Food Chemistry 145 (2014) 756–764

Contents lists available at ScienceDirect

Food Chemistry

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

Physicochemical differences between sorghum starch and sorghum flour modified by heat-moisture treatment

Qingjie Sun *, Zhongjie Han, Li Wang, Liu Xiong

School of Food Science and Engineering, Qingdao Agricultural University, Qingdao, Shandong Province 266109, China

ARTICLE INFO

Article history:
Received 6 July 2013
Received in revised form 22 August 2013
Accepted 29 August 2013
Available online 7 September 2013

Keywords:
Heat-moisture treatment
Physicochemical properties
Sorghum starch
Sorghum flour

ABSTRACT

Sorghum starch and sorghum flour were modified by heat-moisture treatment (HMT) at two different moisture contents, 20% and 25%. The result showed that solubility and swelling power of modified samples decreased. In addition, the pasting viscosities of most modified samples were lower than that of native samples. The onset, peak and conclusion temperatures of gelatinization, and the enthalpy of samples modified by HMT increased. The crystallinity of the modified samples was higher than that of control samples. HMT had a far greater effect on the solubility, swelling power, setback viscosity, through viscosity, enthalpy and crystallinity of sorghum flour than of sorghum starch. On the granules surface there were more holes for the HMT starches than for HMT flours. The microstructure of HMT sorghum starch gel had a more orderly and smaller holey structure. The sorghum flour gel had originally a crackled structure, but after the HMT treatment, it had many ordered and small holes.

1. Introduction

Sorghum is an important grain crop. Like other cereals, sorghum is rich in starch (approximately 70%) and has excellent potential for global industrial applications (Singh, Chang, Lin, Singh, & Singh, 2011). Sorghum flour is produced either by dry or wet milling of sorghum grains whereas sorghum starch is generally obtained by the alkaline steeping method with multistage purification. This type of treatment results in a significant reduction of protein contents as well as other components in sorghum starch (Puncha-arnon & Uttapap, 2013).

Heat moisture treatment (HMT) is an important physical treatment method utilized to improve the poor functional properties of native starch and is particularly favourable for food applications. Moreover, there are no residual chemical reagents, therefore HMT is an environmentally friendly and low cost method for starch modification (Zavareze & Dias, 2011). Several studies have demonstrated that HMT significantly alters the molecular structure and physicochemical properties of chestnut corn, rice, potato, sorghum starches and early indica rice. The changes include the pasting characteristics, granule morphology, amylose leaching, swelling factor, starch chain length distribution, crystalline structure, enzyme hydrolysis, textural properties and thermal properties (Jiranuntakul, Puttanlek, Rungsardthong, Puncha-arnon, & Uttapap, 2011; Lee, Kim, Choi, & Moon, 2012; Singh et al., 2011; Sun, Wang, Liu, & Zhao, 2013; Yadav, Guleria, & Yadav, 2013). Singh et al. (2011) reported that heat moisture treated starches, as compared to native starch, showed lower granule sizes, swelling power, peak and setback viscosity, but higher retrogradation. In our recent study we reported that after HMT, the amylose content, pasting temperature and gel hardness of early indica rice increased. However, its peak viscosity, final viscosity, solubility and swelling power decreased significantly (Sun, Wang et al., 2013). Ahn et al. (2013) prepared slowly digestible sweet potato flour by HMT and studied the physicochemical properties of modified flour.

Khamthong and Lumdubwong (2012) presented in their study the effect of HMT on normal and waxy rice flours. They found that HMT changed the chemical composition and functional properties of both flours. Other researchers performed studies on the effect of HMT on the physicochemical properties of rice flour (Lorlowhakarn & Naivikul, 2007; Satmalee & Matsuki, 2011).

