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Honey, trehalose and erythritol as sucrose-alternative sweeteners for artisanal ice cream. A pilot study

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ABSTRACT

The use of sucrose-alternative sweeteners in ice cream production could satisfy requirements of modern consumers focused on natural and nutritionally balanced foods. The aim of this work was to fill the gap in basic knowledge about the effects of honey, trehalose, and erythritol on the properties of artisanal ice cream. A milk-based sucrose-sweetened ice cream was produced as reference sample (REF), using then the alternative sweeteners to partially (50%) or totally (100%) substitute sucrose. With respect to REF, honey-containing ice cream mix revealed a significantly lower value of soluble solids (30.4 °Bx *vs.* 34.5 °Bx) and apparent viscosity (36.5 mPa s *vs.* 47.6 mPa s) and a significantly higher extrusion time (8.18 min *vs.* 7.04 min). The total substitution of sucrose with trehalose and erythritol led to a melting rate (2.07 and 1.56 g/min, respectively) significantly lower than REF (2.75 g/min), a very high firmness (508 and 725 N *vs.* 4 N), and a higher extrusion temperature (−7.1 and −5.3 °C *vs.* −9.3 °C). The results of this study represent a guideline for the successfully utilization of honey, trehalose, and erythritol in peculiar ice cream formulations (e.g. non-sweet or low-calorie products).

1. Introduction

In recent years, the market for foods claiming nutritionally balanced profile and healthy characteristics has steadily grown, as well as demand for natural products. Health and fitness, together with cultural and ethical concerns, have designed new behaviors towards food selection (Falguera, Aliguer, & Falguera, 2012). Thus, researchers continuously focus on reformulating products traditionally rich in saturated fat and sugar using healthier ingredients with positive physiological effects. In this context, efforts have been made to transform ice cream from indulgent snack and dessert into a nutritionally and physiologically beneficial product, without renouncing to the pleasure of consumption (Akalin & Erisir, 2008; Akalin, Karagözlü, & Ünal, 2008; Rossa, Burin, & Bordignon-Luiz, 2012; Sun-Waterhouse, Edmonds, Wadhwa, & Wibisono, 2013).

Substituting the traditional sweeteners, i.e. sucrose and glucose syrup, with other bulk sweeteners affects, beyond sensory properties, the freezing behavior and the stability of the ice cream (Cadena, Cruz, Faria, & Bolini, 2012; Hagiwara & Hartel, 1996; Muse & Hartel, 2004; Ozdemir, Dagdemir, Ozdemir, & Sagdic, 2008). Thus, the substitution strategy may give uncertain results in terms of physico-chemical and sensory properties of the final product and experimental trials are needed to clarify the effects of the different sucrose alternatives present on the market.

Among sucrose alternatives, honey is one of the oldest natural sweeteners; its use in artisanal production may add a unique value to ice cream, due to the characteristic aromatic profile and the positive effects on consumers' health. Honey has a medium glycemic index (GI) of 55 (Foster-Powell, Holt, & Brand-Miller, 2002) in comparison to sucrose (GI = 100). It has been claimed to promote the reduction of blood glucose levels in diabetics (Busserolles, Gueux, Rock, Mazur, & Rayssiguier, 2002), as well as a marked reduction of plasmatic triglycerides (Al-Waili, 2004).

Other new alternative-sweeteners have recently gained the attention of ice cream producers due to their unique properties. For instance, trehalose, naturally occurring in some foods (i.e. honey, mushrooms, yeasts, shellfish), is interesting for its stabilizing effect on systems subjected to freezing and thawing processes (Richards et al., 2002). It is a disaccharide made up of two D-glucose molecules linked by an α,α-1,1 bond, showing a relative sweetness of 0.45 (Portmann & Birch, 1996). Another recent alternative to sucrose is represented by erythritol (1,2,3,4-butanetetrol), a natural polyalcohol found in small quantities in fruits, vegetables, mushrooms and fermented foods. It has a sweetening power of

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approximately 0.7 in comparison to sucrose, with a mild cooling effect and no after taste (Mitchell, 2006). The interest in erythritol is due to its high stability towards temperature and extreme pH conditions (Boesten et al., 2015), zero-calorie value, zero GI, and non-cariogenic properties (Mitchell, 2006; Whelan, Vega, Kerry, & Goff, 2008b). Moreover, unlike other polyols, erythritol shows a high intestinal tolerance (Arrigoni, Brouns, & Amadò, 2007).

Very few studies deal with the effects of using honey, threalose, and erythritol as sucrose alternatives in ice cream production (Fuangpaiboon & Kijroongrojana, 2013, 2015; Ozdemir et al., 2008; Whelan et al., 2008b; Whelan, Regand, Vega, Kerry, & Goff, 2008a). In addition, these alternative sweeteners have been mainly considered in complex systems, with the aim to develop a complete ice cream formulation, with optimal quality characteristics. Sucrose substitution was mainly carried out with the new sweeteners in combination with other ingredients (e.g. polidextrose), thus hindering the real effect of the single ingredient. Thus, the aim of this study was to systematically evaluate the effects of honey, trehalose, or erythritol on the quality characteristics of artisanal ice cream. A partial or complete substitution of sucrose in basic formulations with a high added sugar content (20 g/100 g) has been studied, in order to enhance the role of the single sweetener used and draw basic information useful for an easier application.

