

Effect of resistant starch and aging conditions on the physicochemical properties of frozen soy yogurt

Rahil Rezaei¹ · Morteza Khomeiri¹ · Mahdi Kashaninejad¹ ·
Mostafa Mazaheri-Tehrani² · Mehran Aalami¹

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Abstract The present study investigated the effects of resistant starch concentration (0, 1, 2 %), aging time (2, 13, 24 h) and aging temperature (2, 4, 6 °C) on the physicochemical properties of frozen soy yogurt. The results showed that resistant starch increased viscosity because of its water binding properties. Resistant starch also increased foam stability, fat destabilization, and hardness, but it decreased overrun and meltdown rate. Viscosity, hardness and fat destabilization increased as aging time increased. An increase in aging temperature decreased viscosity, overrun, hardness and fat destabilization of frozen yoghurt, but increased the meltdown rate.

Keywords Resistant starch · Frozen soy yogurt · Aging time · Aging temperature

Introduction

Frozen yogurt, or yogurt ice cream, is a complex of yogurt and ice cream. This dessert combines the flavor

Research highlights 1- Addition of resistant starch as a dietary fiber could modify textural properties of frozen soy yogurt.
2- Prolonged aging time could improve properties of this frozen dessert.
3- Higher aging temperature had negative effect on the quality of frozen soy yogurt.

✉ Rahil Rezaei
azar_rahil_64@yahoo.com

¹ Food Science and Technology Faculty, Agricultural and Natural Resources University of Gorgan, Gorgan, Iran

² Food Science and Technology Faculty, Ferdowsi University, Mashahd, Iran

of yogurt and texture of ice cream. Consumers have a strong preference for functional foods containing specific ingredients and can reduce the threat of diseases such as cancer and heart diseases (Champagne et al. 2009). Soybean has been reported to contain a high concentration of isoflavones with potential health-enhancing properties (Chen et al. 2012). Also, Soy oil can reduce bad cholesterol due to its polyunsaturated fatty acid. The incorporation of soy and its products into the human diet is attractive because of its perceived nutritional properties (Rinaldoni et al. 2012). There has also been increasing demand for substitutes to cow's milk for those who should avoid its consumption. Soy-based products also meet the needs of vegetarians and therefore interest in soy-based products has developed (Farnworth et al. 2007).

The addition of dietary fiber to dairy products is one of the fields of functional foods. Dietary fiber is a class of compounds that includes a mixture of plant carbohydrate polymers, oligosaccharides and polysaccharides, resistant starch, beta glucan and inulin (Elleuch et al. 2010). Dietary fibers have many health profits. They regulate bowel movement and help maintain bowel health. Fiber can modify and improve the texture and sensory properties of food because of its ability to bind with water, form gels, and its thickening properties (Soukoulis et al. 2009). Resistant starch (RS) is a fraction of starch that can resist digestion thus attains the colon (Fuentes-Zaragoza et al. 2011). Its physiological properties are similar to that of soluble fiber and it is fermented by useful microorganisms in the colon (Dundar and Gocmen 2013).

Aging is a key step in ice cream production. This step is defined as the time in the procedure where the mix will be cooled for a period of 2–24 h (Marshall et al. 2003). Aging improves the viscosity, whipping ability of mix, body and

texture of the final product. It also decreases stabilization fat globules and causes fat crystallization (Issariachaikul 2008). The present study evaluated the effect of RS and aging time and temperature on the physicochemical properties of frozen soy yogurt.

Materials and Methods

Soy yogurt preparation

Soymilk blend containing 8 % soy flour, 4 % skim milk and 1 % food grade sodium citrate was prepared by dissolving in hot water (90–95 °C). Different amounts of RS (0, 1, 2 %) were then added. The mixture was stirred thoroughly so that the soy milk was homogenous and smooth. This mixture was heated to 85 °C for 30 min. After cooling the mixture to 42 °C, yogurt starter (YF-L812; CR-Hansen; Denmark) was added and the mixture was incubated at 42 °C. When acidity reached 80° Dornic, fermentation process was stopped and the yogurt was cooled to 10 °C.

$$\% \text{ Overrun} = [(weight\ of\ unit\ volume\ of\ mix - weight\ of\ unit\ volume\ of\ frozen\ yogurt) / weight\ of\ unit\ volume\ of\ frozen\ yogurt] \times 100 \quad (1)$$

Viscosity

Viscosity of the frozen soy yogurt mix was determined according to Pintor and Totosaus (2012) with some modifications. Measurements were carried out at 5 °C using a Brookfield DVII viscometer with RV spindle (#4) after aging. All measurements were recorded at 100 rpm.

