Iranian Food Science and Technology Research Journal
Vol. 15, No. 3, Aug. Sep. 2019, p. 1-12

نشریه پژوهشهای علوم و صنایع غذایی ایران
جلد 15، شماره 3، مرداد - شهریور 1398، ص. 12-1

# Potential of β-d- glucan to enhance physicochemical quality of frozen soy yogurt at different aging conditions

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Received: 2017.10.24
Accepted: 2018.09.17

**Abstract**

β-d- glucan as a soluble dietary fiber, has many desirable physical and physiological characteristic. In this research the effect of β-d- glucan and aging conditions (Time and Temperature) on some physicochemical and textural properties of frozen soy yogurt was investigated. Three variables including concentration of oat β-d-glucan (0, 1 and 2%), aging time (2, 13 and 24 h) and aging temperature (2, 4 and 6°C) were studied. The results showed that the addition of β-d- glucan to frozen yogurt increased viscosity, overrun, hardness and fat destabilization but the melting resistance and L*value were decreased. In terms of aging conditions, it was revealed that increasing aging time could improve the quality of product whereas higher temperature had an undesirable effect on the quality of frozen soy yogurt. Longer aging time caused an increase in viscosity, hardness, fat destabilization and melting resistance. By increasing aging temperature, fat destabilization, overrun and viscosity were decreased and melting rate was increased. It was concluded that addition of β-d-glucan as a dietary fiber and prolonged aging time at low temperature could adjust textural properties of frozen soy yogurt and improve quality of this frozen dessert.

**Key words**: Frozen soy yogurt, β -d- glucan, Aging time, Aging temperature

## Introduction

Food producers attempt to develop new food formulations towards functional foods and ingredients according to the customer demands for healthy nutrition (Havrlentova *et al*., 2011). Addition of soluble dietary fiber to foods is one of the ways to produce functional food and to improve health. Dietary fibers are a class of storage and cell wall polysaccharides that resist to human digestive enzymes (Bangari, 2011).

β -d- glucan is a soluble fiber that found in some cereals such as oat and barely. It is a polymer of glucose with β (1→3) and β (1→6) glycosidic linkage and is extracted from cereal, mushroom, seaweed and yeasts (Kobayashi *et al*. 2005; Rhee *et al*., 2008). Addition of this dietary fiber to food is beneficial physiologically because it can reduce the serum LDL and total cholesterol level. It also adjust glycemic index due to its fermentability effect (Nikoofar *et al*., 2013). Furthermore, it could affect textural characteristic of products and therefore sensory perception (Vasiljevic *et al*., 2007). There are some researches about application of β-d- glucan in dairy. Nikoofar *et al*. (2013) studied the effect of oat β-d- glucan as a fat replacer on rheological properties of nonfat set yogurt. They stated that yogurt containing β-d- glucan had firm and creamy texture with darker color. Vasiljevic *et al*. (2007) investigated the effect of β-d- glucan on a probiotic yogurt. They reported that addition of β-d- glucan caused a weaker gel incapable of retaining water. Bangari (2011) studied the effects of oat β-d- glucan on the stability and textural properties of milk beverage fortified with β-d- glucan. The author reported that samples containing different levels of β-d-glucan had higher viscosity than control

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DOI: 10.22067/ifstrj.v15i3.69900

sample. However there is no report about applying β-d- glucan in frozen soy yogurt.

Frozen yogurt or yogurt ice cream is a functional dairy dessert that combines the physical characteristics of ice cream with the sensory properties of fermented milk product (Marshall *et al.* 2003). It is prepared by freezing a pasteurized mix containing milk fat, SNF, sweetener, stabilizer and yogurt (Guner *et al*., 2007). The use of soy products in the manufacturing of foodstuff has some positive effects related to human health. It has capability to reduce the risk of cancers such as breast and prostate cancers. Incorporating soy to dairy dessert may potentially serve as carriers of valuable soy ingredients (Mahdian *et al*., 2012). Dervisoglou *et al*. (2005) investigated the effect of soy protein concentrate (SPC) on physical, chemical and sensory properties of ice cream. Their results showed that SPC positively influenced viscosity, melting rate and appearance.

Aging is an important step of production dairy dessert such as ice cream and frozen yogurt. Aging condition promotes some significant effect in ice cream mix (Botega, 2012). In this process, the fat crystallizes, protein adsorbs on the fat globules and hydration of the protein occurs (Issariyachaikul, 2008). These events need to continue for a few hours. Aging conditions could affect the events that occured in this period. Thus, the objective of this study was to investigate the effects of β-d- glucan addition and aging conditions on some physicochemical and qualitative properties of frozen soy yogurt.

