Food Research International 51 (2013) 797–803

Contents lists available at SciVerse ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Ethylcellulose solvent substitution method of preparing heat resistant chocolate

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ARTICLE INFO

Article history:
Received 26 October 2012
Accepted 27 January 2013

Keywords:
Chocolate
Compound chocolate
Heat resistant
Ethylcellulose
Organogel

ABSTRACT

In the present study a structuring technique was developed to produce chocolate which resists deformation at temperatures above 40 °C. It was hypothesized that by adding ethylcellulose (EC) solubilized in ethanol (EtOH) to chocolate and evaporating the EtOH an organogel could be formed in situ with the fat phase of the chocolate. Heat resistant chocolate (HRC) was produced by mixing a 20% EC in EtOH solution with molten chocolate. The EtOH was evaporated and the resulting chocolate was incubated at 40 °C for 2 h and tested for hardness. The effect of various EC viscosities (4, 10, 20, 22, and 45 cP) and concentrations ranging from 1.0 to 2.2% on different types of chocolates was studied. Milk chocolate containing 1.9% EC had a hardness of 26.0 N whereas the control chocolate was too soft to be tested. Further experiments revealed that white and dark chocolates had hardnesses of 29.5 and 10.5 N, respectively. The hardness of the chocolate was dependent on the chocolate formulation and concentration of EC, and independent of EC viscosity. It was observed that the addition and evaporation of EtOH from the compound milk chocolate samples led to an increase in the lightness of the chocolate surface if the EtOH was evaporated at temperatures of 40 °C or higher. Addition of EC to chocolate represents a new strategy for the manufacture of HRC. Future work should focus on determining the mechanism by which heat resistance is achieved in these chocolates.

1. Introduction

Chocolate is a widely loved treat that has been enjoyed for centuries. Worldwide chocolate sales have surpassed US$90 billion (Schmitz & Shapiro, 2012). This confection is known for its desirable melt-in-your-mouth characteristic, a phenomenon attributed to the melting point of cocoa butter (34 °C) (DeMan, 1999), the main fat constituent in chocolate, being just slightly below body temperature (37 °C). However, this melting point is problematic when manufacturing or selling chocolate at ambient temperatures close to or above this temperature such as what occurs in summertime or in tropical climates. A chocolate that resists melting and deformation at temperatures above 34 °C is therefore advantageous in these situations.

Various efforts have been made in the past to develop heat resistant chocolate (HRC), the details of which can be found elsewhere (Stortz & Marangoni, 2011). Three main strategies to produce HRC have been identified: enhancing network microstructure, adding an oil binding polymer, and increasing the melting point of the fat phase. Currently, none of these strategies has been successfully commercialized, thus further research is necessary. Of particular interest is the advancement in the development of HRC utilizing polymer organogelation.

Gels in which the liquid phase is oil are classified as organogels (Marangoni & Garti, 2011). Ethylcellulose (EC) has been shown to have oil gelling abilities when added at levels of ≥2% by weight to oil (Aiache, Gauthier, & Aiache, 1992; Gauthier, Aiache, & Aiache, 1996; Howard, 1976) and heating above the glass transition temperature of the EC which is around 145 °C (Dey, Kim, & Marangoni, 2011). This polymer is a derivative of cellulose in which some hydroxyl groups on the glucose monomers are substituted with ethoxyl groups.

The use of EC to gel the fat phase of chocolate may represent a novel strategy to produce HRC. At elevated temperatures, the EC gel network could trap liquid cocoa butter and prevent collapse of the chocolate structure. However, using EC to gel the fat phase of chocolate is problematic since the typical method to create an EC gel requires the ingredients to be heated at around 145 °C for a gel to form and chocolate should never be heated at a temperature this high. The purpose of this study was to develop a low temperature method to introduce EC into chocolate such that heat resistance was incurred, and to characterize and optimize this HRC. It was hypothesized that a good solvent for EC such as ethanol (EtOH) could be used to solubilize the EC at room temperature. This mix could then be added to chocolate and the solvent could be evaporated leaving behind the EC where it could form a gel with the fat phase of the chocolate in situ. This method would thereby avoid the high heat normally associated with the formation of EC oleogels by employing the use of a volatile solvent.

Abbreviations: HRC, heat resistant chocolate; EC, ethylcellulose; EtOH, ethanol; PKO, palm kernel oil; EtOHC, ethanol control; DSC, differential scanning calorimeter; EA, ethyl acetate; CMC, compound milk chocolate; CDC, compound dark chocolate.

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0963-9969/$ – see front matter
http://dx.doi.org/10.1016/j.foodres.2013.01.059

2. Materials and methods

2.1. Materials

Samples were prepared using commercially available chocolates. Milk, dark, and white chocolates were attained from Barry Callebaut (Chicago, IL). Compound chocolate refers to chocolate made with hydrogenated palm kernel oil (PKO) instead of cocoa butter. Compound chocolate was acquired from Bulk Barn (Richmond Hill, ON). A list of the types of chocolate used in this study can be found in Table 1.

EC standard premium grade polymers of various viscosities were attained from Dow Wolff Cellulosics (Midland, MI). The viscosity of the EC was determined by the manufacturer by dissolving 5% EC in a mix of 80% toluene and 20% ethanol (EtOH) and tested using an Ubbelohde viscometer at 25 °C. EC viscosities of 4, 10, 20, or 45 cP were used. EC 22 cP was obtained from Sigma-Aldrich (Oakville, ON); the viscosity of EC 22 cP was measured in the same manner as above. Absolute EtOH was obtained from Commercial Alcohols (Brampton, ON) and was stored in a refrigerator (5 °C) with a dessicant in the bottle to minimize absorption of water. The EC in EtOH mix was prepared by slowly adding 20 or 25% EC to EtOH with stirring in a sealable container. This mix was left overnight and stirred again to ensure full dissolution and homogeneity.