Meltdown rate

Meltdown tests were carried out on frozen soy yogurt samples stored at −18 °C. The samples were placed onto a stainless steel screen (hole diameter: 0.5 mm) over a beaker. The serum passing through the screen was weighed after 45 min at 20 °C (Akalin and Erisir 2008).

Fat destabilization

Fat destabilization was evaluated by spectroturbidometry. Briefly, an aliquot of frozen yogurt mix and final frozen yogurt were diluted at 1:500 with distilled water and their absorbance was measured using a spectrophotometer at 540 nm. Distilled water was used as a blank (Issariachaikul 2008). Equation (2) was used to determine the percentage of fat destabilization. The smaller

Frozen yogurt mix

To prepare the frozen yogurt mix, sugar (16 %), stabilizer-emulsifier mix (0.5 %, Lux6700; Cargill; France) and skim milk powder (adjusted to total solids of 30 %) were dissolved in water and heated to 85 °C for 30 min. After cooling, the mixture was blended with yogurt and aged at different temperatures (2, 4, 6 °C) for different lengths of time (2, 13, 24 h). The aged mix was then frozen using a laboratory batch ice cream maker. After freezing, samples were distributed into plastic cups (50 ml) and hardened at −18 °C.

Frozen soy yogurt analysis

Overrun

Overrun was determined by measuring the weight of a specific volume of frozen yogurt mix and final frozen yogurt and is calculated as (Adapa et al. 2000):

the percentage of fat destabilization, the greater is the fat destabilization in the ice cream (Adapa et al. 2000).

$$\text{Turbidity of final frozen yogurt} / \text{Turbidity of frozen yogurt mix} \times 100 \quad (2)$$

Foam stability

To determine foam stability, 200 ml of the frozen yogurt mix was blended for 2 min in a domestic blender. The mix was then poured into a 250 ml graduated cylinder and the volume of foam produced was recorded. After 15 min, the final volume of foam was measured. The percentage of foam stability was expressed as the percentage of final volume of foam to initial volume of foam.

Color

The color was measured using an image processing method (Hashemi Shahraki et al. 2014). A digital camera adjusted to the top of a sample in a box (60 × 60 cm in size). The interior of the box was covered with dark cloth to prevent light scattering. The images were directly transferred to a computer for image processing using Image J software (Version 1.42, National Institutes of Health, USA). The color space of the

