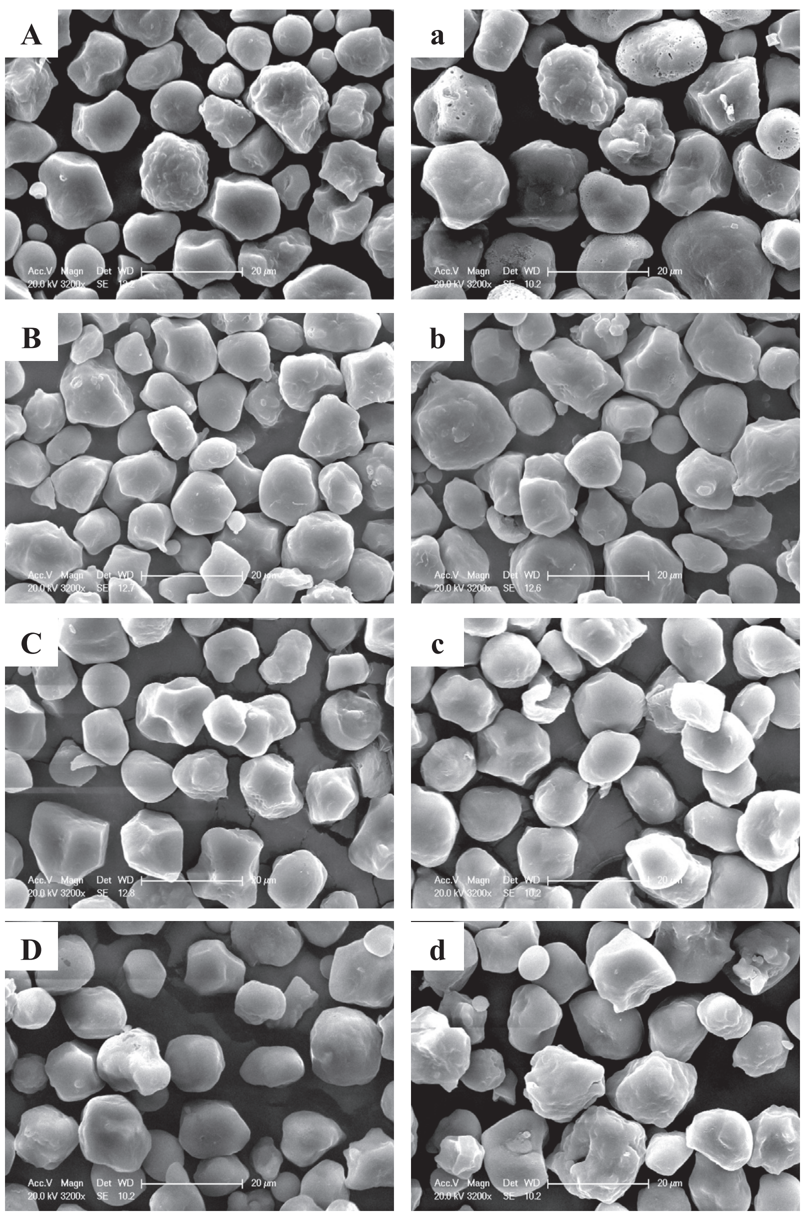

Fig. 1. A–D refer to Suyunuo5, Yunuo7, Lainongnuo11, and Huaikenuo3, respectively. Capital and lowercase alphabet are control and heat stress treatments, respectively. Effects of heat stress during grain filling on the morphology of waxy maize starch.