## Materials and Methods

Soymilk was prepared according to the method of Mahdian *et al*. (2012) with some modifications. Soymilk blend contains 8% soy flour (Toos soyan Co. Iran), 4% skim milk powder (Pegah Co. Iran) and 1% food grade sodium citrate (Merck, Germany) was prepared by dissolving the mentioned components in hot water (90-95°C). β-d- glucan from oat (Imam Co. China) was added to the mixture at different levels (0, 1 and 2%). The mixture (13% dry matter) was stirred completely by a hand blender (Gosonic, Turkey) so that homogenous and free of sandy mouth feel soy milk was obtained. This mixture was heated at 85 °C for 30 minutes. After cooling to 42°C, yogurt starter (0.2 %) (YF-L812, CR-Hansen, Denmark) was added and followed by incubation at 42°C. When acidity reached to 80° Dornic, fermentation process was stopped and the yogurt was cooled to 10°C.

To prepare frozen yogurt mix, sugar (16%), stabilizer- emulsifier mix (0.2%, lux6700, Cargill, France) and skim milk powder (to adjust total solid to 35%) were dissolved in water and heated at 85°C for 30 minutes. After cooling to 10°C, the mixture was blended with yogurt and aged at different temperatures (2, 4 and 6°C) for certain times (2, 13 and 24 hr). The aged frozen soy yogurt mix was frozen using a laboratory batch ice cream maker (Musso, Italy) for 30 minutes. After freezing, samples were distributed among polyethylene cups (50 ml) and hardened at -18°C until analysis.

### Measurement of overrun

Overrun is an important property of ice cream and frozen yogurt that affects the physical condition and storage stability. The overrun was calculated using the following equation (Rossa *et al*., 2012):

(Weight of unit volume of mix before freezing– weight of unit volume of ice cream)/ Weight of unit volume of ice cream)×100 (1)

### Measurement of viscosity

Viscosity measurement was done for frozen soy yogurt mix immediately after aging. Apparent viscosity of samples (250 ml) was measured according to the method of Akalin and Erisir (2008) with some modifications. Viscosity was determined using Brookfield DVII RV (USA) viscometer equipped with spindle 4 at 100 rpm and at 4°C after 20s. Viscosity reported in Centipoises.

### Measurement of melting rate

Melting resistance of frozen yogurt samples was determined according to the method of Mahdian *et al*. (2013) with some modifications. Frozen yogurt (30 ± 2 gr) was placed on a wire screen (o.5 mm hole diameter) on top of a funnel that was attached to a flask. The samples were placed in a controlled temperature chamber at 25°C. The weight of melted frozen yogurt was recorded after 45 min and expressed as percentage of melted weight.

**Measurement of fat destabilization**

Fat destabilization was determined by spectrophotometery method. Briefly, an aliquot of frozen yogurt mix and final frozen yogurt was diluted to 1: 500 with distilled water and absorbance was measured at 540nm (Issariyachaikul, 2008).The smaller the fat destabilization value, the greater is the fat destabilization in the ice cream (Adapa *et al*., 2000). The percent of fat destabilization was determined using the following formula:

(Turbidity of the final frozen yogurt/ turbidity of the frozen yogurt mix)*100 (2)

**Hardness determination**

Hardness of frozen yogurt samples was measured using Texture Analyzer (TA-TX, Stable Microsystem Ltd, Uk). Samples were rapidly transported to the texture analyzer and analysis completed within 30s to minimize variability due to sample warming (Muse & Hartel, 2004). Measurements were carried out with a cylindrical probe (2 mm diameter). The penetration depth in the samples was 10mm and penetration speed was set at 2 mm/s. hardness of sample was determined as the maximum compression force during penetration.

**Measurement of foam stability**

To evaluate the foam stability, 200 ml of the frozen yogurt mix after aging was blended for 2 min in a domestic blender (Gosonic). Then the mix was poured into 250 ml graduated cylinder and the volume of produced foam was recorded. After 15 min, the final volume of foam was measured. Percent of foam stability was expressed as percent of final volume of foam to initial volume of foam (Alakali *et al*., 2009).

**Color measurement**

The color of samples was evaluated by image processing method (Hashemi-Shahraki *et al.* 2014). A digital camera was fitted on top of sample in a box (with 60 × 60 cm length and width). Interior walls of the box were covered with dark cloth for evade light scattering. The obtained pictures were transferred to a computer and saved in JPEG format. Image processing analysis was conducted using Image J software (Version 1.42, Wayne Rasband, National Institue of Health, USA). The color space of picture was converted from RGB to CIElab by using of converter space color. Mean of each color parameter was expressed as L* (lightness), a* (redness) and b* (yellowness).

