

Original Research Article

Comparison of Effects of Oligosaccharides on Physicochemical Properties of Corn 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

Received: 7 April 2014

Revised accepted: 9 June 2014

Abstract

Purpose: To investigate the effect of different oligosaccharides on the physicochemical properties of corn starch.

Methods: The blue value and retrogradation of corn starch were evaluated following the addition of different oligosaccharides and compared with control. Pasting properties, melting enthalpy and melting temperature were determined by rapid viscosity analysis (RVA) and differential scanning calorimetry (DSC).

Results: Maltose, lactose and fructo-oligosaccharides significantly affected iodine binding ability of corn starch. Retrogradation of corn starch was significantly inhibited by maltose, xylooligosaccharide and fructooligosaccharides. RVA analysis showed that the addition of oligosaccharides increased the peak viscosity of corn starch (from 3180 cP to 3687 cP) but decreased that of corn starch (from 896cP to 625 cP). DSC analysis showed that there was a large reduction in recrystallisation of corn starch by oligosaccharide. The samples containing xylooligosaccharide and fructooligosaccharides showed lower melting enthalpy (142.7 J/g and 143.5 J/g, respectively) than that of control (209.4 J/g), and their onset temperature (-10.9 °C and -8.89 °C, respectively) were also lower than that of control (-5.92 °C). In addition, the melting enthalpy and melting temperature of the samples containing oligosaccharides also showed lower values than those of control during storage.

Conclusion: The finding that oligosaccharides modify the physicochemical properties of corn starch would be of practical importance in broadening their application prospects of the starch in the food and pharmaceutical industries.

Keywords: Corn starch, Oligosaccharides, Pasting properties, Iodine binding, Retrogradation, Water activity, Enthalpy

Tropical Journal of Pharmaceutical Research is indexed by Science Citation Index (SciSearch), Scopus, International Pharmaceutical Abstract, Chemical Abstracts, Embase, Index Copernicus, EBSCO, African Index Medicus, JournalSeek, Journal Citation Reports/Science Edition, Directory of Open Access Journals (DOAJ), African Journal Online, Bioline International, Open-J-Gate and Pharmacy Abstracts

INTRODUCTION

Starch constitutes the major carbohydrate in the corn endosperm. Corn starch serves as a multifunctional ingredient to the food or nonfood industries [1-3]. Corn starch is widely used as a thickener, gelling agent, bulking agent or water retention agent [4-6]. When heated, starch usually gelatinizes fully or partially and can be transformed from semi-crystalline granular

material to an amorphous paste, or to a system containing granular remnants [7,8]. In the presence of sufficient water, starch granules swell and lose their crystallinity during gelatinization until they are completely dissolved [9]. The influence of plasticisers such as water or sugars on the recrystallisation of gelatinized starch is important for the processing of starch-based foods and its application in pharmaceutical industries [10].

Today, food innovation is built on the concept of functional foods, which is based on the use of nutrition knowledge in the food industry with the aim of improving human health [11]. Oligosaccharides are carbohydrate chains containing 2-10 sugar units [12]. Some authors have also described oligosaccharides as carbohydrates with up to 20 residues. It was reported that some oligosaccharides might have anticarcinogenic effects [13]. The Indigestible oligosaccharides, such as fructooligosaccharides and xylooligosaccharide, named as prebiotics, can promote the growth of bifidobacteria and lactobacilli. Besides, the health benefits of indigestible oligosaccharides are similar to those of fermentable dietary fiber and resistant starch [14-16].

In recent years, oligosaccharides have been widely used in the food and pharmaceutical industries. The objective of this paper was to investigate the effects of several oligosaccharides on the physicochemical properties of corn starch, including iodine blue value, retrogradation, pasting properties, water activity and melting properties, in order to provide some theoretical references for the application of oligosaccharides in the food industry and medicine.

EXPERIMENTAL

Materials

Corn starch (amylose content, 25.43 %) was purchased from local market. Sucrose, maltose and lactose were purchased from Tianjin Kemiou Chemical Reagent Co., Tianjin, China. Fructooligosaccharides (FOS) and xylooligosaccharide (XOS) were purchased from Tianrun Biological Technology Co., Henan, China. Other reagents and chemicals used were of analytical grade.

