Tropical Journal of Pharmaceutical Research January 2015; 14 (1): 7-14
ISSN: 1596-5996 (print); 1596-9827 (electronic)

Available online at http://www.tjpr.org
http://dx.doi.org/10.4314/tjpr.v14i1.2

Original Research Article

Effect of Some Oligosaccharides on Functional Properties of Wheat Starch

Jie Zeng*, Haiyan Gao, GuangLei Li, Junliang Sun and Hanjun Ma
School of Food Science, Henan Institute of Science and Technology, Xinxiang, 453003, China

For correspondence: **Email: zengjie623@163.com; **Tel:** +86 373 3693005; **Fax:** +86 373 3693005*

Received: 25 August 2013 *Revised accepted: 10 December 2014*

Abstract

Purpose: *To investigate the effects of oligosaccharides on the functional properties of wheat starch.*
Methods: *The blue value, retrogradation and pasting properties of wheat starch were determined. In addition, water activity (Aw), melting enthalpy and melting temperature of wheat starch paste were analyzed.*
Results: *Fructo-oligosaccharide (FOS) and xylo-oligosaccharide (XOS) inhibited the retrogradation of wheat starch. The peak viscosity of wheat starch with oligosaccharides increased from 3238 ± 8 to 3822 ± 10 cP, with the highest peak obtained for sucrose. The setback of wheat starch decreased (from 1158 ± 5 to 799 ± 6 cP), with the lowest setback for FOS. Aw of control sample changed significantly (falling from 0.978 ± 0.025 to 0.397 ± 0.013) when the drying time was from 6 to 12 hours, while the Aw of the samples to which different oligosaccharides were added only showed slight decrease (from 0.98 ± 0.019 to 0.854 ± 0.022). During storage, the Aw of all starch pastes decreased, and the Aw and melting enthalpy of the samples containing FOS and XOS were significantly lower than that of the control after 6 days storage at 4 and 30 °C.*
Conclusion: *A certain level of oligosaccharides can improve the functional properties of wheat starch paste and thus broaden its application prospects in food and pharmaceutical industries.*

Keywords: *Melting enthalpy, Oligosaccharides, Pasting properties, Water activity, Wheat starch*

INTRODUCTION

It is well known that starch consists of amylose and amylopectin. Starch usually exists in the form of starch granules and deposits in the endosperm of grain. Starch granules present a semi-crystalline structure [1]. Starch makes up the main carbohydrate in the endosperm of wheat grain, and it plays a multifunctional role in food or non-food industries [2,3].

When heated at high water contents, starch changes from semi-crystalline structure to amorphous state, that is, resulting in full gelatinization [4-6]. During storage, the gelatinized starch rearranges to form close structure causing the phenomenon of retro-gradation. Given this, many food additives are used to improve the sensory properties and put off staling of starches because they can prevent the gelatinized starch from recrystallization to some extent [7].

Today, the concept of functional foods is based on the use of nutrition knowledge in the food industry with the aim of improving consumers' health [8]. It is reported that some functional oligosaccharides such as fructo-oligosaccharides (FOS) and xylo-oligosaccharide (XOS) may have some anticarcinogenic effects [9-11]. They can promote the growth of bifidobacteria and lactobacilli. These substances are named as prebiotics. Functional oligosaccharides also have some health benefits similar to those of fermentable dietary fiber and resistant starch [12-15]. Hence, the functional oligosaccharides are more and more widely used in food and pharmaceutical industries.

The objective of this paper was to compare the effects of several ordinary oligosaccharides (sucrose, maltose and lactose) and two kinds of functional oligosaccharides (FOS and XOS) on the properties of wheat starch. The iodine blue value, retro-gradation, pasting properties, water activity and aging properties were determined in order to investigate the application of functional oligosaccharides in the food and pharmaceutical industry.