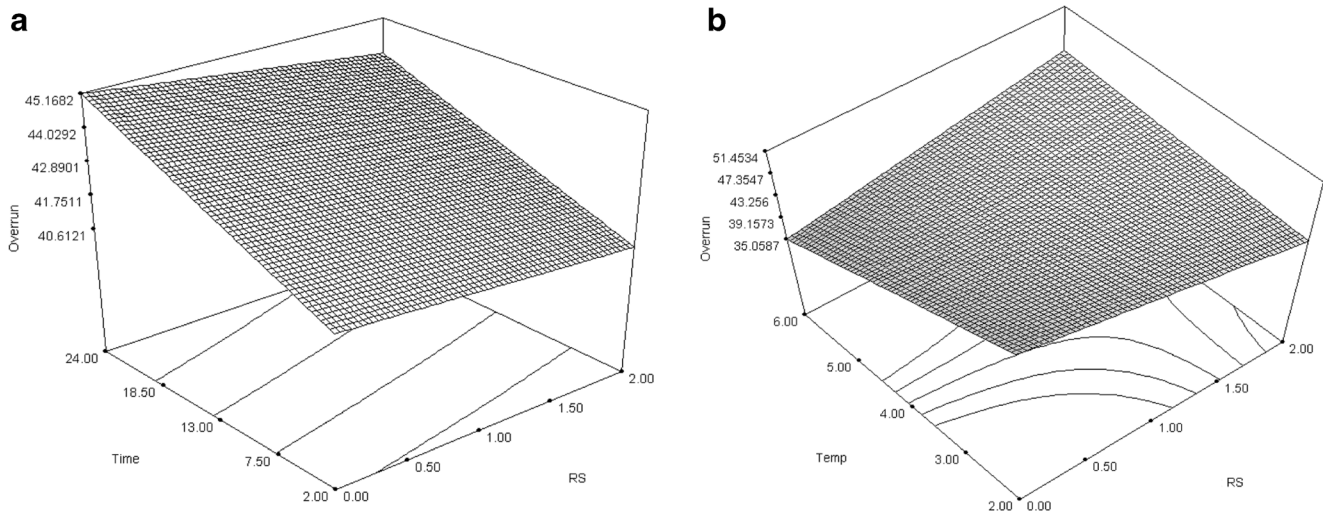


Fig. 1 Effect of RS and aging on overrun: **a** time; **b** temperature

images was converted from RGB to CIElab. The mean of each color parameter was expressed as L* (lightness), a* (redness) and b* (yellowness).

Texture (hardness)

Texture analysis was conducted using a texture analyzer (TA.XT plus, UK). The samples were stored in 50 mm plastic containers at -20°C until analysis. Measurement was carried out using a cylindrical probe (P2). The penetration depth at the geometrical center of the sample was 10 mm and penetration speed was set at 2 mm/s. The hardness was determined as the peak compression force (g) during penetration (Rossa et al. 2012).

Statistical analysis

The parameters in the experimental design were RS concentration, aging time and aging temperature. Response surface

methodology with a central composite design was used to evaluate the effects of these three variables. The independent variables were RS (0, 1, 2 %), aging time (2, 13, 24 h) and aging temperature (2, 4, 6 $^{\circ}\text{C}$). Design-Expert software (Version 6.0.2, Stat-Ease) was used to design and arrange the experiments. All testing was carried out in triplicate.

Results and discussion

Overrun

The results showed that the addition of RS decreased overrun, but not considerably (Fig. 1a). Whipping ability associated with overrun determines the simplicity of air integration into the mix and subsequent diffusion and the stability of air cells in the ice cream (Baer et al. 1999). It has been reported that viscous components could prohibit air incorporation and high