Sorghum flour provides a good basis for breads and other baked products such as pasta, cookies and snacks among other popular consumable goods. But in its native form, sorghum flour has

Abbreviations: HMT, heat moisture treatment; HMT-20, 20% content moisture HMT; HMT-25, 25% content moisture HMT; SOL, solubility; SP, swelling power; SS, sorghum starch; SF, sorghum flour; AC, amylose content; AAC, apparent amylose content; SAC, soluble amylose content; IAC, insoluble amylose content; RVA, rapid visco analyser; FV, final viscosity; PT, pasting temperature; PV, peak viscosity; SB, setback viscosity; TV, trough viscosity; DSC, differential scanning calorimetry; T_o, onset temperature; T_p, peak temperature; T_c, conclusion temperature; T_c–T_o, the range of gelatinization temperature; ΔH, enthalpy of gelatinization.

* Corresponding author. Address: School of Food Science and Engineering, Qingdao Agricultural University, 700 Changcheng Road, Chengyang District, Qingdao 266109, China. Tel.: +86 532 88030448; fax: +86 532 88030449.

E-mail address: phdsun@163.com (Q. Sun).

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http://dx.doi.org/10.1016/j.foodchem.2013.08.129

limited use in the food production industry. Consequently, there is an urgent need to modify sorghum flour. Sorghum flour contains starch granules and non-starch components including non-starch polysaccharides, lipids and proteins. The interactions between starch and non-starch components of flour during HMT are possibly different from that of starch. However, few studies on the comparison of HMT flour and starch were conducted except HMT rice starch and flour (Puncha-arnon & Uttapap, 2013). A literature review indicated that the physicochemical differences between sorghum starch and sorghum flour modified by HMT have not yet been investigated.

This study aims to investigate the physicochemical differences between sorghum starch and sorghum flour modified by HMT as well as to obtain a better understanding of the properties of HMT products. More specifically, the amylose content, swelling power, solubility thermal properties, pasting properties, gel texture properties, crystal properties, and the morphological properties of HMT sorghum starch and sorghum flour were studied.

2. Materials and methods

2.1. Materials

Sorghum grains (starch: 72.08%, protein: 11.45%, lipid: 3.44%, ash: 1.10%, fiber: 1.05%, moisture content: 10.88%) were purchased from Chinese National Center for Sorghum Improvement, Liaoning (China). All other reagents were of analytical grade.

2.2. Methods

2.2.1. Sorghum starch and sorghum flour preparations

Sorghum starch was extracted from sorghum grains using alkaline steeping method as described in Sira and Amaiz (2004) with some modifications. Sorghum grains were steeped in a 0.25% alkali solution (w/v) with the ratio of 1:5 (w/v) and at 4 °C for 24 h. The supernatant was discarded and the sorghum grains were washed with water. The steeped sorghum grains were grinded with a blender and filtered (200 mesh sieves). The slurry was steeped in a 0.25% alkali solution (w/v) with the ratio of 1:5 (w/v) and stored at 4 °C for 24 h. The slurry was then centrifuged (3000 rpm, 30 min). The crude starch (the sediment of white cake) was re-suspended in a 0.25% alkali solution (w/v) with the ratio of 1:5 (w/v) and stored at 4 °C for 24 h. This procedure was repeated four times. The starch was finally washed with distilled water until a neutral (pH 7) was reached. Finally, the sorghum starch was dried at 45 °C for 24 h. The resultant starch has a purity of 97% (dry basis). For sorghum flour, sorghum grains were wet milling with a blender 1:5 (w/v) and filtered (200 mesh sieve), dried at 45 °C for 24 h.

2.2.2. Heat-moisture treatment sorghum starch and sorghum flour

Samples (sorghum starch and sorghum flour) were weighed in a glass container, and the moisture content was adjusted to 20% or 25%, equilibrated for 24 h at 4 °C. The exact moisture content was measured by using a moisture analyzer (MA-45, Sartorius AG, Goettingen, Germany). The mixture was the heated in air tight glass bottles at 100 °C in a convection oven for 10 h. The starches were then dried at 50 °C overnight for further analysis.