Iodine binding test

The blue value (BV) was measured in triplicate according to the method of Zeng *et al* [17]. The addition of oligosaccharide was based on the weight of starch, viz, 0.1, 0.2, 0.3, 0.4, 0.5 g per 1 g starch, respectively. The data were averages of three replicates of each starch sample. The sample without oligosaccharide was used as the control (ck).

Retrogradation test

A corn starch suspension (1 %) was heated at 95 °C and maintained for 30 min in a thermostat

water bath (Changcheng Instruments Co, Ltd, Zhengzhou, China), followed by a natural cooling to room temperature (about 25 °C). The starch paste was transferred into a 100 mL graduated cylinder. Starch retrogradation property was calculated by supernatant volume (SV) after standing for 24 h. The addition of oligosaccharide was based on the weight of starch, viz, 0.1, 0.2, 0.3, 0.4 and 0.5 g oligosaccharide per 1 g starch. The data are mean of three replicates of each starch sample. The sample without oligosaccharide was used as control (ck).

Pasting test

Pasting properties of the corn starch were determined by using a Rapid Visco Analyzer (RVA IV, Newport Scientific Pty. Ltd., Warriewood, Australia). A rotation speed of the paddle of 160 rpm was used except that the paddle speed was set at 960 rpm in the first 10 s. Each starch suspension (3 g corn starch, 1 g oligosaccharide and 25 g distilled water) was equilibrated at 50 °C for 1 min, 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.

Differential scanning calorimetry (DSC)

Gelatinized starch samples prepared according to the above pasting properties method. Starch pastes (containing 3 g corn starch, 1 g oligosaccharide and 25 g distilled water) were stored in a refrigerator at 4 °C for several days (0, 2, 4, 6, 8 d); 5 mg paste was taken and scanned in a differential scanning calorimeter (DSC, Q200, Thermal Analysis Instruments, USA) instrument. Cooling rate was 5 °C per min over the temperature range of 20 to -45 °C and then heated to 30 °C. An empty pan was used as

the reference standard. Melting enthalpy (ΔH),

melting onset temperature (T_o), melting peak temperature (T_p) and melting conclusion temperature (T_c) were measured. The data were recorded as the mean of triplicate measurements for each starch sample.

RESULTS

Iodine binding behavior

Fig 1 shows the iodine binding behavior of corn starch after adding varying amounts of oligosaccharides. Comparing with control, the iodine binding behavior of all the samples with

oligosaccharides changed greatly. The addition of oligosaccharide decreased the iodine binding ability comparing with the control. And the iodine binding ability of the samples with maltose, lactose and FOS showed severe decreasing trend as observed from Fig 1, while the samples added sucrose and XOS showed a slight increasing trend when the addition in excess of 0.3 g/g starch.

Retrogradation properties

Fig 2 showed the SV of corn starch solution with different contents of oligosaccharides. Generally speaking, the greater the SV is, the stronger the retrogradation is. On the other hand, the smaller the SV is, the weaker the retrogradation is, that is, the more slowly the starch ages. From Fig 2, a higher rate of retrogradation was observed in

control sample. The SV decreased significantly with the increase of maltose and XOS addition. The samples with FOS also showed lower SV than that of the control. The SV of samples with sucrose and lactose slightly decreased at first and then increased a little.

Pasting properties

Fig 3 showed the RVA viscosities of corn starch adding different oligosaccharides and Table 1 summarized their characteristics. All the oligosaccharides increased the peak viscosity of corn starch with the highest value observed in the sample containing maltose. In addition, the setback of all the samples decreased and the lowest was observed in the sample with sucrose.