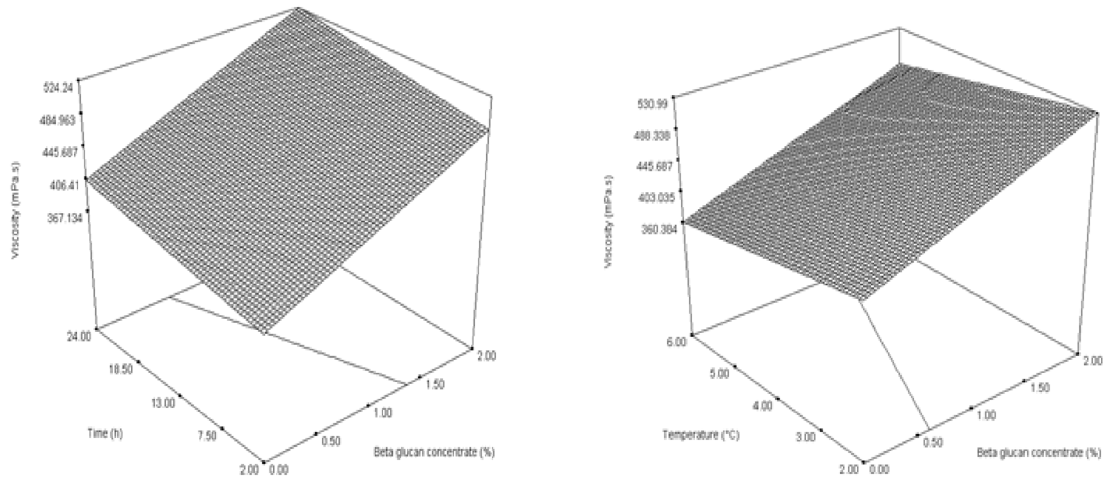
**Statistical analysis**

Response surface methodology with a central composite design was used to design and analyze the experiments. B-d- glucan concentration, aging temperature and aging time were chosen as independent variables. Design Expert software (Version 6.0.2, Stat-Ease, Inc) was used to design, arrange and analyze of experiments.

## Results and Discussion

**Viscosity**

Viscosity as one of the most important rheological properties of ice cream mix is affected by mix composition, type and quality of the ingredients, processing of the mix and temperature (Bahram Parvar and Mazaheri-Tehrani, 2011). Fig.1 shows the effect of β-d-glucan and aging condition on the viscosity of soy frozen mix. The results showed that β-d-glucan addition and extended aging time caused an increase in viscosity of soy frozen mix (Fig. 1-a) but aging temperature had inverse effect (Fig. 1-b). Higher apparent viscosity of samples containing higher concentration of β-d- glucan could be explained by potential ability of β-d-glucan to interact with soy milk protein. Maximum viscosity was observed when β-d-glucan concentration was 2% and after 24 hours aging. In terms of aging temperature, the highest viscosity was observed at 2°C. Previous studies also reported that addition of some fibers such as inulin to ice cream (Issaryachakul 2008) and frozen yogurt (Rezaei *et al*., 2014) caused a significant increase in viscosity. They stated that interaction of this dietary fiber and the liquid part of ice cream mix is the main reason for viscosity improvement. Hydration of β-d- glucan and other hydrocolloids occur during aging time so it was expectable an increase in viscosity.



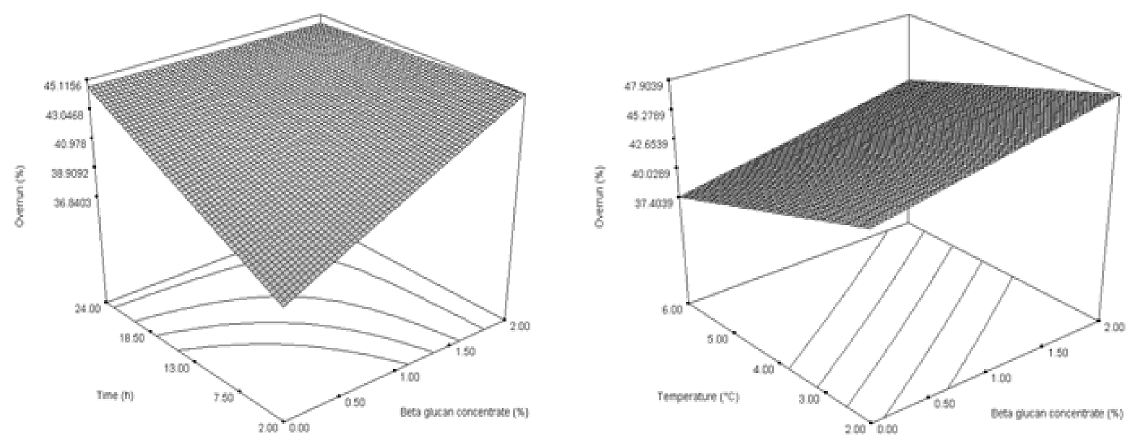

(a) (b)