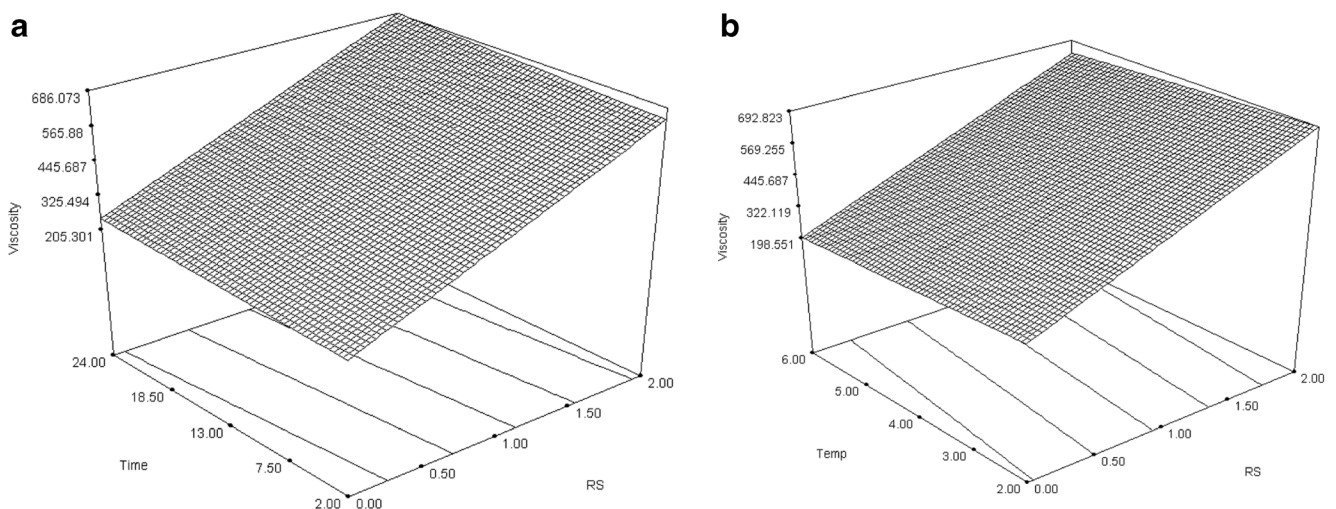


Fig. 2 Effect of RS and aging on viscosity: **a** time **b** temperature

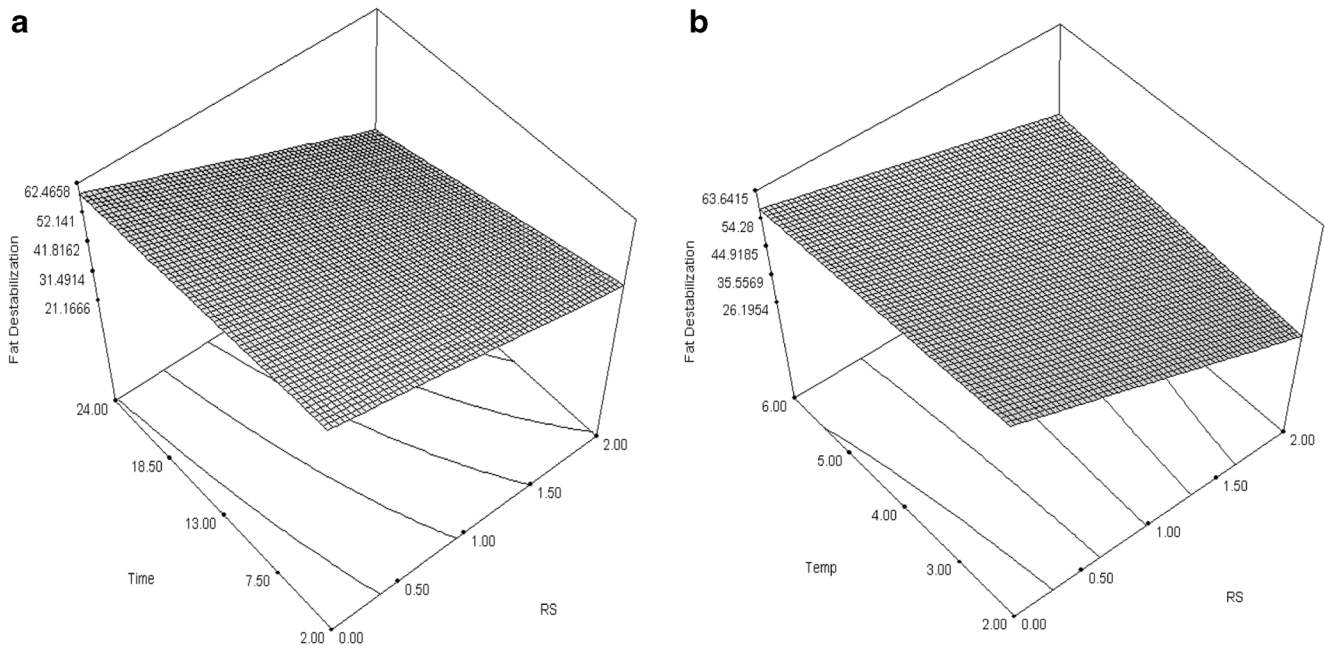


Fig. 3 Effect of RS and aging on fat destabilization: **a** time **b** temperature

viscosity systems do not support foaming ability (Adapa et al. 2000). The results also showed that overrun increased with aging time. This could be attributed to the increase in viscosity over aging time. An adequate level of viscosity is necessary to maintain air bubbles, although when viscosity increases considerably, the whipping ability decreased (Marshall et al. 2003). Increased aging temperature had a negative effect on overrun (Fig. 1b).

Viscosity

The addition of RS strongly increased the viscosity of the frozen soy yogurt mix (Fig. 2a). A similar result was obtained

for aging time, but the effect was unimportant. Aging temperature decreased the viscosity of the mix (Fig. 2b). Dietary fibers such as RS can impart functional properties to foods such as increasing the water retention capacity that improves the viscosity (Elleuch et al. 2010).