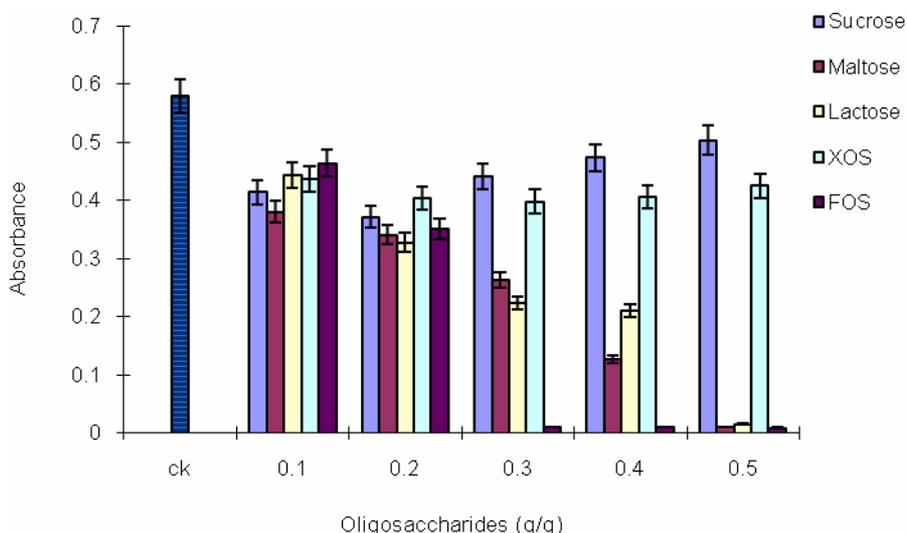


Fig 1: Iodine binding behavior of corn starches containing varying levels of oligosaccharides

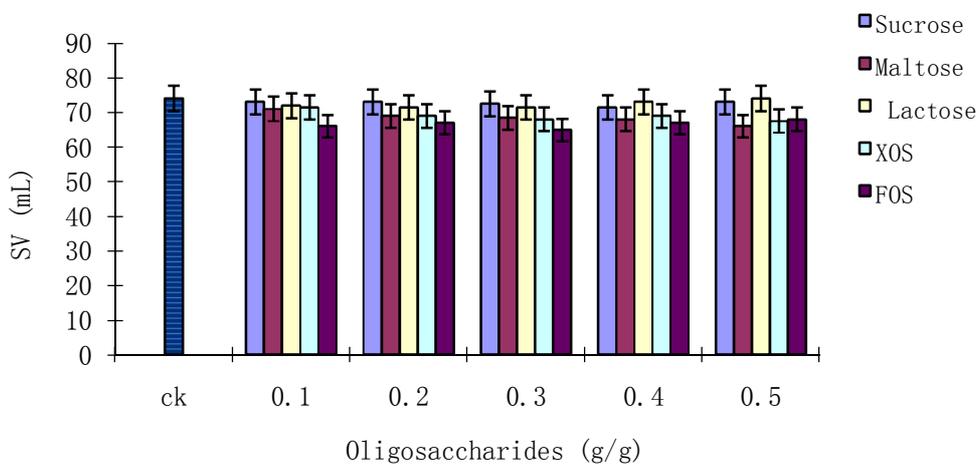
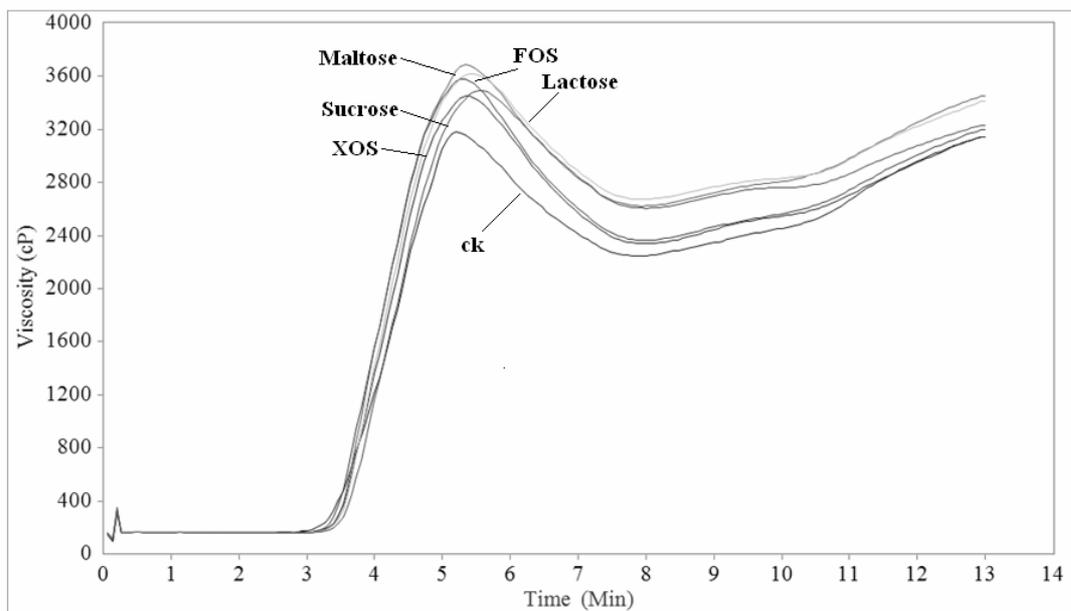