**Fig. 1. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the viscosity of frozen soy yogurt mix**

**Overrun**

Overrun is a numerical indicator of the amount of air that is whipped into a product. The amount of air in frozen dessert is important because it affects the quality and profit (Bahram Parvar and Mazaheri-Tehrani, 2011). This factor also influences melting rate and sensory properties of product. It has been shown that hydrocolloids affect the ability of product to incorporate air and hold it for sufficient period of time (Lammann, 2011).

Results of this study showed that addition of β-d- glucan increased overrun of frozen soy yogurt and maximum overrun was attained by addition of 2% β-d- glucan (Fig. 2-a).



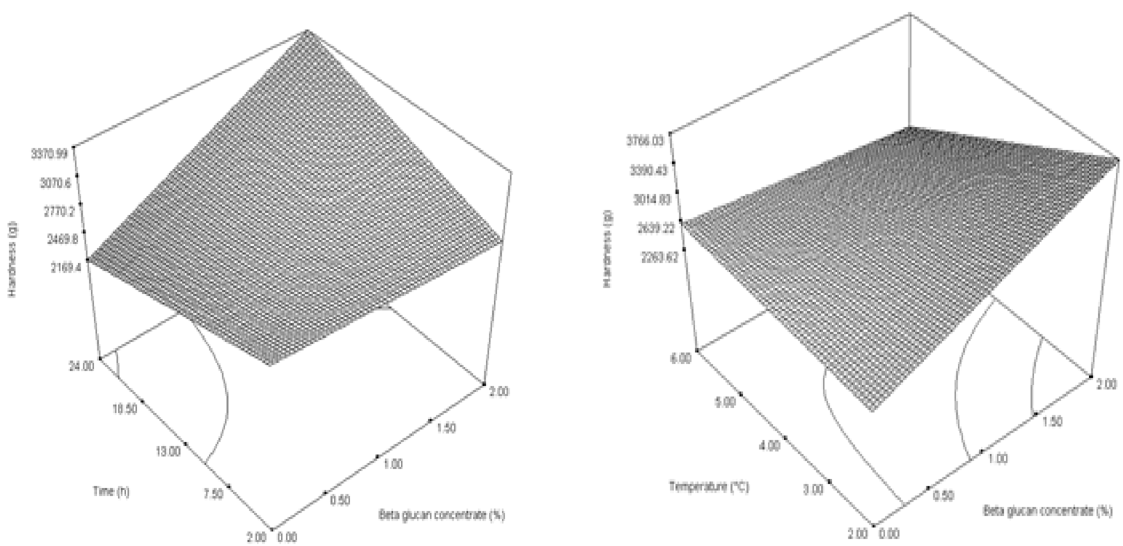

(a) (b)

**Fig. 2. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the overrun of frozen soy yogurt**

Ability of a hydrocolloid to increase overrun could be attributed to their capability to form a polymer entanglement and control the air cells unstability (Soukoulis *et al.*, 2008). Akin *et al.* (2007) reported that addition of inulin increase overrun values of the ice cream sample but it was insignificant. A similar result was obtained by Rezaei *et al.* (2011). They also stated inulin increased the overrun of frozen yogurt. Aging time also had a positive effect on the overrun and highest overrun was observed after 24h of aging period (Fig. 2-a). Non-aged ice cream mix shows a loose stand up and unpredictable whipping. The whipping ability of the mix usually improves with aging (Goff, 1997). Temperature of aging had negative effect on overrun and decreased it. Lowest overrun was belonged to sample without β-d- glucan that aged at 6°C and it was seen that overrun increased at lower temperature (Fig. 2-b).

**Hardness**

Hardness of ice cream is an index of resistance of ice cream to deformation when an exterior force is applied (Muse and Hartel, 2004). Conventionally, hardness of frozen dairy products is determined by a penetrometer test (Adapa *et al.*, 2000). This test shows the required force to penetrate the probe into samples. The higher the force, the higher is the hardness. Soukoulis *et al.* (2008) reported that hardness measurments reveal the impact of ingredients such as hydrocolloids and processing conditions (such as aging) on the product. Our results showed that hardness enhanced with increasing β-d- glucan level and aging time. The maximum hardness was observed in sample containing 2% β-d- glucan and aged for 24 hours (Fig. 3-a). Actually, addition of β-d- glucan and increasing aging time caused an increase in viscosity that resulted in rising the hardness. Rheological property of the mix is a factor that affects the hardness. The ice cream was harder when the apparent viscosity was greater (Muse and Hartel, 2004).