2.2. HRC preparation

Compound chocolate was melted using a microwave in short time increments with stirring between heating until it reached 40–50 °C. When the chocolate reached 40 °C the EC mix was added quickly and the sample was stirred until homogeneous or for 1 min. The sample was then poured into room temperature molds. Once filled, the mold was tapped for 15 s on the counter to remove air bubbles from the chocolate. The mold was then placed in a refrigerator (5 °C) for 20 min. Once hardened, the sample was removed from the mold by tapping the mold on the counter.

To prepare HRC made with chocolate containing cocoa butter, the chocolate was first tempered using a seed tempering method and a Revolation 2 chocolate tempering machine (ChocoVision, Poughkeepsie, NY). The seed chocolate was produced using the table top tempering method. Chocolate was melted slowly in a microwave until a temperature of around 40 °C was attained. Approximately one-third of the melted chocolate was poured onto a cool, thick, metal table. The chocolate was spread out then folded back into a mound using a flat, metal spatula. This was repeated until some of the chocolate showed signs of crystallization which was visible as patches of lighter, thicker, and less shiny chocolate. The chocolate was added back to the rest of the warm chocolate and stirred. The spreading, folding and reincorporation steps were repeated until the chocolate reached its working temperature (31 °C, 30 °C, and 28 °C for dark, milk and white chocolates, respectively). If the chocolate temperature dropped too low then it was warmed to its working temperature using a water bath. To ensure that the chocolate was in temper, the tip of a small spatula was dipped in the chocolate and left for a few minutes at room temperature. Temper was achieved if after a few minutes the chocolate was hard, glossy, smooth, and lacked streaks. The properly tempered chocolate was then molded and placed in the fridge for 20 min. A cheese grater with fine grating slots was used to shave the chocolate into small seeds. The seed chocolate was then used with the Revolation 2 machine to temper the chocolate. Chocolate was added to the assembled machine, melted and brought to 34.4 °C. Once melted, the chocolate was cooled to the working temperature mentioned previously. During this cooling period, seed chocolate was slowly added to the melted chocolate. The amount of seed added was approximately 3–6% by weight of the total weight of chocolate. A plastic spatula was used to enhance mixing during this stage. When the working temperature was achieved the chocolate was checked as above to make certain it was in temper. The EC mix was then added to the tempered chocolate and the procedure continued as described above. All chocolates were molded into a tablet that was 3.60 cm long by 1.90 cm wide with a depth of 0.68 cm.

After storage at room temperature for one night the EtOH was evaporated from the HRC in an incubator at 40 °C unless otherwise indicated.

2.3. Heat resistance measurements

Heat resistance of the chocolate was tested using a texture analyzer (Stable Micro Systems Ltd, Surrey, UK) and a cylinder probe with a diameter of 1.80 cm. The testing mode was set displacement in compression with a displacement of 4 mm. Following removal of the EtOH, samples were placed in an incubator at 40 °C, unless otherwise indicated, for 2 h prior to testing. Samples were then individually transferred to the tester stage and placed with their center directly below the cylindrical probe. The test was run and the force (N) at 2 mm displacement was recorded. This method was used to obtain a numerical measure of heat resistance for all samples tested.

2.4. Effect of EC viscosity on heat resistance

HRC was made in the manner described above using compound milk or dark chocolate. EC of various viscosities was mixed with EtOH to give a 20% solution in the EtOH. The EC viscosities used included 4, 10, 20, and 45 cP. The chocolate was prepared, dried, and tested for heat resistance at 40 °C using the texture analyzer as described above.

2.5. Measuring ethanol loss

Ethanol loss from the chocolate was measured during various evaporation treatments. HRC was prepared by adding 10% of a mix of 20% EC 45 cP in EtOH to compound milk chocolate. The chocolate therefore contained 8% EtOH. The chocolate was prepared as described above. Immediately following demolding two pieces of chocolate were added to weighed tin containers and the initial total weight was measured and recorded. Three tins of chocolate were maintained in one of six drying environments: 20 °C or 50 °C with vacuum (13 kPa), 30 °C, 30 °C wrapped, 40 °C, or 50 °C. Each piece of chocolate in the 30 °C wrapped treatment was individually wrapped with a single layer of

Table 1
Types of chocolate used to manufacture HRC.

Chocolate type	Product name	Ingredients	% fat
Compound milk	Compound milk chocolate wafers	Sugar, hydrogenated palm kernel oil, cocoa powder, powdered whey protein concentrate, whole milk powder, soy lecithin, vanilla	31
Compound dark	Compound dark chocolate wafers	Sugar, hydrogenated palm kernel oil, powdered whey protein concentrate, cocoa powder, chocolate liquor, black cocoa powder, soy lecithin, vanilla	31
Milk	Kenosha milk chocolate	Sugar, cocoa butter, whole milk powder, chocolate liquor, nonfat dry milk, butter oil, soya lecithin, vanilla extract	34.5
Dark	Tulsa dark chocolate	Chocolate liquor, sugar, cocoa butter, soya lecithin, vanilla extract	34.1
White	Ultimate white chocolate chips	Sugar, cocoa butter, whole milk powder, nonfat dry milk, milk fat, soya lecithin, vanilla extract	27.9