EXPERIMENTAL

Materials

Wheat grains were provided by the Wheat Research Center, Henan Institute of Science and Technology, China. Sucrose, maltose and lactose were purchased from Tianjin Kemiou Chemical Reagent Co., Tianjin, China. FOS and XOS were purchased from Henan Tianrun Biological Technology Co., Henan Province, China. Other reagents and chemicals were of analytical grade.

Isolation of starch

The wheat starch is isolated according to the method of Kasemsuwan *et al* [16]. The isolated starch was washed with water and ethanol, and filtrated by using filter paper, and then dried in a convection oven at 32 °C for 48 h.

Determination of blue value

The blue value (BV) was determined in triplicate according to the method of Zeng *et al* [17]. Amylose could bind with iodine to form a blue compound, and the BV was the extinction at 620 nm when samples were scanned from 500 to 800 nm with an Ultraspec III UV–visible spectrophotometer (Amersham Pharmacia Biotech, Uppsala, Sweden). The addition of oligosaccharide was based on the weight of wheat starch, viz, 0.1, 0.2, 0.3, 0.4, 0.5 g per 1 g wheat starch, respectively. The absorbance was recorded at 620 nm and used as BV. The data were mean of three replicates of each wheat starch sample. The sample without oligosaccharide was used as control.

Evaluation of retrogradation properties

Retro-gradation of wheat starch samples was determined according to the method of Zeng *et al* [17]. Starch retro-gradation property was calculated by supernatant volume (SV) after standing for 24 h. The addition of oligosaccharide was based on the weight of wheat starch, viz, 0.1, 0.2, 0.3, 0.4, 0.5 g oligosaccharide per 1 g wheat starch. Each wheat starch sample was measured three times and the mean supernatant volume was recorded as the SV. The sample without oligosaccharide was used as control.

Determination of pasting properties

Pasting properties of the wheat starch were measured with standard 1 method by Rapid Visco-Analyzer (RVA) (RVA-Tecmaster, Newport Scientific Pty. Ltd., Warri wood, Australia). Each wheat starch solution (3 g wheat starch, 1 g oligosaccharide and 25 g distilled water) was maintained at 50 °C for 1 min. It was then heated to 95 °C in 3.7 min and maintained at 95 °C for 2.5 min. The sample was then cooled to 50 °C in 3.8 min, and maintained at 50 °C for 2 min. A rotating paddle at a speed of 160 rpm was used during the preparation of paste except that the paddle speed was 960 rpm in the first 10 s.

Measurement of water activity (Aw) during drying

Wheat starch (30 g) and oligosaccharide (30 g) were placed in a big beaker; 170 mL of distilled water was added, stirred well, heated up to 100 °C and kept for 30 min, while still stirring during the heating. When the wheat starch was completely gelatinized, the starch paste was poured into several petri dishes and cooled to room temperature. Aw of the wheat starch paste was determined by a water activity detector (HD-4, Suzhou Qile Electronic Technology Co, Ltd, Suzhou City, China). The gelatinized starch was dried by hot air drier (9030A, Nanjing Mingshida Drying Equipment Factory, Nanjing, China) at 45 °C. Aw was determined every 3 h during drying. Each wheat starch paste was measured three times and the data was recorded.

Measurement of water activity during storage

Wheat starch paste was prepared as described under water activity and stored at 4 °C for some days (0, 3 and 6 days). The water activity (Aw) of the paste samples was determined every three days. Each wheat starch paste was measured three times and the data was recorded.

Determination of melting enthalpy

Wheat starch paste was prepared as described for water activity determination. Half of wheat starch paste was stored in a refrigerator at 4 °C and the rest was stored in an ageing oven (KY401A, Kaiyuan Test Machinary Factory, Jiangdu City, China) at 30 °C for 0, 2, 4, 6 and 8 days); thereafter, 5 mg of the paste was placed in a differential scanning calorimeter (DSC, Q200, TA, USA). The cooling rate was 5 °C per min over the temperature range of 30 to -45 °C. Indium and zinc were used as the reference standards. Melting enthalpy (∆H) was recorded.

Each starch paste sample was measured three times and the mean data recorded.