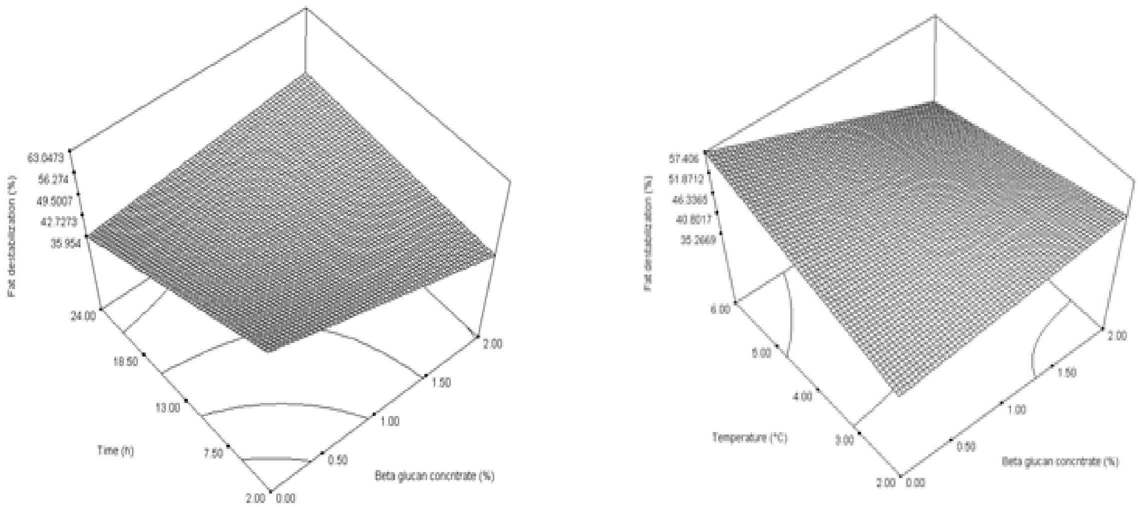

(a) (b)

**Fig. 3. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the hardness of frozen soy yogurt**

According to Akalin and Erisir (2008) ability of some ingredients to bind water and form a gel network can improve the firmness of products. Gustaw *et al.* (2011) studied the influence of selected prebiotic on the some properties of bio-yogurt. They reported that addition of 1% FOS increased viscosity and hardness of yogurt. They explained it was a part of the structural network being formed during fermentation. Another factor that affects the hardness is fat destabilization. Hardness of ice cream increased as level of destabilized fat increased. Results of fat destabilization measurement of this study confirmed this claim. Lower temperature had a positive impact on the hardness and maximum hardness was detected at 2°C and 2% β-d- glucan (Fig. 3-b)

**Fat destabilization**

Destabilized fat in the form of partially coalesced fat globules coats and stabilizes air cells (Mous and Hartel, 2004). Fat destabilization in ice cream affects some properties such as melting rate and overrun. Segall and Goff (2002) reported that positive characteristics of ice cream that associated with the destabilized fat are the high overrun and slow melt down rate. Our results showed that maximum fat destabilization occurred when β-d- glucan concentration and aging time were in the highest level (Fig. 4-a).