Fig 2: SV of corn starch with different addition of oligosaccharides

Table 1: Rapid visco-analyzer parameters for corn starches containing oligosaccharides

| Sample | Peak (cP) | Trough (cP) | Breakdown (cP) | Final (cP) | Setback (cP) | Peak time (min) | Pasting temp (°C) |
|---------|-----------|-------------|----------------|------------|--------------|-----------------|-------------------|
| ck | 3180 | 2246 | 934 | 3142 | 896 | 5.2 | 76 |
| Sucrose | 3496 | 2607 | 889 | 3232 | 625 | 5.53 | 78.5 |
| Maltose | 3687 | 2622 | 1065 | 3449 | 827 | 5.33 | 77.7 |
| Lactose | 3622 | 2675 | 947 | 3411 | 736 | 5.4 | 78.5 |
| XOS | 3453 | 2340 | 1113 | 3142 | 802 | 5.4 | 77.75 |
| FOS | 3581 | 2365 | 1216 | 3200 | 835 | 5.27 | 76.95 |

**Fig 3:** Viscosity profiles of corn starches containing oligosaccharides

However, breakdown of all the samples were higher than that of control except for sucrose sample. The peak time was postponed after adding oligosaccharide while the pasting temperature increased.

Melting transitions

DSC has been widely used to investigate thermal transitions in materials. From Fig 4, the melting enthalpies of corn starch gels with oligosaccharides were lower than that of the control after storing 3 days or 6 days at 4 °C. In other words, the oligosaccharides prevented starch molecules to form hydrogen bonds with one another and hence the hydroxyl groups are free to form hydrogen bonds with water molecules. Moreover, the enthalpies of the samples with sucrose, XOS and FOS increased with the increase of storing time. The enthalpy of the samples with maltose slightly went down during storage. Among the five kinds of oligosaccharides, XOS and FOS showed better anti-aging effects on corn starch because their

melting enthalpies were lower than that of other samples. These results indicated that there were larger reductions in recrystallisation of starch molecules when XOS and FOS were added in corn starch.

Fig 5 shows the effect of oligosaccharides on the melting temperature of corn starch gels. For control samples, T_o value slightly increased while the T_c value decreased during storage. T_o and T_c values of all samples with oligosaccharides were lower than that of the control. The T_o value of samples with sucrose, maltose, lactose and FOS decreased after storage 3 days, but slightly increased after storage 6 days. After storage for 3 days, the T_c values of corn starch gels with oligosaccharides were higher than that of the fresh gels (Fig 5, 0 d) except samples with sucrose. However, the T_c of all samples with oligosaccharides storage 6 days decreased more than that of storage 3 days. Besides, the T_o and T_c of samples with XOS and FOS were relative lower than that of