RESULTS

Blue value (BV)

Fig 1 shows the BV of wheat starch containing various amounts of oligosaccharides. The BV of all the samples containing oligosaccharides changed significantly compared to control. There was an increase in BV when FOS was added at 0.2 g and XOS or sucrose at 0.1 g, while the BV of wheat starch decreased with increase in FOS, XOS and sucrose. However, the BV of the samples containing maltose and lactose showed a downward trend.

Retro-gradation properties

Fig 2 shows the SV of wheat starches with varying contents of oligosaccharides. SV slightly increased with increase in sucrose or lactose addition. When of sucrose or lactose was added at a level < 0.4 g/g starch, the retro-gradation of wheat starches was accelerated. Maltose showed no obvious effect on the retro-gradation of wheat starch while XOS or FOS showed significant effect on the retro-gradation of wheat starch with a sharp decrease occurring when when the amount added was < 0.3 (g/g starch). SV increased when the addition of FOS and XOS < 0.3 g/g starch).

Pasting properties

Fig 3 shows the RVA viscosities of wheat starch samples with oligosaccharides while Table 1 summarizes their characteristics. All the oligosaccharides increase the peak viscosity of wheat starches and the highest is observed in the sucrose samples. In addition, the setback (= Final - Trough) of all the samples decrease and the lowest is observed in the FOS samples. However, the breakdown (= Peak - Trough) of all the samples increase compared with control. The peak time of all the samples reduces and the pasting temperature decrease after adding oligosaccharide.