**(a)** **(b)**

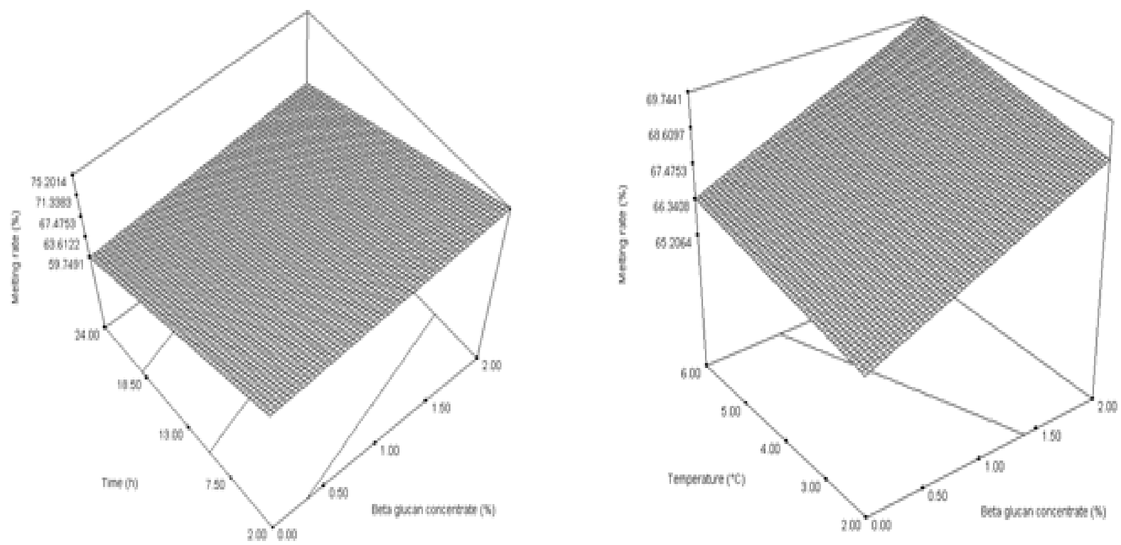
**Fig. 4. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the fat destabilization of frozen soy yogurt**

By increasing β-d- glucan, the level of destabilized fat increased. This phenomenon could be attributed to high viscosity of mix as a result of β-d- glucan addition. Muse and Hartel (2004) also reported that ice cream made with corn syrup (DE=20) had higher viscosity that led to higher level of fat destabilization. Higher aging temperature had an inverse effect on fat destabilization (Fig. 4-b). Lower temperature of aging led to the formation of partially crystalline fat droplet. Partial crystallization of fat droplet in ice cream mix promoted partial coalescence which caused to formation of a stable ice cream structure (Botega, 2012).

**Melting rate**

The melt down rate of ice cream is affected by many factors including the amount of incorporated air, the nature of ice crystals and the network of fat globules formed during freezing (Muse and Hartel, 2004). A slow, uniform melting of ice cream is desirable (Baer *et al.*, 1999).Our results showed that addition of β-d- glucan increased melt down rate of soy frozen yogurt (Fig. 5-a).

Our findings were in contrast with some researches that stated dietary fibers such as inulin reduced melting rate (Aykan *et al*. 2008; Rezaei *et al*. 2011). This event may be related to incompatibility between casein and β-d-glucan as a non-interacting polysaccharide that led to form a weak network (Nikoofar *et al.*, 2013). Vasiljevic *et al.* (2007) also verified this behavior of β-d- glucan in network containing casein. Unlike β-d- glucan concentration, prolongation of aging time caused a decrease in melt down (Fig. 5-a). This effect may be explained with higher consistency of mixes when aged for long time. Higher viscosity could retard the melting of product (Akalin and Erisir, 2008). Actually, when serum viscosity increased, more time is required for the water to be diffused into the concentrated serum before it flows to the ice cream exterior (Sokoulis *et al.*, 2008). Moeen Fard and Mazaheri-Tehrani (2008) showed that in all samples containing different stabilizers (Panisol ex, salab and a mix of stabilizers and emulsifiers include sodium alginate, guar, carageenan and polysorbate 80) melting resistance increased significantly. Temperature of aging caused an increase in melt down rate of soy frozen yogurt and maximum melt down rate was observed at 6°C. This event could be explained with lower viscosity and lower overrun of samples that aged at higher temperature. Lower overrun is correlated to higher heat transfer rate and therefore fast melting rate of these samples.




**(a)** **(b)**

**Fig. 5. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the melting rate of frozen soy yogurt**

**Color**

Color is a key attribute in foods because it is usually the first property that observed by the customer (Sanabria, 2007). Different factors such as ingredients and manufacturing parameters influence the color of products. Results of this study showed that addition of β-d- glucan had considerable effect on the color of soy frozen yogurt. It lowered the L*(lightness) and increased b* (yellowness) values that could be related to pale yellow color of β-d- glucan powder that was used for frozen soy yogurt formulation. Nikoofar *et al.* (2013) investigated yogurt containing β-d- glucan and explained L* value was decreased with increase in amount of β-d- glucan and b* values in yogurt containing β-d- glucan were decreased. Aging conditions also affected on color indexes. Whereas aging time increased L* and b* values, aging temperature decreased L* and increased b*. Effects of β-d- glucan, aging time and aging temperature on a* was observed in Fig. 6-a and 6-b.

**Foam stability**

Fig. 7 shows the effect of β-d- glucan and aging conditions on the foam stability of soy frozen yogurt mix.

According to our data, it is found that maximum foam stability was obtained in central point of aging time and highest concentration of β-d- glucan. Temperature had no considerable effect on the foam stability. Amount of foam formation of soy frozen yogurt mix inversely correlated with foam stability (data not shown).