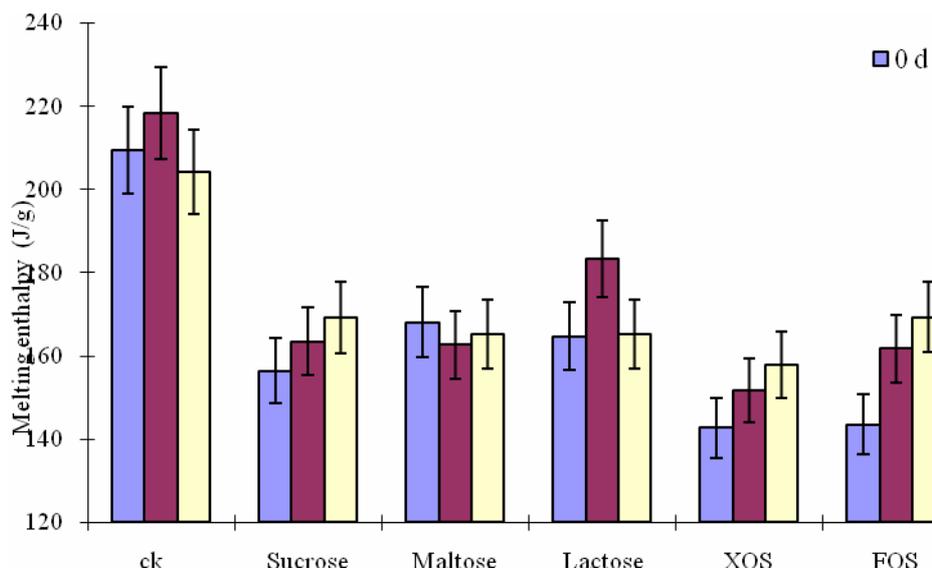


Fig 4: Melting enthalpy of corn starches gels after different storing time

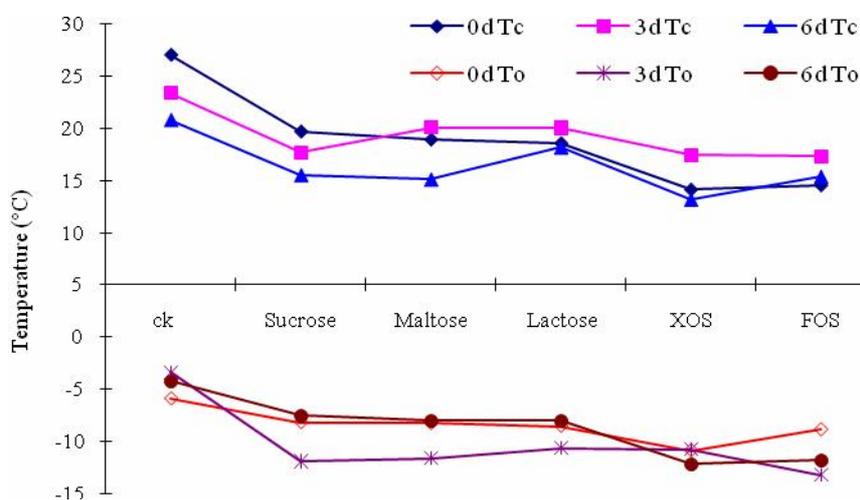


Fig 5: Melting temperature of corn starch gels after storage

samples with other three oligosaccharides. These results indicated that the interaction between oligosaccharides and water built a more complex system, thus reduced the freezing point and the melting temperature of the system. Among the five oligosaccharides, XOS and FOS exhibited obvious effects in particular.

DISCUSSION

In the present study, oligosaccharides were used to improve some properties of corn starch. The results obtained indicate that oligosaccharide interfered with iodine binding behavior of corn starch. Retrogradation test also indicates that retrogradation of corn starch can be inhibited by maltose, XOS and FOS. It is well known that the structural arrangement of starch chains within the amorphous and crystalline regions of the

ungelatinized granule indirectly influences the retrogradation properties of starch gels, and influenced the extent of granule breakdown during gelatinization and the interaction that occurred between starch chains during gel storage [18]. In this light, the addition of oligosaccharide might affect the structural arrangement of starch gels.

When corn starch paste was stored for a period of time, part of the combined water with starch during pasting would be free from the starch molecules because of starch's recrystallization. As a result, the free water in the starch gel increased. The more the amount of free water is, the greater the melting enthalpy becomes, and the faster the recrystallization rate of starch is.

DSC analysis showed that the oligosaccharides decreased the melting enthalpies and melting temperature of corn starch. It was reported that the melting temperature and enthalpy depended on crystal size. In particular, crystal size decrease reflects in melting temperature/enthalpy decrease [19]. From this point of view, the samples with XOS and FOS were easier to form small crystal. Moreover, one of the most important consequences of the crystal melting temperature and enthalpy decrease is the increase in crystal solubility [20]. Therefore, it is important for the solubility of food or medicine containing oligosaccharides. Hence, the interaction between oligosaccharides and water contributed to the reduction in the melting enthalpy and melting temperature of retrograded starch gels which indicated that the samples with XOS and FOS more easily formed small crystals and improved solubility.