The effect of the addition of RS on viscosity is the result of water retention by soluble fiber and the increase in serum concentration (Soukoulis et al. 2009). Rezaei et al. (2014) reported that inulin increased the viscosity of frozen yogurt significantly. They stated that the hygroscopic nature of inulin was responsible for the improvement of viscosity. During aging, hydration of components became complete, meaning that increased aging time increased viscosity, as expected.

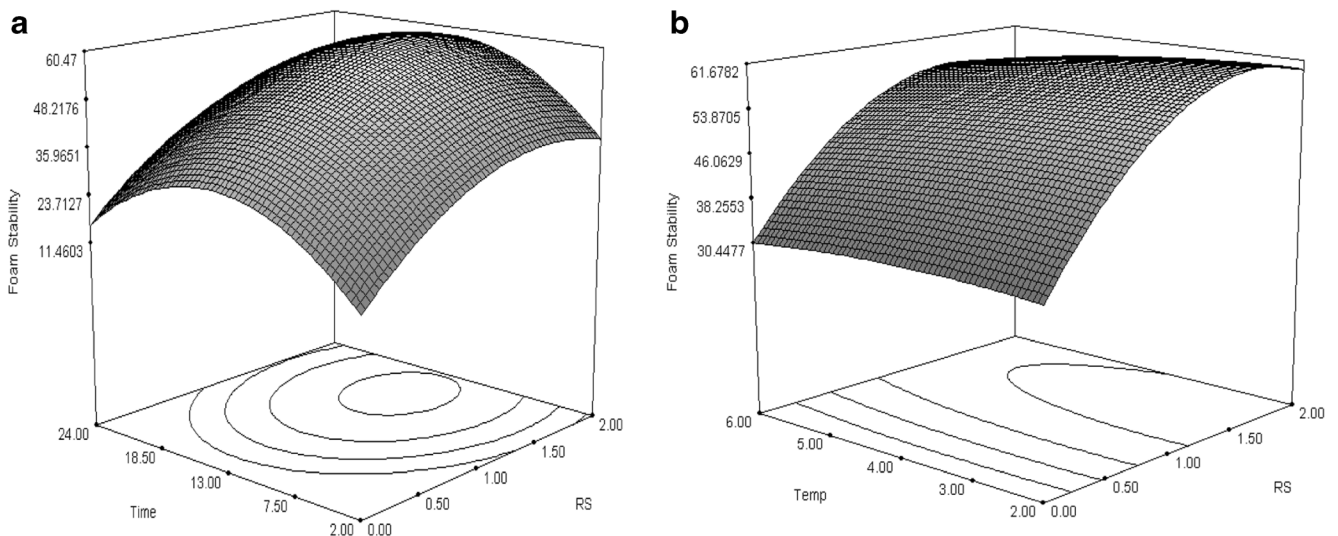


Fig. 4 Effect of RS and aging on foam stability: **a** time **b** temperature

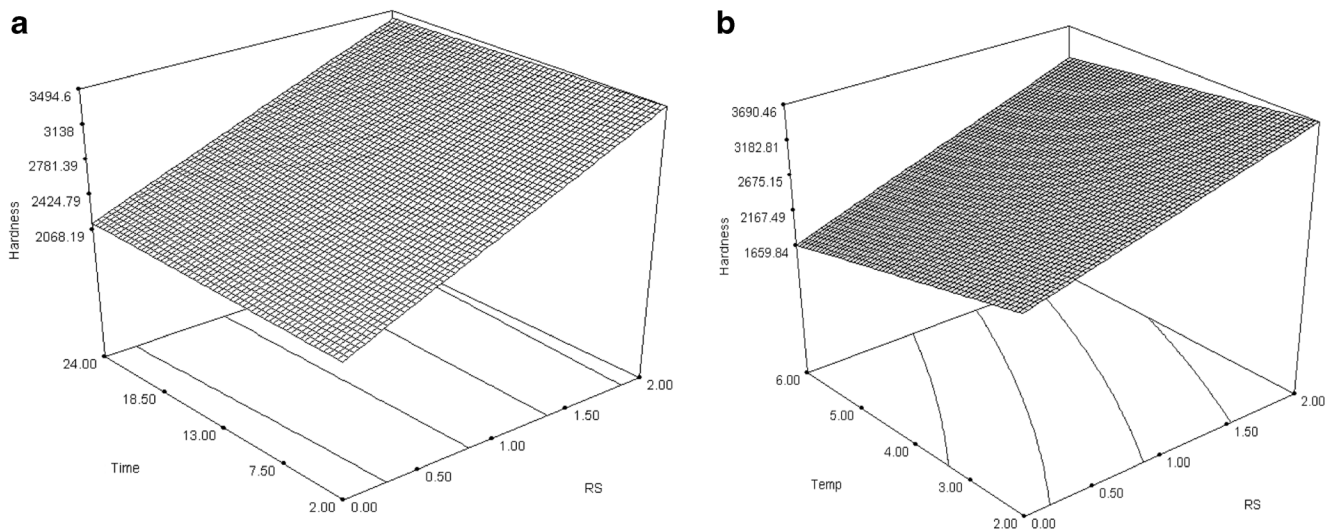


Fig. 5 Effect of RS and aging on hardness: **a** time **b** temperature

Fat destabilization

Fat acts as an important component in stabilization of the ice cream structure. Partly coalesced fat is responsible for stabilizing the air bubbles and foam formation (Koxholt et al. 2001). Some experiments demonstrated that fat destabilization has significant effect on ice cream properties such as mouth feel, appearance, overrun and meltdown (Berger and White 1971; Koxholt et al. 2001). The results showed that an increase RS concentration decreased the percentage of fat destabilization (Fig. 3a). As stated, the smaller the fat destabilization value, the greater is the fat destabilization in ice cream. RS increased fat destabilization in frozen soy yogurt. This result could be attributed to the ability of RS to improve the stability of foam in the food system, which gives the emulsion

destabilization power (Franck 2002). Issariachaikul (2008) also confirmed that the formulas for ice cream have been shown to influence fat destabilization. They reported that the addition of inulin significantly increased fat destabilization of ice cream. Aging temperature decreased fat destabilization (Fig. 3b).

Foam stability

Results showed that increasing RS concentration increased the foam stability of the frozen yogurt mix (Fig. 4a). This was attributed to the heavy and soggy texture of the mix, which produced a comparatively low foaming ability and high foam stability (Alakali et al. 2009). Rossa et al. (2012) stated that high viscosity does not favor the formation of foam, but does