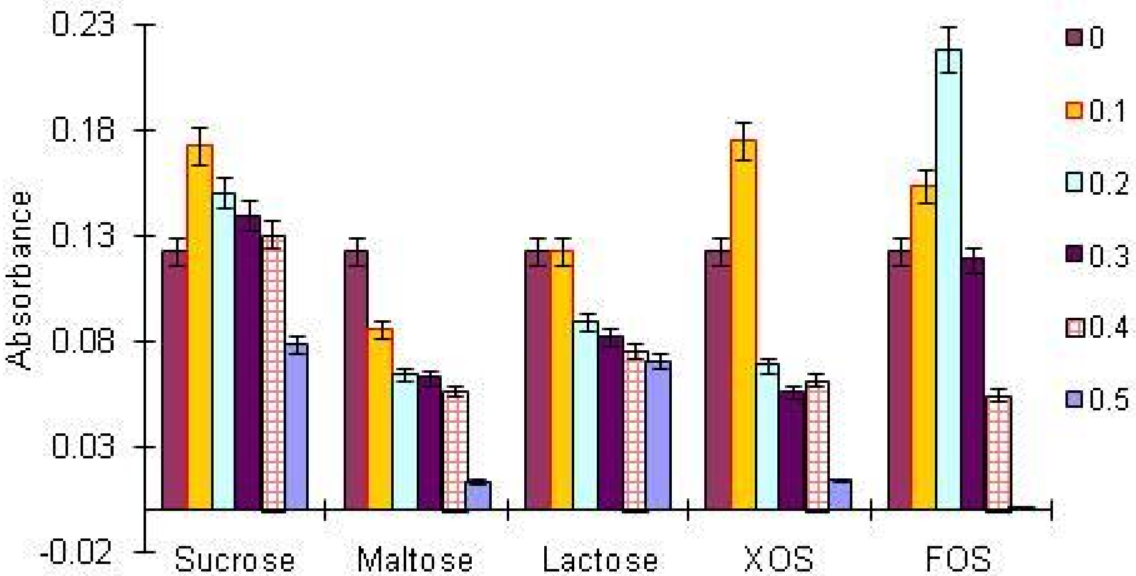

Fig.1. Blue value of wheat starches with varying levels of oligosaccharides

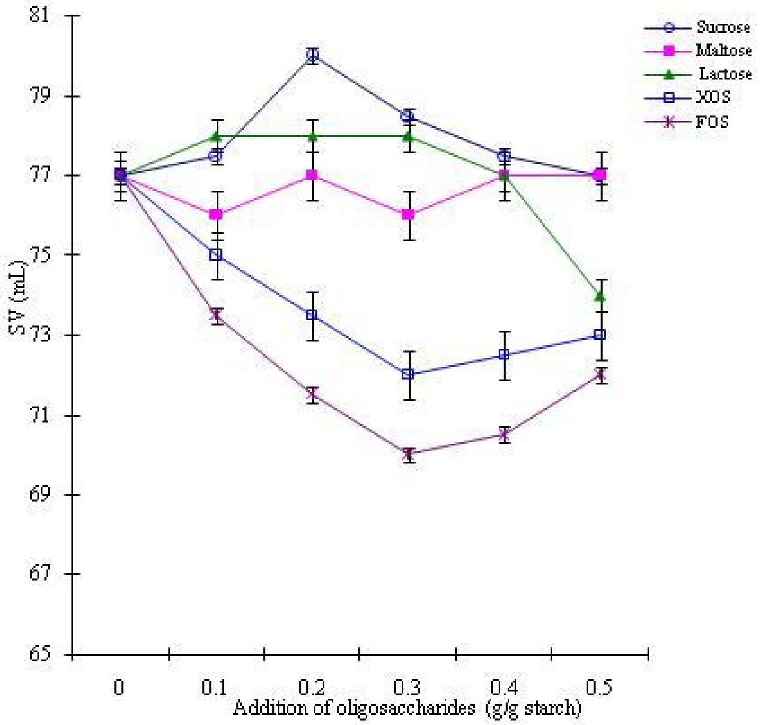

Fig. 2: SV of wheat starch with different addition of oligosaccharides

Table 1: RVA parameters of wheat starch containing oligosaccharides

Additive	Peak (cP)	Trough (cP)	Breakdown (cP)	Final (cP)	Setback (cP)	Peak Time (min)	Pasting Temp (°C)
CK	3238±8	2651±3	587±5	3809±2	1158±5	6.8±0.1	87.5±0.1
Sucrose	3822±10	2913±4	909±3	4036±4	1123±2	7.6±0.1	85±0.1
Maltose	3351±7	2564±6	787±2	3536±8	972±4	7.1±0.1	86.5±0.2
Lactose	3452±4	2608±5	844±5	3570±5	962±6	7.3±0.2	87.45±0.1
XOS	3365±9	2609±3	756±4	3518±6	909±2	7.5±0.1	86.7±0.1
FOS	3449±7	2842±4	607±2	3641±8	799±6	7.9±0.1	84.9±0.1

