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Influence of hydrogenated oil as cocoa butter replacers in the development of sugar-free compound chocolates: Use of inulin as stabilizing agent

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ABSTRACT

The effect of the addition of inulin as a surfactant or stability agent on white compound chocolate sweetened with sucralose and Stevia was studied. Samples were stored at 7, 15 and 30 °C during 100 days and the influence of inulin on rheological properties, sensorial attributes, shelf-life, physical properties such as melting, crystallization and blooming were analyzed. The shelf-life of the compound chocolate with the incorporation of inulin was higher than the control sample without replacement. Compound chocolate with inulin at 10% w/w showed a dense matrix structure, reducing the size and number of fat crystals formed during storage; furthermore they presented higher values of brightness and *WI*. This chocolate also showed less fracturability and improved thermal properties. DSC studies revealed increased values of onset and peak temperatures and enthalpy of melting of the polymorphic form V, at higher storage temperatures, achieving greater stability against degradation processes.

1. Introduction

Chocolate is a high energy product with a unique taste and texture, containing many carbohydrates and fats. True chocolate contains cocoa butter, which is extracted from cacao beans. Cocoa butter is an expensive ingredient that requires going through a tempering process during melting, which re-establishes the cocoa butter crystals, giving the chocolate the proper sheen, snap and taste. Tempering prevents bloom, where the cocoa butter separates from the cocoa solids and comes to the surface, turning the chocolate whitish or grayish in colour. Compound chocolate is a product made from a combination of cocoa, vegetable fat, and sweeteners. It is used as a lower-cost alternative to true chocolate; it utilizes less-expensive hard vegetable fats instead of the more expensive cocoa butter (Geron & Charaderian, 2013).

Sucrose is the most commonly used sugar in the confectionery industry and constitutes 30–60% of the chocolate, depending on type (Aidoo, Depypere, OheneAfoakwa, & Dewettinck, 2013). It is a multi-functional ingredient due to the structural and sweetening characteristics that sugar offer to these types of products (Aidoo, Afoakwa, & Dewettinck, 2015; Aidoo et al., 2013). However, there is a large market of consumers who demand sugar-free chocolates because diabetes is one of the fastest-growing chronic diseases. Low calorie sweeteners are an important alternative for the production of no- and low-sugar products. The full replacement of sugar represents a challenge because it affects physical quality characteristics like rheological properties and texture, melting behaviors, bloom formation and other characteristics that influence the final stability of chocolate, requiring strategy for their formulation. Combination of sweeteners with bulking and stabilizing agents is needed to provide an integral solution for sugar replacement. A technological resource for this problem may be the addition of fiber or fiber-like ingredients known as low-digestible carbohydrate polymers. Regarding this, the oligosaccharide inulin can be a good alternative as a stabilizing for the manufacture of sugar-free chocolates, trying to keep all the characteristic sensory properties. The incorporation of inulin in foods presents different technology advantages, such as texturizing, humectant, water holding agent, thickener, emulsifier, gelling agent, sugar and fat substitute, among others (Rosell, Santos, & Collar, 2009; Shourideh, Taslimi, Azizi, & Mohammadifar, 2012).

The use of surfactants and polymers as stabilizing agent in emulsions and suspensions has attracted much attention in recent years. Surfactants are important ingredients in the manufacture of chocolate; their function is to coat the surfaces of the sugar and cocoa particles dispersed in fat, generally cocoa butter, to maintain or improve the fluidity of the melted chocolate. Coating the

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surfaces of the dispersed particles with a surfactant reduces interparticle interactions responsible of particle aggregation (Do, Mitchell, & Vieira, 2010). The flow behavior of molten chocolate is an important characteristic directly related with an optimal mouthfeel. Polymeric surfactants of high molecular weight contribute to the stability of the sample, improving the dispersion of the product matrix in time; they are very efficient in terms of steric stabilization due to their molecular size and the formation of multiple binding sites at the interface (Do et al., 2010).

Previous studies reported the influence of fibers in chocolate formulations. The polysaccharide inulin was previously employed in sugar-free chocolate sweetened with Stevia and thaumatin by Aidoo et al. (2015). Tadros, Vandamme, Levecke, Booten, and Stevens (2004), found that inulin, a sugar-based polymeric surfactant is effective in long-term stabilization of emulsions. Inulin and polydextrose were used as bulking agent in the production of free sucrose chocolates (Shah, Jones, & Vasiljevic, 2010). Shourideh et al. (2012) studied the effect of d-tagatose and inulin on some physicochemical, sensory and rheological properties of black chocolate. Farzanmehr and Abbasi (2009) evaluated the effects of inulin, polydextrose and maltodextrin as bulking agents on the rheological properties of chocolate formulations and concluded that inulin and polydextrose can be used to improve the properties of chocolate.

Hydrogenated fat used in compound chocolate have a different triglyceride structure with respect to cocoa butter and can only support a small proportion of this ingredient (Lipp & Anklam, 1998). Cocoa butter has a unique triglyceride composition responsible for its various polymorphic crystallized forms that determines its chemical and physical properties, like melting and crystallization behavior. Moreover, the fatty acid composition results in the form that liquid fat converts into a solid that influences the final texture and microstructure properties (Jahurul et al., 2014).