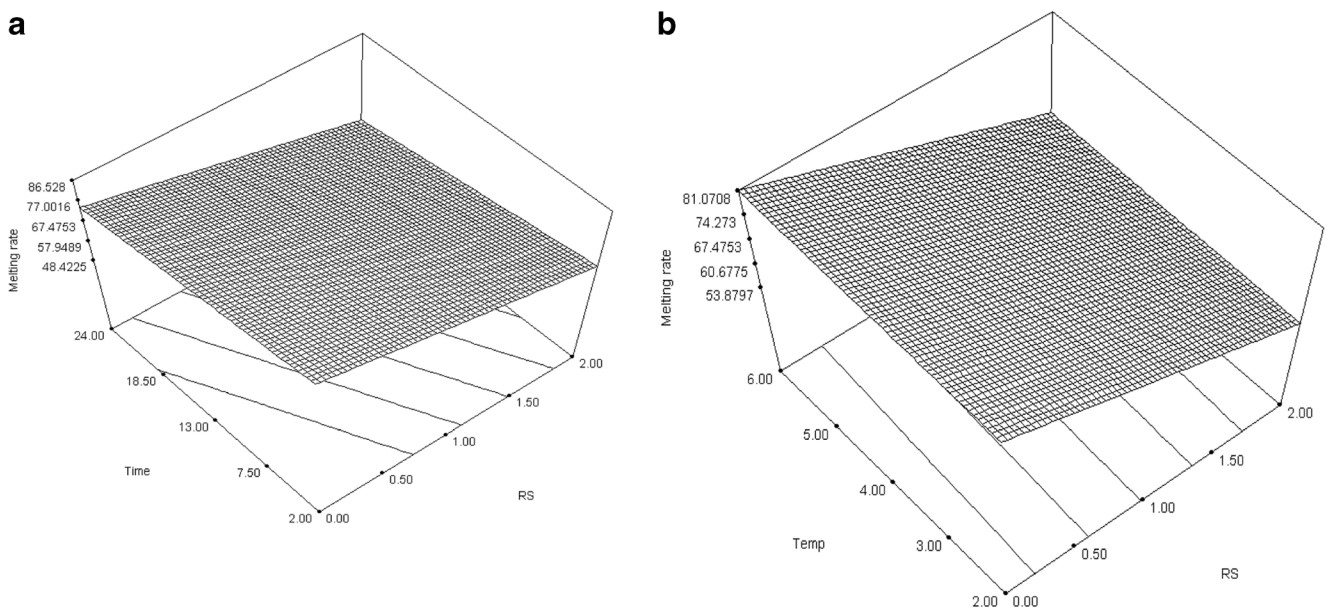


Fig. 6 Effect of RS and aging on meltdown rate: **a** time; **b** temperature

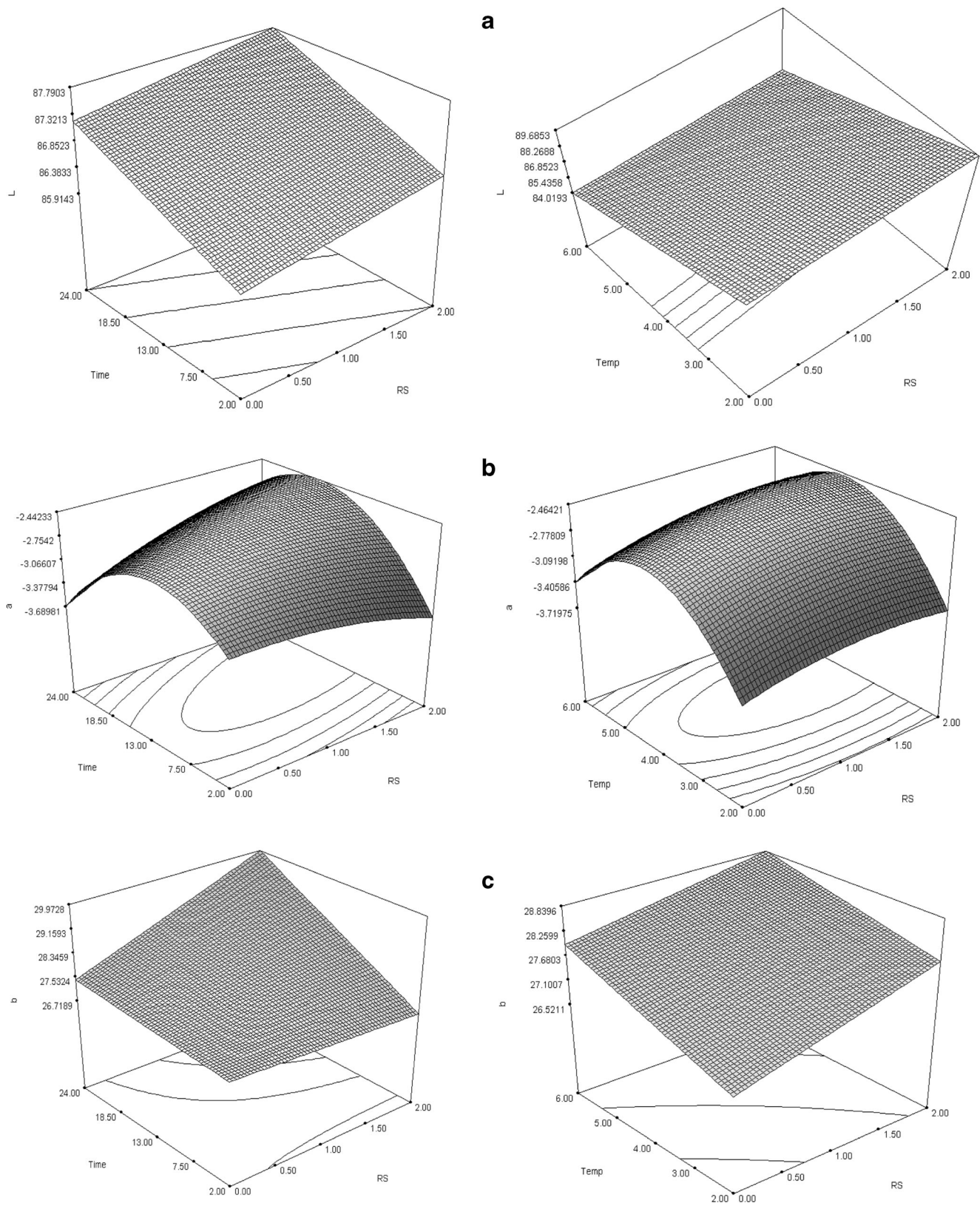


Fig. 7 Effect of RS, aging time and aging temperature on: **a** L^* **b** a^* **c** b^*

contribute somewhat to the stability of foam. RS and aging time increased viscosity, which increased foam stability.

Aging temperature decreased foam stability (Fig. 4b). Fat destabilization is another factor affecting foam stability. Fat that

was destabilized by the addition of RS contributes to stabilization of the structure of the air and foam (Granger et al. 2005).

Hardness

The hardness of ice cream correlated with its resistance to deformation when an exterior force is applied (Muse and Hartel 2004). Hardness reveals the effect of the ingredients and processing conditions (Mahdian and Karazhian 2013). Overrun, the size of ice crystals and fat destabilization are factors that affect ice cream hardness. The results showed that hardness of samples corresponded with viscosity and hardness increased sharply when RS concentration and aging time increased (Fig. 5a). This result could be attributed to ability of RS to entrap water and form a gel network (Akalin and Erisir 2008).

Muse and Hartel (2004) reported that rheological properties such as viscosity of ice cream mix could influence hardness and that samples were harder when their apparent viscosities were greater. They also confirmed that increased fat destabilization increased hardness because destabilized fat supplies a network between the air cells in the ice cream that can enhance the hardness of ice cream. The results of the present study showed that the hardness of frozen yogurt decreased when the aging temperature increased (Fig. 5b).

Meltdown rate

The meltdown rate of frozen soy yogurt was measured at 20 °C for 45 min. The results showed that samples with higher concentrations of RS melted more slowly (Fig. 6a). Increases in aging time decreased the meltdown rate of samples. The meltdown rate is an important characteristic of ice cream. Slow meltdown and good shape retention are some of the ideal quality parameters of ice cream (BahramParvar and Mazaheri-Tehrani 