*Values are mean±SD (n = 3); *Significant at p < 0.05 level*

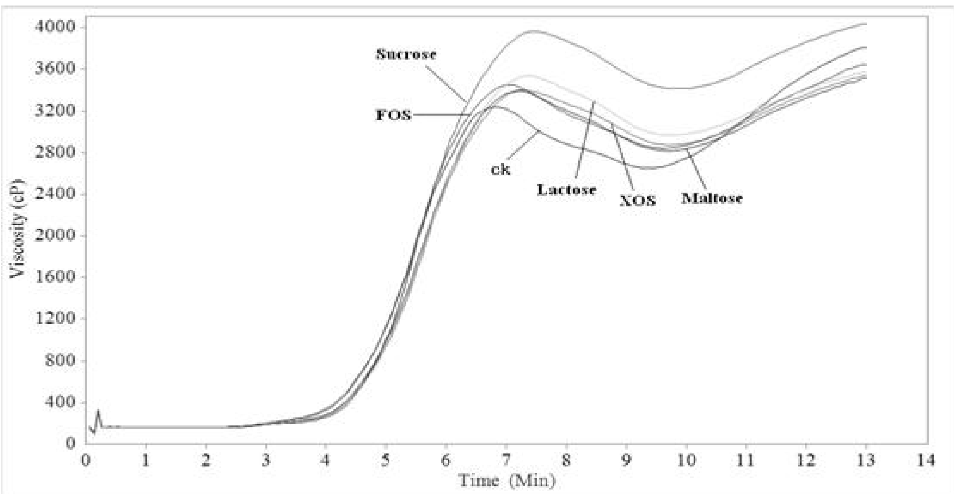

Fig. 3: Viscosity profiles of wheat starch containing oligosaccharides

A_w during drying

From Fig. 4, the A_w of all the samples falls slightly in the first 6 hours during drying. When the drying time exceeds 6 h, A_w of control samples changes significantly and decreases from 0.978 ± 0.025 to 0.397 ± 0.013. On the other hand, the A_w of samples added different oligosaccharides goes down slowly (about from 0.98 ± 0.019 to 0.854 ± 0.022). Changes in A_w indicate that during the drying process, oligosaccharides retain water molecules in the starch paste during pasting.

A_w during storage

Fig. 5 shows that the A_w of wheat starch pastes decreases gradually during storage. The A_w of samples added oligosaccharides goes down more than that of the control. Among the five kinds of oligosaccharide samples, the A_w of adding XOS, FOS and maltose decreases more in particular.