Moreover, the triglyceride compositions of cocoa butter are responsible for its various polymorphic crystallization forms, whereas liquid fat converts into a solid as a result of fatty acid compositions

The aim of this work was to investigate the influence of inulin as a surfactant on the stability and physicochemical properties of sugar-free white compound chocolate using Stevia and sucralose as sweeteners. Cocoa butter was replaced partially with hydrogenated oil (20% w/w) to obtain compound chocolate. Kinetic studies on the formation of non-enzymatic browning products, evaluation of the changes in surface colour, free fat, rheological behavior of the melted product, textural properties and sensory analysis were carried out. Microstructure was analyzed by scanning electron microscopy and differential scanning calorimetry was applied to characterize the effect of inulin addition, on the crystallinity and melting profiles of the products.

2. Materials and methods

2.1. Raw materials

The raw materials used for production of white compound chocolate were: Cocoa Butter (Arcor SAIC, San Luis, Argentine), whole milk powder (Ylolay, Argentine), skim milk powder (La Serenisima, Argentine), Stevia powder (Tanki SA, Argentine), sucralose (Sucaryl Sucralosa, Merisant, Argentine), vanilla (Alicante, Argentine), soy lecithin, inulin (Orafti Chile S. A.) as surfactant or stabilizer agent (anti-bloom agent) and hydrogenated oil (Danica, Argentine) as cocoa butter replacer.

2.2. Chocolate formulations

Low sugar white chocolate was obtained using Cocoa butter 50%, w/w; Stevia 2.1% w/w; sucralose 1.4% w/w; whole milk powder 26% w/w; skim milk powder 19.7% w/w; soya lecithin 0.7% w/w; vanilla 0.1% w/w. Cocoa butter was partially replaced in a 20% (w/w) with hydrogenated oils (Sample 20%R) to obtain compound chocolate. Inulin at 5% and 10% (w/w) of the total weight of chocolate (20%R + 5%I and 20%R + 10%I) was added as surfactant agent.

2.3. Manufacture process of white chocolate

The low sugar white chocolate was produced through the following stages: sugar was milled together with milk powder using a grain mill (Corn-Grain-Cereal-Mill, Chinese) and a grinder. Then, cocoa butter or/and dehydrated oils were melted in a water bath (T < 45 °C). Sweeteners, milk powder and cocoa butter were mixed in a planetary mixer, (Santini, model MP8, Italian), for 5 min. Preparation was refined using a multi-hole screw extruder for 1 h at 35 °C. The conched was carried out under constant stirring at 200 rpm at 45 °C for 7 h. Lecithin and vanilla were added in the last 30 min of conching. Subsequently tempered by cooling to 23–24 °C and then heating to 28–29 °C was performed. All samples were tempered because cocoa butter in compound chocolate was not completely replaced. Samples were molded and cooled for 2 h at 7 °C. After cooling the product was packaged with a flexible material (Al-PET, water vapor transmission rate (WVTR) < 1 g m^{-2} day^{-1}) to avoid the effect of the ambient humidity.

2.4. Determination of white chocolate shelf life

For the kinetics study the samples were stored in chambers at a constant temperature of 30 °C and refrigerated at 7 ± 2 °C or 15 ± 2 °C over a period of 100 days. Non-enzymatic browning compounds and surface colour were periodically tested in triplicate during storage.

2.4.1. Non-enzymatic browning reactions

Four grams of grated chocolate in centrifuge tubes were weighted, and defatted with 25 ml of a mixture of chloroform/methanol (95:5) the sample was vigorously stirred and centrifuged at 3000 rpm for 30 min. The solvent fraction was decanted and solvent was evaporated in a bath under constant air flow, obtaining fatty extract. The fatty extract was weighted to obtain the percentage of fat in the sample. Then, the defatted pellet was suspended in deionized water at 50 °C in a 50-ml volumetric flask and vigorously stirred for 1 min and clarified with 0.5 ml each of Carrez I (potassium ferrocyanide, 15% w/v) and Carrez II (zinc acetate 30% w/v) solutions. The solution was left to rest for 10 min and the volume was adjusted to 50 ml with distilled water. The solution was filtered and the filtrate was used for PNE measurements by reading the absorbance at 280 nm using a spectrophotometer UV–Visible, double beam – (Shimadzu, USA), (Vercet, 2003).

2.4.2. Surface colour determination

The surface colour of the chocolate samples were measured in three different zones with a spectrophotometer MiniScan EZ, using the CIELAB colour parameters (L^*, a^* and b^*). "L^*" value defines luminance of the samples between 0 and 100 scale in which 0 defines black and 100 defines white colour, "a^*" value describes colour categorizing from green (−) to red (+), while "b^*" value describes colour categorizing form yellow (+) to blue (−). The measurement was performed at 7, 15 and 30 °C. Whiteness Index (WI)