2011). Overrun, fat destabilization and viscosity of the ice cream mix influenced meltdown rate. An increase in coalesced fat increased resistance to flow of the liquid phase and resulted in slower melting (Nuernberg-Rossa et al. 2012). Botega et al. (2013) stated the increase in melting resistance was associated with the presence of larger fat aggregates. RS increased fat destabilization and decreased meltdown. Rezaei et al. (2011) reported arabic gum and guar gum can form sticky network that results in more resistance to melting.

Herald et al. (2008) found that increasing the viscosity of the ice cream mix decreased the melting rate. Increasing aging temperature slightly increased the meltdown rate (Fig. 6b), perhaps as a result of the considerable effect of temperature on overrun. According to the results of this study, higher aging temperature decreased overrun sharply; this decreased the air

content of samples, which led to more heat delivery and increased meltdown (Phianmongkhoh et al. 2012).

Color

Evaluation of color of samples revealed that the addition of RS increased whiteness (L^*). Aging time had a similar effect on L^* , but higher aging temperature decreased L^* (Fig. 7a). The effect of RS on L^* could be attributed to the white color of the RS, which decreased the color of the soy milk and increased whiteness.

All samples showed negative a^* (greenness) values. Increasing the RS concentration up to 1 % increased a^* , but after 1 %, a^* was unaffected. Aging time (up to 13 h) and aging temperature (up to 4 °C) increased a^* and then decreased it (Fig. 7b). RS concentration, aging time and aging temperature increased b^* (yellowness) (Fig. 7c).

Conclusion

The best improvement in textural properties and appearance of frozen soy yogurt in terms of viscosity, hardness, meltdown rate, foam stability and color was obtained in samples with 2 % resistant starch. More investigation such as rheological, sensory and microstructure analysis of product are required for understanding effect of RS incorporation. Lower aging temperature (2 °C) and longer aging time (24 h) promoted quality of frozen soy yogurt.

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