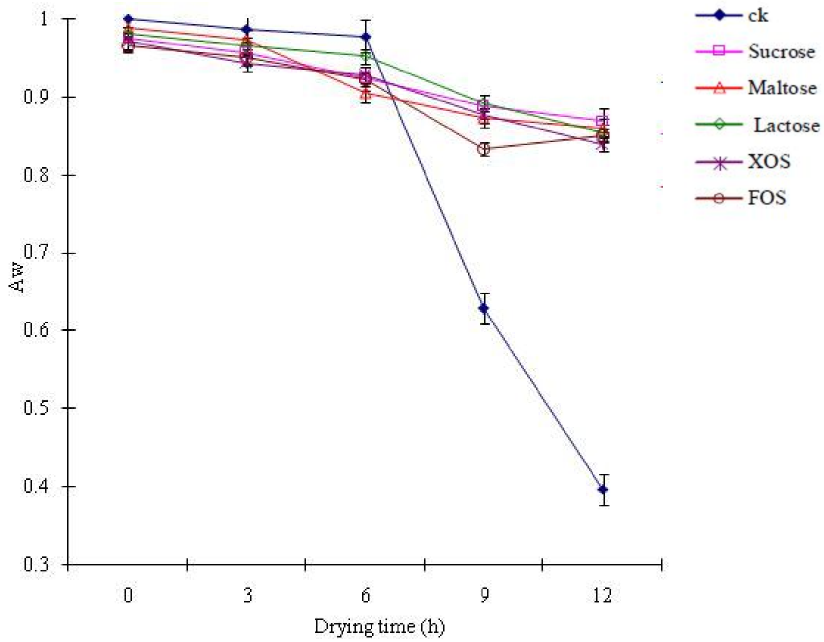

Fig 4: Water activity of wheat starch paste during drying

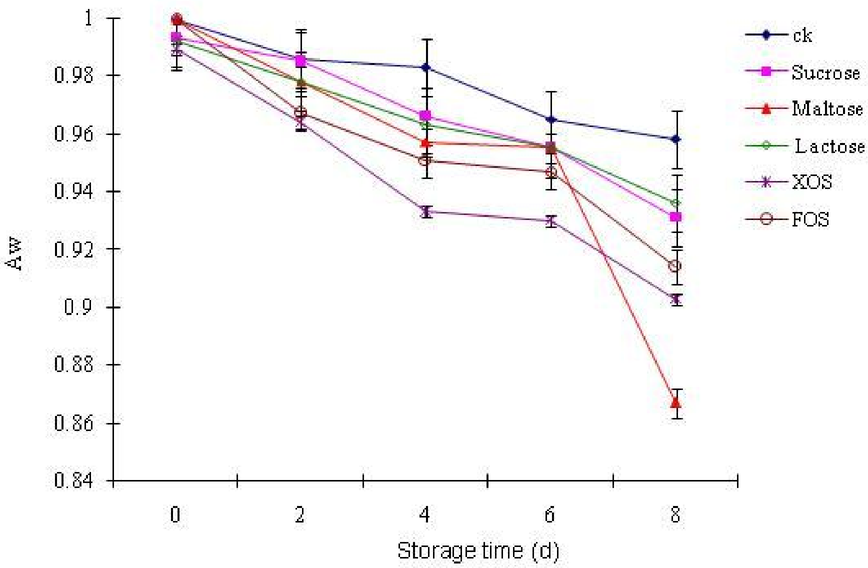

Fig 5: Water activity of wheat starch paste during storage

Melting enthalpy with storage

From Fig. 6(A), during storage at 4 °C, the melting enthalpies of all the samples added oligosaccharides are lower than that of the control. Among the five kinds of oligosaccharides, XOS showed better anti-aging effects because the melting enthalpies are almost no change.

Fig 6(B) shows the change in the melting enthalpy of wheat starch gels stored at 30 °C. Compared with the samples stored at 4 °C, the enthalpy of the control increased by 20 J/g and the enthalpy of adding XOS increases by 47 J/g when stored 3 days. However, enthalpy decreased after storage for 6 days. The melting enthalpies of all the samples containing oligosaccharides were lower than that of the control. Among the five oligosaccharides, FOS showed better anti-aging effects.

DISCUSSION

Through iodine binding test, it was found that a number of sucrose, XOS and FOS could bind water molecules by hydrogen bonds, thus promoting the combination of iodine and starch molecules, while a large amount of sucrose, XOS and FOS might interfere with the iodine binding