CONCLUSION

A certain amount of oligosaccharides can affect the physicochemical properties of corn starch. Among of the five kinds of oligosaccharides, XOS and FOS exert significant effects on iodine binding behavior, melting enthalpy and melting temperature. These results indicate that XOS and FOS have better anti-aging effects, and to some extent, these properties can help to meet various needs in the food and pharmaceutical industries.

ACKNOWLEDGEMENT

This study was funded by Program for Innovative Research Team (in Science and Technology) in University of Henan Province (no. 13IRTSTHN006), Science and Technology Projects in Henan Province (nos. 132102110032, 13A550288, 14A550011), and Key Teachers Funding Scheme in Henan Province (no. 2010GGJS-141).

REFERENCES

- 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.
- 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.
- Sandhu KS, Singh N. Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. *Food Chem*, 2007; 101: 1499-1507.
- Singh N, Singh J, Kaur L, Sodhi NS, Gill BS. Morphological, thermal and rheological properties of starches from different botanical sources. *Food Chem*, 2003; 81: 219-223.
- Paul C. The structure of starch. *Nature*, 1997; 389: 338-339.
- Pineda-Gómez P, Coral DF, Ramos-Rivera D, Rosales-Rivera A, Rodríguez-García ME. Thermo-alkaline treatment. A process that changes the thermal properties of corn starch. *Proc Food Sci* 2011; 1: 370-378
- Blazek J, Copeland L. Pasting and swelling properties of wheat flour and starch in relation to amylose content. *Carbohydr Polym*, 2008; 71: 380-387.
- Smits ALM, Kruiskamp PH, van Soest JJG, Vliegenthart JFG. The influence of various small plasticisers and malto-oligosaccharides on the retrogradation of (partly) gelatinised starch. *Carbohydr Polym*, 2003; 51: 417-424.
- Atkin NJ, Abeysekera RM, Robards AW. The events leading to the formation of ghost remnants from the starch granule surface and the contribution of the granule surface to the gelatinization endotherm. *Carbohydr Polym*, 1998; 36: 193-204.
- 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.
- Peressini D, Sensidoni A. Effect of soluble dietary fibre addition on rheological and bread making properties of wheat doughs. *J Cereal Sci*, 2009; 49(2): 190-201.
- Delzenne NM. Oligosaccharides: State of the art. *P Nutr Soc*, 2003; 62: 177-182.
- Laurentin A, Edwards CA. Resistant Starch and Oligosaccharides. *Encyclopedia of Human Nutrition*, 2013; 2: 246-253.
- Hofl SM, Miller-Fosmore1 CM, Cote GL. Growth of various intestinal bacteria on alternansucrase derived oligosaccharides. *Lett Appl Microbiol*, 2005; 40: 385-390.
- Hsu C-K, Liao J-W, Chung YC, Hsieh CP, Chan Y-C. Xylooligosaccharides and fructooligosaccharides affect the intestinal microbiota and precancerous colonic lesion development in rats. *J Nutr*, 2004; 134: 1523-1528.
- 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. *Carbohydr Polym*, 2010; 80: 599-617.
- Zeng J, Gao HY, Li GL. Effect of Sucrose Esters on the Physicochemical Properties of Wheat Starch. *Trop J Pharm Res*. 2013; 12: 685-690.
- Sandhu KS, Singh N, Kaur M. Characteristics of the different corn types and their grain fractions: physicochemical, thermal, morphological, and

- rheological properties of starches. J Food Eng, 2004; 64: 119–127*
19. Lubashenko VV. *Size-dependent melting of nanocrystals: a self-consistent statistical approach. J Nanopart. Research, 2010; 12: 1837–1844.*
20. Hasa D, Voinovich D, Perissutti B, Grassi G, Fiorentino S, Farra R, Abrami M, Colombo I, Grassi M. *Reduction of melting temperature and enthalpy of drug crystals: Theoretical aspects. Eur J Pharm Sci, 2013; 50: 17–28.*