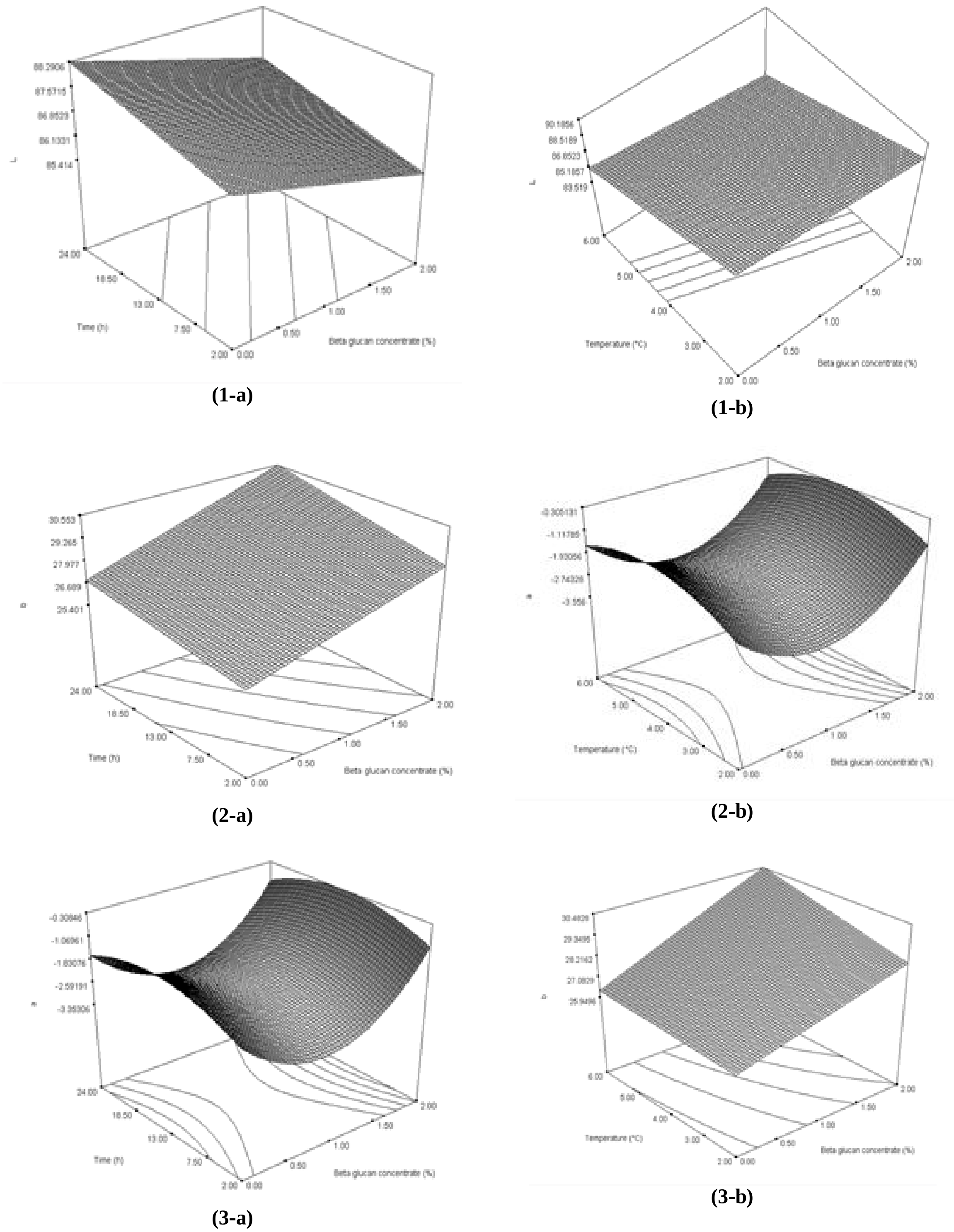
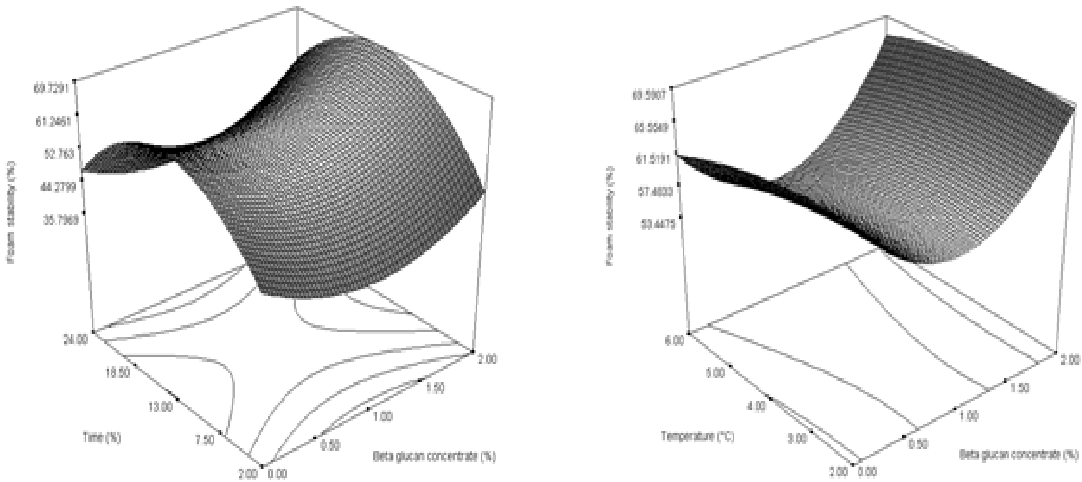