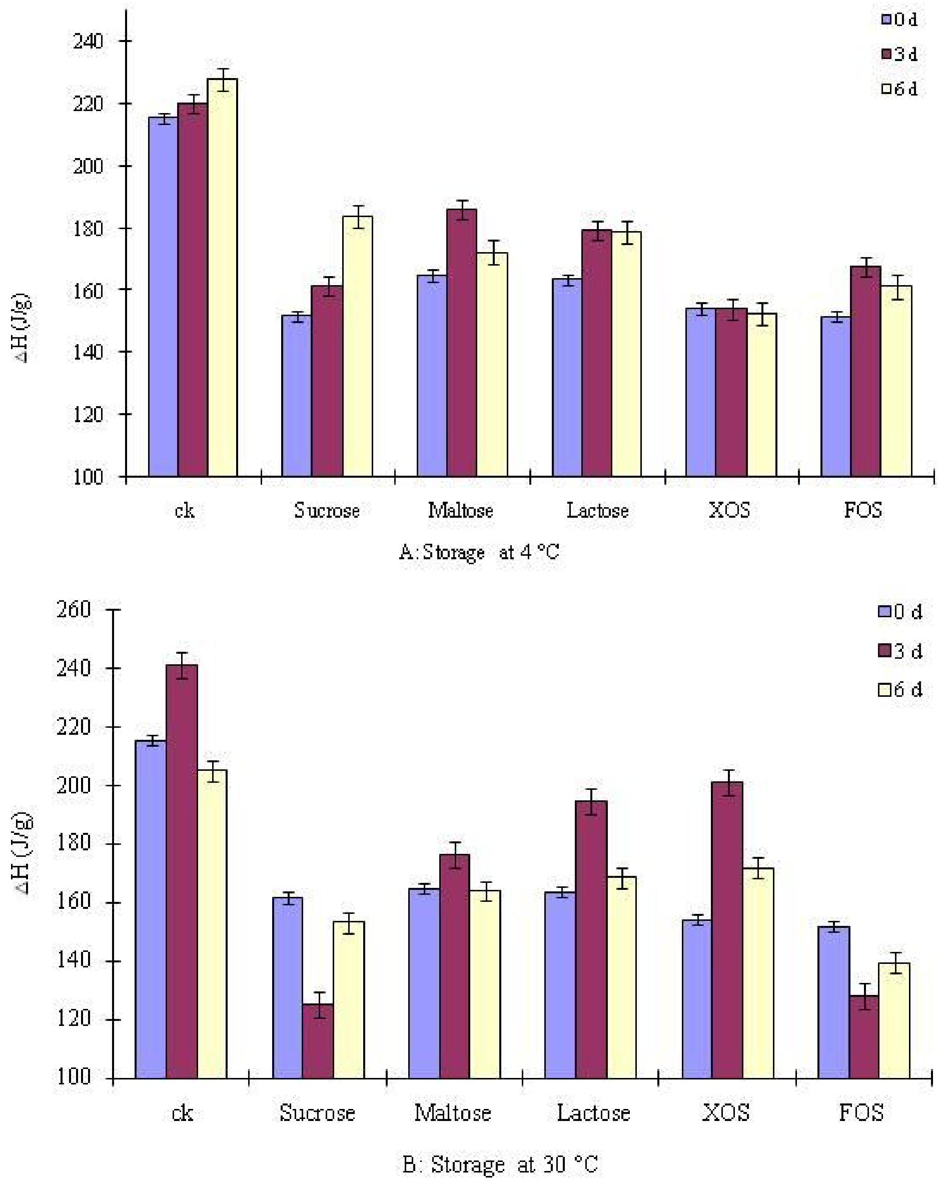

Fig.6: Melting enthalpy of wheat starch gels at different storing time

abilities of wheat starch. The retrogradation test also indicated that XOS and FOS inhibit the retrogradation of wheat starches.

All the oligosaccharides increased peak viscosity and decreased the setback of wheat starches. This indicated that oligosaccharides could improve the pasting properties of wheat starch to some extent.

It is well known that the growth of micro-organisms and physiochemical reaction are not only affected by water content, but also by the aqueous environment [18], that is A_w. A_w has been widely used to control and predict chemical reactivity in foods. During drying, the A_w of the samples added oligosaccharides was higher than that of the control due to the weak bonding between water molecules and starch molecules, and thus there was a large amount of free water in the gel system. These results indicate that oligosaccharides are hydrophilic components which can bind water molecules by hydrogen bonds, and the bound water molecules was not easy to remove from the starch paste during drying.

During storage, the A_w of all samples went down because of the continuing binding of water molecules. The A_w of samples added oligosaccharides went down more than that of the control, because oligosaccharides continued to bind water molecules through hydrogen bond during storage. Among the five oligosaccharides, the A_w of samples added XOS and FOS showed lower A_w value, thus it is inferred that these two oligosaccharides exerted higher hydrophilic ability than the others. The lower the amount of free water, the lower the water activity of the starch paste. In this light, oligosaccharides could bind a great deal water molecules and inhibit the aging of starch.

When wheat starch paste was stored for a period of time, the starch molecules gradually aged. Part of the water molecules which bonded with starch molecules during gelatinization are released free from the starch molecules because of recrystallization. Therefore, the content of free water in the starch paste increased. The more the free water the greater the melting enthalpy. This indicates that the aging rate of starch would be faster [19]. DSC analysis showed that the melting enthalpy of all the samples containing oligosaccharides was lower than that of the control after storage at 4 and 30 °C. In general, XOS and FOS showed more pronounced effects on the properties of wheat starches.

CONCLUSION

Oligosaccharides affect the physicochemical properties of wheat starch. XOS and FOS showed significant effects on the properties of wheat starches; for example, they interfered with iodine binding behavior, inhibited the retrogradation, increased peak viscosity and decreased setback. In particular, during drying and storage, XOS and FOS retain water molecules in wheat starch paste and exerted better anti-aging effects. These changes may improve the application value of wheat starch in the food and pharmaceutical industries.

ACKNOWLEDGEMENT

The various tests were conducted at the Engineering Laboratory of Grain Resources Deep Utilization of Henan Province, China. This study was funded by Program for Innovative Research Team (in Science and Technology) of University of Henan Province (13IRTSTHN006), Science and Technology Projects in Henan Province (132102110032, 13A550288, 14A550011), China and Key Teachers Funding Scheme in Henan Province, China (2010GGJS-141).