2. Materials and methods

2.1. Ice cream formulations

Reference ice cream (REF) was formulated as reported in Table 1, with fresh pasteurized whole milk (Centrale del Latte di Milano, Milan, Italy), pasteurized cream (Centrale del Latte di Milano, Milan, Italy), skim milk powder (Comprital S.p.A., Settala, Milan, Italy), stabilizers and emulsifiers (Neumilk 5C, Comprital S.p.A.) and sucrose (Comprital S.p.A). In experimental samples sucrose was partially (50%) or completed (100%) substituted on a weight basis with multifloral honey, crystalline trehalose dihydrate, or erythritol. All the formulations had the same total solid content (36.5 g/100 g), with the exception of samples produced with 50% or 100% sucrose substitution with honey (H50 and H100, respectively). Due to the water contained in honey (about 18 g/100 g, according to Ozdemir et al., 2008), H50 and H100 had a total solid content of about 34.7 g/100 g and 32.9 g/100 g, respectively. A basic ice cream formulation with a high content of added sugars (20 g/100 g) was used, in order to enhance the real effect of the different sweeteners.

Honey and all powder ingredients were kindly supplied by Comprital S.p.A., with the exception of trehalose (Hayashibara, Okayama, Japan) and erythritol (Giusto Faravelli S.p.A., Milan, Italy). Experimental samples were identified by a code consisting of a letter and a number: the letter refers to the type of sweetener used (H, honey; T, trehalose; E, erythritol) and the number to the percentage of sucrose substitution (100% or 50%).

Table 1
Formulation and composition of the reference ice cream (REF).

Ingredient	Amount (%)	Fat (g/100 g)	MSNF (g/100 g)	Total solids (g/100 g)
Whole milk	64.5	2.42	5.39	7.8
Milk cream	10.5	3.68	0.57	4.2
Skim milk powder	4.5	0.03	3.96	4.0
Sucrose	20.0			20.0
Emulsifier and stabilizers	0.5			0.5
Total	100.0	6.13	9.91	36.5

MSNF, milk solids not fat.

2.2. Ice cream production

Ice cream mixes were prepared as reported in Rossi, Casiraghi, Alamprese, and Pompei (1999), by using a Pastomaster 60 Tronic and a Labotronic 20–30 batch freezer (Carpigiani S.r.l, Anzola Emilia, Italy). Briefly, pasteurization was carried out up to 85 °C for 30 s on a 15 kg batch, with continuous mix circulation. After 24 h ageing at 4 °C, the mix was frozen in four aliquots (3 L each) and packed either in 230 mL HDPE lid containers or in smaller 50 mL polythene hinged-lid containers. Ice cream samples were stored for 24 h at −30 °C and then conditioned for 24 h at −16 °C before analyses. Two technological replicates were carried out for each formulation. During production the time lasting from the beginning of mix freezing until the extrusion of ice cream was measured by a timer (extrusion time). The ice cream extrusion automatically occurs at a given level of stress (pre-determined by the equipment constructor) registered by the freezer dasher. Immediately after extrusion, the ice cream temperature was determined inserting a thermometer in the center of the product, just before packaging.

2.3. Relative freezing point depression of sweeteners

In order to calculate the relative freezing point depression (FPD) of sweeteners, osmolality (mOsmol/kg) of 20 g/100 mL aqueous solutions of sucrose, trehalose and erythritol was measured by a Semi-Micro Osmometer K-7400 (Knauer, Berlin, Germany). Results were converted in freezing points (FP) by means of the following equation:

$$\text{FP}\ (^\circ\text{C}) = -0.0019 \cdot \text{osmolality}\ (\text{mOsmol/kg}) + 0.0009 \quad (1)$$

Relative FPD was then calculated as the ratio between the freezing point of the solution containing sucrose and the freezing point of the solution containing the considered sweetener.

2.4. Ice cream mix analyses

Analyses of ice cream mixes were carried out after 24 h ageing at 4 °C. Mix density was determined at 4 °C measuring the weight of a fixed volume (50 mL) of mix. Results are expressed as the average of three replicates (g/mL). The quantity of soluble solids was determined at 4 °C by a digital refractometer DBX-55 (Atago, Tokyo, Japan) and expressed as the average of at least five measurements (°Bx). Flow curves were measured at 4 °C using a Physica MCR 300 rheometer (Anton Paar, Graz, Austria) equipped with coaxial cylinders (CC27), in a 20–500 s^{-1} range of shear rate. Results are expressed as the average of two replicates in terms of apparent viscosity (mPa s) at 290 s^{-1}. This shear rate value has been chosen in a portion of the flow curve where the viscosity is not greatly influenced by the shear rate itself. Flow curves were also fitted by the power law equation (Eq. (2)), in order to calculate the consistency coefficient (K) and the flow behavior index (n):

$$\tau = K \cdot \dot{\gamma}^n \quad (2)$$

where τ is the shear stress (mPa) and $\dot{\gamma}$ is the shear rate (s^{-1}) (Steffe, 1996).

2.5. Ice cream analyses

Overrun, firmness and melting behavior of ice cream samples were determined as reported in Rossi et al. (1999) and Alamprese, Foschino, Rossi, Pompei, and Savani (2002).

Ice cream ability to retain its shape during melting was evaluated through an image analysis method. Pictures of the samples