**Fig. 6. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the color (1: L*, 2: a* and 3: b*) of frozen soy yogurt**

It seems that viscosity plays an important role for foam formation and its stability. By increasing viscosity, foam stability was improved. Higher viscosity and heavy body of ice cream mix caused that air cells remain invariable, consequently foam stability increased (Alakali *et al.*, 2009).




**(a)** **(b)**

**Fig. 7. Effect of β-d- glucan and aging condition (a: time and b: temperature) on the foam stability of frozen soy yogurt**

## Conclusion

This study investigated some physicochemical properties of frozen soy yogurt containing β-d- glucan manufactured at different aging conditions. Results of this study showed that addition of β-d- glucan could improve some characteristics of frozen soy yogurt. Overrun viscosity, hardness and fat destabilization of product increased by adding β-d- glucan. Prolongation aging time to 24 hour had positive effect on viscosity and hardness but decreased overrun. Our results also revealed that aging at lower temperature (2°C) is preferable to make this dessert. So, we can introduce β-d-glucan as a proper option to modify frozen soy yogurt texture and sensory properties

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Iranian Food Science and Technology Research Journal
Vol. 15, No. 3, Aug. Sep. 2019, p. 1-12

**نشریه پژوهشهای علوم و صنایع غذایی ایران**
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# پتانسیل بتاگلوکان جهت بهبود کیفیت ماست سویا منجمد تحت شرایط مختلف دوره رساندن

**راحیل رضایی[1]- مرتضی خمیری[*1]- مهدی کاشانی‌نژاد[1]- مصطفی مظاهری تهرانی[2]- مهران اعلمی[1]**

تاریخ دریافت: 1396/10/13
تاریخ پذیرش: 1397/06/26

**چکیده**

در این مطالعه، تاثیر بتاگلوکان و شـرایط رساندن (دما و زمان) بر برخی ویژگی‌های فیزیکوشیمیایی و بافتی ماست سویا منجمد مورد بررسی قرار گرفته است. سه متغیر شامل مقدار بتاگلوکان (صفر، 1و 2 درصد)، زمان رساندن (2، 13 و 24 ساعت) و دمای رساندن (2، 4 و 6 درجه سانتی‌گراد) مورد مطالعه قرار گرفت. نتایج نشان داد که افزودن بتاگلوکان به ماست منجمد باعث افزایش ویسکوزیته، اوران، سختی و ناپایداری چربی گردید اما مقاومت به ذوب و شـاخص *L را کاهش داد. از نظر شرایط رساندن، مشخص شد که افزایش زمان رساندن کیفیت محصول را افزایش داده در حالی که دمای بالاتر تاثیر نامطلوبی بر کیفیت ماست سویا منجمد بر جای گذاشت. زمان رساندن طولانی ترسبب افزایش ویسکوزیته، سختی، ناپایداری چربی و مقاومت به ذوب شـد. با افزایش دمای رسـاندن ناپایداری چربی، اوران و ویسکوزیته کاهش یافت و سرعت ذوب افزایش یافت. بر اساس این یافته‌ها می‌توان نتیجه گرفت که افزودن بتاگلوکان به‌عنوان فیبر رژیمی و زمان رساندن طولانی در دمای کمتر می‌تواند ویژگی‌های بافتی ماست سویا منجمد را تعدیل و کیفیت این دسر منجمد را بهبود دهد.

**واژه‌های کلیدی:** ماست سویا منجمد، بتاگلوکان، دمای رساندن، زمان رساندن

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