2.2.3. Amylose content and soluble amylose content

The apparent amylose content of sorghum starch and sorghum flour were estimated by using the method of Sun and Wang et al. (2013). The starch (20 mg, dry weight basis) was dissolved in 90% dimethylsulfoxide (8 mL) in 10 mL screw-cap reaction vials. The contents of the vials were vigorously agitated for 20 min and then heated in a water bath (with intermittent shaking) at 85 °C for 15 min. The vials were then cooled to ambient temperature and the contents diluted with water to 25 mL in a volumetric flask. The diluted solution (1.0 mL) was mixed with water (40 mL) and 5 mL of iodine (I_2)/potassium iodide (KI) solution (0.0025 M I_2 and 0.0065 M KI) and the final volume was 50 mL. The solution was allowed to stand for 15 min at ambient temperature prior to absorbance measurements at 600 nm. A standard curve of amylose standard was plotted for estimating the content of amylose and amylopectin for sorghum starch and sorghum flour. The apparent amylose content of sorghum starch and sorghum flour was calculated using Eq. (1):

$$\text{The apparent amylose content } (\%) = A \times 100/(W \times 5) \times 100 \quad (1)$$

where A = weight of the apparent amylose found in standard curve according to the absorbance of apparent amylose; W = weight of dried sample (sorghum starch and sorghum flour).

The next step of the experiment involved accurately weighing about 100 mg of starches or flours and placed it in a 100 mL conical flask. The starches or flours were wetted with 1 mL distilled alcohol, and then about 50 mL distilled water were added. The flask was then covered with a bulb stopper, heated for 20 min in a boiling water bath with occasional shaking, then cooled in ambient temperature water to room temperature. Boiled and cooled distilled water was then added to the content in a volumetric flask such that the resulting content had a volume of 100 mL. The mixture was then filtered through a Whatman No. 4 filter paper and the first portion was rejected. About 20 mL of the extract were then transferred into a graduated 50 mL glass-stoppered cylinder and 7 mL of petroleum ether (boiling range, 60–80 °C) were added. The cylinder was shaken intermittently for 10 min and let to stand for 10–15 min. The ether layer was then suctioned off with a water suction device. The extraction with petroleum ether was repeated. 5 mL of the extracted solution were pipetted into a 100 mL volumetric flask and about 50 mL of distilled water (boiled and cooled) and 2 mL of iodine solution were added, and then the volume (100 mL) was made up with distilled water (boiled and cooled). An iodine blank was prepared by adding 2 mL iodine solution to 100 mL with ordinary distilled water. The solutions were read after approximately 20 min in a spectrocolorimeter such as the Spectronic 20 or the Zeiss Spekol, at 630 nm against the blank.

The soluble amylose content and insoluble content of sorghum starch and sorghum flour were calculated using Eqs. (2) and (3):

$$\text{The soluble amylose content } (\%) = R/A \times a/r \times 1/5 \times 100 \quad (2)$$

where, A = the absorbance of standard amylose; R = the absorbance of soluble amylose; a = weight of standard amylose; r = weight of dried samples (sorghum starch and sorghum flour).

$$\text{The insoluble amylose content } (\%) = \text{CAA} - \text{CSA} \quad (3)$$

where, CAA: the content of apparent amylose; CSA: the content of soluble amylose (sorghum starch and sorghum flour).

2.2.4. Swelling power (SP) and solubility (% SOL)

The swelling power (SP) and solubility (% SOL) of the starch samples were determined by a method of Adebooye and Singh (2008) with a slight modification. Approximately 800 mg (db) of sample was cooked in about 80 mL of water at different temperatures of 55, 65, 75, 85 and 95 °C for 30 min, respectively. Then they were cooled to room temperature and centrifuged at 3000 rpm (AnkeLXJ-IIB Centrifuge, Shanghai, China) for 15 min. The supernatant was decanted carefully and kept and the residue was weighed for SP determination. The supernatant was then poured out from the tube to a glass dish (of known weight). Afterwards, the dish was dried at 105 °C to constant and weighed.

All measurements were done in triplicates. The swelling power and percent solubility were calculated.