REFERENCES

1. *Li WY, Yan SH, Yin YP, Li Y, Liang TB, Gu F, Dai ZM, Wang ZL. Comparison of starch granule size distribution between hard and soft wheat cultivars in eastern China.Agr Sci China 2008; 7: 907-914.*
2. *Maeda T, Morita N. Study on Physicochemical Characteristics of Waxy and High-amylose Wheat Starches in Comparison with Normal Wheat Starch. Starch – Stärke 2007; 59: 125-131.*
3. *Alamri MS, Mohamed AA, Hussain S. Effects of alkaline-soluble okra gum on rheological and thermal properties of systems with wheat or corn starch. Food Hydrocolloid 2013; 30: 541-551.*
4. *Blazek J, Copeland L. Pasting and swelling properties of wheat flour and starch in relation to amylose content. Carbohyd Polym 2008; 71: 380–387.*
5. *Liu Zd, Yang Y, Gao XL, Gao L. Study on the Preparation of Wheat Starch Phosphate with Low Degree of Substitution. J Carbohyd Chem 2008; 183: 547-554.*
6. *Smits ALM, Kruiskamp PH, van Soest JJG, Vliegenthart JFG. The influence of various small plasticisers and malto-oligosaccharides on the retro-gradation of (partly) gelatinised starch. Carbohyd Polym 2003; 51: 417–424.*
7. *Chiotelli E, Role´e A, Le Meste M. Effect of sucrose on the thermomechanical behavior of concentrated wheat and waxy corn starch–water preparations. J Agr Food Chem 2000; 48: 1327–1339.*

8. Peressini D, Sensidoni A. Effect of soluble dietary fibre addition on rheological and bread making properties of wheat doughs. J Cereal Sci 2009; 49: 190-201.
9. Laurentin A, Edwards CA. Resistant Starch and Oligosaccharides. Reference Module in Biomedical Sciences, from Encyclopedia of Human Nutrition (Third Edition) 2013; 2: 246–253.
10. Delzenne NM. Oligosaccharides: State of the art. P Nutr Soc 2003; 62:177–182.
11. Manisseri C, Gudipati M. Bioactive xylo-oligosaccharides from wheat bran soluble polysaccharides. LWT – Food Sci Technol 2010; 43: 421–430.
12. Holtl SM, Miller-Fosmore1 CM, Cote GL. Growth of various intestinal bacteria on alternansucrase derived oligosaccharides. Lett Appl Microbiol 2005; 40:385–390.
13. Hsu CK, Liao JW, Chung YC, Hsieh CP, ChanYC. Xylo-oligosaccharides and fructo-oligosaccharides affect the intestinal microbiota and precancerous colonic lesion development in rats. J Nutr 2004; 134: 1523–1528.
14. Rycroft CE, Jones MR, Gibson GR, Rastall RA. A comparative in vitro evaluation of the fermentation properties of prebiotic oligosaccharides. J Appl Microbiol 2001; 91: 878–887.
15. Dona AC, Pages G, Gilbert RG, Kuchel PW. Digestion of starch: In vivo and in vitro kinetic models used to characterise oligosaccharide or glucose release. Carbohyd Polym 2010; 80: 599–617.
16. Kasemsuwan T, Jane J, Schnable P, Stinard P, Robertson D. Characterization of the dominant mutant amylose-extender (Ael-5180) maize starch. Cereal Chem 1995; 71: 457-464.
17. Zeng J, Gao HY, Li GL. Comparison of Effects of Oligosaccharides on Physicochemical Properties of Corn Starch. Trop J Pharm Res 2014; 13: 1055-1061.
18. Troller J A. Trends in Research Related to the Influence of “Water Activity” on Microorganisms in Food. Adv Exp Med Bio 1991; 302: 305-313
19. Zeng J, Gao HY, Li GL. Functional properties of wheat starch with different particle size distribution. J Sci Food Agr 2014; 94: 57-62.